University of Reading

# Investigating the effects of dietary flavonoid supplementation on mood and cognition in the postpartum

Submitted for the degree of Doctor of Philosophy

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Declaration

I confirm that this is my own work and the use of all material from other sources has been properly and fully acknowledged.

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Abstract

Diet has gained increasing attention for its crucial role in supporting mental health and overall wellbeing. Among its many components, phytochemicals such as flavonoids have emerged as key contributors to health, with growing evidence indicating their potential to reduce the prevalence of mood disorders. The postpartum period is a particularly vulnerable time, marked by significant changes in mood and cognition. Rates of mood disorders often rise within the first year after childbirth, especially among mothers. Access to conventional treatments during this period may be limited, highlighting the need for accessible, and cost-effective interventions such as dietary flavonoid supplementation. Prior research has shown that dietary flavonoids can improve anxiety and quality of life during the first postpartum year. However, it remains unclear if these benefits extend to fathers or whether the timing of supplementation influences its effectiveness. Additionally, although flavonoids have been linked to cognitive enhancements in various groups, it is unknown whether these effects hold during the postpartum period, when the brain undergoes notable structural and functional adaptations.

The current work aims to deepen understanding of dietary flavonoids' effects in postpartum parents. Following a 2-week flavonoid supplementation in mothers 0–6 months postpartum, reductions in postpartum depression symptoms were observed, though fathers did not engage effectively. An earlier postpartum intervention, starting within four days of delivery for 30-days was then investigated, revealing improvements in executive function and fewer subjective cognitive complaints, while mood outcomes showed no significant change. Furthermore, acute supplementation with anthocyanin-rich wild blueberries in the 0–6 month postpartum period improved verbal and working memory in both mothers and fathers, though without additional mood benefits. This work therefore provides novel insights into the benefits of dietary flavonoid supplementation to this population, and evidence to suggest ideal timepoints to supplementation, for a population who may uniquely benefit from a cost-effective and accessible intervention.

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Chapter 1- An introduction to flavonoids and their mechanisms of action

## 1.1. General introduction

Diet has become a significantly important subject of interest in today's society. A healthy, diverse diet is deemed essential for human health and development, particularly when considering ways to ameliorate risk factors for mood disorders throughout the lifespan (Firth et al., 2020). To date, a considerable amount of research has investigated risk factors and preventative actions for mood disorders in the postpartum, however the impact of diet during this time is often neglected by research and in clinical practice. Evidence has shown that diets rich in flavonoids, a naturally occurring polyphenolic compound, can reduce prevalences of mood disorders in healthy populations, and contribute to symptom reduction in clinical groups (for review see Chapter 2). The broad aim of this work is to review whether flavonoids can benefit mood and mental health in healthy populations and to investigate whether dietary flavonoids can promote mood for parents during the critical period following birth.

## 1.2. Flavonoid structure and sub-classes

Polyphenols are a large group of plant compounds abundant in many fruits, vegetables, and beverages, and are known for their potential health benefits. These compounds can be divided into several categories, one of the most notable being flavonoids. There are six subclasses of flavonoids; flavonols, flavones, isoflavones, flavanones, flavanols, and anthocyanins, each comprised of two aromatic carbon rings (benzopyran A and C rings) and benzene (B ring), though each subclass differs according to the degree of oxidation in one of the benzopyran rings, the hydroxylation pattern of the ring structure or substitution of the 3 position (Spencer, 2008).

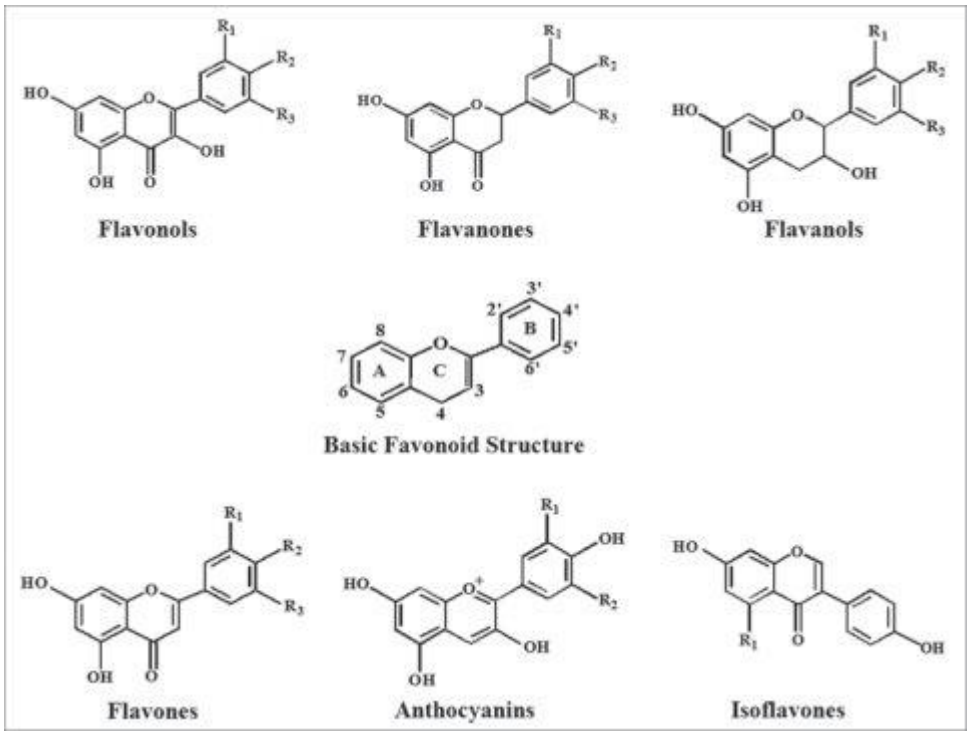


*Figure 1. The general flavonoid structure, containing a benzene ring (ring B) and a benzopyran ring (rings A and C), in the centre with the six subclasses of flavonoids also shown, their structure differing based on ring C alterations (Pandey & Rizvi, 2009)*

## 1.3. Flavonoids in the diet

Major dietary sources of flavonoids include berry fruits (anthocyanins; pelargonidin, cyanidin, malvidin). cocoa (flavanols; catechin, epicatechin, epigallocatechin, epigallocatechin gallate (EGCG)) citrus fruits and juices (flavanones; hesperidin, naringenin), soy products (isoflavones; daidzein, genistein), onions and broccoli (flavonols; kaempferol, quercetin), parsley and celery (flavones; apigenin, luteolin) (Beking & Vieira, 2011; Vogiatzoglou et al., 2015).

Flavonoids have long been cited for their benefits to human health, with evidence supporting intake of flavonoids within the diet supporting cardiovascular health (Micek et al., 2021; Rees et al., 2018), reduced cancer risk (Grosso et al., 2017; Neuhouser, 2004), management of diabetes (Xiao, 2022), and improved cognitive function (Cheng et al., 2022; Lamport & Williams, 2020). Investigating the effects of foods rich in flavonoids are of public health benefit as simple dietary changes represent a lifestyle intervention that is accessible, relatively cost effective and easy to implement into one's life to make considerable change. Interestingly, when considering flavonoids in the diet and its benefits for public health, recent evidence highlights that consuming a diverse range of flavonoid-rich foods may reduce risk of mortality (Bondonno et al., 2023). Specifically, Bondonno and colleagues included 55,786 females from the Nurses' Health Study and found that consuming three servings per day in the 'Flavodiet' score was associated with an 8% lower risk of mortality and a 13% lower risk of neurological mortality. The Flavodiet score encompassed intakes of flavonoid-rich food/beverages that contributed over 1% to the total flavonoid intakes in the cohort, including foods such as tea, apples, oranges, grapefruits, blueberries, strawberries and red wine (servings/day). More recently, Parmenter et al. (2025) expanded this evidence using data from 124,805 UK Biobank participants, showing that both the quantity and diversity of flavonoid intake independently predicted a lower risk of all-cause mortality and a range of chronic diseases, including cardiovascular disease, type 2 diabetes, cancer, respiratory disease and neurodegenerative disease. These findings suggest that consuming several different daily servings of flavonoid-rich foods or beverages such as tea, berries, apples, oranges or grapes may offer stronger long-term protection than focusing on quantity alone. Furthermore, subsequent cross-sectional research highlights that plant diversity may also be key for cognitive outcomes (Ye et al., 2013), whereby greater variety, but not quantity, of fruits and vegetables lead to higher scores on the Mini Mental State Examination (MMSE), a tool for assessing global cognitive function. Taken together, these studies suggest that consuming even moderate amounts of diverse and flavonoid-rich foods may offer significant protective effects on long-term health, particularly regarding mortality and neurological outcomes.

Research in support of plant diversity on health outcomes has further been shown in randomised controlled trials (RCT). Del Bo et al. (2021) found changes in gut microbiota, following an 8-week polyphenol rich, diverse dietary pattern, consisting of 3 small portions of either berries and related products, blood orange and juice, pomegranate juice, green tea, Renetta apple and purée, and dark chocolate (724 mg/day of polyphenols) compared to a control diet. These findings highlight health benefits may be due to how these foods interact with the gut microbiome and that diversity of the intervention may be a key factor to see improvements in outcomes. Much of the above evidence focuses on habitual flavonoid consumption and associated health benefits. The benefits of consuming foods rich in flavonoids in their whole form regularly may be due to the synergistic interactions between flavonoids and other compounds such as fibre, vitamins and minerals. Whilst interactions between flavonoids and other compounds within food matrices are still tentative (Kamiloglu et al., 2021), Zhang et al. (2024) reports that lipids, protein, carbohydrates and minerals in the food matrix, combined with flavonoids shaping gut microbiota, may improve flavonoid bioavailability and subsequent outcomes (Manach et al., 2005). Further mechanisms of action for flavonoids and behavioural outcomes will be discussed in Chapter 1.7, though overall highlights the complexity of flavonoid bioavailability and its potential interaction with the gut microbiome, shedding light on possible pathways through which flavonoids could influence cognition and mood regulation.

Flavonoid intake shows considerable variation across different countries, reflecting regional disparities in dietary patterns. For instance, in the United Kingdom, men report an average intake of 548.8 mg/day, and women consume 501.7 mg/day (Zamora-Ros et al., 2012). Comparatively, in

Spain, the mean flavonoid intake is 313.26 mg/day (Zamora-Ros et al., 2010) and Australia estimates a mean intake of 683 mg/day (Kent et al., 2018), indicating higher intake compared to certain European populations. Dietary variations across regions were highlighted in Vogiatzoglou et al. (2015). The UK intake in this study was much lower than reported in Zamora-Ros et al. (2012) at 352 mg/d. However one factor potentially driving this difference is the differences in ages between the two studies, whereby Zamora-Ros et al. (2012) participants range from 35-74 and Vogiatzoglou et al. (2015) included younger participants within an age range of 18-64. Dietary habits of young adults often include less fruits and vegetables compared with the respective RDA's (Guenther et al., 2006), potentially due to time, food preferences, convenience, less knowledge around preparing and cooking food and economic factors, therefore overall flavonoid intake is likely to be reduced in this cohort, potentially skewing regional flavonoid intakes. In summary, both regional and demographic variations appear to shape flavonoid intake, showing as an important consideration when evaluating their potential role in health outcomes.

## 1.4. Flavonoids and mood

### *1.4.1. Epidemiological evidence*

Evidence has shown that consuming a healthy diet, rich in a diverse array of fruits, vegetables, legumes, nuts and wholegrains can result in a lower risk of mood disorders (Adan et al., 2019). This effect is thought to be partly due to the presence of flavonoids in these foods, as supported by several large cross-sectional studies. In example, Sun et al. (2021) found in 16,925 adults, consuming higher proportions of dark green vegetables and berries were all inversely related to depressive symptoms. This relationship was further elucidated by Godos et al. (2018) who assessed participants from southern Italy (n=1572) with a food frequency questionnaire and the Centre for Epidemiologic Studies (CES-D), finding that dietary intake of flavanones and anthocyanins showed significant inverse association with depressive symptoms in a dose-response manner. In similar findings, Chang et al. (2016) found increased consumption of total flavonoids, flavonols, anthocyanins, flavones and flavanones were significantly inversely associated with depression risk, in a dose-response fashion. Chang and colleagues found this association within the Nurses' Health study, a sample of 82,463 women, highlighting the strength of the relationship between consumption of dietary flavonoids and mood outcomes in a large population. Further to this, Radavelli-Bagatini et al. (2021) found at the 12 year timepoint in the Australian Diabetes, Obesity and Lifestyle Study cohort (n=4105), habitual fruit and vegetable intake was linked to a lower likelihood of depressive symptoms, with yellow, orange, red and leafy green vegetables driving the association. Interestingly, greater vegetable diversity (4–6 types per day) was also associated with fewer depressive symptoms, building on the evidence outlined in section 1.3. regarding flavonoid diversity and highlighting the importance of quantity and diversity for supporting mental health.

These findings suggest that not only total flavonoid intake, but also the specific food sources and therefore the particular subclasses of flavonoids they provide, may play an important role in this relationship. Recently, Ma et al. (2024) found higher consumption of flavanones and flavonols were associated with positive mood, measured via the positive and negative affect schedule (PANAS). A strength of this particular study comes from the collection of plasma, 24hr urinary polyphenol metabolites alongside the EPIC Norfolk food frequency questionnaire (FFQ's) to determine polyphenol consumption. Discrepancies were seen here between FFQ reporting and metabolites, whereby less negative mood was linked to higher urinary flavones, but not with FFQ-estimated flavone intake. The authors commented that this may be due to the fact that the FFQ does not include major flavone sources, such as soups which may be better captured in tools such as 7-day food diaries. This stands out as a significant limitation of FFQs in this type of epidemiological research, highlighting the FFQ may have limited ability to capture and discriminate food sources of flavonoids due to the defined list of food items. Furthermore, as a self-report method, FFQs are subject to recall and social desirability bias. Estimating flavonoid intake using FFQs also presents challenges, as different reference databases (e.g., USDA vs. Phenol-Explorer) can yield varying estimates of flavonoid content in foods. Although combining FFQs with physiological measures, such as plasma or urinary phenolic metabolites, can strengthen dietary assessments, these approaches capture different

timeframes of intake. Metabolite levels reflect recent consumption (24–48 hours), whereas FFQs represent habitual intake over the past year; consequently, discrepancies between these measures and the limitations described above, may introduce variability into the results.

Despite limitations in estimating polyphenol intake, epidemiological research highlights that the anthocyanin subclass of flavonoids seems to have a strong relationship with mood. Within the National Health and Nutrition Examination Survey (NHANES) cohort, Chen and Zhao (2023) found that those with high scores of depression had a significantly lower dietary intake of anthocyanins compared to those without depression. In another sample of adults with depression, Mestrom et al. (2024) found low consumption of dietary anthocyanins was evident in participants with major depressive disorder. This finding is especially noteworthy due to the nature of the population studied. Participants were divided into those with and without a diagnosis of major depressive disorder (MDD), novelly highlighting the role of anthocyanins in mental wellbeing in clinical and non-clinical populations. However, the authors comment that broader dietary patterns, such as adherence to a Mediterranean diet, which is well established to support mood and wellbeing, were not considered in their analysis (Lai et al., 2014). This omission highlights the need to account for overall dietary context when interpreting the role of individual nutrients like anthocyanins in mental health. Global dietary patterns may be especially important concerning those with MDD, whereby bidirectional relationships are seen between food choices with depressive symptoms. On one hand, individuals with depressive symptoms may be more likely to adopt poor dietary habits such as skipping meals, consuming high-sugar or ultra-processed foods, and lacking dietary variety, due to low motivation, fatigue, or altered appetite (Korczak et al., 2022; Ortega et al., 2022). On the other hand, these suboptimal eating patterns may further exacerbate or sustain depressive symptoms by limiting the intake of essential nutrients involved in brain function and mood regulation. Overall, outcomes from Mestrom et al. (2024) combined with Chen and Zhao (2023) suggests that even in clinical samples, the relationship between consumption of anthocyanins and depressive symptoms has significant strength, though further investigation of this relationship is warranted in larger samples of both depressed and non-depressed participants, considering the additional confounding variables such as overall dietary patterns and lifestyle factors.

These studies focus on western populations, though it is worth noting that foods rich in flavonoids come from different sources in other eastern populations. For example, Narita et al. (2022) found individuals in the highest quintile of fruit consumption showed decreased odds of major depressive disorder (MDD) in later life in the Japan Public Health Centre-based Prospective Study. However specifically flavonoid-rich fruit and vegetables did not have association with decreased odds of MDD. An interesting aspect to these findings were that food items that correlated with MDD were traditional to Asian diets, such as mugwort and loofah, which are not typical in western diets. This raises the possibility that associations observed in western samples may, in part, reflect the types of foods captured by dietary assessment tools designed around western eating patterns. In other words, relationships between flavonoid intake and mood may appear more robust in western contexts simply because the tools used are better suited to detect western dietary sources of flavonoids. Supporting this, increased consumption of non-fruit and vegetable foods like green and black tea, as well as soy products, are associated with reduced odds of depression in Japan and China (Chen et al., 2022; Cui, Huang, et al., 2020; Hozawa et al., 2009). Similarly, higher consumption of overall flavonoid consumption and lower depressive symptoms in Korea (Park et al., 2022) support that though food source may be an important factor, the relationship between flavonoid consumption and mood outcomes remains stable in both western and eastern diets.

Though overall flavonoid intake and certain teas may show positive associations with mood, this may not be the case for all flavonoid-rich foods. Rose et al. (2010) in example, examined the effects of chocolate consumption on mood in healthy adults. Results showed that greater consumption of chocolate was associated with higher depression scores on the CES-D, which was apparent in both men and women (total sample n=931). However, an important limitation of this study is that it did not account for the cocoa percentage in the chocolate consumed. Dark chocolate, which has a higher percentage of cocoa and contains higher levels of polyphenols compared to milk or white chocolate, may have a different impacts on mood. The failure to differentiate cocoa content could explain the

null results observed, as it's possible that the varying polyphenol levels influenced the mood outcomes. Indeed, research from Jackson et al. (2019) suggests a potential benefit of dark chocolate on depressive symptoms in 13,626 US adults using data from the National Health and Nutrition Examination Survey. While non-dark chocolate consumption was not associated with clinically relevant depressive symptoms, dark chocolate consumption was linked to significantly lower odds of depressive symptoms. Further, individuals in the highest quartile of chocolate consumption showed 57% lower odds of depressive symptoms compared to non-consumers. These findings suggest that dark chocolate, specifically, may have a protective effect against depressive symptoms, highlighting the importance of cocoa content in determining chocolate's impact on mood. It is also worth noting that Jackson et al. (2019) had greater statistical power due to its much larger sample size of 13,626 participants, compared to the smaller sample in the first study, which may have contributed to more robust and reliable findings.

It is important to highlight here that whilst large epidemiological trials highlight a relationship between flavonoid intake and behavioural outcomes, causal effects cannot be determined and such relationships may be subject to bidirectionality. As discussed, individuals experiencing depressive symptoms may be less motivated to prepare or consume healthy foods, leading to reduced intake of fruits, vegetables, and other flavonoid-rich foods (Korczak et al., 2022; Ortega et al., 2022). In turn, this reduction in nutrient and phytochemical intake may further exacerbate depressive symptoms. This bidirectional relationship complicates interpretation of cross-sectional findings, as it remains unclear whether lower flavonoid intake precedes the development of depressive symptoms or arises as a behavioural consequence of them. Therefore, while cross-sectional studies provide valuable population-level insights, they cannot confirm causality. Longitudinal and intervention-based designs are needed to disentangle directionality and clarify whether increasing flavonoid intake actively contributes to improved mood outcomes, or simply reflects healthier overall lifestyle behaviours commonly observed in individuals with better mental health.

In summary, consuming a diet rich in flavonoid containing foods such as fruits, vegetables, and cocoa has been linked to a reduced risk of mood disorders, particularly depressive symptoms. Key flavonoid subclasses, such as anthocyanins, flavanones, and flavonols, have shown a significant inverse relationship with depressive symptoms, with stronger associations observed in large-scale studies. However, the specific food sources and measurements may play a critical role in these outcomes. Differences in study methodologies, including self-report dietary assessments, highlight the need for more accurate and diverse measures of flavonoid intake to further clarify these relationships. Further research, particularly in clinical populations, is needed to deepen understanding of how flavonoids impact mental well-being.

### *1.4.2 Experimental evidence*

It is clear that consuming larger quantities of flavonoids within the diet is likely to result in favourable mood outcomes, with evidence suggesting consuming a diverse range of flavonoids and their subclasses may result in desirable effects.

A key trial in the experimental literature within this field comes from Jacka et al. (2017), who conducted a 12-week RCT where participants with major depression received either social support, or nutritional counselling, focused on increasing fruits, vegetables, legumes and other items typically included in a traditional Mediterranean diet. Here, results showed a significant reduction in depressive symptoms (assessed with the Montgomery–Åsberg Depression Rating Scale (MADRS)), as well as remission in 32.3% of participants compared to those receiving social support. Following, Conner et al. (2017) found improved psychological well-being with increased motivation, vitality and flourishing compared to controls following consumption of two additional servings of fruits and vegetables for 14-days in low fruit and vegetable consuming young adults. In a longer intervention period, Kontogianni et al. (2020) found a decrease in depressive symptoms when participants were asked to add six portions of fruits and vegetables into their diet for an 8-week period. Collectively, these trials highlight the potential benefits of consuming diets, rich in plant diversity and flavonoids to benefit mood outcomes across a range of clinical and non-clinical groups.

Previous reviews have summarised this relationship, highlighting flavonoids may be suitable candidates for treatments of mood disorders (Ali et al., 2021; Ko et al., 2020; Pannu et al., 2021). Recently, a systematic review and meta-analysis from Jia et al. (2023) highlighted flavonoids seem to have an overall significant, beneficial impact on depression and anxiety, specifying that optimal doses lay between 50-100 mg/day with a treatment duration of 8-weeks. Much of the experimental work included in these reviews typically discuss only depression or anxiety as facets of mood. Sometimes both conditions are explored as outcomes, though inclusion criteria for other facets of mood seem to be restricted, for example in Jia et al. (2023), outcomes included in the review were listed as 'depression, anxiety, or mixed anxiety-depressive symptoms'. It could be considered that these outcomes may not encapsulate all changes in mood as a result of flavonoid interventions, such as transient mood changes alongside persistent mood disturbances such as anxiety and depression. Further, previous reviews have fewer restrictions on the source of flavonoid, leading to extracts as well as whole foods included in reviews. While this broader approach is valuable for understanding the overall impact of flavonoids on mood disorders, it can also introduce variability in the findings and limit comparability across studies. In example, Bondonno et al. (2017) report evidence of a synergistic relationship between the fibre and flavonoids in whole apples, likely mediated in part by the gut microbiota, which may enhance cardioprotective effects. This underlines the importance of studying flavonoids in the context of whole foods rather than in isolation. Focusing on whole food sources may therefore offer a more ecologically valid and practical framework, particularly for public health messaging, as it reflects real-world dietary habits and promotes easily administrable dietary strategies for improving mental health. Given these considerations, it is challenging to summarise the flavonoid and mood experimental literature from existing reviews. Subsequently, a more in-depth exploration of dietary flavonoids from whole foods and their impact on mood in a systematic review of the evidence will be provided in Chapter 2, where the specific evidence and potential therapeutic implications will be discussed in greater detail.

## 1.5. Flavonoids and cognition

### *1.5.1. Epidemiological evidence*

In addition to flavonoid-related mood effects, a large evidence base suggests that benefits also apply to cognitive function. In example, Yeh et al. (2021) found a higher intake of total flavonoids was associated with lower odds of subjective cognitive decline in a large sample of 49,493 women from the Nurses' Health Study and 27,842 men from the Health Professionals Follow-Up Study. Furthermore, this study showed that flavonoid-rich foods such as strawberries, citrus fruits, apples and pears were also associated with lower odds of subjective cognitive decline, highlighting that specific food sources and subclasses are associated with better cognitive outcomes. The findings from Yeh et al. (2021) are particularly interesting as highlight subjective cognition as an outcome, though objective measures of cognitive function are especially beneficial to explore cognitive outcomes following flavonoids using standardised and precise measures of cognition. As such, objective measures of cognition, such as the Mini-Mental State Examination, utilised in Letenneur et al. (2007), who found that after adjusting for age, sex and education, flavonoid intake at baseline was associated with better cognitive performance, as well as slower cognitive decline after a 10-year follow up period. In similar findings, Devore et al. (2012) showed that greater dietary intakes of blueberries and strawberries were associated with slowing cognitive decline, equivalent to delay cognitive aging by 2.5 years in their cohort of the Nurses' Health Study. Objective measures of cognitive function utilised in this cohort were the Mini-Mental State Examination; East Boston Memory Test: immediate and delayed recalls; category fluency; delayed recall of the Telephone Interview of Cognitive Status 10-word list; and digit span backward.

Wider evidence shows that larger intakes of flavonols within the diet are also associated with slower cognitive decline (Holland et al., 2023; Kesse-Guyot et al., 2012), alongside flavones, flavanones and anthocyanins (Samieri et al., 2014), highlighting that a range of subclasses and flavonoid-rich foods may improve cognition and slow cognitive decline. Much of the evidence for dietary flavonoids and cognition focuses on cognitive decline, particularly in aging populations. Here, there is greater scope for change as a result of flavonoid supplementation, thus offering a potentially effective intervention

for slowing the progression of cognitive impairment in individuals at risk of age-related cognitive decline. A recent systematic review and meta-analysis summarises this evidence, showing that majority of observational studies in this field were conducted with anthocyanins, though significant associations were also found for flavan-3-ols, flavonols and flavones, with higher intakes associated with better cognitive function and reduced risk for cognitive decline and dementia onset (Godos et al., 2024).

Though a range of subclasses seem to benefit cognitive function, one particular stand out subclass is anthocyanins. As with mood, habitual consumption of anthocyanin rich foods seem to benefit cognition over the lifespan. Recent data has elaborated on this relationship, whereby Lorzadeh et al. (2024) collected baseline data from older adults with mild cognitive impairment, conducted repeated 24hr food recalls to estimate anthocyanin intake and a range of cognitive tasks. Associations were found between high anthocyanin intake (>10 mg/day) and higher scores on delayed recall tasks compared with low consumers. In addition to memory, higher intake of dietary anthocyanins have been associated with improved executive functioning (EF) and faster reaction times. Further, MRI imaging in monozygotic twins showed those with higher anthocyanin intake at baseline had significantly larger hippocampal and para-hippocampal volumes after 12-years (Jennings et al., 2021). These brain regions are essential for cognition (Aminoff et al., 2013; Jarrard, 1993; Treves & Rolls, 1994; Tulving & Markowitsch, 1998), suggesting potential structural brain specific mechanisms could be a result of dietary anthocyanins. However, as stressed in section 1.4.1, causation cannot be inferred from cross-sectional studies due to potential bidirectionality of outcomes. Nevertheless, this supports that habitual intake of a range of flavonoid foods and subclasses, as well as specific subclasses, such as anthocyanins and flavonols which may slow cognitive decline and improve global cognitive function.

#### *1.5.3. Chronic interventions*

To date, there has been a significant number of experimental trials investigating the effects of flavonoids on cognition, whereby daily supplementation is likely to promote cognitive function in humans (Bell et al., 2015; Cheng et al., 2022; Lamport et al., 2012). Chronic interventions may benefit mood over time via specific mechanisms of action, such as upregulation of brain derived neurotropic factor (BDNF), or influencing the gut microbiome, though specific mechanisms are not yet known. Whilst there is no conclusive evidence for a specific type of food that may confer most benefit to cognition, it is thought that consuming foods for sustained periods such as cocoa, rich in flavanols, and berry fruits, rich in anthocyanins, may lead to benefits in cognition.

##### *1.5.3.1. Cocoa*

Cocoa has been a popular food source to explore its effects on cognitive function. Sloan et al. (2021) conducted a 12-week RCT with older adults, participants were randomised to 0, 260, 510, or 770 mg of cocoa flavanols per day. Results showed a positive dose dependent effect compared with the placebo on list learning memory. List learning performance was also associated with baseline diet quality, where participants with poorer baseline diet quality performed worse on this task at baseline. However their performance improved with flavonol intake, suggesting that an individual's starting dietary habits may influence the cognitive benefits they experience from flavonoid supplementation. Further analysis of these findings using voxel-based morphometry (VBM) with Magnetic Resonance Imaging (MRI) indicated that cocoa flavanols specifically target the dentate gyrus. This is a region of the hippocampus critical for memory formation and processing (Kesner, 2013), overall providing a neurobiological basis for how cocoa flavanols may enhance memory performance as a potential underlying mechanism for the cognitive benefits observed.

Benefits from flavanols in older adults can further be seen following an 8-week parallel groups intervention of a drink containing 993 mg, 520 mg, or 48 mg cocoa flavonols. While no significant changes were observed in global cognition, as measured by the Mini-Mental State Examination (MMSE), notable improvements were found in specific cognitive tasks, such as the Trail Making Test (TMT) and the Verbal Fluency test, for those consuming the higher flavanol doses (993 mg and 520 mg) (Mastroiacovo et al., 2015). The TMT is divided into two parts, A; which involves connecting numbered circles on paper as quick as the participant can, evaluating their processing speed and visual

scanning; and part B, which requires alternating between numbers and letters which demands not only processing speed but also EF. Significant improvements in both parts of the TMT, particularly among those who consumed higher flavanol doses, suggest that cocoa flavanols may enhance both processing speed and cognitive flexibility in older adults, potentially improving EF. Moreover, the improvements observed in these specific tests underscore the potential of cocoa flavanols to target more nuanced aspects of cognitive function, such as those related to EF, which are often impaired with aging (Salthouse et al., 2003; Tomaszewski Farias et al., 2009). Although no changes were seen in global cognition, the significant performance improvements on tests assessing processing speed and cognitive flexibility suggest that flavanols might have more targeted effects, especially on tasks that challenge higher-order cognitive abilities

Scores in the TMT have also been improved in postmenopausal women following cocoa consumption, whereby *n*=140 participants aged 50-64 were randomised to consume 10g chocolate (99% cocoa, 65.4 mg polyphenols) on top of their usual diet, or just stick to their normal diet in the control group for a period of 6 months (Garcia-Yu et al., 2022). A range of cognitive domains such as EF (Trial Making Test A-B (TMT-A, TMT-B)), verbal memory (Reys Auditory Verbal Learning Task (RAVLT)), working memory (Wechsler Adults Intelligence Scale (WAIS) Digit Span Backward), phonological fluency and category fluency, were taken. The findings of this trial showed a decrease of TMT-B time following daily consumption of cocoa which was not seen in the control. It should be considered here that only polyphenol consumption was recorded in this trial (65.4 mg/day), resulting in unknown doses of flavonoids contributing to this change in cognition. Additionally, this is a rather low polyphenol content compared with studies that show changes in mood and cognition, though highlights that low doses of polyphenol, when consumed in a chronic fashion may be enough to result in cognitive improvements.

A standout trial in cocoa flavanol supplementation is the COcoa Supplement and Multivitamins Outcome Study (COSMOS), which explored the effects of a cocoa flavonol supplement versus multivitamin over a range of outcomes. This randomised, double-blind, placebo-controlled trial utilised four intervention arms; (1) active cocoa extract (containing 500 mg/d flavanols), and an active daily multivitamin (Centrum Silver) (*n* = 5360); (2) active cocoa extract and multivitamin placebo (*n* = 5359); (3) active multivitamin and cocoa extract placebo (*n* = 5360); or (4) both placebos (*n* = 5363), with the primary aim to reduce the risk of cardiovascular disease (CVD) and cancer in 21,442 U.S older adults (>60years of age) (Rist et al., 2022). The trial was run as a hybrid trial, whereby multiple large scale remote interventions were conducted including in-person visits (COSMOS-Clinic, *n*=573), where physiological and neuropsychological measures could be taken, and online visits, where cognitive tasks could be completed (COSMOS-Mind, *n*=2262; COSMOS-Web, *n*=3960). This trial had few participants lost to follow up and high compliance, highlighting the feasibility of such large scale interventions with long supplementation periods. Vyas et al. (2024) explores the outcomes on cognition from the COSMOS-Clinic trial, where participants completed the Modified Mini-Mental State, Consortium to Establish a Registry for Alzheimer's Disease (CERAD), immediate and delayed recall trials of the East Boston Memory Test (EBMT), category fluency (naming animals and vegetables), Trail Making Test (TMT) and Digit Span Backward test. Outcomes for the COSMOS-Clinic were taken at baseline and 2 years follow up. In this cohort, daily supplementation with cocoa extract did not have any effect on global, or domain specific cognitive function. These results from the COSMOS-Clinic trial oppose earlier findings for cocoa and cognition (Garcia-Yu et al., 2022; Mastroiacovo et al., 2015; Sloan et al., 2021), however one key aspect of this trial is the length of supplementation being 2-years, whereas the other trials longest duration was 6-months (Garcia-Yu et al., 2022). This could be that the effects seen in these shorter trials are dependent on different mechanisms and may not be sustained over longer periods of time.

Indeed, changes in blood flow have been seen following cocoa flavanols (Mastroiacovo et al., 2015; Sorond et al., 2008). Specifically, Sorond et al. (2008) utilised transcranial doppler ultrasound in healthy older adults (*n*=34) following flavanol rich cocoa (900 mg flavanols/day) consumption versus flavanol poor cocoa (36 mg/day) for a two-week period. Here, blood flow velocity increased in the middle cerebral artery following the flavanol rich cocoa supplement at 1-week and 2-weeks of supplementation, showing cocoa supplementation can lead to significant improvements in cerebral

blood flow following even short supplementation periods as little as 1-week. Interestingly, one key finding from the overall COSMOS trial, was that following an intervention phase (median treatment length 3.6 years), participants randomised to the cocoa extract had reduced CVD death by 27%, but no other significant reductions in cardiovascular events or cancers (Sesso et al., 2022). Again, this underscores the potential cardiovascular benefits of cocoa, however as this was not coupled with changes in cognition in the COSMOS-Clinic trial, highlights the need to investigate further mechanisms associated with cognitive improvements following cocoa flavanol consumption, especially over sustained periods of supplementation, as it may be that changes in blood flow as a mechanism of action driving cognitive changes are limited to shorter supplement durations.

It is clear here that chronic cocoa flavanol supplementation studies have been conducted primarily in older adult populations with mixed effects. Studies on younger populations are more limited, however provide evidence that flavanols may provide benefits to cognition (Calderon-Garciduenas et al., 2013; Sumiyoshi et al., 2019). Calderon-Garciduenas et al. (2013) supplemented 30g dark chocolate cocoa (680 mg flavonoids) for 10 days to children ($n$=18, mean age 10 years old). A range of outcomes were taken, including blood samples, Magnetic Spectroscopy Imaging (MRS), and cognition (Wechsler Intelligence Scale for Children-Revised (WISC-R)). Results showed that 83% of the sample had significant improvement in the short memory tasks as part of the WISC-R. The authors performed binomial tests, enabling them to observe how many participants improved, however considering this small sample size, this choice of test, could have led to loss of sensitivity to detect true effects. It is also important to consider dosage for why these trials may have different outcomes, for cocoa flavanols it seems higher doses, such as 770 mg, 993 mg, 680 mg (Calderon-Garciduenas et al., 2013; Mastroiacovo et al., 2015; Sloan et al., 2021) may confer to improvements in cognitive function and may also explain why the COSMOS-Clinic trial did not see effects following 500 mg cocoa flavanols.

#### *1.5.3.2. Berry fruits*

Another popular intervention food is berry fruits, which are rich in anthocyanins. These have also risen in popularity in RCT's where they have demonstrated to host several benefits to cognitive function. Executive functioning (EF), for example, encompasses a range of cognitive processes which are essential for goal-directed behaviour including planning and decision making. EF also includes working memory (the ability to hold and manipulate information while performing a task); cognitive flexibility (ability to switch between different goals or rules smoothly, important for adaptability and task-switching) and inhibitory control (the ability to suppress or control automatic responses in favour of more goal directed or appropriate behaviours) (Diamond, 2013). Following a 12-week RCT, of either Wild Blueberry (WBB) (264 mg anthocyanins) versus a placebo matched control in $n$=61 65-80 year olds, Hein et al. (2021) found significant improvements in accuracy scores following WBB treatment which was not evident in the placebo. This effect was also seen for episodic memory (measured with the Rey's Auditory Verbal Learning Test (RAVLT)), showing improvements in several cognitive domains in this population following chronic WBB. In an additional older adult trial, Miller et al. (2018) provided participants ($n$=37, aged 60-75) with WBB (24 g/day, equivalent to 1 cup of fresh blueberries containing ≈36 mg/g total phenolics and ≈19.2 mg/g anthocyanins). Following treatment, participants in the blueberry group had fewer errors in the California Verbal Learning test, a measure of verbal memory and reduced switch cost on the task switching test, meaning that smaller increases in reaction time were made when switching between rules of the cognitive task, indicating better cognitive flexibility. Further EF and memory benefits have been seen in older adult populations following WBB containing 302 mg anthocyanins (Wood et al., 2023) and following 3 months of a purified extract at 100 mg (WBE111) (Whyte et al., 2018).

EF improvements have further been shown in 7-10 year olds, whereby 4-week WBB supplementation (766 mg total polyphenols; 253 mg anthocyanins; equivalent to 240 g fresh blueberries per day) was seen to maintain higher accuracy on incongruent trials of the Modified Attention Network Task (MANT) (Barfoot et al., 2021). In this task, load and congruency are altered between trial types, whereby high load and incongruent trials are more cognitively demanding, compared to low load and congruent trials (for a more detailed task breakdown, see Chapter 5). This suggests that benefits of anthocyanin rich interventions are seen on the harder aspects of a task, demonstrating its benefits to

EF. Further, chronic WBB consumption resulted in changes to different polyphenol metabolites over the 4-weeks, though change in total polyphenols was non-significant. It is important to note, that this RCT was a pilot study to explore underlying mechanisms of action and associated behavioural effects in this cohort. Whilst changes in EF were seen, repeat testing in a larger sample of participants is necessary. In another young sample, Velichkov et al. (2024) studied the effects of chronic WBB supplementation in emerging adults ($n$=60, mean age 20 years) with moderate to severe depressive symptoms. Participants received either a 22g WBB drink containing the equivalent of 1 cup or 150 g fresh fruit with 121 mg anthocyanins or a placebo matched control for 6-weeks. Following the intervention, participants in the WBB group had significant improvement in EF, as measured by the Task Switching Test (TST). Fossati et al. (2002) reports that EF is often worse in depressed subjects, whereby EF may also predict poorer outcomes in depression. Therefore, finding EF improvements following berry interventions in a range of different ages, and especially in a depressed cohort highlights how influential diet, especially diets that are anthocyanin rich is to both cognitive function and mood.

#### *1.5.3.3. Soy*

Soy supplementation is another popular food source to see changes in cognitive function. The evidence here mostly focuses on postmenopausal women due to the role isoflavones in soy play as agonists at oestrogen receptors, which may improve a range of physiological symptoms as well as cognitive function. Duffy et al. (2003) supplemented postmenopausal women ($n$=33) who were not receiving hormone replacement therapy, with a soy supplement containing 60 mg isoflavone equivalents/day for 12-weeks. Participants completed a range of cognitive outcomes, on top of mood, sleep and menopausal symptom questionnaires. Those receiving the isoflavone treatment showed an improvement in sustained attention (Paced Auditory Serial Addition Test) and episodic memory (Weschler Memory Scale). No changes were seen following treatment for mood or menopausal symptoms, however this study suggests that cognition benefits can be observed following soy supplementation, independent of changes in mood and wellbeing. Improvements following soy supplementation have also been found for this population in tests of cognition such as category fluency, verbal memory following a longer supplementation period of 6-months with 110 mg soy isoflavones per day (Kritz-Silverstein et al., 2003).

It is not only postmenopausal women that see cognitive benefits from soy. In a 12-week double blind crossover trial, healthy male participants 30-80y ($n$=34) received soy isoflavone capsules containing 116 mg isoflavones for 6 weeks in addition to a placebo matched control (Thorp et al., 2009). Isoflavone supplementation significantly improved spatial working memory, though no other cognitive outcomes, suggesting that soy isoflavones can be beneficial in improving cognition in populations outside postmenopausal cohorts, however these findings may only be restricted to one cognitive outcome. The authors commented that these effects may be explained by activation of oestrogen β receptors (ERβ), which are abundant in brain regions such as the hippocampus (Courtney et al., 1998). Since men also have circulating oestrogen, ERβ activation could still play a role in the demonstrated improvements in cognitive function (Lee et al., 2004).Evidence also suggests that soy may benefit a range of cognitive outcomes in young adults following either a high soy (100 mg/day isoflavones) or low soy (0.5 mg soy isoflavones/day) diet for 10 weeks (File et al., 2001). In this trial, participants had significant improvements in short term and long term memory in addition to mental flexibility following the high soy diet, however only females had benefits from letter fluency tests following the high soy diet. Overall, this stresses that soy benefits can extend to younger populations, however female participants may benefit more from soy, potentially due to underlying mechanisms, such as oestrogenic effects (Cui, Birru, et al., 2020). As such, due to these potential mechanisms of action, this particular flavonoid-rich food may be of benefit towards certain populations such as postmenopausal women, or during the postpartum where similar trajectories are seen for oestrogen (Dukic & Ehlert, 2023; Dukic et al., 2024; Sherwin, 2000). There are few studies investigating the effects soy products on mood and cognition in the postpartum. However, due to the unique mechanism soy may act on these outcomes, warrants further investigation.

On the other hand, not all studies show benefits for cognitive function following soy supplementation, in example six months of 100 mg/day isoflavone treatment was not associated with any improvements in cognition in patients with Alzheimer's disease (Gleason et al., 2015). Additionally, a number of studies in postmenopausal women were not able to detect effects over a range of supplementation periods (range 6-weeks to 12-months), receiving a range of doses (60 mg - 99 mg isoflavones) (File et al., 2005; Ho et al., 2007; Howes et al., 2004; Kreijkamp-Kaspers et al., 2004), suggesting the evidence based is mixed for this food source, and may be dependent on sex, dose, and cognitive domain tested.

#### *1.5.3.4. Other flavonoid sources*

It is clear that cognitive benefits can be seen following a range of flavonoid-rich foods. Additional benefits have been found following Gingko extract (Herrschaft et al., 2012; Ihl et al., 2011), tea (de la Torre et al., 2016) and orange juice (Kean et al., 2015). Interestingly, (Kean et al., 2015), found improvements in global cognition following consumption of high flavanone (305 mg) orange juice compared with a placebo matched control (37 mg flavanone) in healthy older adults ($n$=37). This trial was conducted with a crossover design, separated with a 4-week out. Results here showed that improvements in cognitive function were maintained after the 4-week washout period, suggesting potential carry over effects and that the benefits linked to the high flavonoid drink may have continued into the second arm of the trial. Although this may be problematic due to potential residual effects of the drink in the subsequent phase, the findings imply that the benefits of the intervention could persist beyond the supplementation period. This has important implications for the potential lasting effects of day-to-day flavanone consumption. Studies should therefore include follow-up visits after a break from the intervention to assess whether any effects of flavonoids are sustained over longer periods.

Finally, mixed flavonoid-rich food interventions have shown improved cognitive function. Neshatdoust et al. (2016) recruited participants (26-70 years) who consumed an average of 3 portions of fruit and vegetables per day at baseline. Participants were assigned to one of three groups: a high-flavonoid (HF) fruit and vegetable group, a low-flavonoid group (LF), or a control group who maintained their habitual diet. HF foods were defined as containing >15 mg/100 g of total flavonoids and LF foods as containing <5 mg/100 g. Over the 18-week intervention, participants in the HF and LF groups increased their fruit and vegetable intake by 2 portions every 6 weeks, resulting in total flavonoid intakes of 49, 121, and 198 mg/day in the HF group, and 3, 6, and 7 mg/day in the LF group. The results showed improvements in global cognition following the HF intervention, which was comprised of EF and episodic memory and secondary measures of working memory, spatial memory, implicit memory, attention and information processing and psychomotor speed. Mirroring these results, increases in serum Brain Derived Neurotrophic Factor (BDNF), were found following flavonoid consumption in the HF group only, BDNF is a key protein to learning and memory (discussed in greater detail in 1.7.3), therefore, this increase signifies the importance of flavonoids for brain health and cognition, though effect may only be apparent when high flavonoid foods are consumed for a sustained period.

Not all flavonoid and cognition studies produce significant results', Camfield et al. (2012) randomised participants ($n$=63) to receive either a flavanol drink containing 250 mg or 500 mg cocoa flavanols versus a placebo matched control for a period of 30-days. No changes were seen in spatial working memory, however, significant changes were seen in Steady State Probe Topography, utilised to assess neurocognitive changes. Authors found changes in amplitude and phase following the 30-day cocoa intervention in regions linked with memory encoding, such as the posterior parietal and centro-frontal sites. The lack of behavioural findings in this study may again be attributed to dose, whereby higher cocoa flavanol doses, over 500 mg may be attributed to improved cognition, whereas Camfield et al. (2012) highest dose was 500 mg. Though the changes in physiological measures following cocoa intervention may suggest that flavonoids may lead to neurocognitive benefits, and underlying mechanisms to support brain health in as little dose as 250 mg, though higher doses may be required for observable behavioural changes. Similar findings were also found in Boespflug et al. (2018) who did not find changes in cognitive function following daily blueberry supplementation on older adults with mild cognitive impairment (MCI). In a double-blind, parallel groups design, participants

consumed either blueberry intervention (269 mg anthocyanin/day) or placebo matched control for 16-weeks. No significant differences between groups were found at follow up, though a marginally significant trend was found where accuracy was higher in the blueberry group in the 1-back condition of the N-Back, a working memory task, with 1-back being the least cognitively demanding trial. It should be noted that this study had small sample sizes ($n$=8 per group) which was sufficient for neuroimaging analysis, though likely underpowered for detecting behavioural outcomes. As with Camfield et al. (2012), though no behavioural outcomes were significantly different following the intervention, physiological changes were seen. In Boespflug et al. (2018), Blood Oxygen Level Dependent (BOLD) signal increased in the left pre-central, left middle frontal gyrus, and left inferior parietal lobe following blueberry supplementation relative to pre intervention baseline. A further explanation of blood flow in relation to cognitive changes can be seen in chapter 1.7.4, though overall suggests that flavonoid compounds influence central signalling pathways, which play a role in changes to neuro-vascular interactions, in regions supporting higher cognitive functioning and attention (Boisgueheneuc et al., 2006; Singh-Curry & Husain, 2009). Other studies supplementing older adults with early, or subjective memory complaints have however seen improvements following chronic anthocyanin supplementation (Krikorian et al., 2010; McNamara et al., 2018). Interestingly, McNamara et al. (2018) used the same dose as Boespflug et al. (2018) (269 mg anthocyanins), for 24-weeks supplementation, finding improved cognition in the Hopkins Verbal Learning Task (HVLT) recognition memory domain for the blueberry group which was not seen in the placebo, fish oil, or combined blueberry and fish oil arms. This suggests that flavonoids, particularly anthocyanins may be particularly beneficial for participants with cognitive impairments.

It is therefore clear that chronic flavonoid supplementation, particularly with foods like cocoa and berry fruits, shows potential benefits for cognitive function, especially in older adults. Daily intake of cocoa flavanols and berry anthocyanins may improve cognitive performance in areas like EF, memory, and mood. However, the evidence is mixed, possibly due to differences in supplementation duration or dosage. The mechanisms behind these effects may involve changes in neurovascular interactions, blood flow, and neural signalling, but further research is needed to better understand how long-term flavonoid intake influences cognition.

### *1.5.2. Acute interventions*

Given the promising effects of chronic flavonoid interventions on cognition, it is equally plausible that acute mechanisms could play a role in cognitive enhancement as well. While chronic supplementation may lead to longer term changes in brain function and mood, acute interventions, exploring the effects of a single dose over a shorter period, may exert more immediate effects on cognition and may be beneficial for situations that require mental performance over short timeframes, such as high-stress environments or to optimise acute mood and cognitive function for a specific event or performance over the course of the day.

As mentioned, it is clear that EF improvements are seen following chronic supplementation, however this area of cognition has also been found to improve following single doses of flavonoids. A large number of these trials have been conducted in young children (Barfoot et al., 2019; Whyte et al., 2016; Whyte & Williams, 2012, 2015; Whyte et al., 2017), as this group is undergoing biological changes in the brain, such as synaptic pruning and maturation of the prefrontal cortex (Best & Miller, 2010; Blakemore & Choudhury, 2006). Given this heightened neuroplasticity, there is significant potential for flavonoids to support vascular function, enhance cerebral blood flow, and modulate neurotrophic factors such as BDNF during this critical period, potentially leading to both immediate cognitive benefits and longer-term developmental gains. Whyte et al. (2016) supplemented participants ($n$ = 21; 7–9 year olds) with a blueberry intervention containing either control, 126.5 mg or 253 mg anthocyanins. Cognitive tasks were presented at 1.5, 3 and 6 hours following the intervention, including an Auditory Verbal Learning Task (AVLT) and Flanker task to measure both episodic memory and EF. Following the intervention, both the 126.5 mg and 253 mg anthocyanin treatments produced better performance in delayed word recognition. Only the 253 mg anthocyanin treatment however, produced improved accuracy on incongruent trials, with strongest effects 3 hours post supplementation. Barfoot et al. (2019) also found improvements in a similar EF task, whereby

quicker reaction times were seen in 7–10-year-old children 2 hours following consumption of 253 mg anthocyanins in addition to improvements in the AVLT. Combined, these studies suggest that blueberry drinks containing 253 mg anthocyanins are likely to elicit effects in cognition within this cohort.

Typically, benefits following flavonoid consumption are seen in EF tasks during the more cognitively demanding trials such as incongruent, high load and fast trials. This effect was seen in children in Barfoot et al. (2019); Whyte et al. (2016) and Whyte et al. (2017). However, similar improvements are also seen in reaction times and accuracy on congruent trials (Whyte et al., 2020), these trials are less cognitively demanding compared with incongruent, therefore despite this opposing previous work, does show the wider benefits of flavonoids for EF. Contrasting research further comes from Whyte and Williams (2015) who conducted a crossover trial with children ages 8-10 ($n$=14) where participants consumed a blueberry intervention or a matched placebo control. Outcomes were taken 2 hours following the intervention, with outcomes being the Go-NoGo (inhibitory response), RAVLT (episodic memory), Stroop test (EF), Visuospatial N-Back (working memory), and Object location task (spatial memory). In this study, no effects were seen for the Go-NoGo, Stroop, N-Back and Object location task, however the RAVLT was found to be sensitive, whereby word recall improved significantly following the blueberry treatment, but not the placebo. These results support the ongoing evidence where episodic memory has shown to benefit following flavonoid consumption in both acute and chronic interventions, however it is of interest that no effects were found in EF and inhibitory response tasks, opposing the previous body of evidence. It could be suggested however that the dose of 143 mg anthocyanins may have been too small to detect an effect for this region of cognitive function, whereby in example Barfoot et al. (2019) and Whyte et al. (2020) utilised 253 mg anthocyanins and found improvements in accuracy and reaction time in EF tasks. Additionally, the intervention used in Whyte et al. (2016) combined 100ml semi-skimmed milk with both interventions, however later research has since shown that milk may hinder the absorption of polyphenols (Yildirim-Elikoglu & Erdem, 2018). As a result, the effects in other cognitive areas may not have been evident, as the reduced uptake of blueberry polyphenols led to a dose that was insufficient to produce further cognitive benefits. Overall, this may suggest that smaller doses of anthocyanins may elicit benefits to episodic memory, though higher doses may be required for EF following acute supplementation, highlighting a potential dose-dependent effect. It is clear here that again, anthocyanin rich and in particular berry based interventions are key for changes in cognitive functioning, with a large focus on children of school age, where brain plasticity is likely high.

Acute improvements have also been found in older populations, Scholey et al. (2010) found improvements in the Serial 3's following consumption of both 520 mg and 994 mg cocoa flavanols which was not seen following consumption of a matched control drink. Interestingly, the higher cocoa flavanol drink also resulted in quicker response times in the RVIP task, however this came at a cost to accuracy. Additionally, Lamport et al. (2020) recruited healthy young adults 18-24 ($n$=98) who were randomised to consume either a 35g dark chocolate bar or calorie matched, low flavonoid, 35g white chocolate bar. Only episodic memory was tested for cognition (using the RAVLT) alongside mood questionnaires (BL-VAS; PANAS). Participants allocated to the dark chocolate condition had significantly better scores on the RAVLT, 2-hours following the intervention, indicating better episodic memory performance following acute flavonoid consumption. One limitation of this study and its findings, is that exact flavonoid content could not be ascertained, the authors did however use polyphenol databases to estimate flavonoid in the chocolate bars, estimating content to be 83 mg in the 35g dark chocolate bar. In the context of the literature above of acute doses on cognition this is not a large dose of flavonoids, therefore shows that in doses as small as 83 mg can elicit effects. It is also noteworthy that smaller doses, such as the 126.5 mg dose in Whyte et al. (2016) seem to lead to changes in effects for the RAVLT, again showing that this measure of cognition seems to be particularly sensitive to flavonoid interventions, even at low doses. In support of these cognitive changes within the 2hr timeframe, acute physiological changes have been found following cocoa flavanol supplementation. Increases in cerebral blood flow following the consumption of flavonoid-rich cocoa, has been demonstrated using MRI arterial spin labelling. Studies have shown this effect in healthy older adults after consuming a 493 mg flavanol cocoa drink (Lamport et al., 2015), as well as

in healthy young females following a 519 mg flavanol drink (Francis et al., 2006), suggesting a potential mechanism of action.

Anthocyanin rich interventions have further been conducted in populations outside of school children, Whyte et al. (2021) found that 8 hours following a single dose of WBB (475 mg anthocyanins), participants in the placebo group had a decline in RAVLT performance which was not seen in the WBB intervention, suggesting WBB attenuated this decline. Fewer errors were also seen in an EF task (Go/No-Go) with fewer errors on the cognitively demanding trial compared to placebo. Participants in this trial were between 40-65 years old, indicating that acute flavonoid interventions may be able to produce cognitive changes throughout the lifespan. However, this was a higher dose, at nearly double seen in previous trials which typically served 253 mg anthocyanins, considering a dose response relationship has been elicited in both epidemiological and chronic supplementation studies, which is also mirrored by their mechanisms of action, potentially a higher dose may be necessary to lead to effects in this population.

Comparatively, Keane et al. (2016a) did not find effects at 1, 2,3, and 5 hours following a 60ml dose of Montmorency tart cherry concentrate in 45-60 year olds ($n$=30) on tasks measuring psychomotor speed and attention (digit vigilance), working memory (Rapid Visual Information Processing (RVIP)) and EF (Stroop). However, Keane et al. (2016a) did find physiological effects, such as a reduction in systolic blood pressure following the intervention, with peak reductions occurring around 3 hours post intervention, suggesting anthocyanin effects on vascular function, but not cognition. One difference between these two studies that may be driving the differences in effects is that Whyte et al. (2021) took outcomes at 8 hours following a high dose of anthocyanin, whereas Keane et al. (2016a) tested at latest 5 hours following supplementation with lower anthocyanin dose, estimated at 68.0 (SD 0.26) mg cyanidin-3-glucoside/l, 160.75 (SD 0.55) mean gallic acid equivalent/l. It may be that higher doses, with outcomes measured around 8 hours are likely to emit better outcomes for this specific cohort. Another study that did not find effects following anthocyanin intake in this cohort comes from Igwe et al. (2017), who provided participants with either (1) a single dose of 300 mL (369 mg total anthocyanins) or (2) 3 x 100-mL servings (123 mg total anthocyanins/serving) of the same plum juice at 0, 1, and 3 hours using a crossover design. Participants were two separate groups of 65+ ($n$=12) and 18-45 year olds ($n$=12). Like in Keane et al (2016a), decreases in blood pressure were seen following the intervention in both age groups, which was more pronounced following the single dose of anthocyanins. However, no differences were seen following a broad range of cognitive outcomes, such as EF and episodic memory. The lack of effects is noteworthy here, considering that the study had a reasonable dose of anthocyanins, timing of outcome measures may be driving these lack of effects, where outcomes in Igwe et al. were taken at 0 and 6 hours. It could therefore be that the absence of a significant effect could be attributed to the timing of cognitive task administration, missing the initial peak action time following anthocyanin consumption, by which the authors comment could be driven by polyphenol reuptake in the colon (Wang et al., 2015).

It may however be the food source responsible for the lack of effects here, as attenuation in cognitive decline was seen 6 hours following a mixed berry (blueberry, strawberry, raspberry and blackberry) intervention (Whyte et al., 2019). This was conducted in young adults however, suggesting further research may be required to investigate if berry based anthocyanins may have greater benefits to cognition versus plums and cherries in both young and middle age adults. Outside of anthocyanin rich foods, acute improvements on tests of EF and processing speed were found 6 hours following flavonoid-rich orange juice consumption versus a low flavanone control (Alharbi et al., 2016), supporting a range of food sources may support cognition.

Regarding older adults, there is also a larger scope for improvement for cognitive outcomes due to the natural cognitive decline seen in this age group. As with school age children, improvement across a range of cognitive domains have been seen following acute flavonoid consumption. Bell and Williams (2019) found improved word recall 1.5 hours following 200 mg and 400 mg doses of Haskap berry extract. To note, this intervention was extract based, rather than the whole food, which typically provide much higher concentrations of flavonoids compared to the whole food, which may therefore have different effects on cognitive function. This effect following polyphenol extracts has also been

seen following a combination of grape and blueberry extracts (Philip et al., 2019), and wild blueberry extracts on healthy older adults (Cheng et al., 2024) highlighting the potential of flavonoid extracts also benefitting cognitive function alongside consumption of the whole food and freeze-dried varieties.

It is clear that interventions using various food sources with different flavonoid sub-classes lead to varied results, influenced by factors such as timing, dosages, and the specific traits of the populations under study. For example, the positive effects of blueberries on cognition in older adults and children seem to be primarily focused on episodic memory, while improvements in EF are more consistently observed in young adults (Ahles et al., 2021). These differences in cognitive domains could reflect age-related variations in the capacity for improvement in underlying neuronal structures. One key takeaway from this literature is that anthocyanin rich interventions may benefit cognition over the lifespan. Many reviews have summarised these effects, suggesting that beneficial cognitive effects are apparent following anthocyanin rich intervention, with stronger effects found in attention and EF tasks in acute studies, whereas memory outcomes may be improved following longer supplementation periods, however population and dose also play a key role (Ahles et al., 2021; De Amicis et al., 2022).

Regarding acute effects of wider polyphenol intake, Hepsomali et al. (2021) observed acute polyphenol consumption may improve processing speed in measures of attentional processes such as the RVIP in a meta-analysis. The findings of improved cognition following polyphenols was further supported in Cheng et al. (2022), who observed similar effects in their meta-analysis whilst specifically focussing on flavonoid supplementation. Overall, Cheng and colleagues found largest effects on cognition following cocoa interventions, though the authors highlighted cocoa studies were the most commonly included studies with 56 out of 80 reviewed studies in the review. Results here also reveal that chronic interventions seem to benefit cognition in their included studies. These chronic flavonoid interventions had an overall small but significant benefit to cognition, whereas acute interventions overall approached significance, opposing results following Ahles et al. (2021) and Hepsomali et al. (2021). However, a caveat of these chronic interventions was that durations less than 6-weeks did not produce significant effects, though durations for greater than 6-weeks produced significant benefits for cognition, highlighting that longer supplementation periods may be key for cognition, as with mood.

Regarding dose, Cheng et al. (2022) suggests low and medium doses may be optimal for cognitive effects. This was quantified based on habitual dietary averages for flavonoid-rich foods, in example berry and cocoa low doses ranged from 0-349 mg, and high doses were 700+ mg, comparatively and, low doses of citrus were 0-74 mg and high doses were 150+ mg. This is in line with previous systematic reviews, such as Ammar et al. (2020) who's review of thirteen studies identified that larger doses of polyphenols (>500 mg/day) can attenuate cognitive decline over 3-6 months, and smaller doses may only be beneficial over a shorter timespan of 1 month. This signifies that though specific dose ranges are important to observing changes for cognitive health, consideration of length of supplementation is also important. Lamport and Williams (2020) provide an overview of published systematic reviews and meta-analyses on polyphenol supplementation and cognitive function, summarising seventeen reviews that span a broad evidence base. The authors concluded that due to the significant heterogeneity in the data, no definitive conclusions could be drawn regarding factors such as dose, duration, population sensitivity, or specific cognitive domains. While this review primarily focuses on the broader effects of polyphenols rather than flavonoids specifically, which may influence the overall conclusions, combining it with findings from Cheng et al. (2022) which adds a more nuanced perspective, both overall suggest that flavonoids and the wider family of phytochemicals are beneficial to both reducing cognitive decline and benefitting cognitive performance, though specific aspects such as dose, duration and food type requires further investigation.

### *1.6. Summary of the effects of flavonoids on mood and cognitive function*

Numerous studies suggest that a healthy diet rich in fruits, vegetables, legumes, nuts, and whole grains can lower the risk of mood disorders, with flavonoids playing a key role. Flavonoid-rich foods have been linked to reduced depressive symptoms in both Western and Eastern populations, though

food sources vary by region. Specific subclasses of flavonoids, like anthocyanins, have shown strong associations with better mood outcomes, with clinical studies suggesting a dietary deficit of anthocyanins in individuals with depression.

Experimental research supports the potential of flavonoids to improve mood, with randomised controlled trials indicating that flavonoids may be effective in treating mood disorders like depression and anxiety. Optimal doses are typically between 50-100 mg/day for 8 weeks. Though many studies focus on depression and anxiety, future research should explore broader mood changes and refine the source and dosage of flavonoids.

Flavonoids also benefit cognition, particularly in young and aging populations. Higher intake of flavonoids, especially from foods like berries, citrus, and apples, is associated with lower risk of cognitive decline. Experimental evidence further supports flavonoid supplementation for cognitive health, with studies showing improvements in EF, memory, and processing speed. Specific foods such as blueberries have shown acute cognitive benefits in both children and older adults whist chronic flavonoid supplementation (lasting over 6 weeks) also offers significant cognitive benefits, suggesting that both short-term and long-term interventions can enhance cognitive function, though this effect may be dependent on dose, length of intervention and cognitive domain.

### *1.7 Bioavailability and mechanisms of action*

#### *1.7.1. Bioavailability*

Health benefits of flavonoids are dependent on bioavailability and metabolism in the body, which is easily influenced by other compounds and nutrients consumed in the diet. Kamiloglu et al. (2021) summarises this process, whereby it's estimated that 5-10% of total flavonoid intake is absorbed in the small intestine following deconjugation reactions. The remaining processing occurs in the large intestine and liver, where flavonoids undergo further microbial metabolism, conjugation, and modification, ultimately enhancing their bioavailability and bioactivity for absorption. However, it's important to note that when consumed with other foods, and as part of the food matrix, macro and micro-nutrients are thought to have a significant effect on flavonoid bioavailability (Jakobek, 2015) as they can either enhance or inhibit the absorption, metabolism, and overall bioactivity of flavonoids, highlighting the complexity of flavonoid bioavailability.

#### *1.7.2. Monoamine oxidase*

A hypothesis for how flavonoids may benefit mood is via the mechanism of monoamine oxidase (MAO). MAO metabolises monoamine neurotransmitters such as serotonin, dopamine and norepinephrine in the brain, and subsequently elevated MAO levels have been associated with mood disorders such as depression (Mulinari, 2012). Introduction of monoamine oxidase inhibitors have further been found to have therapeutic benefits (Jenkins et al., 2016) where they are commonly used in affective disorders to increase brain levels of dopamine, noradrenaline and serotonin (5-HT), thus often resulting in improved mood (Youdim et al., 2006). The blood-brain barrier is a key feature of the central nervous system microvasculature that controls the exchange of cells, molecules, and ions between the bloodstream and the CNS (Daneman & Prat, 2015; Zlokovic, 2008). Polyphenols, have been shown to cross the blood brain barrier (Vauzour, 2012), evidenced by localisation of flavonoids within the brain in animal studies. In example, epicatechin was detected in rat brain tissue following oral administration (100 mg/kg body w/day) for 1, 5 and 10 days (Abd El Mohsen et al., 2002). After crossing the blood brain barrier, flavonoids have been reported to act as a MAO inhibitor (Meyer et al., 2006; Youdim et al., 2004), which is likely to benefit mood and mental health (Dreiseitel et al., 2009).

This theory also extends to improvements in cognition whereby acute supplementation with cold-pressed blackcurrant juice found to inhibit MAO and improve cognition (Watson et al., 2015). An interesting finding with this trial was that MAO was inhibited following consumption of the juice, though not the freeze-dried blackcurrant powder, indicating that the way the intervention is prepared may influence underlying mechanisms and cognitive outcomes. Few clinical studies measure MAO

levels alongside cognitive and mood outcomes, however it is worth noting that in vitro and animal studies have shown further MAO inhibition for a range of flavonoid subclasses, such as flavonols, flavones, flavan-3-ols, often found in berries, leafy green vegetables and cocoa (Jäger & Saaby, 2011) indicating this may be a key underlying mechanism following consumption of a range of flavonoid-rich foods.

### *1.7.3. Neuroplasticity*

There is also evidence that flavonoids may regulate mood via maintaining neuroplasticity. One key study in this field includes work from Williams et al. (2008) whereby CREB (cAMP response element-binding protein) and BDNF activity were assessed to determine the effects of chronic (12-week) blueberry supplementation in aged animals. CREB, a transcription factor activated by phosphorylation, plays a key role in regulating genes involved in memory and neuron survival, including BDNF, which supports neuronal plasticity and survival (Bekinschtein et al., 2007). The results showed that CREB phosphorylation in the hippocampus was significantly increased in aged animals supplemented with blueberry, reaching levels similar to those in young control animals. In contrast, CREB phosphorylation was significantly reduced in the brains of control-fed aged animals, indicating increased neuronal degeneration in memory-related regions. Furthermore, BDNF levels were also significantly increased in the blueberry-fed rats compared to control-fed rats, in addition to the activation of Akt, mTOR, and increased levels of Arc/Arg3.1 in the hippocampus, suggesting the involvement of pathways related to de novo protein synthesis. These mechanisms were correlated with spatial working memory improvements, thus indicating the blueberry intervention may promote neuron growth and survival in memory specific regions leading to significant behavioural changes. It has also been established that those with mood disorders, such as anxiety and depression have a reduction in circulating BDNF (Hashimoto et al., 2004; Lee & Kim, 2010). A review from German-Ponciano et al. (2022) concluded that flavonoid supplementation in rodents has the ability to reverse depressive behaviours via increasing BDNF levels, with evidence suggesting this can happen in as little as 14-days with daily administration of flavones (baicalein at 10, 20, and 40 mg/kg via intraperitoneal injection).

Regarding human trials, evidence from Neshatdoust et al. (2016) showed that higher baseline serum BDNF levels were associated with better global cognition, showing that this relationship is prevalent in humans as well as animal trials. Following their intervention (as described in 1.5.3) results showed improvements in global cognition following the intervention which was in parallel with increases in serum BDNF following both a high flavonoid diet as well as a shorter flavonol intervention. WBB has also been shown to attenuate the decline in plasma BDNF concentrations compared to the control one hour following WBB supplementation in older adults (n=18, 579 mg of anthocyanidins); although this effect was not statistically significant, blood samples collected at this time point revealed a trend towards higher plasma levels of brain-derived neurotrophic factor (BDNF) in the blueberry condition (Dodd et al., 2019). However, cognition was not assessed at this time, making it impossible to determine if the neurochemical changes are linked to cognitive outcomes in this short timespan, though suggests that trend towards changes in physiology following flavonoids can be seen in within this timeframe. Further, though these findings do not necessarily underpin the neuroplasticity mechanism for mood outcomes, where cognitive improvements are observed, mood enhancements may also occur, given the overlapping neural pathways involved in both functions (Price & Drevets, 2012).

### *1.7.4. Blood flow*

Research has shown that flavonoid supplementation enhances blood flow, indicating a potential additional mechanism by which these compounds may improve behavioural outcomes. Initial studies have focused on the vasoactive effects of flavonoids, often assessing flow-mediated dilation (FMD) in peripheral arteries, such as the brachial or carotid, as a key measure of vascular function. A review on the effects of flavonoid supplementation on FMD responses from Kay et al. (2012) revealed improvements both acutely and chronically following supplementation. Specifically, acute FMD

responses ranged from 2.33% to 3.68%, while chronic responses were more modest, ranging from 0.17% to 1.30%, with subclasses such as epicatechin, catechin, and procyanidins producing more significant acute FMD effects (ranging from 3.22% to 3.38%).

This methodology was further elaborated in a trial by Rodriguez-Mateos et al. (2013), who observed increases in flow-mediated dilation (FMD) at both 1-2 hours and 6 hours following the consumption of three different doses of WBB (766 mg, 1278 mg, and 1791 mg total polyphenols), in line with peaks in circulating metabolites. In a second arm of the study, the effects of the lowest dose were evaluated 1-hour post-consumption, showing a dose-dependent increase in FMD up to 766 mg of total polyphenols, beyond which the response plateaued. These results suggest that 766 mg may represent an optimal dose as well as optimal timeframe to detect FMD responses from supplementation. Moreover, in a later trial Hein et al. (2021) a lower dose of 260 mg was found to improve FMD response by 0.86% following consumption of WBB for 12-weeks. This further shows the potential of WBB to improve vascular function over longer timeframes at lower doses, however an interesting finding of this trial was improvements in EF (measured by task switching) as well as short term memory (measured by the RAVLT) following the intervention. Improvements in cognitive functioning have been shown following chronic WBB supplementation in chapter 1.5.2, however, this study goes further to suggest that FMD responses could serve as an underlying mechanism for cognitive improvements.

An additional measure of this mechanism of action is via cerebral blood flow, often measured with fMRI, which uses blood oxygenated level-dependant (BOLD) signals to reflect changes in blood oxygenation in brain regions, giving an indirect measure of neural activity (Logothetis & Wandell, 2004). The mechanisms underlying these effects are thought to be similar to those in the periphery, such as enhanced bioavailability of nitric oxide (NO), which supports optimal blood flow (Aliev et al., 2009; Gladwin et al., 2004). As such, enhancements in blood flow have been found following citrus and grape drinks in acute Lamport et al. (2016) and chronic study designs (Krikorian et al., 2012), with a large evidence base following cocoa supplementation, highlighting this mechanism may be optimal following this particular food (Brickman et al., 2014; Francis et al., 2006). Specifically, Lamport et al. (2016) found improved cognitive function, measured using the Digit Symbol Substitution Test at 2hr following consumption of orange juice containing 70.5 mg flavonoids in the 500ml drink. The flavonoid content here is considerably low compared to those of previous trials (discussed in chapter 1.5.2), though clearly supports this underlying mechanism and associated behavioural outcomes.

As mentioned, peripheral vasodilatory effects are thought to be due to nitric oxide bioavailability. Specifically, flavanol-rich cocoa has been shown to improve endothelium dependent vasodilation via acting on nitric oxide pathways (Fisher et al., 2003; Heiss et al., 2003). These responses have a clear implication to the cardiovascular system, and as a result, flavonoids have been shown to lead to improvements in blood pressure due to the improved endothelial function and increased vasodilation (Bondonno et al., 2018; Hodgson & Croft, 2006; Parmenter et al., 2022). Indeed, Keane et al. (2016b) found decreased systolic blood pressure 1-3 hours following cherry juice consumption, with no changes to mood or cognition, followed by a later study which found similar blood pressure reductions following chronic WBB extract supplementation for 3-months (Whyte et al., 2018), with associated improvements in cognitive functioning. Decreases in blood pressure following acute flavonoid-rich apple supplementation have also been found, concurrently with an acute increase in nitric oxide status (Bondonno et al., 2014) although no corresponding improvements or declines in cognitive function or mood were observed.

Subsequently, it could be considered that changes in blood flow, both cerebral and peripheral, are likely to act via improving nitric oxide bioavailability. This mechanism may increase delivery of oxygenated blood and therefore nutrients to the brain and therefore may be a plausible mechanism of mood and cognition improvement following flavonoid interventions.

### *1.7.5. Gut microbiome*

As mentioned in section 1.3, flavonoids may influence the gut microbiome by acting as prebiotics, a form of non-digestible fibre which has been shown to stimulate the growth of beneficial microbes within the gut, promoting host health (Pandey et al., 2015). Through this interaction, the gut microbiota can further impact the central nervous system, particularly through the production of neurotransmitters such as γ-amino butyric acid (GABA), which is synthesised by species like Lactobacillus and Bifidobacterium (Yunes et al., 2016). Mithul Aravind et al. (2021) provides a comprehensive review of the processes by which polyphenols may act upon the gut microbiota, such as modification via prebiotic effects, influencing microbial metabolism and growth, and affecting the cells lining the gastrointestinal tract, highlighting that these processes enable polyphenols to have a wider systemic effect in the host. In example, Horasan Sagbasan et al. (2024) supplemented children ($n$=13) with either WBB, inulin or a maltodextrin placebo, with outcome measures following 4-weeks of supplementation measuring cognition and changes in the gut microbiome. Both inulin and WBB lead to increases in short chain fatty acids (SCFAs), which coincided with improvements in executive functioning and memory compared to the placebo. This suggests that changes in cognitive functioning could be mediated by the gut microbiota via activating SCFA, a main metabolite produced in the colon, which may exert effects in the brain via regulating central nervous system processes (Silva et al., 2020).

In regards to mood, Shin et al. (2022a) supplemented participants with 30g of either 70% or 85% cocoa chocolate for 3-weeks, finding a significant reduction in negative affect scores following consumption of the 85% cocoa chocolate which was not seen in the control (no chocolate) or 70% cocoa chocolate conditions. Alongside this, the authors found significant differences in gut microbiota diversity between the control and 85% dark chocolate group, but not in the 70% dark chocolate group, suggesting that the changes in the gut microbiota could be driving this effect. Interestingly, short term dietary interventions such as this have been evidenced to show changes in gut microbial composition (Leeming et al., 2019). Changes following dietary interventions have been seen in as little as 5 days following either an animal-based or plant-based diet (Johnson et al., 2019). However, Leeming et al. (2019) notes that in a number of studies, gut microbiota tends to revert back to its original state post intervention, and that longer term dietary interventions may be necessary to make long lasting changes to the microbiome composition and therefore wider behavioural outcomes, signifying a potential area for future research to determine this sweet-spot. However, it is clear that emerging research shows changes in diet can have significant and meaningful effects on the gut microbiota in a short time span, which could drive changes in mood outcomes.

## 1.8. Thesis objectives and specific research questions

### *1.8.1. Objectives*

It is clear that mood and cognitive benefits are evident following dietary flavonoid supplementation. However, the literature to date requires an updated systematic overview on flavonoid food sources that may be most optimal, or particular facets of mood and key objective measures that are utilised in healthy populations throughout the lifespan. Postnatal literature (outlined in Chapter 3) highlights that diet plays a significant role in the development of mood disorders throughout pregnancy and the postpartum, though the role of flavonoids has yet to be extensively investigated in robust clinical trials. As such, the objective of this PhD thesis is three-fold: firstly, to provide an updated systematic review on the existing evidence for the effects of flavonoid-rich foods within the diet on mood and mental health throughout the lifespan, secondly, to explore the effects of chronic flavonoid-rich food supplementation on mood and cognition in the immediate and 6-months postpartum, and finally, to investigate the acute effects of WBB on mood and cognition on parents in the 6-months postpartum.

### *1.8.2. Research questions*

The specific research questions addressed in this thesis are as follows:

1. What is the current evidence for dietary flavonoids on mood and mental health in healthy populations throughout the lifespan (reported in Chapter 2)?

*Rationale and hypothesis:* There has been a surge in the number of trials investigating the effects of flavonoid-rich foods and their effects on mood and mental health. While there have been a number of reviews looking at the relationship between flavonoids and an individual facet of mood, such as depression, these reviews often include flavonoid extracts and foods not given in their whole form. By addressing the literature with a 'whole food' approach, a larger evidence base can be systematically observed, rather than solely extracting papers for flavonoids and flavonoid extracts. Furthermore, from a public health perspective, considering the food in its whole form and its effects on mood and mental health, compared with flavonoid extracts, could be more beneficial due to the accessibility and synergistic nature of these beneficial phytochemicals within the whole food matrix and wider diet. Reviewing the literature in this style would provide clarity on the extent to which flavonoids may benefit outcomes, as well as identifying any favourable food source or outcome measure. Additionally, reviewing the full scope of the literature allows for an evaluation of the research quality and brings attention to any widespread limitations that could affect the ability to assess the effectiveness of the compound on mood outcomes.

2. Can chronic dietary flavonoid supplementation benefit mood and cognition in the postpartum, and are there specific timeframes of supplementation that may host greater benefits (reported in Chapters 4 and 5)?

*Rationale and hypothesis:* The first 6-months postpartum are associated with psychological challenges and subsequently, increased prevalences of mood disorders can occur between 1-6 months postpartum. Additionally, cognitive changes are seen during this timeframe in areas such as working memory, verbal memory, executive functioning and processing speed. Evidence highlights that chronic supplementation of flavonoids may benefit mood in various populations, in addition to cognitive function, where benefits of flavonoids are seen to overlap with areas of cognitive change that is seen in the postpartum. Novel evidence has shown that 2-week flavonoid supplementation can improve anxiety symptoms and aspects of quality of life (Barfoot. et al., 2021), though further investigation is required to elucidate the relationship between flavonoid supplementation and mood within this population. Furthermore, investigating the effect on fathers is also required as both parents are almost equally affected by postnatal mood disorders, though investigation into paternal mental health is rarely conducted. Finally, exploration into where the most optimal timeframe for supplementation is necessary. The immediate postpartum hosts opportunity to provide parents with an intervention that may benefit mood, due to mood being most labile in the first few weeks following birth. However, it could be that nutritional interventions may provide greater benefit when provided in the later postpartum, where mood is less labile, though risks for mood disorders are still high. It was hypothesised that chronic flavonoid supplementation would lead to improvements in mood, cognitive function and blood pressure for parents in the 6-month postpartum.

3. Can a single dose of WBB improve parent's mood, cognitive function and blood pressure (reported in Chapter 6)?

*Rationale and hypothesis:* Previous evidence shows that single doses of flavonoid-rich foods, such as WBB have the potential to benefit mood and cognition to various healthy, as well as clinical populations. This finding is evidenced between 1.5- 2-hours following supplementation, in line with previous mechanism of actions, highlighting a peak in circulating metabolites, blood flow, alongside cognitive and mood benefits between 2-6hr post WBB consumption. Given that flavonoids may provide greater benefit to mood and cognition within the 6-months postpartum, the final chapter of this thesis will therefore employ a placebo-controlled crossover trial to explore the effect of a single dose of WBB on various mood outcomes, cognitive function and blood pressure in mothers and fathers in the first 6-months postpartum. It was hypothesised that there will be an improvement in mood, cognitive function and blood pressure 2-hours following consumption of WBB, compared with a placebo matched control.

# Chapter 2: Effects of flavonoids from the diet on mood and mental health: A systematic review

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## 2.1. Introduction

Mental health problems have emerged as a pressing and increasingly prevalent concern worldwide with depression and anxiety standing out as significant contributors to global health-related pressures. Since the Covid-19 pandemic, it has been estimated that major depressive and anxiety disorders have had an additional 53.2 million cases and 76.2 million cases respectively (Santomauro et al., 2021). Psychotropic medications including antidepressants and anxiolytic medications are typically used in treatments for mood disorders and are often used in conjunction with talking therapies (Otto et al., 2006). However, there are limitations, such as delayed onset and side effects with this line of treatment (Goethe et al., 2007; Masand & Gupta, 2002). Importantly, not all those diagnosed with mood disorders have access to treatments, and 76.3% to 85.4% of those in less developed countries don't receive adequate treatment (Lépine & Briley, 2011). Moreover, even when availability is good, Jorm et al. (2017) highlight challenges with implementation of these treatments, such as access to care and individual variability and adherence to treatments. Collectively, this emphasises a need to further explore adjunctive treatments which are better accessible and cost effective for all.

Chapter 1.4.1. of this thesis outlines evidence which suggests that lifestyle factors such as diet, in particular diets abundant in fruits and vegetables, may play a mediating role in the treatment of mood disorders. Recently, O'Neil et al. (2024) found that lifestyle interventions which targeted nutrition and physical activity are effective when considering both clinical and cost-effective outcomes, suggesting a suitable treatment alternative or addition to traditional therapies for mood disorders. It is clear that flavonoids, when consumed as part of the diet may harbour benefits for mood. Reviewing the experimental evidence for flavonoids and mood may further explore this relationship, whilst controlling for aspects such as dose and duration which may modulate mood and wellbeing differently. Previous reviews of flavonoids on mood (Ali et al., 2021; Jia et al., 2023; Pizarro Melendez et al., 2024) suggest benefits for depression, anxiety and overall mood and wellbeing. However, they also indicate that the evidence is hampered by methodological disparity and more conclusive evidence for mechanistic pathways is needed. As discussed in Chapter 1.4.2. one important factor when it comes to consideration of public health interventions is accessibility of these beneficial phytochemicals and focussing on trials which aim investigate consumption of the food in its whole form, or freeze-dried parts, may be hold benefits to public health due to accessibility, cost and potential synergistic effects when consumed as part of the food matrix (Chapter 1.3.). Therefore, this systematic review will focus solely on the benefits of flavonoids which can be consumed in the diet, either from a food or drink in its natural state, or in a freeze-dried form. Additionally, this review did not include studies examining cognitive outcomes, as the focus was specifically on mood and mental health. Furthermore, recent systematic and meta-analytic reviews have already examined the effects of flavonoids on cognitive function (Cheng et al., 2022; Lamport & Williams, 2020). Therefore, re-evaluating cognitive outcomes here was unnecessary and would have shifted the focus away from mood-related effects.

Therefore, the aim of this chapter is to conduct a systematic review of human experimental studies investigating the efficacy of dietary flavonoids on mood and mental health in healthy populations across the lifespan.

## 2.2. Methods

This review followed the PRISMA 2020 guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) and was registered in the International Prospective Register of Systematic Reviews PROSPERO (no. CRD42021293040).

*2.2.1. Eligibility criteria*

The eligibility criteria were defined according to the PICOS framework as shown in Table 1. Experimental human trials with any age, gender or ethnicity were eligible for inclusion if they supplemented with at least one flavonoid-rich food either as lyophilised powder or whole food and measured at least one mood or mental health outcome. No restrictions were placed on interventions with various types of flavonoid-rich food or length of supplementation. Additionally, no restrictions were placed on participants with existing mood and mental health conditions, however studies were excluded if participants had existing physical health or hormonal imbalance conditions in order to assess outcomes in physically healthy populations. Additionally, papers exploring the effects of flavonoids on mood for participants experiencing menopause were also excluded, due to the hormonal influence on mood during the menopausal period which could confound the interpretation of results for this population. The included experimental studies were required to have a well-matched (in terms of composition), low flavonoid control group and to have controlled for caffeine intake either methodologically or statistically. Foods were defined as flavonoid-rich following Neshatdoust et al. (2016) who defined low flavonoid foods as those containing between 5-15 mg/100g total flavonoids, a cutoff which has also been previously utilised in Chong et al. (2013) and Macready et al. (2014) therefore, studies were excluded if they utilised foods or beverages that were <15 mg per 100g/ml of flavonoid constituents. In order to be as inclusive as possible with regards to mood and mental health outcomes, mood was defined as "*a state of mind characterised by emotional and psychological wellbeing. This includes any symptoms relating to mood disorders either at clinical or sub-clinical levels. For the purpose of this research, items and data relating to social wellbeing, social belonging and social engagement were excluded and items and data relating to mood evaluations of cognitive performance or mental fatigue were excluded*". Studies were excluded if they did not assess mood or mental health per this definition. Additionally, studies were excluded if they contained flavonoid extracts or were experimental studies on red wine due to the confounding effects of alcohol on mood.

*Table 1. PICOS framework*

| | |
|---|---|
| Population | Human participants of any age, gender, or ethnicity. Studies were included if participants were physically healthy; those with existing physical or hormonal health conditions were excluded. |
| Intervention | Experimental studies with flavonoid-rich foods on mood and/or mental health |
| Comparator | Experimental trials that have a well-matched, low flavonoid control group. |
| Outcome | Self-reported mood and mental health |
| Study design | Randomised controlled studies regardless of duration or blinding procedures |

*2.2.2. Search strategy:*

The electronic databases PubMed, Web of Science and Scopus were searched with no restriction on publication start date to March 2025 to identify peer-reviewed, English language publications that met the eligibility criteria, reference lists of relevant studies, including review papers, were also manually checked. Flavonoid-rich food items were identified using the USDA database for the flavonoid content of selected foods (Bhagwat & Haytowitz, 2023). Each database was systematically searched using the following terms:

Mood OR Positive mood OR Negative mood OR Affect OR Mental health OR Anxiety OR Anxiousness OR Restlessness OR Nervousness OR Low mood OR Sadness OR Sad OR Depression AND Polyphenols OR Flavonoids OR Apples OR Artichokes OR Cacao beans OR Dessert wine OR

Celery seed OR Blackberries OR Radishes OR Cocoa powder OR Green tea OR Decaffeinated green tea OR Thyme OR Blueberries OR Broad beans OR Dark chocolate OR Black tea OR Rosemary OR Cherries OR Eggplant OR Soy yogurt OR Decaffeinated black tea OR Peppermint OR Cranberries OR Red cabbage OR Milk chocolate OR Parsley OR Currants OR Peppers OR Red wine OR Organo OR Elderberries OR Celery OR Natto OR Gooseberries OR Broccoli OR White tea OR Almonds OR Lemons OR Capers OR Soy drink OR Hazelnuts OR Limes OR Pecans OR Oranges OR Asparagus OR Oolong tea OR Pistachios OR Peaches OR Curly kale OR Walnuts OR Plums OR Watercress OR Prune juice OR Chives OR Raspberries OR Green hot peppers OR Soy milk OR Soybeans OR Strawberries OR Black bean OR Rhubarb OR Swiss chard OR Miso soup OR Rocket OR Tofu OR Nectarines OR Shallot OR Prune juice OR Tempeh OR Red grapes OR Red onion OR Cow peas OR Grapefruit OR Tasmanian pepper OR Acai OR Juniper berries OR Blackcurrant OR Apricots OR Tangerine OR Pear OR Satsumas OR Gogi berries OR White grapes OR Black grapes OR Jostaberry OR Rowanberries OR Jumbulberry OR Crowberries OR fruits OR vegetables OR superfoods (including plurals or truncated forms).

In PubMed, the search was run through 'all fields' including title, abstract, keywords and Medical Subject Headings (MeSH) using the advanced search feature. The advanced search feature was also used for Scopus where the search was run through the 'search within' toolbar to include article title, abstract and keywords. The Core Collection from Web of Science was used so that it did not return a number of duplicate references from Medline, here each term was searched using the 'topic' search fields, which included title, abstract and keywords. Full text, human and English filters were applied to all searches to help refine the large volume of unrelated papers. The bibliographic data was managed using EndNote X9.2 (Clarivate, Philadelphia, PA, USA). Initial searches, removal of duplicates, and title and abstract screening were performed by RC followed by the included papers independently verified by DL. Titles of the 15,398 records identified were manually screened using EndNote by one reviewer (RC), followed by abstract review of eligible titles. Abstracts meeting the criteria were then processed for full-text screening. A second reviewer (DL) independently verified the included papers. Discrepancies were resolved through discussion with a third reviewer (KB). No automated tools or software were used during the screening process.

Studies selected for inclusion were assessed using the Evidence Analysis Manual Quality Criteria Checklist (QCC) from the Academy of Nutrition and Dietetics Evidence Analysis Library® for quality of methodology and risk of bias. This tool was chosen as it is specifically designed to assess nutrition and dietary intervention studies, allowing for a more targeted and relevant evaluation of the included trials. Studies were assessed independently by RC and DL with disagreements resolved using a third party. All papers were included regardless of methodological quality so that the current limitations in the literature could be highlighted. Data extraction was conducted using the Academy of Nutrition and Dietetics Evidence Analysis Library® Evidence Analysis Manual Data Extraction Template extracting information on key information including study design, type of flavonoid-rich food, treatment duration, participant characteristics, outcome measure and results. Many papers also explored physical and biochemical outcome measures, however only data relevant to psychological outcome measures were extracted. Studies selected for synthesis were presented in a table to display individual study characteristics (Table 2).

## 2.3. Results

### *2.3.1. Study characteristics*

The search identified 35 publications, however, the manuscript by Khalid et al. (2017) outcomes from two studies alongside Velichkov et al. (2024) and Pase et al. (2013) who reported acute and chronic outcomes (Figure 2). As such, 38 data sets are reported, of which 13 were acute and 25 were chronic (Table 3). It is worth noting that for the age group sub-category, there is a total of 40 studies, as it was intended to analyse each age category in Garrido et al. (2012) as separate studies. The review inclusion and exclusion criteria reported in the study are reported in the PRISMA flow diagram: two studies did not have psychometric outcomes (Achour et al., 2022; Weisenberg et al., 1993), one intervention contained caffeine (Smit et al., 2004); three studies were on flavonoid extracts (Gibson et al., 2020; Meyer et al., 2024; Scholey et al., 2012); three studies did not have an adequate low

flavonoid control group (Evans et al., 2018; Macht & Dettmer, 2006; Unno et al., 2017); three studies did not measure mood per the definition (Keane et al., 2016a; Nemoto et al., 2022; Watson et al., 2019); two studies reported mood outcomes elsewhere (Barfoot et al., 2019; Pribis et al., 2012); one study could not ascertain exact flavonoid content in the intervention (Chiochetta et al., 2018) and one study focused on emotional eating (Macht & Mueller, 2007).

The interventions included in the eligible studies consisted of wild blueberry *(n*=8), cocoa *(n*=9), grape *(n*=2), berry *(n*=6), green tea *(n*=1), orange juice *(n*=3), soy *(n*=2), nuts *(n*=2), apples *(n*=1), peppermint *(n*=1) and a range of flavonoid foods *(n*=2). The most commonly used intervention was cocoa where flavonoid doses ranged from 16.72 mg (Marsh et al., 2017) to 994 mg (Scholey et al., 2010). Where studies did not state the exact flavonoid content, databases were used 19.3.24 (http://phenol-explorer.eu/contents/food/439 and the USDA) to calculate flavonoid content based on the weight of the intervention given (Abdelhalim, 2021; Marsh et al., 2017; Martin et al., 2012). Twenty-one of 25 chronic studies and 4 of 13 acute studies were parallel groups. The duration of the chronic studies ranged from 5 days to 12 months. Included studies were conducted in 1,972 participants; age ranging from 8 years (Khalid et al., 2017) to 69 years (Crews et al., 2005) with the majority (*n*=17) of studies utilising young adult populations (aged 20-35). The most commonly used measure in both acute and chronic designs was the Positive and Negative Affect Schedule *(n=6* acute, *n=8* chronic), followed by the Profile of mood states in chronic designs (*n=5)* and the Bond-Lader Visual Analogue Scales in acute designs *(n=4*) (Table 4).

*2.3.2. Methodological quality*

Using the QCC, 8 studies recorded as a 'positive' rating, indicating less risk of bias (Barfoot. et al., 2021; Boolani et al., 2017; Colombage et al., 2024; Crews et al., 2005; Haskell-Ramsay et al., 2017; Kean et al., 2015; Lamport. et al., 2016; Marsh et al., 2017; Simpson et al., 2019; Velichkov et al., 2024)a. Three studies were rated as 'negative' using the QCC criteria (Abdelhalim, 2021; Martin et al., 2012; Park et al., 2020). often not reporting information regarding withdrawals or using inappropriate blinding procedures. The remaining studies were regarded as 'neutral' using the checklist, indicating a low risk of bias from sources of funding, outcome measures and regimen, however randomisation of participants, reporting of withdrawals and stating clear research questions presented a higher risk for bias.

*Table 2. Quality criteria Checklist results for each study*

| | Alharbi et al. (2016) | Bondonno et al. (2014) | Boolani et al. (2017) | Haskell-Ramsay et al. (2017) | Khalid et al (2017) Study 2 | Khalid et al. (2017) Study 1 | Lamport et al. (2020) | Marsh et al. (2017) | Martin et al. (2012) | Pase et al. (2013) (acute) | Scholey et al. (2010) | Whyte et al. (2019) | Abdelhalim (2021) | Barfoot et al. (2021) a | Barfoot et al. (2021) b | Park et al. (2020) | Coates et al. (2020) | Crews et al. (2005) | Fisk et al. (2020) | Garrido et al. (2012) | Pribis. (2016) | Herselman et al. (2022) | Kean et al. (2015) | Kimble et al. (2022) | Kok et al. (2005) | Krikorian et al. (2022) | Lamport. et al. (2016) | Miller et al. (2018) | Miller et al. (2021) | Pase et al. (2013) (chronic) | Shin et al. (2022b) | Simpson et al. (2019) | Sinclair et al. (2022) | Tsang et al. (2019) | Zhang et al. (2013) | Colombage et al. (2024) | Velichkov et al. (2024) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Overall quality rating | 0 | 0 | + | + | 0 | 0 | 0 | + | - | 0 | 0 | 0 | - | + | 0 | - | 0 | + | 0 | 0 | 0 | 0 | + | 0 | 0 | 0 | + | 0 | 0 | 0 | 0 | + | 0 | 0 | + | + |
| Class | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A | A |
| Relevance questions | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1. Research question | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 2. Selection Bias | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | -1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 3. Comparable study groups | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 4. Handling of withdrawals | 0 | 0 | 1 | 1 | -1 | -1 | 0 | 1 | -1 | -1 | -1 | 0 | 0 | 1 | -1 | -1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | -1 | 0 | 1 | -1 | -1 | -1 | 0 | 1 | 0 | -1 | 0 | 1 | 1 |
| 5. Blinding | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | -1 | 1 | 0 | 0 | 0 | 0 | 0 | -1 | 1 | 1 | 1 | 1 | 1 | -1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | -1 | 1 | -1 | 0 | 0 | 1 |

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| 6. Regimen | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | -1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 7. Outcomes and methods | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | -1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 8. Statistics | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | -1 | 1 | 1 | -1 | 1 | -1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 9. Conclusions/ Limitations | -1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |
| 10. Funding bias | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

For overall quality assessment: 0, neutral; +, positive, -, negative. For class: A, Randomised Controlled Trial. For assessment regarding each relevance and validation question: 1, yes; -1, no, 0, neutral.

*Table 3. Key characteristics of experimental trials*

| Food category | Trial type | Age category | Citation | Design | Sample | Flavonoid source | Intervention details | | Duration | Outcomes | Findings |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Experimental | Placebo | | | |
| Berry fruits | Acute | 7-18 | Khalid et al (2017) Study 2 [27] UK | Crossover (n=52) | Healthy children (8.24 ± 0.96) | WBB | 30g freeze-dried WBB with 30ml orange squash and 170ml water (253 mg anthocyanins) | Placebo drink matched for volume, taste, appearance and sugar content. | 2hr | PANAS-C | Significant interaction effect where there was a significant increase in PA after consuming the WBB drink, not seen in placebo. No effect on NA. |
| | | | Khalid et al. (2017) Study 1 [27] UK | Crossover (n=21) | Healthy young adults (20.14 ± 1.01) | WBB | 30g freeze-dried WBB with 30ml orange squash and 220ml water (253 mg anthocyanins) | Placebo drink matched for volume, taste, appearance and sugar content. | 2hr | PANAS | Significant interaction effect where there was a significant increase in PA after consuming the WBB drink, not seen in placebo. No effect on NA. |
| | | 18-35 | Velichkov et al. (2024) acute data UK[60] | Parallel groups (n=60) | Emerging adults with self-reported symptoms of depression (20 ± 1.4) | WBB | 22g freeze-dried WBB mixed with water (121 mg anthocyanins) | Placebo drink matched for volume, taste, appearance and sugar content. | 2hr | PANAS-X | Significant effect of treatment, where PA scores are higher post intervention in low consumers of fruit and vegetables |

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| | | Haskell-Ramsay et al. (2017)[54] UK | Crossover (n=20) | Healthy young adults (21.05 ± 0.89) | Purple grape juice | 200ml commercially available purple grape juice plus 30ml blackcurrant flavour cordial (138.3 mg/L anthocyanins) | 200ml commercially available white grape juice plus 10ml blackcurrant flavour cordial and 20ml cold water. | 20 mins | Bond-Lader VAS | Main effect of treatment found for calm ratings, where higher calm scores were found following consumption of purple grape compared to placebo. |
| | | Whyte et al. (2019)[76] UK | Parallel groups (n=40) | Healthy young adults (22.8 ± 2.63) | Mixed berry | 400 mL 'smoothie' consisting of 75 g each of whole strawberries, blueberries, blackberries, and raspberries, blended with 100 mL water and containing 569.7 estimated flavonoid content. | Placebo drink matched for volume, taste, appearance and sugar content. | 2, 4, 6hr | PANAS-NOW | No effect of intervention on PA or NA. |
| Chronic | 7-18 | Barfoot et al. (2021)a[43] UK | Parallel groups (n=15) | Healthy children (7–10-year-olds), (8.38 ± 0.93) | Wild blueberry (WBB) | WBB drink containing 253 mg anthocyanins and was prepared by mixing 170 ml water, 13.3 g of freeze- dried WBB and 30 ml of low-flavonoid Rocks Orange Squash. | Placebo beverage matched for sugar content taste and colour | 4- weeks (with a 2 week visit) | PANAS-C | PA lower at 4 weeks compared to 2 weeks, no significant effect of intervention drinks on PA or NA. |

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| | Fisk et al. (2020)[66] UK | Parallel groups (n=64) | Healthy adolescents (14.20 ± 1.71) | WBB | 13 g of freeze-dried WBB powder (containing about 253 mg anthocyanins) | Placebo beverage matched for sugar content, taste and colour. | 4- weeks, 2-week checkpoint where PANAS-NOW completed. | MFQ, RCADS, PANAS-NOW | MFQ scores were significantly lower at 4 weeks when consuming WBB compared to placebo. No effect on RCADS or PANAS at 2 and 4 weeks. |
| 18-35 | Velichkov et al. (2024) [60] chronic data UK | Parallel groups (n=60) | Emerging adults with self-reported symptoms of depression (20 ± 1.4) | WBB | 22g freeze-dried WBB mixed with water (121 mg anthocyanins) | Placebo drink matched for volume, taste, appearance and sugar content. | 6-weeks | BDI, PANAS-X, PHQ-9, GAD-7, SHAPS, PSS-10 | No effects of intervention |
| | Sinclair et al. (2022)[74] UK | Parallel groups (n=44) | Healthy adults (34 ± 13) | Blueberry and cherry | (1) 60 mL blueberry concentrate diluted in water (774 mg anthocyanins) (2) 60 mL tart cherry concentrate diluted in water (640 mg anthocyanins) | Placebo beverage matched for sugar content, flavour and colour | 20 days | BDI-II, STAI | Significant interaction effect where depression and anxiety scores significantly reduced following blueberry treatment compared to placebo. Anxiety scores also reduced significantly in blueberry arm compared to cherry. |
| 35-65 | Lamport et al. (2016)[56] UK | Crossover (n=19) | Healthy mothers of preteen children | Concord grape juice | 355 mL Concord grape juice/day (777 mg polyphenolics as a | Placebo beverage matched for sugar conte | 12-weeks | Bond-Lader VAS, STAI-6 | No significant interaction effects of treatment, some treatment and study |

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| | | | (42.8 ± 0.7) | | gallic acid equivalent/355-mL daily serving (167 mg anthocyanins as malvidin equivalent and 334 mg proanthocyanidins as catechin equivalent). | nt, taste and colour | | | phase interactions seen for Bond-Lader scores |
| | Kimble et al. (2022)[68] UK | Parallel groups (n=50) | Non-smoking adults, low consumers of fruit and vegetables, low levels of physical activity with a risk factor for type II diabetes (48 ± 6) | Montmorency cherries | 30ml cherry juice found to contain 370·2 (sd: 112·2) mg/l of cyanidin-3-glucoside equivalents and 3259·0 (sd: 218·9) mg/l gallic acid equivalents diluted in ~240ml water. | Placebo beverage matched for sugar content, taste and colour | 3-months | Bond-Lader VAS | Main effect of treatment where alertness was higher in the intervention group. Post supplementation, mental fatigue was lower in the intervention group. |
| | Krikorian et al. (2022)[70] USA | Parallel groups (n=27) | Middle aged overweight adults (56.4 ± ns) | WBB | 12 g freeze-dried blueberries/day mixed with water, flavonoid content not reported | Placebo powder matched for sugar content, flavour and colour | 12 weeks | BDI-II | No significant effect of Intervention |
| | Garrido et al. (2012)[30] Spain | Crossover (n=30) | Healthy volunteers, mixed age range 20-30, 35-55, 65-85 | Jerte Valley cherry | 27.85g cherry product consisting of 18.85g pitted freeze-dried cherries (equivalent to 141g fresh | Commercial cherry flavoured soft drink. | 5 days (consumed twice a day) | STAI | Significant main effect of intervention on state anxiety for middle-aged and elderly participants |

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| | | | | | cherries) plus 7.5 g maltodextrin and 1.5 g ascorbic acid dried to a powder then diluted in water producing 125ml cherry based product per dose. One dose of the product provided roughly 1580 mg phenolic compounds (expressed as gallic acid equivalents), 30 mg anthocyanins (calculated as malvidin equivalents) | | | | compared to baseline. Effect was maintained 1-day after the intervention was discontinued. A significant decrease in trait anxiety in middle-aged and elderly, compared to baseline, effect also maintained 1-day post-trial. No changes found as a result of consuming placebo. |
| 65+ | Miller et al. (2018)[71] USA | Parallel groups (n=37) | Healthy older adults (67.6 ± 4.7) | WBB | 24 g freeze-dried blueberries/day mixed with water (461 mg anthocyanins) | Placebo powder matched for sugar content, flavour and aroma | 3 months | GDS, POMS | No significant effect of intervention on mood outcomes |
| | Miller et al. (2021)[72] USA | Parallel groups (n=37) | Healthy older adults (67.6 ± 4.3 years) | Strawberries | 24 g freeze-dried strawberries/day mixed with water, 114 mg flavonoids (Rutledge et al., 2019) | Placebo powder matched for sugar content, flavour and aroma | 3 months | GDS, POMS | No significant effect of intervention. |
| | Crews et al. (2005)[51] USA | Parallel groups (n=50) | Healthy older adults | Cranberry juice | Low calorie cranberry juice product containing | Placebo beverage matched for | 6-weeks | Follow up self-report questionnai | No significant effects of treatment. |

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| | | | | | (69.28 ± 6.45) | | 27% juice/volume, flavonoid content not reported | sugar conte nt, taste and colour | | re measuring perceptions of participants moods | |
| Cocoa | Acute | 18-35 | Lamport et al., 2020)[61] UK | Parallel groups (n= 98) | Healthy young adults, (20.65 ± 0.18) | Cocoa | 35g commercially available dark chocolate bar (70% cocoa) 83 mg flavonoids. | 35g commercial ly available white chocolate bar | 2hr | PANAS, Bond-Lader VAS | No effects of treatment for any outcomes. |
| | | | Boolani et al. (2017)[53] USA | Crossover (n=23) | Low polyphenol consumers without elevated feelings of energy (20.25 ± 2.23) | Cocoa | 473ml cocoa drink 499 mg flavanols | 473ml placebo drink matched for volume, taste, appearance and sugar content. | 22-48 mins, 60-86 mins, 98-124 mins | POMS | No effects of treatment for any outcomes. |
| | | | Scholey et al. (2010)[36] UK | Crossover (n=30) | Healthy student volunteers (21.9 ± 0.61) | Cocoa | Two doses of cocoa powder mixed with 200ml hot water. Powders contained either 520 mg cocoa flavanols or 994 mg cocoa flavanols. | Cocoa powder containing 46 mg CF mixed with 200ml hot water. | 90 min | STAI | No effect of intervention on STAI. |
| | | | Martin et al. (2012)[50] The Netherlands | Parallel groups (n=90) | Healthy participants , divided into high and low anxiety, | Cocoa | 20g dark chocolate (75%) 25g milk chocolate KitKat, flavonoid content not reported | 2 crackers and 15g cheese spread | 60 min | STAI | High trait anxiety individuals had higher state anxiety 60 mins after eating the milk chocolate bar The cheese and |

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| | | | | according to baseline STAI scores (22.8 ± 3.6) | | | | | | cracker group had lower state anxiety at 60 mins and no changes were found in the dark chocolate group or for the low trait anxiety group for any product. |
| | 35-65 | Pase et al. (2013)[29] (acute data) Australia | Parallel groups (n=71) | Healthy middle-aged adults (52.37 ± 7.72) | Cocoa | 20g dark chocolate drink mix containing either 250 mg or 500 mg cocoa flavonols in 200ml water | 20g dark chocolate drink mix containing 0 polyphenols in 200ml water | 1, 2.5, 4hr | Bond-Lader VAS | No effect of intervention on any outcomes. |
| | | Marsh et al. (2017)[47] Australia | Crossover (n=14) | Healthy postmenopausal women (57.6 ± 4.8) | Cocoa | 84 g of a high concentration cocoa (80%) 'dark' chocolate (395 mg polyphenols), or 87 g of a lower concentration cocoa (35%) 'milk' chocolate (200 mg polyphenols) | 85 g of a cocoa butter 'white' chocolate (0% cocoa solids) (35 mg polyphenols) | 30, 90 mins | POMS-A | No effect of intervention |
| Chronic | 18-35 | Shin et al. (2022)[73] South Korea | Parallel groups (n=48) | Healthy adults (23.95 ± 3.05) | Cocoa | 10g of 1. 85% cocoa chocolate 2. 70% cocoa chocolate three times a day, flavonoid content not reported | Not supplied any chocolate | 3 weeks | PANAS | Significant effect of treatment where negative affect scores were significantly reduced following consumption of |

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| | | | | | | | | | | 85% dark chocolate |
| | | 35-65 | Tsang et al. (2019)[75] UK | Parallel groups (n=26) | Healthy adults (38.8 ± 11.1) | Cocoa | 25 g serving of high polyphenol dark chocolate (HPDC) which contained 500 mg flavonoids | Similar serving of low polyphenol dark chocolate (LPDC) co ntaining negligible flavonoids. | 4-weeks | PANAS | No significant interaction effect for PA or NA. Within groups treatment effect was seen where a significant main effect of time and treatment on NA scores following high polyphenol dark chocolate, not seen in low polyphenol group. |
| | | | Pase et al. (2013) [29] (chronic data) Australia | Parallel groups (n=71) | Healthy middle-aged adults (52.37 ± 7.72) | Cocoa | 20g dark chocolate drink mix containing either 1) 250 mg or 2) 500 mg cocoa flavonols in 200ml water | 20g dark chocolate drink mix containing 0 polyphenol s in 200ml water | 30-days | Bond-Lader VAS | Significant effect of treatment for Calm and Content VAS. Significant increase found for calmness and contentedness in high polyphenol group but not for low or placebo. |
| Orange juice | Acute | 35-65 | Alharbi et al. (2016)[62] UK | Crossover (n=24) | Healthy males (51± 6.6) | Orange juice | 240-ml flavonoid-rich orange juice (272 mg flavonoids). | 240-ml placebo drink matched for volume, taste, appearance, energy and | Acute 2, 6 hours | PANAS | Main effect of drink for ‘alertness’ subscale, no other significant main effects or interactions. |

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| | | | | | | | sugar content. | | | |
| | Chronic | 18-35 | Park et al. (2020)[59] South Korea | Parallel groups (n=40) | Young adults (21.83±2.43) | Orange juice | 300ml Orange juice (600 mg flavonoids) | 300ml matched placebo | 8 weeks | CES-D | Significant reduction in CES-D scores in intervention group not seen in placebo. |
| | | 65+ | Kean et al., 2015)[40] UK | Crossover (n=37) | Healthy older adults (66.7 ± 5.3) | Orange juice | 500ml serving of orange juice containing 305 mg flavanones | 500ml matched placebo drink containing 37 mg flavanones | 8 weeks | PANAS | No significant effect of intervention |
| Green tea | Chronic | 18-35 | Zhang et al. (2013)[77] China | Parallel groups (n=46) | Healthy participants (25.67 ± 4.61) | Green tea | 400 mg three times a day | Cellulose three times a day | 5 weeks | MADRS, HRSD-17 | Significant decrease in scores for MADRS and HRSD-17 in green tea group, not observed in placebo |
| Soy | Chronic | 35-55 | Simpson et al. (2019)[57] UK | Parallel groups (n=101) | Postmenopausal women (53.75 ± 3.87) | Soy | 1. Medium (35 mg/350 mL), 2. or high (60 mg/600 mL) dose of isoflavones contained within a soy drink | Low dose isoflavones within a soy drink (10 mg/100 mL) | 12 weeks | PANAS | Significant difference between doses but no significant interaction for PA or NA. |
| | | 65+ | Kok et al. (2005)[69] The Netherlands | Parallel groups (n=202) | Postmenopausal women (66.7 ± 4.75) | Soy | 36.5g of powder containing 25.6 g soy protein containing 52 mg genistein, 41 mg | Placebo powder matched for taste and | 12 months | SF-36 mental health dimension, GDS | No significant interaction for any mood outcome |

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| | | | | | | | daidzein, and 6 mg glycitein aglycone weights as a powder. | appearance. | | | |
| Tree nuts | Chronic | 18-35 | Pribis (2016)[44] USA | Crossover (n=64) | Young adults (20.65±2.05) | Walnuts | 60g English walnuts in banana bread, flavonoid content not reported | Banana bread without walnuts | 8 weeks | POMS | No significant effect of intervention. |
| | | | Herselman et al. (2022)[67] Australia | Parallel groups (n=60) | Healthy undergraduate university students during examination period (22.0 ± ns) | Walnuts | 56g walnuts per day, flavonoid content not reported | Continue normal diet, avoid nuts or fatty fish for study duration. | 16 weeks | DASS21, MHC, POMS | Trend for improvement in depressive symptoms on the DASS21 in walnut group where participants did not have an increase in depression over exam period as seen in control group, though not a significant interaction. Similar results observed in the Psychological well-being |
| | | 65+ | Coates et al. (2020)[65] Australia | Parallel groups (n=128) | Postmenopausal women (65 ± 8) | Almonds | Based on participants individual estimated energy requirements (EER), participants were provided with a portion of snack foods equivalent to | Carbohydrate rich snack foods (The Original Scotch Finger, Arnott's Biscuits, | 6 days per week for 12 weeks | Bond-Lader VAS, POMS | No significant effects of treatment for any mood outcome. |

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| | | | | | | | ~15% of their EER. | North Strathfield, Australia and No Added Salt Potato Chips, Freedom Foods, Taren Point, Australia). | | | |
| Apples | Chronic | 35-65 | Bondonno et al. (2014)[64] Australia | Crossover (n=30) | Healthy middle-aged adults (47.3± 13.6) | Apples | Prepared by homogenising Cripps Pink apple skin (80 g) and apple flesh (120 g), where, half of each dose was provided raw and the other half was provided cooked (184 mg of total quercetin glycosides and 180 mg of (−)-epicatechin). | Apple flesh only (less than 5 mg of total quercetin glycosides and (−)-epicatechin ). | Acute 2.5 hours | Bond-Lader VAS | No significant effect of treatment found. |
| Peppermint | Chronic | 18-35 | Abdelhalim (2021)[49] Saudi Arabia | Parallel groups (n=124) | Healthy young adults (21.96 ± 1.7) | Peppermint | Infusion of 250 mg fresh aerial parts of the peppermint plant (infused for 10 min in hot water) 30 min before bedtime daily for 30-days, | Asked not to drink peppermint or any other herbs | 30-days | STAI | Significant reduction in STAI scores in intervention group. |

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| | | | | | | | flavonoid content not reported | | | | |
| Mixed foods | Chronic | 18-35 | Barfoot et al. (2021)b[52] UK | Parallel groups (n=38) | Postnatal mothers (1 year), (29.21 ± 5.67) | Mixed | Added one high flavonoid food item per day to current diet including 'berry fruits (~120 g) e.g. blueberries, raspberries, strawberries, blackberries, blackcurrants, mixed berries', '2 large squares of (min. 70% cocoa) dark chocolate', '4–5 cups of black/green tea or caffeinated/decaffeinated coffee', '1 large glass of red wine (250 mL)', '1 portion of leafy green vegetables such as spinach or cabbage (~70 g)' and '1 glass (250 mL) of fresh orange or grapefruit juice (not from concentrate)'. | Continue normal diet | 14-days | STAI, PHQ-8, PANAS , WHOQOL-BREF | Significant interaction effect for state anxiety where mothers in the experimental group reported lower state anxiety after the intervention compared to controls. |
| | | | Colombage et al. (2024)[58] | Parallel groups (n=38) | Postnatal mothers (6 months), | Mixed | Added two high flavonoid food item per day to current | Continue normal diet | 14-days | STAI, EPDS, PANAS, | Significant interaction effect for postnatal |

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| UK | (35.11 ± 3.77) | diet including 'berry fruits (~120 g) e.g. blueberries, raspberries, strawberries, blackberries, blackcurrants, mixed berries', '2 large squares of (min. 70% cocoa) dark chocolate', '4–5 cups of black/green tea or caffeinated/decaffeinated coffee', '1 large glass of red wine (250 mL)', '1 portion of leafy green vegetables such as spinach or cabbage (~70 g)' and '1 glass (250 mL) of fresh orange or grapefruit juice (not from concentrate)'. | WHOQOL-BREF, PSAS-RSF-C | depression and positive affect, where participants in the experimental condition reported lower EPDS scores and higher PA scores following the intervention. [1] |

WBB (Wild Blueberry); BDI (Beck Depression Inventory); BL-VAS (Bond-Lader Visual Analogue Scales); CES-D (Centre for Epidemiologic Studies Depression Scale); DASS (Depression, Anxiety, and Stress Scales); GDS (Geriatric Depression Scale); HRSD-17 (Hamilton Rating Scale for Depression, 17-item); MADRS (Montgomery-Åsberg Depression Rating Scale); MFQ (Mood and Feelings Questionnaire); MHC-SF (Mental Health Continuum -short form); PANAS (Positive and Negative Affect Schedule); PHQ (Patient Health Questionnaire); POMS (Profile of Mood States; RCADS (Revised Child Anxiety and Depression Scale); SF-36 (Short Form Health Survey, 36 items); STAI (State-Trait Anxiety Inventory); GAD-7 (Generalised Anxiety Disorder 7-item scale); SHAPS (Snaith-Hamilton Pleasure Scale); EPDS (Edinburgh Postnatal Depression Scale); PSAS-RSF-C (Postnatal Specific Anxiety Scale Research Short Form for global Crisis); WHOQOL-BREF (World Health Organisation Quality Of Life Brief Version)

*Table 4: Number of studies reporting positive effect of a flavonoid-rich food intervention versus control (effect/no effect) on mood outcomes*

| Measure | Outcome | Effect/no effect | Citation |
|---|---|---|---|
| BDI | Depression | 1/2 | Krikorian et al. (2022); Sinclair et al. (2022), Velichkov et al. (2024) chronic data |
| BL-VAS | Transient affective state | 3/5 | Bondonno et al. (2014); Haskell-Ramsay et al. (2017); Lamport et al. (2020); Pase et al. (2013) (acute and chronic data); Coates et al. (2020); Kimble et al. (2022); Lamport et al. (2016) |
| CES-D | Depression | 1/1 | Park et al. (2020) |
| DASS | Depression & anxiety | 1/1 | Herselman et al. (2022) |
| GDS | Depression | 0/3 | Miller et al. (2018); Miller et al. (2021); Kok et al., (2005) |
| HRSD-17 | Depression | 1/1 | Zhang et al. (2013) |
| MADRS | Depression | 1/1 | Zhang et al. (2013) |
| MFQ | Depression | 1/1 | Fisk et al. (2020) |
| MHC-SF | General mental health and wellbeing | 1/1 | Herselman et al. (2022) |
| PANAS | Transient affective state | 7/7 | Alharbi et al. (2016); Khalid et al (2017) Study 1; Khalid et al (2017) Study 2; Lamport et al. (2020); Whyte et al. (2019); Barfoot et al. (2021) a; Barfoot et al. (2021) b; Fisk et al. (2020); Kean et al. (2015); Shin et al. (2022); Simpson et al. (2019); Tsang et al. (2019); Velichkov et al. (2024) acute data; Colombage et al. (2024) |
| PHQ | Depression | 0/2 | Barfoot et al. (2021) b; Velichkov et al. (2024) chronic data |
| POMS | Transient affective state | 0/7 | Boolani et al. (2017); Marsh et al. (2017); Coates et al. (2020); Pribis. (2016); Herselman et al. (2022); Miller et al. (2018); Miller et al. (2021) |
| RCADS | Depression & anxiety | 0/1 | Fisk et al. (2020) |
| SF-36 | General mental health and wellbeing | 0/1 | Kok et al. (2005) |
| STAI | Anxiety | 4/4 | Martin et al. (2012); Scholey et al. (2010); Abdelhalim (2021); Barfoot et al. (2021) b; Garrido et al. (2012); Lamport et al. (2016); Sinclair et al. (2022); Colombage et al. (2024) |
| GAD-7 | Anxiety | 0/1 | Velichkov et al. (2024) chronic data |
| SHAPS | Depression | 0/1 | Velichkov et al. (2024) chronic data |
| EPDS | Depression (postpartum) | 1/0 | Colombage et al. (2024) |
| PSAS-RSF-C | Anxiety (postpartum) | 0/1 | Colombage et al. (2024) |

| | | | |
|---|---|---|---|
| WHOQOL-BREF | General mental health and wellbeing | 1/1 | Barfoot et al. (2021)b; Colombage et al. (2024) |

BDI (Beck Depression Inventory); BL-VAS (Bond-Lader Visual Analogue Scales); CES-D (Centre for Epidemiologic Studies Depression Scale); DASS (Depression, Anxiety, and Stress Scales); GDS (Geriatric Depression Scale); HRSD-17 (Hamilton Rating Scale for Depression, 17-item); MADRS (Montgomery-Åsberg Depression Rating Scale); MFQ (Mood and Feelings Questionnaire); MHC-SF (Mental Health Continuum -short form); PANAS (Positive and Negative Affect Schedule); PHQ (Patient Health Questionnaire); POMS (Profile of Mood States; RCADS (Revised Child Anxiety and Depression Scale); SF-36 (Short Form Health Survey, 36 items); STAI (State-Trait Anxiety Inventory); GAD-7 (Generalised Anxiety Disorder 7-item scale); SHAPS (Snaith-Hamilton Pleasure Scale); EPDS (Edinburgh Postnatal Depression Scale); PSAS-RSF-C (Postnatal Specific Anxiety Scale Research Short Form for global Crisis); WHOQOL-BREF (World Health Organisation Quality Of Life Brief Version)

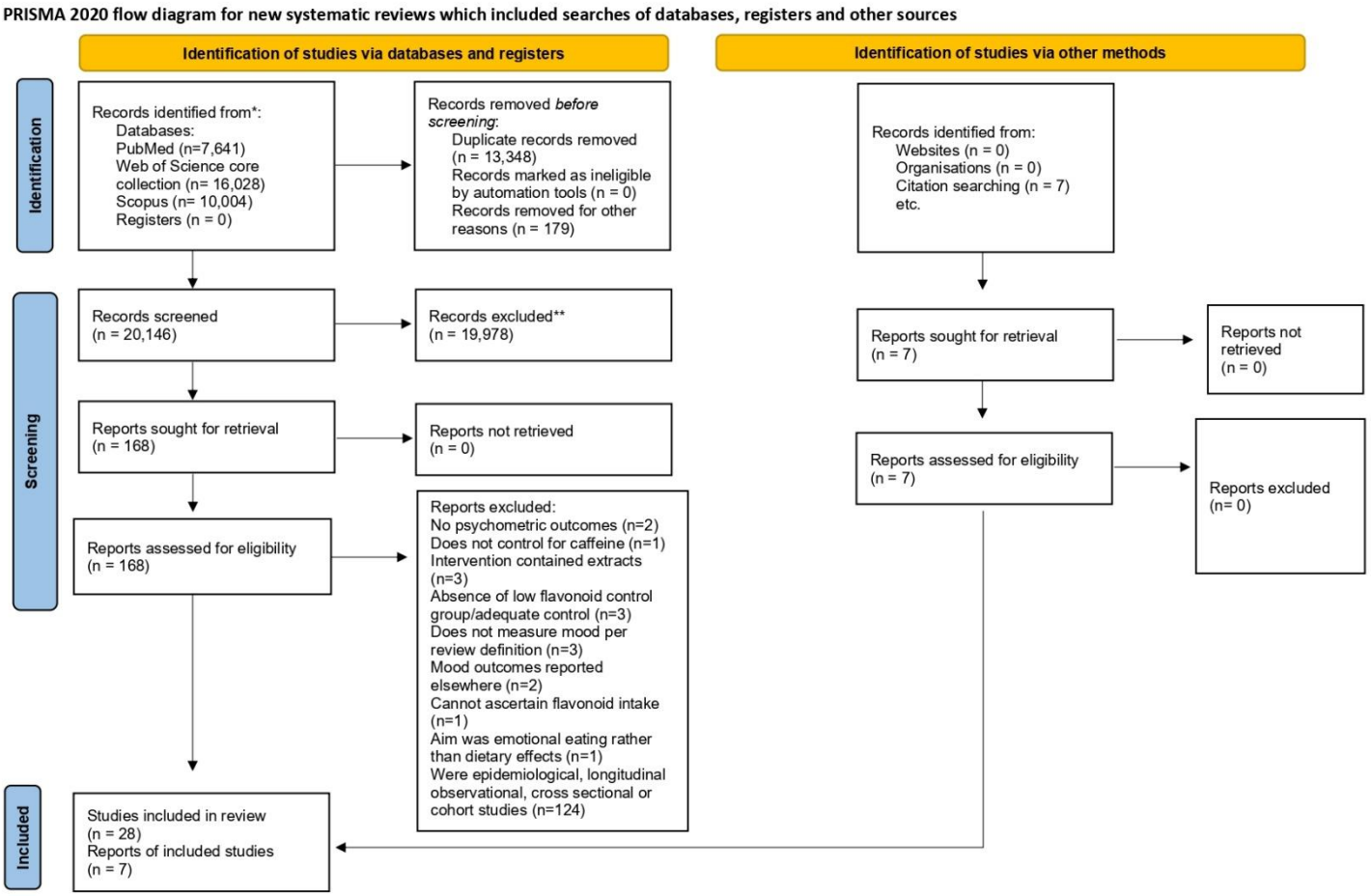


*Figure 2. PRISMA flow diagram for the identification of studies included in the review*

### *2.3.3. Findings from acute studies*

Of the 13 studies included, five studies (38%) found evidence that acute flavonoid supplementation with anthocyanin-rich foods held benefits for mood. Khalid et al. (2017) (studies 1 and 2) found improved mood, measured by the PANAS in both children and young adult populations 2 hours following a WBB intervention (253 mg anthocyanins). Additionally, Haskell-Ramsay et al. (2017) found an improvement in calm ratings using the Bond-Lader VAS 20 minutes following a purple grape juice intervention (138.3 mg/L anthocyanins) in healthy young adults. Finally, Velichkov et al. (2024) found a main effect of treatment for WBB, whereby positive affect increased in the experimental condition 2 hours post consumption in those with low fruit and vegetable intake.

Considering the acute literature, it is worth noting that in the Haskell-Ramsay et al. (2017) trial, 20 minutes may be too short a period to elicit the benefits of flavonoids, given that circulating anthocyanin metabolites peak between 1-2 and 6 hours (Rodriguez-Mateos et al., 2013). Therefore, where effects are observed in a timeframe <1 hour, it is important to consider non-flavonoid related mechanisms when interpreting findings. On the other hand, cocoa was used as an intervention vehicle for 50% of the included acute studies, none of which found positive effects on mood. However, improvements in alertness were also found 2-hours following flavonoid-rich orange juice, supporting that orange juice may also support mood acutely (Alharbi et al. 2016). Overall, this suggests that anthocyanin-based interventions, with doses between 183-253 mg anthocyanins in addition to 272 mg flavonoids in orange juice, with outcomes measured around 2 hours following the intervention may be an optimal dose and timepoint for observing acute benefits of flavonoids on mood, though other flavonoid-rich foods may be less promising for acute effects on mood.

*2. 3. 4. Findings from chronic studies*

Of the 25 chronic studies included, 12 (48%) found a significant effect of flavonoids on mood and/or mental health. Due to the diversity of the interventions used, there wasn't clear evidence for any singular food being most likely to confer benefits if consumed over a sustained period. However, 3 out of 4 studies that utilised the State Trait Anxiety Inventory (STAI) found benefits of flavonoids on anxiety symptoms, highlighting a potentially sensitive measure to detect mood changes in chronic interventions. For example, Garrido et al. (2012) conducted a crossover study utilising Jerte Valley cherries over a period of 5 days and found significant improvements in anxiety using the STAI. This finding was also reported by Sinclair et al. (2022) and Barfoot et al. (2021b) who found improvements in anxiety symptoms (STAI) following a flavonoid intervention in blueberries over 20 days and mixed flavonoid-rich foods over 14 days respectively. Furthermore, 9 of the included studies that did not find effects were conducted in middle-age and older adults which could indicate that this population are less likely to benefit from flavonoid interventions, particularly with chronic study designs.

*2. 3. 5. Flavonoid Food Source*

*2. 3. 5. 1. Blueberry*

Seven studies used a wild blueberry intervention, four (57%) of these found benefits of flavonoids. Here, Khalid et al. (2017) found a significant increase in positive affect following a Wild Blueberry (WBB) intervention at 2 hours post consumption in both children and young adult populations. Fisk et al. (2020) also found benefits to mood where healthy adolescents had a significant decrease in scores on the Mood and Feelings Questionnaire following a 4-week WBB intervention, representing a reduction in depression symptoms in this cohort. These three data sets all used a 253 mg dose of anthocyanin (equivalent to 240g of fresh blueberries), representing a potentially optimal dose to elicit changes in mood. On the other hand, Velichkov et al. (2024) used a smaller dose of anthocyanins (121 mg) and found an increase in positive affect. This finding was present in a population with self-reported depressive symptoms, which combined with the smaller dose (150g vs 240g fresh fruit equivalent in the other acute WBB trials), promotes the potential for acute WBB interventions for clinical as well as general populations for mood and mental health. Comparatively, the studies that did not find significant effects were all chronic designs using a range of durations from 4-weeks to 3-months. For, example, Miller et al. (2018) did not find mood effects following a 3-month blueberry intervention (19.2 mg anthocyanins) in healthy older adults in addition to WBB (253 mg anthocyanins) not eliciting changes in mood in 7–10-year-old children following a 4-week intervention (Barfoot et al., 2021a). However, it is worth noting that this particular study ran a post-hoc power analysis on their cognitive outcomes, finding low power, which therefore may affect outcomes. Overall, these findings may infer that acute doses of blueberry may lead to better mood outcomes compared to when consumed over a period of time whilst also suggesting that adolescents and young adults may benefit most from these interventions.

*2. 3. 5. 2. Cocoa*

Three of the 9 studies (33%) that used cocoa as an intervention found significant effects of supplementation on mood. The studies finding benefits of the intervention were all chronic studies with two studies lasting 30-days and one study lasting 4-weeks. Here, Pase et al. (2013) found that supplementing healthy middle-aged adults with a 20g dark chocolate drink (500 mg cocoa flavonols) had a significant increase in calmness and contentedness after 30-days which was not replicated in the low flavonol (250 mg cocoa flavonols) or control group. Similarly, Tsang et al. (2019) found significant within groups treatment effects for negative affect following 500 mg cocoa flavonoid supplementation for 4-weeks in adults, representing a decrease in negative mood following the intervention. The remaining studies finding non-significant effects of cocoa flavonoids on mood were all conducted in an acute setting. Together, these studies suggest an optimal supplementation duration of 4-weeks and dosage of around 500 mg/day flavonols for cocoa interventions on mood.

*2. 3. 5. 3. Grape*

Only two studies in this review used grape as an intervention. One (50%) of the studies found positive effects on mood following supplementation; Haskell-Ramsay et al. (2017). Comparatively, Lamport et al. (2016) conducted a 12-week intervention in mothers of preteen children using concord grape juice

(167 mg anthocyanins as malvidin equivalent and 334 mg proanthocyanidins as catechin equivalent). They both used the Bond-Lader VAS however, Lamport et al. (2016) did not find significant effects as seen in the Haskell-Ramsay et al. (2017) study. These findings could be partly explained by the study population whereby the mothers of pre-teen children were likely been maximally stressed, which was a purposeful aim of the study; so therefore, the effects of concord grape juice were not as effective compared to the healthy young adult population used in the Haskell-Ramsay et al. (2017) study. Furthermore, differences can also be noted in the total phenolic concentration of the active treatment groups, where the Haskell-Ramsay et al. (2017) paper had a total phenolic content of 336.34 mg gallic acid equivalent in the 200ml intervention compared to Lamport et al. (2016) reporting 777 mg total polyphenolics as a gallic acid equivalent in the 355ml intervention. Therefore, it could be suggested that larger quantities of total phenolics may not confer greater benefits to mood compared to smaller quantities.

*2. 3. 5. 4. Berry (not including blueberry)*

Six studies used a berry intervention (cherry, strawberry, cranberry, mixed berry and cherry) of which three (50%) found significant effects on mood using the STAI, BDI-II and Bond-Lader alertness. Of the trials that found effects, all were chronic studies lasting between 5-days 3-months. Comparatively, of the three studies that did not find effects, one used an acute design (Whyte et al., 2019) and two used chronic designs (Crews et al., 2005; Miller et al., 2021). Miller et al. (2021) conducted a parallel groups design study over a 3-month period, supplementing with 24g freeze-dried strawberries in older adults and did not find effects on the Geriatric Depression Scale (GDS) and the Profile of Mood States (POMS), which measures a range of mood states including anxiety, anger, fatigue, and depression. Kimble et al. (2022) on the other hand, found that supplementing participants with Montmorency cherries for 3-months lead to improvements in alertness following the intervention. Whilst the change in alertness is only one facet out of three from the outcome measure which was sensitive to the intervention, it is an interesting finding considering the study population whereby participants were low consumers of fruit and vegetables, and had low levels of physical activity with a risk factor for type II diabetes. This has been a consistent finding for recent research, whereby low consumers of fruit and vegetables seemed to benefit from a dietary intervention in terms of mood and wellbeing (e.g. Conner et al., 2017; Kontogianni et al., 2020). Recently, Velichkov et al. (2024) found participants who consumed <3 portions of fruit and vegetables per week had improvements in positive affect to a greater extent compared to those who were high consumers following a 6-week WBB intervention. Collectively, these results may signify benefits of flavonoid interventions may be more prominent in specific populations, such as those with low fruit and vegetable intake or physical activity.

*2. 3. 5. 5. Green tea*

There was only one included study that explored green tea on mood. Zhang et al. (2013) conducted a parallel groups trial, supplementing healthy young adults' green tea three times a day for 5-weeks. The trial utilised the MADRS and HRSD-17, both measuring depression and found a significant decrease in scores in the green tea group that was not observed in their cellulose placebo group, indicating green tea may be effective in reducing depression scores in this cohort.

*2. 3. 5. 6. Orange juice*

Two out of the three (66%) studies evaluating orange juice on mood found significant benefits to mental health following the intervention. Park et al. (2020) supplemented young adults for 8-weeks with 300ml orange juice and found improvements in CES-D scores following the intervention. Additionally, a main effect of treatment was found in Alharbi et al. (2016) whereby the flavonoid-rich drink attenuated a decline in alertness seen in the placebo at 2-hours. In contrast, no significant changes were seen form mood in another 8-week intervention (Kean et al., 2015). It is noteworthy, however that the disparity in findings between Kean et al. (2015) and Park et al. (2020) may be due to the lower quantity of flavanones in the Kean et al. (2015) study (305 mg) compared to nearly double in the later trial (600 mg), or perhaps the different study populations from young adults to older adults, where younger adults may have benefitted more from the intervention compared to older adults. Interestingly, both Kean et al. (2015) and Alharbi et al. (2016) utilised the PANAS in their

work, which was found to be sensitive to other food interventions such as berries, as mentioned above, suggesting an ideal measure of transient mood for nutritional interventions. However, Park et al. (2020) used the CES-D, which detected changes in mood, indicating this measure may also be sensitive to flavonoid supplementation. In review of the studies of dietary flavonoids for mood, older adults seem to benefit less from the intervention as seen in Crews et al. (2005); Kok et al. (2005); Miller et al. (2018) and Miller et al. (2021) all of which had similar study durations to Kean et al. (2015) lasting between 6-12 weeks. Therefore, whilst the higher flavanone content may explain the disparity in findings in the orange juice subclass, it may be that overall, older adults' mood and mental health may be less sensitive to dietary flavonoid interventions.

*2. 3. 5. 7. Soy*

In regard to soy studies, two chronic studies did not find benefits to mood and mental health as a result of a 12 month and 12-week supplementation period; Kok et al. (2005) and Simpson et al. (2019) respectively. Both studies used a similar study design with the same population of postmenopausal women, highlighting a chronic supplementation of soy may not elicit mood benefits in this population. It could be said however, that mood it much more stable in postmenopausal women in comparison to those who are peri-menopausal or going through the menopause transition period (Brown et al., 2015) therefore these studies may have missed the most sensitive period for mood change in this population.

*2. 3. 5. 8. Tree nuts*

None of the included studies showed a benefit of a tree nut intervention on mood and mental health. All studies evaluated the intervention in a chronic design ranging from 8-16-weeks. The POMS were used in all interventions, highlighting that this measure may not be particularly sensitive to detect mood effects following flavonoid supplementation. Further to this, there could be a need to develop more standardised protocols for control groups in nutritional interventions, whereby Herselman et al. (2022) asked participants in their control group to continue with their normal diet, and to avoid other nuts and fatty fish for the study duration. This indicates a potential withdrawal effect may be present within this study and highlights the need for further research of flavonoid-rich tree nuts on mood and mental health outcomes with more standardised procedures and better use of nutritionally matched placebos.

*2. 3. 5. 9. Apples*

One study (Bondonno et al., 2014) explored the acute effects of apples on mood using the Bond-Lader VAS. This was a crossover trial with apple skin and apple flesh, providing 184 mg of total quercetin glycosides and 180 mg of (−)-epicatechin. Mood was tested at 2.5 hours and no benefits of the apple intervention were observed.

*2. 3. 5. 10. Peppermint*

Abdelhalim (2021) supplemented healthy young adults with 250 mg peppermint tea (estimated total flavonoids 147 mg) for a period of 30-days, finding that participants had a significant reduction of state anxiety (STAI) scores post intervention compared to those in the control group.

*2. 3. 5. 10. Range of foods*

Barfoot et al. (2021b) evaluated mood after an intervention of a range of flavonoid-rich foods. They asked a sample of postnatal mothers (0-12 months postpartum) to include a single flavonoid-rich food into their diet for a period of two weeks. Post intervention, they found that the mothers had a significant reduction in state anxiety (STAI) in the intervention group which was not seen in the control group. In a similar study, Colombage et al. (2024) found a significant decrease in postnatal depression scores and increase in positive affect in postnatal mothers (0-6 months postpartum) after consuming two flavonoid-rich foods in their diet every day for 2-weeks. Overall, these findings show promise for the effects of flavonoid supplementation on a range of mood outcomes during the postpartum period.

*2. 3. 6. Findings separated by age groups*

For this analysis, there is a total of 37 studies, as it was intended to analyse each age category by Garrido et al. (2012) as separate studies.

*2.3.6.1. Children and adolescents (7-18)*

Three studies included in this review use a children and adolescents sample (ages 7-15). Only one of the studies did not find significant benefits from the flavonoid intervention (Barfoot et al., 2021a). All trials used the same flavonoid content (253 mg anthocyanins) with similar designs and outcome measures (PANAS used in Fisk et al., 2020); PANAS-C in Barfoot et al., 2021a). Simply comparing these studies indicates that adolescents may be more sensitive than children to mood changes as a result of a chronic flavonoid-rich blueberry intervention, however it is worth noting that there are no studies in these populations with other flavonoid-rich foods. Interestingly, these findings may be strengthened due to the fact that adolescence is a particularly sensitive period for development, whereby there are changes in emotion and executive functioning from prefrontal cortex growth (Ahmed et al., 2015; Best & Miller, 2010; Davey et al., 2008; De Luca et al., 2003), therefore the effects of flavonoids could be enhanced during this period of development.

*2.3.6.2. Young adults (19-35)*

This was the largest age category with 17 trials included of which, 8 studies (47%) were found to show benefits of flavonoids on mood. Most of these studies are chronic studies, ranging from 5-days to 16 weeks, utilising a range of flavonoid-rich foods for their interventions, though the majority (*n=5)* are cocoa based. One example of these studies, Shin et al. (2022) supplemented participants with 30g of either 70% or 85% cocoa chocolate for 3-weeks, finding a significant reduction in negative affect scores following consumption of the 85% cocoa chocolate which was not seen in the control (no chocolate) or 70% cocoa chocolate conditions. It is surprising that this difference was elicited between the two dark chocolate groups, however the difference in polyphenols was large between the two groups, where the 70% group contained 250 mg polyphenols and 85% contained 500 mg cocoa polyphenols, which could contribute to changes in mood, as outlined in other cocoa studies with similar dosages. Furthermore, Shin et al. (2022) found significant differences in gut microbiota diversity between the control and 85% dark chocolate group, but not in the 70% dark chocolate group, suggesting a potential mechanistic link driving changes in mood between the two interventions.

*2.3.6.3. Middle aged adults (36-65)*

Thirteen studies that fit the inclusion criteria had samples of middle-aged adults (aged 35-65), 6 (46%) of which found benefits of supplementing whole flavonoids. Garrido et al. (2012) found after a 5-day Jerte Valley Cherry intervention both middle aged, and older adults had significantly reduced state anxiety compared to baseline. Four out of the 6 of the studies found effects utilising the STAI or Bond-Lader VAS, suggesting changes in anxiety and transient mood outcomes. Furthermore, three of the studies explore the effects of berries on mood, indicating that potentially berry flavonoids may result in greater mood changes compared with other intervention food sources for this population. However, Lamport et al. (2016) investigated the effects of a 12-week concord grape juice intervention in this population, finding no changes in mood whilst using the STAI however, as previously mentioned, this null effect may be due to the higher levels of stress and worse baseline mood state from the specific population of mothers with pre-teen children.

*2.3.6.4. Older adults (65+)*

Seven studies were identified in this review with a sample of older adults (65+). Here only one study found benefits of whole flavonoid supplementation on mood and mental health for this population (Garrido et al., 2012). All included studies had a chronic design, highlighting a need to explore acute mood effects of flavonoid-rich whole foods in older adults.

2.4. Discussion

This review aimed to evaluate the effects of flavonoids from the diet on mood and mental health, in healthy populations throughout the lifespan.

Overall, the evidence suggests that supplementing participants with flavonoid-rich foods in their whole or freeze-dried parts may benefit mood. However, further research with consistent methodology, such as carefully controlled dose response studies and systematic approaches with clear rationales regarding choice of outcome measures is recommended. Consideration of bias within the studies is also important going forward, with more transparent recording of randomisation procedures, handling of withdrawals as well as continuing to state clear sources of funding.

Duration of supplementation appears to be a key driver for benefits following this form of intervention, with chronic intake showing more consistent benefits compared to acute doses. However, when considering acute interventions timing of intake and testing outcomes relative to peak metabolite levels is critical for observing changes in mood, which may be especially relevant for anthocyanin rich interventions where effects may be dependent on absorption. As mentioned above, circulating anthocyanin metabolites have been found to peak between 1-2 and 6 hours, coinciding with changes in flow mediated dilation (Rodriguez-Mateos et al., 2013), which could explain why anthocyanin based interventions seem more likely to find acute benefits to mood. On the other hand, food sources such as cocoa may require chronic supplementation periods to result in changes in mood. These findings are indeed replicated when observing the cardiovascular effects of cocoa on mood, whereby improvements in vascular function are seen following chronic consumption of cocoa flavonoids (Bauer et al., 2011; Grassi et al., 2005). Cardiovascular and neuroprotective effects may emerge with sustained consumption of cocoa flavonoids, as whereas the evidence for acute mood benefits following cocoa was less compelling. These findings highlight that further research must be conducted to investigate the mechanisms of how flavonoids may benefit mood, whilst taking into account the different food sources and timeframes of supplementation. A better, systematic approach to considering dosage effects is required. Currently, there is variability in the doses used across the trials, and it could be suggested that there is some standardisation in future research to better understand optimal intake levels for flavonoid-rich foods and mental health.

This review provides an updated overview of the effects of flavonoids on mood and mental health, with a focus on the benefits of flavonoid-rich foods consumed in their whole form, as opposed to flavonoid extracts. A limitation of this review is that it did not encompass all evidence on the effects of flavonoids on mood, as studies utilising flavonoid extracts were excluded. While flavonoid extracts have been shown to benefit mood outcomes (Calapai et al., 2017), the strength of this evidence may be weaker (Jia et al., 2023) Additionally, the broader public health message of incorporating flavonoid-rich foods into the diet may not be fully represented by extract-based interventions. A further limitation is the absence of a meta-analysis. While the inclusion of a meta-analysis could have provided a more quantitative synthesis of the data and enhanced the robustness of the findings, the decision was made to focus on a narrative summary of the included studies. This approach was chosen to allow for a more detailed and contextual discussion of the diverse methodologies, populations, and outcomes across the studies, which may not always be directly comparable in a meta-analysis. Nevertheless, this review provides an updated perspective on the topic, which, in conjunction with prior meta-analyses in the field, contributes to the broader understanding of the effects of flavonoids on mood.

### *2.4.1. Discussion of findings for trial designs*

The included studies in this review (Table 3) suggest that longer supplementation of dietary flavonoids may benefit mood compared to a single acute dose. That is not to say, however that flavonoids may not benefit mood acutely, though these acute effects seem to be greater when the intervention is anthocyanin based. Considering the benefits can be found following a short period of supplementation, both considering chronic and acute trial designs, it could be suggested that flavonoids don't require habitual consumption to harbour benefits to mood. Instead, increasing flavonoid consumption at specific timepoints, when mood is expected to be poorer may have greater benefits. For example, Baynham et al. (2021) suggested that a high flavanol cocoa intervention (150 mg flavanols) attenuated a decline in endothelial function following a mental stress task, suggesting a dose of flavonoids prior to mental stress may be physiologically beneficial. Furthermore, Herselman et al. (2022) reported a trend for improvement, where walnut consumption improved some aspects of

mood during examination periods in university students. Subsequently, flavonoid-rich foods may be optimal for dosing during times of mental stress, though specific food item, dose and length of dose for these specific events requires further research.

### *2.4.2. Discussion of findings by food source*

Overall, the included studies reviewed suggest that increasing berries and cocoa in the diet may provide benefit to mood and mental health throughout the lifespan. However, the efficacy of the interventions on mood may depend on factors such as dosage of the intervention, whereby dosing between 30-774 mg berry anthocyanins, with an optimal dose around 250 mg; and approximately 500 mg cocoa flavonols may elicit optimal effects. This was also evident in the orange juice interventions whereby 600 mg in Park et al. (2020) lead to significant changes in depression which was not seen in the other orange juice interventions. As mentioned above, different sources of flavonoid-rich foods may also confer benefits over different timeframes such as acute blueberry and anthocyanin rich interventions and chronic cocoa interventions.

### *2.4.3. Discussion of findings by age group*

The review highlights that flavonoid supplementation may effect mood with varying efficacy across age groups and intervention types. Only three eligible studies involving children and adolescents were identified in the review, despite these suggesting benefits of flavonoids on mood in this cohort, the limited number of trials available make it difficult to draw firm conclusions, and these findings should be interpreted with caution. Conversely, young adults appear to benefit more from chronic interventions, particularly with high doses of anthocyanins. Middle-aged adults also show positive responses to flavonoid interventions, especially if the intervention is berry based. However, the older adult literature lacks acute intervention studies, suggesting more acute designs are needed for this demographic. The evidence in the review also highlights that specific population characteristics could also benefit more from flavonoid supplementation such as individuals with low fruit and vegetable intake, which may be even more pronounced in young adults where diets are typically lower in fruit and vegetables (Lipsky et al., 2017), representing a larger opportunity for change.

### *2.4.4. Measures*

Mood measures were incredibly varied throughout the included studies as shown in Table 3 and Table 4, though certain measures such as the STAI which measures state and trait anxiety, BL-VAS assessing subjective mood states and PANAS which explores positive and negative affect may suggest suitability for use in future dietary flavonoid and mood interventions due to the potential sensitivity to detect changes stemming from dietary interventions. In contrast, while the POMS, which measures dimensions of mood and GDS, assessing depression in older adults were commonly used instruments, they did not demonstrate significant effects in the context of flavonoid-rich food interventions.

### *2.4.5. Conclusions*

The impact of flavonoids within the diet on mood and mental health looks promising, though it may vary by age group and dietary habits. Younger populations, particularly adolescents and young adults, benefit more noticeably from chronic interventions, whereas older adults show less pronounced effects. This may be due to the way younger and older adults perceive their mood, with evidence suggesting older adults feeling happier on average and having different emotion regulation strategies compared to younger adults (Machado et al., 2019; Urry & Gross, 2010). This indicates a larger scope for change in mood ratings as a result of dietary interventions in specific populations. Additionally, individuals with lower baseline fruit and vegetable intake might experience more significant mood enhancements from flavonoid supplementation, highlighting a potential area for dietary improvement. Finally, measures like the STAI, BL-VAS, and PANAS may offer good sensitivity to changes induced by dietary interventions, suggesting their suitability for future studies on this topic. Overall, while flavonoid supplementation shows promise for mood and mental health, particularly with chronic intake and specific sources of flavonoid-rich foods, further research is needed to find appropriate doses, explore the mechanisms of action, and examine the effects across different populations and intervention durations.

In previous research, flavonoid supplementation has shown benefits in populations where there is a larger scope for improvement in cognition and mood, such as those with cognitive impairments or major depressive disorder (Chen & Zhao, 2023; Choi et al., 2023; Mestrom et al., 2024). This relationship can also extend to healthy adults, where benefits of flavonoid supplementation are often evident in more cognitively demanding tasks, such as high-load attention network tasks for executive function (EF) and delayed recall or recognition in episodic memory tasks (Whyte et al., 2016; Whyte & Williams, 2015; Whyte et al., 2017). These populations often exhibit greater cognitive or emotional dysfunction, or higher cognitive demand, providing a larger capacity for improvement from dietary flavonoid interventions.

Additionally, some studies have suggested that specific flavonoid interventions may provide physiological benefits, such as a high flavanol cocoa intervention (150 mg flavanols) that attenuated a decline in endothelial function following a mental stress task (Baynham et al., 2021). Likewise, Herselman et al. (2022) found that walnut consumption improved some aspects of mood in university students during examination periods, suggesting that flavonoid-rich foods may be particularly effective when consumed during times of stress or mental challenges. One critical period defined by stress and psychological challenges is the postpartum period, during which there is an increased prevalence of mood disorders. This makes the postpartum population an ideal group for flavonoid interventions. Similar to other populations that show cognitive or emotional dysfunction, individuals in the postpartum period may benefit from dietary interventions aimed at improving mood and reducing the prevalence of mood disorders. Thus, as discussed fully in Chapter's 4, 5 and 6, flavonoid-rich foods could provide a promising approach to enhancing mood during the postpartum period, potentially offering improvements similar to those seen in other populations with scope for improvement.

# Chapter 3: Diet, mood and cognition in the postpartum

## *3.1. Maternal Postpartum mood*

The postpartum period presents significant challenges, marked not only by the physical recovery from childbirth but also by rapid hormonal and physiological changes (Hendrick et al., 1998). These, combined with psychosocial adjustments, can contribute to heightened vulnerability to mood disorders, such as depression and anxiety.

A prevalent mood disorder during this period is postpartum depression (PPD), which is considered an episode of Major Depressive Disorder (MDD). The American Psychiatric Association (2013) characterises PPD as symptoms such as feeling sad, loss of interest or pleasure in activities, changes in appetite and irritability, all lasting longer than two weeks, with onset either during pregnancy (peripartum onset) or within the first six months to one year after childbirth (postpartum onset). Anxiety is another mood disorder often experienced during this time, and often less acknowledged compared to PPD (Miller et al., 2006). Research indicates that postpartum anxiety is common among women following childbirth (Heron et al., 2004; Woolhouse et al., 2009) and may be more prevalent than postpartum depression (Giardinelli et al., 2012; Woolhouse et al., 2009). Giardinelli et al. (2012) found that at three months postpartum, 25.3% of women in their Italian cohort (n = 590) experienced clinically significant anxiety symptoms (measured by the STAI), compared to only 13.2% who scored above the clinical cut-off for depression on the Edinburgh Postnatal Depression Scale (EPDS). Similarly, Reck et al. (2008) reported anxiety prevalence of 11.1%, nearly double the depression prevalence (6.1%) in a sample of 1,024 women. These findings suggest that postpartum anxiety is not only common but may exceed rates of postpartum depression, highlighting the importance of recognising anxiety as a distinct and prevalent postpartum mental health concern. In addition to its high prevalence, anxiety frequently co-occurs with depression in the postpartum period. Reck et al. (2008) found that 33.9% of women in their sample experienced comorbid anxiety and depression, suggesting that these conditions often overlap. This is echoed in broader systematic reviews (Falah-Hassani et al., 2016; Farr et al., 2014) which emphasise the need for both disorders to be measured concurrently to fully capture the postpartum mental health landscape. Without attention to comorbidity, symptoms of anxiety may go undetected or be misattributed to depression alone (Pollack, 2005), potentially leading to incomplete assessment and less effective intervention.

The precise timing of PPD onset also remains a topic of discussion, with some research suggesting symptoms can manifest up to a year after birth (Gaynes et al., 2005), while the DSM-5 limits the diagnosis to the first four weeks postpartum (American Psychiatric Association, 2013). In a large cohort study, Munk-Olsen et al. (2006) found that the first 90 days following delivery posed a heightened risk for new-onset psychiatric disorders, primarily PPD, in first-time mothers. Despite these discrepancies, there is agreement that the incidence of PPD is highest within the first two and six months after childbirth (Gavin et al., 2005; O'hara & Swain, 1996), with a gradual decrease over the next 18 months (Monti et al., 2008). Comparatively, the opposite may be seen for anxiety, whereby mothers are reported to have higher anxiety symptoms throughout pregnancy and immediate postpartum, though may decrease over the postpartum (Breitkopf et al., 2006; Cheng et al., 2021; van Bussel et al., 2009). Lilja et al. (2012) conducted a longitudinal study evaluating mothers' feelings in the first year postpartum. Low mood was seen in 22% of the participants ($n$=419), furthermore, these mothers with higher depressive symptoms had poorer infant and partner relationships, however this did not extend to 6 or 12 months postpartum. This divergence in timing may reflect differences in underlying mechanisms. For instance, anxiety symptoms often emerge during pregnancy and peak in the early postpartum period, likely due to anticipatory concerns about childbirth, infant health, and maternal role adjustment (Reck et al., 2008; Wenzel et al., 2005). These symptoms may decline as mothers gain confidence in caregiving and as the pregnancy-related uncertainties are resolved (Jover et al., 2014). In contrast, depressive symptoms may develop more gradually as the cumulative effects of hormonal fluctuations and disrupted sleep become more pronounced. Sleep disturbance, in particular, has been repeatedly associated with PPD (Bei et al., 2015; Okun et al., 2018), with poor sleep quality acting as both a symptom and predictor of depressive episodes in postpartum women (Tikotzky, 2016). Overall, this suggests that given the vulnerability of new mothers during this time,

particularly within the first six months, this period represents a crucial window for interventions aimed at preventing or reducing symptoms of mood disturbances.

As outlined in Chapter 2.1, prevalences and symptomology of mental health disorders has rapidly increased following the COVID-19 pandemic. It is therefore not a surprise to see this replicated in the postpartum, where increases in postpartum depression were seen to rise to 22% (Yan et al., 2020), from the 12% pre-COVID-19 prevalence estimate (Shorey et al., 2018). This highlights the impact the pandemic and lock downs may have had on women's mental health in the postpartum. One limitation of the review is that it was published in 2020 and focused on studies conducted between 2019 and early 2020. Since the pandemic and subsequent lockdowns extended into 2021, the prevalence rates reported may not fully reflect the broader scope of research conducted throughout the entire duration of the pandemic. Indeed, subsequent reviews, including later publications confirm higher prevalence rates, estimated to be between 24% and 34% (Chen. et al., 2022; Lin et al., 2023; Safi-Keykaleh et al., 2022). Anxiety during this period was also reported to increase, with prevalences around 30% (Caffieri et al., 2024; Gao et al., 2022) highlighting the significant psychological burden placed on new mothers navigating pregnancy, birth, and early parenthood amid heightened uncertainty, reduced access to social and healthcare support, and increased isolation.

Overall, it is estimated that 10–15% of new mothers are diagnosed with postpartum depression (PPD) (Halbreich & Karkun, 2006), and 10–16% with anxiety (Matthey et al., 2003). However, these figures likely underrepresent the true scale of the issue. Reported symptom prevalence rates are consistently higher than formal diagnosis rates, suggesting that many women experiencing significant distress may not be seeking, or receiving, professional support. This gap between symptomatology and diagnosis reflects more than just clinical oversight, it reveals how structural, cultural, and individual barriers intersect to prevent women from accessing care. Garapati et al. (2023), for instance, highlight how the blurred line between 'normal' emotional adjustment after childbirth and more persistent impairments in functioning can delay recognition and response. This resonates with broader concerns about how maternal distress is normalised or dismissed during the postpartum period. Mood disorders during this time can vary widely in severity and presentation, and yet many women may not have the language or knowledge to articulate these experiences. Stigma, in particular, seems to play a critical role. As Dennis and Chung-Lee (2006) highlight, many women may be reluctant to acknowledge their symptoms, especially if they perceive that family or healthcare providers are unresponsive or minimising their emotional needs. This may explain why treatment uptake remains low, even when effective options are available. Furthermore, although treatments for PPD typically mirror those used for other depressive disorders, such as antidepressant medication and psychological therapy (Fisher et al., 2016) they are not always easily accessible or appropriate for postpartum women. Barriers may include not only logistical challenges, like availability and cost (Hansotte et al., 2017) but also practical and emotional concerns, such as childcare demands, fear of stigma, or uncertainty about the safety of medications while breastfeeding.

Moreover, rates of diagnosis and prevalence differ markedly across countries. For instance, studies report the highest PPD rates in Chile (38%) and the lowest in the Netherlands (8%) and Switzerland (11%) (Hahn-Holbrook et al., 2018; Halbreich & Karkun, 2006; Wang et al., 2021). These disparities likely reflect more than epidemiological variation and point to wider socioeconomic and cultural factors. Countries with greater wealth inequality and higher proportions of women in full-time employment tend to report higher PPD prevalence, suggesting that broader structural pressures may significantly influence maternal mental health. Overall, these disparities between prevalence rates and actual diagnoses suggest that many more women may be suffering from postpartum mood disorders than current diagnostic data reflects, with a significant number likely not seeking formal diagnosis or treatment despite experiencing symptoms, highlighting the need for more comprehensive, accessible, and cost effective interventions to support women during this critical period.

It has long been speculated that one of the mechanisms driving postpartum mood is the rapid change in hormones following delivery (Abou-Saleh et al., 1998; Hendrick et al., 1998; Schiller et al., 2015). Following delivery, oestrogen and progesterone levels drop sharply which has been shown to contribute to poorer mood (Dukic et al., 2024). The relationship between these specific hormones and

depression has further been elucidated whereby oestrogen supplementation in the 1-3 months following delivery has been associated with reductions in postpartum depression symptoms (Gregoire et al., 1996; Sichel et al., 1995), emphasising the strength of the relationship between postpartum mood and circulating hormones. Regarding circulating progesterone, the evidence is less clear whereby Nott et al. (1976) reported a weak association between depressive symptoms and fluctuations in progesterone during the first six weeks postpartum. Interestingly, Schiller et al. (2015) outlines evidence supporting this relationship, suggesting that in both animal models and human cross-sectional studies, there may be a hormone sensitive phenotype of postpartum depression. As Schiller and Colleagues suggest, women with these phenotypes may be more sensitive to the large changes in hormones in the first few weeks postpartum, however, the authors also highlight, the difficulty in drawing conclusions due to the heterogeneity in methodology, such as lack of control groups, measuring salivary versus serum levels of hormones as well as accounting for nursing, which may influence prolactin, progesterone, oestrogen, oxytocin, and cortisol and also has been associated with changes in mood state, further confounding this relationship (Alder & Cox, 1983; Harris et al., 1994; Hendrick et al., 1998; Warner et al., 1996). Following from this, a major challenge in studying the causes of postpartum depression is the variability of the condition. Depression that begins one week after childbirth may have different underlying causes than depression that develops three months after delivery, or depression that starts during pregnancy and persists into the postpartum period (Hendrick et al., 1998). Therefore, despite hormonal shifts following delivery being associated with changes in mood, these may not wholly be driving poorer mood during this time, and may only be responsible for changes in mood in the first few weeks following delivery (Dukic et al., 2024; Schiller et al., 2015).

Postpartum depression not only affects the mother but can also have profound consequences for the entire family unit, particularly the mother-infant relationship. Letourneau et al. (2012) underline that mothers experiencing PPD often face a decline in the responsiveness and greater increases of anxiety during maternal-infant interactions, which can significantly hinder infant development, particularly in areas such as emotional regulation, attachment, and social skills. This disruption in the bonding process can lead to long-term developmental consequences for the child, such as behavioural problems and difficulties with attachment later in life. Clearly, the impact of maternal mental health extends beyond PPD, with maternal anxiety disorders similarly linked to poor maternal-infant interactions and emotional neglect (Ali, 2018; Hoffman et al., 2017), however, the exact mechanisms underlying the effects of these disorders on bonding are still not fully understood. Moreover, these disruptions not only affect the child but can also create significant strain within the family, leading to broader relational and caregiving challenges. Given the intergenerational impact, it is crucial that interventions and research efforts focus not only on improving maternal mental health but also on supporting the broader family system to foster healthier developmental and relational outcomes.

### *3.2. Maternal cognition*

Changes in maternal cognition are a well-documented phenomenon that begin during pregnancy and continue into the postpartum period, manifesting in various cognitive domains, such as memory, executive functioning, and processing speed. While some studies report declines in these cognitive abilities, others suggest potential improvements or functional reorganisations that may be driven by the unique demands of pregnancy and postpartum. This subchapter will explore the cognitive changes that occur across pregnancy and into the postpartum period, highlighting key findings, potential mechanisms, and the implications for maternal cognitive health and well-being.

Changes in maternal cognition have been noted to start as early as pregnancy; Davies et al. (2018) report meta-analytical findings that show general cognitive functioning, memory and executive functioning are reduced in the third trimester of pregnancy compared with non-pregnant controls. Memory seems to be a key element affected by pregnancy, with deficits in working memory, (Hampson et al., 2015) subjective memory (Mazor et al., 2019), and verbal memory (Glynn, 2010; Henry & Rendell, 2007), which all show a gradual decrease in memory performance over each trimester of pregnancy. Interestingly, Henry and Rendell. (2007) comment that these changes in pregnancy cognition were observed in some, but not all domains of cognition, with Hampson et al. (2015) finding a larger decrease in maternal cognition when depression is also present.

Comparatively, it is possible that the tasks used to assess cognitive function and memory may be biased toward skills that are not particularly relevant to the maternal role (Davies et al. 2018). As a result, these tests may not be able to distinguish whether the changes in cognition reflect an actual decline or a shift in cognitive functioning that has been adapted for the upcoming responsibility of caring for children (Macbeth & Luine, 2010).

This experience has been referred to as functional reorganisation. It may be that social cognition and emotional processing improve, whereas other areas of cognition such as executive functioning and aspects of memory may be utilised less, reflecting in reduced function of these domains (Barha & Galea, 2017; Glynn, 2010; Ziomkiewicz et al., 2019). Ziomkiewicz et al. (2019) suggests that this may be driven by physiological mechanisms during pregnancy, where women experience limited energy availability for non-essential cognitive functions due to the foetus maximising the allocation of glucose and other nutrients from the mother. Subsequently, there may be costly trade-offs for energy and nutrients, leading to deficits in areas such as memory and executive functioning. Another mechanism potentially driving overall changes in cognition may be changes in hormones, as seen for the mechanisms underlying changes in mood, such as oestrogen (Glynn, 2010; Grattan & Ladyman, 2020). In support, hormonal shifts and their effects on cognitive function are evident at various stages throughout the lifespan (Kimura, 2002; Maki & Jaff, 2022; McEwen & Alves, 1999). For example, findings from a review by Weber et al. (2014) highlight that postmenopausal women perform worse than pre-and perimenopausal women on tasks such as phonemic verbal fluency and delayed verbal memory tests. Importantly, these results were adjusted for age, suggesting that the observed differences in cognitive performance are more likely attributable to menopausal status and associated hormonal changes rather than age alone. The review also noted that postmenopausal women were more likely to experience significant depressive symptoms.

As outlined above, following pregnancy, significant shifts in hormones are seen in the postpartum period (Bonnar et al., 1975; Hendrick et al., 1998). These hormonal shifts are also associated with changes in cognitive function. Henry and Sherwin (2012b) investigated this relationship, comparing women shortly following birth compared to age and education matched controls. At postpartum (12-weeks following delivery), oestrogen was negatively associated with attention, suggesting some cognitive changes were associated with reductions in this hormone. At this postpartum timepoint, women also performed worse on verbal memory compared to the non-pregnant control group, indicating the aforementioned cognitive decline, though this was not associated with hormonal fluctuations. This finding of increased difficulties in verbal memory in the postpartum is not standalone, as poorer scores have been seen in the first few days (Eidelman et al., 1993) and up to three months postpartum (Glynn, 2010; Silber et al., 1990), but not at 6 and 12 months postpartum (Silber et al., 1990), potentially reflecting the large changes in hormones within the first weeks postpartum, which gradually return to normal in the later months (Bonnar et al., 2975). Wider cognitive changes are also pronounced during the postpartum period, highlighting decrements in executive functioning (Almanza-Sepulveda et al., 2018; Chico et al., 2014), processing speed (Anderson & Rutherford, 2012), and working memory (Almanza-Sepulveda et al., 2018; Anderson & Rutherford, 2012; Pieters et al., 2021), suggesting that timing, as well as cognitive domain are crucial for assessing maternal cognition.

Comparatively, Buckwalter et al. (1999) found improvements on a range of cognitive domains including executive function, memory and processing speed from pregnancy to postpartum, indicating some cognitive improvements between these two stages. However, the relatively small sample size of those finishing the neuropsychological battery ($n$=19) may hinder the generalisability of the findings and limit the ability to draw definitive conclusions about the broader population Additionally, it is possible that only the most capable or motivated individuals finished the testing, potentially biasing the results toward better performance. Further to this, participants were tested at 25 days postpartum, which provides clarity on whether their cognitive state has changed since pregnancy, though considering the hormonal effects may last 6-8 weeks postpartum, testing at this timepoint may not give a clear idea of cognitive outcomes throughout the whole postpartum. Finally, this study did not have a non-pregnant control group, therefore, although outcomes may be improved compared to pregnancy, it is not known whether cognitive deficits remain in this population relative to controls.

Future research should include testing during late pregnancy and at various stages of the postpartum period using a cognitive battery that spans multiple cognitive domains to examine how cognition may change across the peripartum.

Some research has reported no change in cognition between pregnancy and postpartum. Changes in cognition were not seen in an executive function task in Bannbers et al. (2013), where 13 women performed the Go/NoGo task whilst undergoing fMRI imaging at 48hr, and 4-7 weeks postpartum, alongside 13 non-pregnant controls. Results showed no differences over time and between groups on the EF task, however activity in prefrontal areas decreased over time postpartum, such that it was lower than the non-pregnant control group. This suggests that there may be normal adaptive changes in brain activity during this time, though this may not be strong enough to evoke changes in a behavioural task. Henry and Rendell (2007) argue pregnancy induced changes in EF may only be evident if the task requires relatively effortful processing. Therefore, it could be suggested that the Go/NoGo task may not be challenging enough to show deficits in EF, therefore a task with more cognitively demanding trials may be more suitable to observe these differences in postpartum. Furthermore, considering the wider pregnancy and postpartum cognition literature, Anderson and Rutherford (2012) conducted a systematic review and meta-analysis, highlighting that working memory and general cognition was worse in the postpartum compared to pregnancy, and all aspects of cognition tested in the literature were worse in pregnancy and postpartum, compared to non-pregnant controls. Anderson and Rutherford (2012) also bring to light the changes in processing speed in this period; the authors report this was the largest 'pregnancy induced deficit', which was also continued into in the postpartum. Interestingly, meta-analyses also showed that processing speed effect sizes were mapped closely to the effect size of subjective memory complaints, implying it may be that this particular deficit in processing speed is driving the increase in subjective reports of cognitive dysfunction.

Subjective memory complaints, such as feeling more forgetful, misplacing items, or struggling to recall words or recent events are key factors in pregnancy and postpartum cognitive function studies. For example, in measures of working memory, processing speed and theory of mind, mothers (1-year postpartum) and non-mothers showed no significant differences, though mothers rated their subjective memory to be poorer than non-mothers (Orchard et al., 2022). Results showed that poorer subjective memory was also associated with poorer wellbeing, highlighting the importance of taking these specific cognitive function measures into account. It could be argued though, that given these results were taken at a year postpartum, objective aspects of cognition may have improved over the preceding year, and therefore changes were not evident at the one-year timepoint, as evidenced in Silber et al. (1990). On the other hand, a recent review from Orchard et al. (2023) showed mothers in the postpartum often report decrements in subjective cognition which are not demonstrated in the objective measures. It is also worth noting that some studies in these cohorts included in the review were limited by the absence of an appropriate control group (Pieters et al., 2021), often using non-pregnant control groups. Therefore further research into postpartum cognition at various timepoints, measuring both objective and subjective aspects, with adequate controls is needed.

Interestingly, brain imaging studies provide support for changes in objective measures of cognition, showing decreases in grey matter in the postpartum, suggesting synaptic pruning and an adaptive response to the maternal role. A study using MRI imaging compared women before pregnancy and during the postpartum, revealing a reduction in grey matter volume, particularly in the hippocampus (Hoekzema et al., 2017). These changes persisted even at the end of the 2-year study, and no similar changes were observed in the brains of the fathers. Follow up sessions in this study were taken at approximately 2.4 ±1.6 months postpartum. In a later review of structural and functional brain plasticity changes following delivery, Barba-Müller et al. (2019) suggested changes may be associated with maternal caregiving behaviours, which rely less on hippocampal regions and more on areas involved in social cognition and emotional processing. For instance, mothers showed structural brain changes, including reduced grey matter and increased white matter in regions such as the insula, striatum, and orbitofrontal cortex, with these changes linked to enhanced empathetic abilities and caregiving adaptations (Zhang et al., 2020). However, longitudinal studies are necessary in addition to comprehensive data on environmental changes during both pregnancy and the postpartum period.

Nevertheless, changes seen in the hippocampus evidenced in Hoekzema et al. (2017) coincides with previous evidence showing deficits in memory during this time (Glynn., 2010; Silber et al., 1990), suggesting both structural and functional changes in brain regions related to learning and memory in the postpartum. Changes in connectivity are also observed in postpartum mood disorders, with evidence highlighting reduced neural activation in the para/limbic and prefrontal regions, when exposed to an infant crying (Laurent & Ablow, 2012), which may indicate impaired emotion regulation and reduced sensitivity to infant cues. However, these long-lasting adaptations may provide a protective effect against age-related cognitive decline in women who have had biological children. Specifically, changes in regions related to memory and caregiving, such as the parahippocampus, precuneus, cuneus, and pericalcarine sulcus, are associated with better functional connectivity compared to women without biological children (Orchard, Ward, Chopra, et al., 2020; Orchard, Ward, Sforazzini, et al., 2020). This indicates the magnitude that pregnancy and postpartum may have on structural and functional brain plasticity and consequently mood and cognitive changes. In summary, it is clear there are cognitive changes throughout pregnancy which extend into the postpartum, though there is discrepancy to which domain, the degree of deficit and timespan by which these changes may occur. Maternal cognition is influenced by various factors such as hormonal shifts, mood changes, and adaptive mechanisms, which can impact memory, executive functioning, and other cognitive abilities. While some studies show declines in specific cognitive domains such as memory and executive function, others highlight potential improvements in cognitive abilities (Buckwalter et al., 1999). Moreover, neuroimaging studies support the idea of functional reorganisation of the brain during pregnancy and the postpartum period, and one interpretation is that the described cognitive changes actually represent a shift in cognitive priorities rather than cognitive deficits per se (Macbeth & Luine, 2010).

Future research is needed to better understand the relationship between these cognitive changes and the physiological mechanisms that underlie them, including hormonal fluctuations and brain structural changes. Longitudinal studies that track cognitive function at multiple timepoints throughout pregnancy and the postpartum period, using both subjective and objective measures, will be crucial to provide more definitive answers. The lack of a clear consensus in the current literature points to the importance of well-designed studies with appropriate control groups to explore the nuances of maternal cognition over this critical period. Understanding these cognitive changes is essential not only for supporting mothers during this transition but also for exploring the long-term effects of parenthood on cognition.

### *3.3. Paternal mood and cognition*

While much of the research on mood changes following birth focuses on mothers, it is important to note that nearly 1 in 10 new fathers also experience symptoms of PPD during the postpartum period (Cameron et al., 2016). This highlights the need for equitable attention to both paternal and maternal mental health in the prevention and treatment of mood disorders such as PPD. In fact, in 50% of cases, maternal depression is accompanied by paternal depression (Maleki et al., 2018), indicating that PPD can affect both caregivers simultaneously. A large scoping review of parental dyads ($n$= 29286 couples) found that parents (as dyads) experiencing depression in pregnancy were more likely to experience postpartum depression compared to parents (as dyads) that did not. Interestingly, this relationship was even more striking for fathers, underscoring the need to address antenatal depression in both parents (Smythe et al., 2022). This review also highlighted that paternal symptoms of postpartum depression were greater in the later postpartum, defined as 3-12 months, compared to the early postpartum, suggesting that this later stage may represent a particularly sensitive period for the onset of paternal PPD. In support, Areias et al. (1996) suggests that PPD in fathers is more gradual that maternal PPD, where 4.8% of first-time fathers met the criteria for depression during pregnancy, with the rate remaining the same at 4.8% at three months postpartum. However, by 12 months postpartum, the depression rate among fathers rose significantly to 23.8%. Similarly, 5.3% of first-time fathers were screened positively for depression prenatally, with this rate decreasing to 2.8% at six weeks postpartum before increasing again to 4.7% at 12 months (Matthey et al., 2000). These findings suggest notable fluctuations in paternal depression rates across the postpartum period, with a peak at 12 months. On the other hand, other studies indicate a more stable trajectory of paternal PPD. Deater-

Deckard et al. (1998) found that 3.5% of men were depressed during pregnancy and 3.3% at eight weeks postpartum, showing minimal change. This suggests that, in some cases, paternal depression may exhibit a consistent prevalence across the postpartum period, without the significant peaks and troughs.

Poor paternal mental health is increasingly recognised as a public health concern, due to its prevalence and the negative impact it has on child development and the overall functioning of the family unit (Fisher et al., 2016). In fact, the mental health of a father, particularly in cases of PPD, can significantly affect infant development, as with the mother-infant dyad, such as reduced quality and quantity of interactions. The high comorbidity rate between maternal and paternal PPD suggests a considerable likelihood that both parents may be depressed, which has been shown to more severely disrupt an infant's development than when only one parent is affected (Paulson et al., 2006). However, in cases where only maternal PPD is present, responsive care from the father can serve as a protective factor, buffering the infant from the negative developmental effects of maternal PPD (Hossain et al., 1994). This highlights the importance of paternal involvement in promoting healthier child development, and supportive family and partner relationships, especially when the mother is experiencing depression.

Although fathers do not experience hormonal changes associated with pregnancy to the degree biological mothers do (Kim & Swain, 2007), they are exposed to many of the same environmental stressors and caregiving responsibilities, and so may also be at risk of mood disorder development or cognitive change. Research has shown similar neural circuitry to mothers is activated when processing infant related stimuli (Swain, 2011). In the first year postpartum, increased activation of various networks associated with emotion and attention in fathers (Kuo et al., 2012) has been observed, which may be associated with behavioural outcomes. In fact, Pieters et al. (2021) compared mothers and fathers on a working memory (WM) task (Visuospatial N-back) during late pregnancy and 6-weeks postpartum to assess any differences and whether mothers experienced a decline in WM postpartum. The results showed that both mothers ($n$= 75) and fathers ($n$= 44) performed similarly on the WM task at both time points and improved at an equal rate. Though research into postpartum cognitive changes in fathers is limited, poor paternal mental health has been tied to lower cognitive performance. For example, Pio de Almeida et al. (2012) showed poorer verbal memory, as measured via a word span test, in mothers and fathers was associated with higher EPDS scores. Though this study had uneven groups of mothers and fathers ($n$= 222, $n$=173) affecting interpretation of results, it does show the need to look at both mood and cognitive outcomes in both parents in this time, as where mood is poor, cognition may also be affected.

### *3.4. Factors affecting mood and cognition in the postpartum*

Several factors increase the risk of mood and cognitive disorders during the postpartum period, in both parents. Identifying general risk factors for mood and cognitive disorders in the postpartum period is important because it allows for early detection, targeted support, and prevention of more severe outcomes for both parents and their infants. Maternal age is a significant risk factor, with both younger and older mothers being at higher risk for postpartum mood disturbances (Muraca & Joseph, 2014; Öztora et al., 2019). A history of depression or anxiety (Davey et al., 2011) having multiple children (Tariq et al., 2021), and complications during birth, breastfeeding, or pregnancy (Bell & Andersson, 2016; Pope & Mazmanian, 2016) are also associated with increased risk. In a large population-based study, Silverman et al. (2017) identified a history of depression, maternal age (specifically 15-19 and >35 years), and preterm delivery (<32 weeks' gestation) as key risk factors for postpartum depression, particularly after the first month. Primiparous mothers, or those having their first child, are at a higher risk for postpartum depression (Iwata et al., 2016). Interestingly, higher parity has been linked to attenuated cognitive decline in older adults, suggesting that the more children someone has, the more protected they are against cognitive decline (Zhou et al., 2022).

Furthermore, risk factors for postpartum mood and cognitive disturbances are not limited to mothers alone, though risk factors for fathers has historically been explored less. Ansari et al. (2021) found that a history of paternal mental illness, maternal depression, and various psychosocial factors such as financial instability and low education level were linked to depressive symptoms in fathers during the

postpartum period. Considering risk factors for both mothers and fathers is particularly important in the context of this thesis. Accounting for the broader psychosocial context helps ensure that key covariates are identified and controlled for in analyses, leading to a more accurate and holistic understanding of the factors influencing parental wellbeing.

Diet also plays a crucial role in shaping both mood and cognition during the postpartum period. Chatzi et al. (2011) emphasises that high adherence to diets rich in vegetables, fruit, pulses and nuts was associated with lower maternal depression scores at 8-10 weeks postpartum in women in Greece. As this Mediterranean style diet is rich in polyphenols, this trial highlights the potential impact of a, polyphenol-rich diet on mental health during the postpartum period. In line with this, in a recent review, Sun et al. (2023) synthesised findings from 10 studies and emphasised that poor maternal nutrition, as measured by fewer fruits and vegetables during pregnancy has been implicated in the development of postpartum depression (PPD). This stresses the importance of maternal diets needing to be rich in fruits, vegetables and polyphenols to potentially reduced the prevalence and symptom severity of postpartum mental health issues. While these findings primarily focus on nutrition during pregnancy, they underscore the broader importance of diet in influencing mood disorders in the postpartum period. Additionally, while the evidence regarding the impact of diet on paternal mood is more limited, the existing research points to a necessity to consider nutritional factors in the prevention and management of mood disturbances for both parents in the postpartum period.

### *3.5. Postpartum diet and mood*

Nutrition plays a vital role during pregnancy and postpartum, with evidence supporting a critical role in the prevention of onset of diseases in offspring in later life (Barker, 2004; Chia et al., 2019; Cruz-Rodríguez et al., 2023). There are well-established nutritional guidelines for pregnancy and lactation (Marshall et al., 2022; National Institute for Health and Care Excellence, 2014; WHO, 2020). For example, NHS guidelines recommend taking folic acid prior to conception and throughout the first 12-weeks of pregnancy in addition to a normal diet, rich in fruits and vegetables (NHS, 2022). This advice exists during pregnancy but less so in postpartum, during and beyond lactation, whereby advice begins to cater towards development of the child and is lacking when it comes to supporting the nutritional needs of the mothers' health (Marshall et al., 2022).

In general, maternal postpartum diet has been reported to be poor. Shah et al. (2010) found that in a sample of 125 women, the Healthy Eating Index (HEI) showed lower quality of diet in the 0-4 month postpartum, the, measured by low mean scores of fruits, vegetables and wholegrains. An important factor of this study was that the population was low-income women, therefore diet status during this time may be strongly moderated by income. This relationship has been previously elucidated whereby at 1-year postpartum, low-income women showed poorer adherence to dietary guidelines, with only 30% meeting recommendations for fruits and vegetables (George et al., 2005). However, regardless of income groups, evidence shows that facets of overall diet quality, such as total fruit and vegetable intake and micronutrients, such as vitamins A, C, D, group B vitamins, iron, magnesium, zinc, calcium, phosphorus, manganese, and copper significantly decline from pregnancy over the first 6-months postpartum (Lebrun et al., 2019). This decline may additionally get worse in the later postpartum. For example, Martin et al. (2020) assessed diet quality according to the dietary guideline index, finding that women in the early postpartum (0-6 months) and late (7-12 months) had better dietary quality compared to women with children >12 months of age, commenting that this may be due to increased pressures and balancing childrearing and work responsibilities. It should be noted however that 12% (n = 558) of the women were categorised as early (0–6 months postpartum), 12% (n = 547) were categorised as late (7–12 months postpartum), and 76% (n = 3434) were categorised as >12 months post childbirth. Therefore, results should be interpreted with caution due to the significant imbalance in group sizes, which may affect the generalisability and reliability of the findings across different postpartum stages. Clearly there are challenges to pinpointing exactly when diet may be deteriorating across the postpartum, nevertheless the research highlights that diets at all stages throughout pregnancy and postpartum have scope for improvement (Cuervo et al., 2014; Jardí et al., 2019).

Considering the existing relationship between diet and mental health (Chapter 1.4.) it is unsurprising that the relationship between diet and mood extends to the postpartum. However, much of the evidence base focuses on maternal nutrition during pregnancy and later associated depressive symptoms, whilst there is less evidence exploring whether nutritional interventions can predict postpartum mood states. Of those that do, findings are inconsistent. For example, Baskin et al. (2015) found poor quality diets in pregnancy were related to antenatal depressive symptoms, but this did not extend postnatally. Following this, Gould et al. (2017) commented that nutritional interventions, such as prenatal vitamin D and fish oil supplementation had inconclusive effects on postpartum depression. It is, however worth noting that the included trials in this review typically assessed mood between 6-weeks and 4 months, with the latest measure of depression taken at 7 months (Murphy et al., 2010). Beyond 12-months postpartum, evidence suggests diet is poorer, characterised by lower protein and higher carbohydrate consumption in addition to lower quantities of various micronutrients (Martin et al., 2020), therefore it could be that later in the postpartum, where there is evidence to suggest poorer nutrition, that there is the strongest scope for improvement in perinatal diet, and therefore diet-led improvements in mental health conditions. Sparling et al. (2017) also concluded from their meta-analysis, that a healthy diet with multivitamin supplementation, fish, Poly Unsaturated Fatty Acid (PUFA) intake, calcium, Vitamin D and zinc could be protective factors against postnatal mood disorders,. Indeed, recent longitudinal research from Gow et al. (2023), recruited a sample of 73 women from the 1st trimester to 1-year postpartum, measuring diet quality and depression using the Australian Eating Survey and EPDS, with EPDS measured in the 1st trimester and up to 6-weeks postpartum. Results showed that diet quality in pregnancy has no association with PPD at 6-weeks in adjusted and unadjusted models. This provided an updated look at this relationship, highlighting that perinatal diet may not always be useful for predicting postpartum mood states. However, this study did not test PPD in the later postpartum, suggesting further longitudinal research is required with testing beyond 6-weeks and 7-months postpartum.

An emerging body of work has begun to directly examine dietary patterns during the postpartum period itself. A systematic review from Opie et al. (2020) showed that higher adherence to a healthy diet during the postpartum period was linked to fewer symptoms of postpartum depression (PPD). This suggests that a well-balanced maternal diet rich in fruits, vegetables, fish, grains, legumes, and herbs could serve as an effective approach for reducing incidence of PPD. Similar findings have been observed for postpartum anxiety, with healthy and diverse diets associated with fewer anxiety symptoms at six weeks postpartum (Jiang et al., 2018). Furthermore, RCTs show that nutrients such as omega-3 fatty acids, folic acid, and vitamin D have been linked to improvements in depressive symptoms when reintroduced into the diet (Rupanagunta et al., 2023). One key mechanism which may be driving postpartum mood in relation to diet, is changes in gut microbiota, whereby specific strains of bacteria have been associated with postpartum depression. Specifically, Zhang et al. (2024) investigated relationships between gut microbiota and PPD, finding an association between higher concentrations of Actinomycetota and Holdemanella with symptoms of PPD. The authors did not comment on how many months postpartum the samples were, or the measures used to determine severity of symptoms, however the findings do suggest that there is a relationship between postpartum mood state and changes in the gut microbiome. A review from Zhang et al. (2023) outlines that gut microbiota may play a role in PPD pathogenesis, noting this may be due to various mechanisms of action, such as serotonin, hormone regulation and HPA axis modulation. The authors also outline there may be scope for investigating treatment for PPD and associated mood disorders during this period via improving the gut microbiome. Combined with the evidence in Chapter 1.7.5, this suggest that perhaps altering the gut microbiome via dietary interventions, may be beneficial for postpartum mood. Overall, these findings underscore the importance of adequate nutrition during the postpartum period for the prevention and treatment of mood. Improving maternal diet during this time via increasing specific micronutrients may provide a vital opportunity to enhance mood and support better mental well-being for mothers.

*3.6. Effects of flavonoids on postpartum mood and cognition*

In view of the evidence supporting the potential benefits of flavonoids for mental health and cognition, as outlined in Chapter 1 and Chapter 2, flavonoid-rich foods may offer protection against onset or symptom severity of postpartum mood disorders. Few studies have investigated this relationship. In one study Miranda et al. (2022) recruited 75 women in the postpartum (average 10-weeks postpartum), and participants completed a range of cognitive tests covering a variety of domains such as memory and executive functioning. Participants also completed a food frequency questionnaire, which was analysed using Phenol-Explorer, a database designed to calculate polyphenol content from common food items. Breastmilk samples were also taken and analysed in association with cognition and diet. Findings revealed that women who had increased consumption of polyphenols had improved scores on executive functioning and verbal memory compared to low consumers. In similar findings, Miranda et al. (2021) found that in a sample of 71 postpartum women (average 13-weeks postpartum) dietary intake of anthocyanins, also attained via a FFQ, were also positively associated with learning and memory, supporting the existing evidence for cognitive benefits from habitual anthocyanin consumption (as outlined in Chapter 1.5.1) and extending this to a postnatal population.

Further, in an open-label trial, Dowlati et al. (2017) recruited 41 healthy postpartum women who were administered either a dietary supplement, starting on the night of postpartum day 3, twice on day 4 and the morning of postpartum day 5, consisting of tryptophan, tyrosine, and blueberry juice (unknown flavonoid content), or placebo (ingredients not stated), to evaluate its potential to mitigate the onset of depressed mood during the peak of day 5 postpartum blues (PPB). The severity of PPB was assessed using a sad mood induction procedure (MIP). One key mechanism outlined in this trial was monoamine oxidase inhibition; as outlined in Chapter 1.7.2, this is key in regulating mood and may be sensitive to nutritional interventions, whereby flavonoids may inhibit MAO action. A review from Tosto et al. (2023) outlines monoamine oxidase's involvement with postpartum blues, highlighting tryptophan, a serotonin precursor is often lower in women with postpartum blues, indicating elevated monoamine oxidase or decreased serotonergic activity. This has been further investigated where increases in MAO binding in days 4-6 postpartum, suggesting a potential mechanism behind postpartum blues symptoms (Sacher et al., 2010). Participants in the active group of the Dowlati et al. (2017) trial exhibited no significant increase in depressed mood post-induction, in contrast to the control group who demonstrated a marked elevation in mood disturbance. These findings suggest that an anthocyanin-based supplement, combined with artificial precursors of serotonin, effectively attenuated vulnerability to depressed mood. In a later trial, Meyer et al. (2024) conducted a randomised, double-blind study where 103 postpartum women were randomly assigned to receive the same dietary supplement (containing blueberry juice with added extract, tryptophan, and tyrosine) or placebo, to assess its impact on PPB severity. The primary outcome, assessed using the MIP, revealed no significant difference in the induction of depressed mood between the supplement and placebo groups,. However, the Stein Maternity Blues scale showed that the active group experienced a moderate reduction in PPB severity compared to the placebo group (Cohen's d = 0.62). The authors suggested that the lack of effects using the MIP outcome may be due to the at home administration, compared to hospital administration conducted in the earlier trial, where mothers may have had environmental distractions interfering with their steady mood state. Differences between the two trials also included a larger proportion of participants with >4 years of university education and better baseline mood (as assessed by the Beck Depression Inventory) in Myer et al. (2024) compared to Dowlati et al. (2017), which may have contributed to the lack of intervention effects. Furthermore, the authors noted that COVID-19 precautions may have affected the trial, as researchers wore protective masks during home visits. This could have influenced participants' mood by reducing social engagement, limiting facial cues, and making interactions feel less personal or supportive, potentially dampening any mood benefits from the dietary intervention.

Nevertheless, the strength of the design of this randomised controlled trial, being double blind and a larger sample size relative to the open-label Dowlati et al. (2017) trial, adds strength to the findings and suggests that, while the intervention did not significantly affect all measures of mood, it may offer moderate benefits in alleviating PPB symptoms. The interventions used in both trials aimed to counter

the elevated MOA-A in the postpartum, suggesting that this pathway is a plausible mechanism for the benefits of flavonoid-rich interventions for mood outcomes. A limitation of both trials is that flavonoid content in the blueberry juice was not recorded, and that it was in combination with tyrosine and tryptophan, therefore it is difficult to extrapolate flavonoids as the key contributing factor.

Other recent evidence has also shown that a dietary flavonoid intervention can promote mood regulation in a postpartum population. Barfoot. et al. (2021) conducted a randomised control trial where 0–12-month postpartum mothers ($n$=41) were randomised to a flavonoid intervention group who added one additional flavonoid-rich food item to their normal diet every day for two weeks alongside a control group, who continued with their normal dietary routine. These foods included berry fruits, leafy green vegetables and dark chocolate, which were all chosen based on high flavonoid content, portion size, cost and accessibility for participants. Mothers in the flavonoid group showed significantly reduced state anxiety and increased perceived quality of physical health highlighting that dietary flavonoid intervention has potential to improve mental health and wellbeing in the postpartum period. This implies that regular dietary consumption of flavonoids may offer a promising intervention for promoting healthy mood regulation and reducing anxiety in the postpartum period.

In conclusion, the evidence presented herein supports the identification of the postpartum period as a window where mood and cognition is at higher risk of decline, and therefore there is potential for dietary interventions to have efficacy for improving mood regulation reducing the severity of postpartum mood disorders, such as postpartum blues and later postpartum anxiety, whilst also benefiting cognition in mothers and fathers. The studies by Miranda et al. (2022, 2021), Dowlati et al. (2017), Meyer et al. (2024), and Barfoot et al. (2021) emphasise the promising effects of flavonoid consumption on mental health in postpartum women, suggesting that dietary flavonoids may have a positive impact on both mood and wellbeing. However, the varying results across studies, particularly in terms of the specific outcomes measured, underscore the need for further research. While these interventions have demonstrated some efficacy in alleviating mood disturbance, there is also considerable potential to explore the effects of flavonoid consumption on cognitive outcomes during the postpartum period, given the changes in cognitive function during this time, and given the established benefits of flavonoid intake for cognition in other populations. Additionally, it is important to highlight that similar research has yet to be conducted in fathers, despite increasing evidence of mood disorders such as paternal postpartum depression and anxiety. By broadening the scope of research to include both mothers and fathers, there is a significant opportunity to develop more comprehensive dietary interventions that support both mental and cognitive health in the postpartum period, ultimately contributing to better outcomes for both parents and the family unit.

# Chapter 4: The effects of flavonoid supplementation on the mental health of postpartum parents

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## 4.1. Introduction

Considering the evidence supporting the beneficial effects of flavonoids for mood and wellbeing (Chapter 2), these phytochemicals may also have benefits for the postpartum as this signifies a population with increasing prevalences of mood disorders, representing a large scope for improvement in mood symptomatology. Initial research has begun exploring this relationship (Chapter 3.6.) where that acute administration of flavonoids (Dowlati et al., 2017; Meyer et al., 2024) and chronic supplementation (Barfoot. et al., 2021) may be of benefit to mood in this critical time period. However, further research is needed to explore this relationship using larger sample sizes. Studies should also examine different stages of the postpartum period to identify when interventions may be most effective. Additionally, it is important to include both parents in future research. This consideration reflects the dyadic nature of mood disorders and the potential impact when both parents experience symptoms.

It is clear that whilst cocoa and berries may have the strongest associations with mood and cognition (Chapters 1 and 2), consumption of a range of flavonoid-rich foods, including orange juice, grapes, and green tea have resulted in improvements to measures of mood and cognition (Ali et al., 2021; Cheng et al., 2022; Jia et al., 2023; Lamport & Williams, 2020). This suggests that increasing the consumption of a variety of flavonoid-rich foods may also be optimal, potentially acting on various mechanisms of action, such as changes in gut microbiota, increases in monoamine oxidase inhibition and cerebral blood flow. As such, Barfoot et al. (2021) found improvements to postpartum anxiety and physical health quality of life following consumption from a range of flavonoid-rich food items, highlighting the potential of dietary interventions to support mood in at-risk groups. However, it is important to also acknowledge that the sample in this trial were new mothers with infants aged 0-12 months which is a relatively wide postpartum window over which mood can vary dramatically (Chapter 3.1). Considering that the highest risk to developing PPD is between 2-6 months followed by a gradual decline up to 18 months (Gavin et al., 2005; Monti et al., 2008; O'hara & Swain, 1996), it may be that targeting low mood with such interventions in the more immediate postpartum period (0-6 months) would be especially beneficial to potentially improve mood. Therefore, early dietary interventions in this critical window may offer a promising approach to mitigate the onset of PPD, potentially enhancing overall maternal well-being.

Consideration of mood in populations not diagnosed with postpartum mood disorders is also necessary as low mood, high anxiety and poorer mental health in non-clinical populations have been found to predict onset of postpartum mood disorders (Miller et al., 2017). Specifically, Miller et al. (2006) found positive and negative affect in a sample of non-clinically diagnosed mothers ($n$=380) was associated with postpartum depressive symptoms at 2 and 12 weeks. Though this was not measured at later postpartum, beyond 12 weeks, it does show the importance of measuring mood in non-clinical samples as early disturbances in this group may serve as precursors to the development of more severe postpartum mood disorders, highlighting the need for early identification and intervention before symptoms escalate into diagnosable conditions. Subsequently, it may be beneficial to target interventions that focus on non-clinical populations to potentially prevent severity of symptoms that may contribute to the development of mood disorders. On a similar note, Francis et al. (2019) provided young adults with elevated depressive symptoms, but no diagnosis of depression with a 3-week dietary intervention focussed on increasing intake of foods in the Mediterranean diet and limiting processed foods versus a control who kept with their habitual diet. Results showed significantly reduced depressive symptoms, measured via the DASS-21 (Depression Anxiety and Stress Scale– 21) in the diet group, which was not seen in the control. In addition, Velichkov et al. (2024) found significantly improved positive affect 2- hours following WBB consumption in young adults with self-reported moderate-severe depressive symptoms (scores above $\geq 10$ on the PHQ-9).

These findings suggest that dietary interventions can be effective for managing low mood symptomatology in non-clinical populations. Therefore, a plausible next step in this research is to investigate whether a dietary intervention may have similar effects in a more sensitive window in the postpartum, where participants may not have diagnoses of mood disorders, but mood is often more labile and risk of symptom onset is relatively high (Munk-Olsen et al., 2006). This will identify whether a dietary flavonoid intervention closer to birth (e.g. 0-6 months), offers greater benefits to mood and mental health compared to if employed in the later postpartum (0-12 months), as seen in Barfoot et al. (2021).

Furthermore, as aforementioned in Chapter 3.3. prevention or treatment of paternal PPD is rarely considered; subsequently, research exploring flavonoid intervention in new parents should target both mothers and fathers to address the equivalent risks of low mood in both populations. Further, research suggests that lifestyle interventions focusing on families as a whole may be more feasible compared to existing approaches that primarily target individuals (Yates et al., 2015) likely due to shared motivation and social support (Martire et al., 2010). It is also significant to explore postnatal mood among fathers, or those in father roles in non-traditional family structures such as those with step-fathers and blended families, where instances of paternal depression have been observed to be more prevalent compared to traditional family structures (Deater-Deckard et al., 1998). For the purposes of this study, the focus was postpartum mood in biological mothers and fathers, which remains as the most prevalent family structure of the UK population.

The current experiment follows on from Barfoot et al. (2021) by utilising the same two-week parallel groups design, and the same flavonoid-rich intervention foods to investigate postpartum mood. However, will focus specifically on the 0–6-month postpartum period due to this being a particularly sensitive window for detecting PPD where mood is more labile, in addition to including both parents in the trial. This will identify whether a dietary flavonoid intervention closer to birth, where onset risk is higher, offers greater benefits. Additionally, Barfoot et al. (2021) required participants to consume one flavonoid item per day, whereas the present study increases this to two items per day, as previous research suggests a dose dependency of flavonoids, whereby a higher flavonoid dose may translate to improved mood (Godos et al., 2018; Bell and Williams., 2019; Chang et al., 2016). By increasing the dose, the current study aims to enhance the ability to detect mood-related effects and assess whether a higher intake leads to more pronounced benefits. Furthermore, PPD-specific measures of depression and anxiety, such as the Edinburgh Postnatal Depression Scale and the Postnatal-Specific Anxiety measure, are used in the current study, which may increase sensitivity to changes in postpartum mood compared to the Patient Health Questionnaire (PHQ-8; Kroenke., 2009) previously used by Barfoot et al (2021). This is because the Edinburgh Postnatal Depression Scale and the Postnatal-Specific Anxiety measure are designed specifically to assess mood and anxiety in the postpartum period, addressing symptoms that are unique to the challenges new mothers face. In contrast, the PHQ-8 is a broader measure of depression and anxiety and may not capture the full range of postpartum-specific emotional experiences. In keeping with Barfoot et al. (2021), the STAI, PANAS and WHOQOL-BREF were included in this trial to explore if a replication of results would occur with the different population and increase in flavonoid quantity.

The primary aim of this experiment was to investigate whether a two-week dietary flavonoid intervention would improve parents' mental health in the postpartum period. Based on Barfoot et al (2021), it was hypothesised that mothers and fathers in the flavonoid intervention arm would have a reduction in symptoms of state anxiety and improved quality of life. Due to the potential increased sensitivity of the other measures, it was also hypothesised improved mood and reduced postnatal depression and anxiety as a result of the flavonoid intervention.

## 4.2 Methods

### 4.2.1. Design

The study employed a randomised, parallel groups, controlled design to explore the effects of a two-week flavonoid intervention versus control group on several outcomes. The primary outcome measures for the study were state anxiety (State-Trait Anxiety Inventory-State scale; STAI-S; (Spielberger, 1983)) and depressive symptoms (Edinburgh Postnatal Depression Scale; EPDS; (Cox et al., 1987)). Secondary outcome measures included quality of life (World Health Organisation Quality Of Life; WHOQOL; (Skevington et al., 2004)), postpartum specific anxiety (Postpartum Specific Anxiety Scale- Research Short Form; PSAS-RSF-C; (Silverio et al., 2021)), current affect (Positive And Negative Affect Schedule; PANAS; (Watson et al., 1988)) and general diet (European Prospective Investigation of Cancer- Norfolk-Food Frequency Questionnaire; EPIC-FFQ; (Day et al., 1999)). Outcome measures were assessed at two time points; Baseline (Day 0) and Post Intervention (Day 15). Using a random number generator, participants were randomly assigned to either a 'flavonoid' group or a control group.

### 4.2.2. Participants

A priori-power analysis based on Barfoot et al. (2021) rendered a total sample size of 40 participants to achieve a small effect (0.3) at a power of 0.95 and alpha level of 0.05. To pilot the feasibility of the intervention with fathers, a sample of twenty fathers in the 0-6 month postpartum were also recruited.

The primary inclusion criteria were that participants were a biological parent to an infant between 0-6 months old. This was chosen as allows for an examination of parental mental health specifically within the context of biological parenthood. Research shows higher rates of postpartum depression in non-biological parents (Kirubarajan et al., 2022) and the mechanisms at play are likely to vary, thus including only biological parents here reduced a likely source of uncontrolled variability in the data . Participants were excluded from the study if they had cancer, or conditions affecting the liver, heart or kidneys.

### 4.2.3. Mothers sample

One thousand, three hundred and thirty responses to the online advertisements were received via mum and baby pages on social media and in-person mum and baby groups in Berkshire during a seven-month period of recruitment. Of these, 1,125 were excluded (the majority due to being identified as computerised bot responses, see Figure 3). A total of 55 participants completed baseline data and 40 participants completed the intervention (See Figure 3). At data analysis, two participants (n=2 flavonoid condition) were identified as outliers (outside interquartile ranges) for all mood outcomes both at baseline and post intervention, leaving n=38 participants for analysis.

Of the sample of 38, 78.9% were White or Caucasian, 7.9% Asian or Asian British, 5.3% Black/African/Caribbean/Black British and 7.9% mixed race women, with 94.7% reporting to be married or in a domestic partnership (2.6% single and 2.6% divorced). Half the women had a bachelor's degree as their highest level of education (50%), 50% worked full time where 40% of the sample's occupation was medical professional, with 78.9% earning over £51,000. As per the study criteria, all women had a baby under six months old. For 17 (44.7%) women, this was their first child. In those who reported other children, the age of children ranged from 2 to 11 years. Twenty-two women (57.9%) reported nearby child support. Seven women (18.4%) reported a physical health diagnosis, with the most common being Eczema (5.3%). For psychological health, 4 participants (10.5%) reported a psychological diagnosis, of which, 1 woman had anxiety, 2 had postpartum depression and 1 had comorbid anxiety and depression. Out of these four women, two were taking medication for their mental health. In addition to this, 31 women (81.6%) took vitamins and

supplements, which was majority Vitamin D (31.2%), multivitamin supplement (20.8%) and folic acid (18.2%) (See Table 6 for further demographic details).

To capture other risk factors, questions regarding pregnancy, birth and breastfeeding were included. These factors have long been associated with both pregnancy and postpartum changes in mood and wellbeing in new mothers. During pregnancy, the experience of the pregnancy itself is associated with postpartum mental health, with a negative pregnancy experience linked to poorer mental health outcomes postpartum (Salehi et al., 2020). Interestingly, Salehi et al. (2020) found during COVID-19, the fear and concerns related to COVID-19 during pregnancy mediated this relationship between pregnancy experience and mood, worsening postpartum mental health. Furthermore, it is unsurprising that traumatic birth experiences are associated with later postpartum mental illnesses, usually persisting from birth (Märthesheimer et al., 2025; Simpson et al., 2019), but also evidenced to develop as late as three months postpartum (Kountanis et al., 2020). Finally, though breastfeeding overall is associated with improved mood in new mothers, Yuen et al. (2022) comment that discrepancies between breastfeeding expectations and actual experiences, or the challenges faced during breastfeeding were linked to negative mental health outcomes; this relationship is further nuanced, as it may be worsened if the woman already experiences mental health problems. Subsequently, capturing these variables is important. In the current study, these open-ended questions simply asked, 'have you had any complications during your most recent birth experience?' meaning any medical complications or deviations from the birth plan, 'have you had any complications during your most recent breastfeeding experience?' and 'how do you feel towards your recent birth experience?'

#### 4.2.4. Fathers sample

One hundred and two responses from interested participants were received from recruitment via social media and word of mouth during a seven-month period. Of which, 81 bots were excluded, and 21 fathers completed baseline measures, with one drop out over the intervention (See Figure 3). Three participants from this group were partners of the mothers that also took part in the study. Nineteen participants were White or Caucasian (95%), with one participant categorising as Asian or Asian British (5%). All participants in the sample reported being married or in a domestic partnership. For education, 60% had a bachelor's degree and 50% were employed full time with 50% having a household income between £21,000-£30,000 (see Table 6 for more demographic details).

All men recruited had an infant under six months, for 11 participants, this was their first child. For the remaining nine who reported to have other children, age of children ranged from 4-15 years old. Childcare support outside the family home was reported to be greater compared to mothers, with 17 men (85%) reporting nearby childcare support. Three participants reported a psychological diagnosis, of which, all three reported depression. One participant reported a physical health condition (Asthma), and one participant reported taking medication, which was not described in more detail. Furthermore, 25% participants said they were taking a vitamin or supplement at time of the intervention which ranged from multivitamins, calcium and a protein supplement.

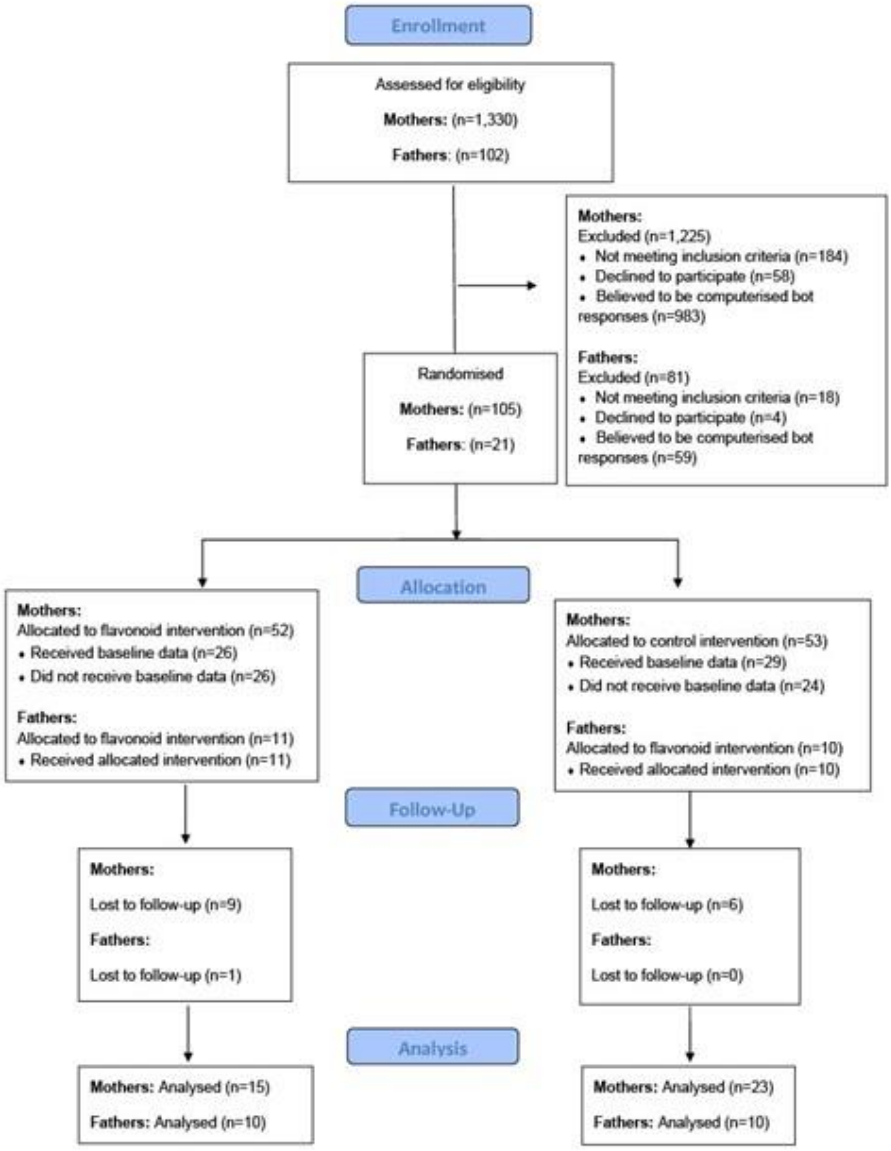


*Figure 3. Experiment 1 consort diagram of participant recruitment.*

4.2.5. Intervention

Those in the flavonoid group were asked to continue with their current diet, but to add two high flavonoid food items per day (see Table 5) into their current diet. Comparatively, controls were asked to continue with their usual diet for two weeks. Two weeks was decided as a suitable intervention length for a number of reasons; firstly as this study aimed to follow on from Barfoot et al. (2021), two weeks would have been suitable to again detect changes from a flavonoid intervention during this time. Secondly, a number of studies have found benefits of chronic flavonoid interventions with shorter durations from 8-days to 3 weeks (Morehen et al. 2020; Shin et al. 2022; Sinclair et al. 2022), highlighting that the benefits from chronic supplementation may also be effective over this period. Mechanistically, Barfoot et al. (2021) found changes in urinary metabolites after 2-weeks of WBB supplementation in children aged 7-10, it is important to note however that this was a pilot study with small sample sizes and different population and intervention, though does highlight capacity for change within this timeframe. Consideration of this population is also necessary when deciding on intervention timeframes, 2-weeks could be considered an agreeable amount of time for this population to implement something daily into their diets without the trial being too demanding, which is an

important feature within the trial for retention of participants as well as compliance with the intervention during an especially challenging time.

Items and portion sizes from the intervention were taken from Barfoot et al. (2021) which were chosen based on their flavonoid content, likability, accessibility, affordability, and typical portion size. The rationale for a variety of flavonoid-rich foods was to enable participants to choose from a range of foods which were likeable to the individual and easily available/affordable. Participants in both groups were asked to keep a food diary for the 2-week intervention to assess compliance (see 4.2.6.8) where the intervention group were asked to highlight the added flavonoid foods which enabled compliance to be tracked (Appendix I.1).

*Table 5. Flavonoid items recommended to intervention group*

| Flavonoid items | Estimated mean flavonoid mg/portion (Rothwell et al., 2013) | Mean (SD) frequency each item was recorded as consumed across participants over 2-week intervention[1] |
|---|---|---|
| | | Mean (SD) |
| Berry fruits (~120g) e.g., blueberries, raspberries, strawberries, blackberries, blackcurrants, mixed berries | 278 | 7.66 (5.08) |
| 1 glass (250ml) of fresh orange or grapefruit juice (not from concentrate) | 110 | 6.30 (6.17) |
| 2 large squares of dark chocolate (at least 70% cocoa) | 47 | 6.06 (5.00) |
| 4-5 cups of coffee (normal or decaf varieties) (250ml) | 1.215 | 4.77 (8.56) |
| 1 portion of leafy green vegetables such as spinach or cabbage (~70g) | 42 | 4.91 (2.34) |
| 4-5 cups of tea (black or green) (250ml) | 894 | 2.11 (3.21) |
| 1 large glass of red wine (250ml) | 206 | 1.92 (2.70) |

[1]Values were derived from participants' food diaries and represent the mean (SD) number of times each flavonoid-rich item was recorded as consumed across all participants during the 2-week intervention period. Values were calculated by summing the total number of times each item was consumed across all participants and dividing by the number of participants (n = 15).

4.2.6. Measures

*4.2.6.1 Demographics*

At the Baseline timepoint (Day 0) (Table 7) data were collected on mother's age and age and sex of the baby. Sleep was self-reported by asking participants to estimate their subjective hours of sleep on average per night. Participants were asked what term the baby was born at, indicated by weeks of pregnancy as multiple-choice answers e.g., Full term, born between 39-40 weeks of pregnancy. Participants were asked how they had been feeding their baby using multiple choice answers of either 'Breast milk', 'Formula milk', 'Combination feeding' or 'Prefer not to say'. Specific diet was indicated by asking participants to note any dietary choices or restrictions e.g., Gluten free or Vegetarian. Participants stated whether they had a psychological or physical health diagnosis by selecting either 'Yes', 'No' or 'Prefer not to say' and giving the participant the option to disclose their physical or psychological health diagnosis. The same question was also asked in reference to whether they were taking medication for psychological or physical health reasons. Finally, participants were asked if they had any other children, where participants selected either 'Yes' or 'No' and had the option to add the number of children and children's age.

*4.2.6.2 Positive and Negative Affect Schedule*

To investigate mood, the Positive and Negative Affect Schedule (PANAS-NOW; Watson, Clark, & Tellegen., 1988) was used. This is a self-report measure consisting of twenty different words to describe feelings and emotions. Ten words reflect positive affect (PA), for example 'interested' and 'excited' and ten words reflect negative affect (NA), for example 'guilty' and 'scared'. The questionnaire is scored on 5-point Likert scale from 1- 'Very slightly or not at all' to 5- 'Extremely' in order to measure participants' feelings at that present time. Scores are then summed to produce a score for each domain of positive and negative affect (scores range from 10-50) where higher scores indicate higher positive and negative affect. The PANAS is a reliable measure which is sensitive for flavonoid interventions (Alharbi et al., 2016) and is widely used in postpartum mood research.

*4.2.6.3 Edinburgh Postnatal Depression Scale*

The Edinburgh Postnatal Depression Scale (EPDS; Cox et al., 1987) is a 10-item self-report measure which can indicate symptoms of depression in a postpartum sample. Responses are on 4-point Likert scales relating to how they have been feeling in the last 7 days on a range from 'Yes, most of the time' to 'Not at all'. Results are scored from 0 to 30, with higher scores reflecting higher depressive symptomatology and a score of 10 being the clinical cut-off to indicate possible postpartum depression in women (Cox et al., 1987) and men (Edmondson et al., 2010). The EPDS is a reliable (Kernot et al., 2015) and valid (Smith-Nielsen et al., 2018) measure and is one of the most widely used tools for measuring postpartum mood.

*4.2.6.4 Postnatal Specific Anxiety Scale*

To measure postpartum anxiety, the Postnatal Specific Anxiety Scale- Research Short Form for global Crises (PSAS-RSF-C; Silverio et al., 2021) was used. This is a shorter version of the original, 51-item scale (Fallon et al., 2016), which was validated for use during the COVID-19 crisis (2020-2022) which this study overlapped with (July 2021-Febuary 2022). Responses are scored on 5-point Likert scales, with possible responses including 'Not at all; Sometimes; Often; Almost always; Not applicable'. After discounting any 'Not applicable' scores, responses are summed with a maximum score of 48. Higher scores indicate higher anxiety, with 26 being a clinical cut-off to detect postpartum anxiety.

*4.2.6.5 World Health Organisation Quality of Life- BREF*

In order to measure perceived quality of life, the World Health Organisation Quality of Life-BREF (WHOQOL-BREF; Skevington at al., 2004) questionnaire was used. The original WHOQOL-100 (The WHOQOL Group., 1998) was deemed too long for the present study. Therefore, the WHOQOL-BREF was included as an internationally used, validated and reliable measure of perceived quality of life. Furthermore, the WHOQOL-BREF has been recognised as a valid measure of quality of life in the postpartum period (Webster et al., 2010). The tool is a 26 item self-report measure of wellbeing over the last two weeks. Responses are scored on a 5-point Likert scale and are each summed into four domains; Physical health, Psychological, Social relationships and Environment. Three questions are negatively phrased and are subsequently reversed coded when scoring, raw scores are then transformed to represent standardised scores from the WHOQOL-100. Higher scores are indicative of higher perceptions of quality of life in each domain.

*4.2.6.6 State Trait Anxiety Inventory*

The STAI state scale (STAI-S; Speilberger et al., 1983) from the STAI was used. The STAI-S consists of 20 self-report questions to measure state anxiety. All items are rated on a 4-point Likert scale from 'Not at all; Somewhat; Moderately so; Very much so'. Scores range from 28-80 with higher scores indicating higher state anxiety. A cut-off of 34 has been recognised to indicate state anxiety in postpartum populations (Tendais et al., 2014).

*4.2.6.7 European Prospective Investigation of Cancer Food Frequency Questionnaire*

In order to understand habitual nutrient intake, the European Prospective Investigation of Cancer (EPIC-Norfolk) FFQ (Day et al., 1999) was used which is a valid and reliable for the measurement for habitual intake of food (Bingham et al., 2001). The questionnaire measures average food consumption over the last year on a 9-point Likert scale from 'Never or less than once per month" to "6+ times per day" for 127 food items. This measure was assessed at baseline and post-intervention; however, the wording was changed to reflect food consumption over a 2-week period rather than the last year. Nutrient intake was then calculated using the FETA software (Mulligan et al., 2014) from the EPIC FFQ, calculating participants' average daily intake of various macronutrients, micronutrients and flavonoids (see Table 8).

*4.2.6.8 Food diaries*

All participants were sent a 14-day food diary template after completing baseline measures (PANAS-NOW, EPDS, PSAS-RSF-C, WHOQOL-BREF, STAI-S and EPIC FFQ). This instructed participants to list what they ate every day, over the intervention period. Participants allocated to the flavonoid group were asked to also note the additional intervention foods they included in their diet. To retain compliance with the intervention schedule, participants were not asked to weigh foods when recording food items in food diaries. In addition, the diaries were used to maintain engagement with the study as the study population needed easy procedures during this period of energy and time constraint. Including the food diary in both groups was an improvement from Barfoot et al (2021) such that both conditions had a matched design. A detailed analysis of the food diaries was not undertaken as this was outside the scope of the study, instead assessment of general diet was monitored with the FFQ. The food diaries were used to assess the nature and quantity of the flavonoids added to the diet in the intervention group and to encourage and monitor compliance.

4.2.7 Procedure

Participants signed up to the study via an online link. Eligible participants were randomised to the intervention or control group and sent links to the relevant first survey to record baseline data

(Appendix F.1, G). Data collection was conducted on two separate occasions, baseline (day 0) and 2-weeks later (day 15).

At baseline, participants completed a demographics questionnaire (see Table 6), then the PANAS-NOW, EPDS, PSAS-RSF-C, WHOQOL-BREF, STAI-S and EPIC FFQ in a fixed order. When baseline data was complete, participants were presented with instructions for the intervention. Those in the intervention condition were instructed to add two additional foods (Table 5) into their diet per day, whilst controls were encouraged to not make any changes to their current diet, though all participants were instructed to log all foods consumed in a daily food diary. If participants had missed a day, they were encouraged to record it as 'missed' and continue as normal the next day. Instructions and the food diary template were emailed to the participant after baseline measures were complete. Half-way through the intervention (day 7), participants were contacted by the researcher to check-in with the progress of the intervention. Finally, at day 15, participants were sent the second survey link which included all outcome measures (the PANAS-NOW, EPDS, PSAS-RSF-C, WHOQOL-BREF, STAI-S and EPIC FFQ), and participants were asked to email their food diaries to the researcher.

Email reminders were sent on day 16 and day 18 for any participants that had not completed the second survey (n=6) or sent their food diaries. Upon debriefing (Appendix H.1), all participants were provided with helplines and weblinks specific to parental mental health support and were encouraged to contact their GP should they wish to seek further support. All participants were reimbursed with a £15 Amazon voucher. Data was collected between July 2021 and February 2022 and the study was given a favourable ethical opinion for conduct by the University of Reading School of Clinical Language Sciences Ethics Committee (2021-171-KB) and is registered at ClinicalTrials.gov (NCT04990622).

#### 4.2.8 Linear Mixed Models

All cognitive and mood data in this thesis were analysed using Linear Mixed Models (LMMs). These models extend simple linear models by incorporating both fixed and random effects. LMMs are particularly well-suited for analysing repeated measures data from chronic randomised controlled trials for several reasons. Firstly, LMMs handle unbalanced data effectively, meaning subjects with missing data can still be included in the analysis, thus preserving statistical power. This is especially important in chronic RCTs, where missing data is common. Furthermore, LMMs provide a more accurate representation of the data because they do not assume that all observations are independent, which is often not the case in repeated measures designs. The model can account for both fixed and random effects, capturing within-subject variance more effectively (Hoffman & Rovine, 2007). For these reasons, LMMs were preferred over alternative models, such as repeated measures ANOVAs.

Models in this thesis were estimated using restricted maximum likelihood (REML), which is standard for LMMs as it produces unbiased estimates of variance. Although LMMs assume that residuals are normally distributed, data from RCTs often violate this assumption. However, simulations suggest that LMMs are robust to such violations (Schielzeth et al., 2020). Furthermore, attempts to reduce violations, such as applying non-linear transformations to the data, can compromise interpretability, making it unnecessary in this case given the robustness of LMMs (Knief & Forstmeier, 2021; Schielzeth et al., 2020). Therefore, LMMs were considered robust to potential violations of distributional assumptions for the data in this thesis.

In all analyses, subject was included as a random factor to account for the non-independence of data within individuals. Partial pooling was applied, allowing both the intercept and slope to vary by subject, which has been shown to improve model estimates (Singmann & Kellen, 2019). Each model included fixed effects for treatment (intervention vs control) session (baseline to post-intervention), and treatment × session interactions, along with fixed covariates dependant on the nature of the trial (varying between Experiments 4-6). Factors that significantly predicted the outcome variable were further explored using Bonferroni-corrected pairwise comparisons, as this correction is considered the most appropriate for controlling Type I error (Field, 2024). When treatment or session significantly

predicted the outcome, pairwise comparisons were conducted at the level of interaction, even if the interaction was not statistically significant (Howell, 1992; Huck, 2012; Wilcox, 1987).

4.2.9 Data analysis

For the qualitative demographic questions, quantitative content analysis was undertaken for participants pregnancy, birth, and breastfeeding experiences whereby the number of yes responses were counted for those experiencing difficulties. For the question 'How do you feel towards your recent birth experience', data was categorised into whether participants had a more negative or positive birth experience overall, based on their qualitative descriptions. This data was then converted into percentages to better understand the proportion of the sample experiencing these symptoms, providing insight into the overall wellbeing of the sample and the presence of potential risk factors.

Quantitative data was analysed using SPSS statistics (version 27). Independent groups t-tests and Chi-squared analysis were conducted to investigate whether there were significant group differences in demographic variables at baseline including parent age, subjective hours of sleep, sex of baby, term baby was born in (e.g., 39-40 weeks), method of feeding baby, specific diets consumed (e.g. vegetarian or vegan), whether the participants had diagnosed psychological or physical health problems, and whether the parents had other children. For PANAS-NOW (PA, NA), STAI-S, EPDS, PSAS-RSF-C, WHOQOL-BREF (physical, psychological, social, environmental), data were analysed using separate linear mixed models where Condition (flavonoid, control) and Time (baseline, 2-weeks) were fixed effects, with the addition of covariates (subjective sleep, maternal age, and baseline habitual flavonoid intake). These covariates were chosen due to their relationship with mood which could potentially influence results. Subjective sleep duration was included as shorter sleep duration and increased sleep disturbances have been well cited with lower levels of mood and wellbeing alongside a greater risk of developing mood disorders (Lemola, Ledermann and Friedman., 2013; Franzen and Buysse. 2008). In particular, postpartum women often experience altered sleep patterns which may affect mood (Ross et al. 2005). Secondly, as discussed, age is a significant predictor of postpartum mood, with older and younger mothers at a larger risk of poorer mood outcomes, hence age is an important factor to control for in the model. Finally, baseline habitual flavonoid intake was included as a covariate to account for the potential impact of habitual diet which may affect mood outcomes according to epidemiological data (Park et al., 2021).

The same structured model was used to analyse nutrients from the EPIC-Norfolk FFQ (flavonoids, calories, carbohydrate, protein, fat, fruit, vegetables) to explore whether enrolment in the dietary study led to any significant changes in habitual diet, macronutrient, and flavonoid intake. One sample t-tests were also conducted to explore differences in mean nutrient intake at baseline with the UK recommended dietary allowance (RDA) for parents in the postpartum period to explore general diet quality in the sample and investigate whether mothers were meeting the RDAs at baseline. Pearson correlations were also ran to investigate the relationship between baseline nutrient intake and mood outcomes.

4.3. Results

4.3.1. Compliance

*4.3.1.1. Mothers sample*

In the mother sample, berry fruits were the most consumed item followed by fruit juice (See Table 5). One participant missed one day of the fourteen-day intervention, indicating good compliance (99.5%).

*4.3.1.2. Fathers sample*

The father sample did not complete adequate food diaries, whereby diaries were often too vague to understand what specific foods were consumed during the intervention, and therefore compliance was unclear for many fathers, though estimated at 55%. In this sample, participants often recorded 'I ate

fruit' rather than noting the type of fruit they ate. This was especially problematic in the flavonoid intervention arm, where it was not able to specify which flavonoid-rich food was consumed over the 14-days. Additionally, some food diaries had many days missing or those in the flavonoid groups did not consume any intervention foods. Therefore, the father's data was not of sufficient quality to undertake a reliable analysis.

### 4.3.2 Demographics

There were no significant differences in demographics (Table 6) and outcome data (Table 7) between flavonoid or control groups at baseline.

*Table 6. Demographic data for both mothers and fathers in flavonoid and control groups collected at baseline.*

| Measures | Mothers (n=38) | | Between groups p-value | Fathers (n=20) | | Between groups p-value |
|---|---|---|---|---|---|---|
| | Control group (n=23) Mean (SD) | Flavonoid group (n=15) Mean (SD) | | Control (n=10) Mean (SD) | Flavonoid (n=10) Mean (SD) | |
| Age Of Parent (Years) | 35.82 (4.04) | 34.40 (3.50) | .852 | 34.80 (4.29) | 32.11 (3.79) | .168 |
| Sleep Of Parent (Hours Per Night) [1] | 5.82 (1.32) | 6.50 (0.52) | .098 | 7.17 (1.41) | 7.15 (1.41) | .158 |
| Age Of Baby (Weeks) | 15.82 (8.53) | 14.60 (4.64) | .330 | 15.50 (9.66) | 18.60 (6.15) | .421 |
| Sex Of Baby (Male: Female) | 18:5 | 8:7 | .106 | 6:4 | 7:3 | .639 |
| Term Of Baby [2] | 4:2:14:2:1 | 2:2:7:4:0 | .538 | 1:2:5:2:0 | 2: 2: 3: 3:0 | .793 |
| Feeding Method[3] | 16:4:3 | 10:0:5 | .111 | 4:0:6 | 5:0:5 | .653 |
| Specific diet[4] | 0:0:1:1:0:21 | 1:1:0:1:112 | .319 | 0:6:0:0:0:4 | 2:2:0:0:0:6 | .273 |
| Psychological diagnosis (Yes: No) | 2:21 | 2:13 | .649 | 1:9 | 2:8 | .531 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Physical health condition (Yes: No) | 4:19 | 2:13 | .737 | 0:10 | 1:9 | .305 |
| Other children (Yes: No) | 11:12 | 10:5 | .254 | 4:6 | 5:5 | .653 |

[1] Assessed by asking parents to estimate, on average how many hours of sleep they estimate to get per night. [2]Very early term (born between 32-36 weeks): Early term (born between 37-38 weeks): Full term (born between 39-40 weeks): Later/Post term (born 41 weeks +): Other. [3] How the baby was fed for the first six-months (Breast milk: Formula: combination). [4] Parents following specific diets (Vegan: Vegetarian: Pescatarian: Dairy free: Gluten free: None).

*Table 7. Mean (SD) raw outcome variable data and interaction effects for mothers in the flavonoid and control groups at baseline and 2-weeks post intervention*

Mothers (n=38)

| | Baseline | | | Post intervention | |
|---|---|---|---|---|---|
| Measures | Control (n=23) (M, SE) | Flavonoid (n=15) (M, SE) | Between groups p-value for baseline comparison | Control (n=23) (M, SE) | Flavonoid (n=15) (M, SE) |
| EPDS | 8.16 (1.10) | 10.29 (1.34) | .237 | 8.88 (1.05) | 7.69 (1.29) |
| STAI-S | 35.63 (2.04) | 41.27 (2.11) | .095 | 34.90 (2.10) | 36.39 (2.57) |
| PSAS-REF-C | 22.04 (1.01) | 21.93 (1.23) | .942 | 20.50 (1.00) | 18.46 (1.22) |
| Positive affect | 30.70 (1.76) | 27.56 (2.15) | .277 | 30.66 (1.63) | 31.96 (2.00) |
| Negative affect | 16.71 (1.10) | 15.82 (1.34) | .617 | 14.40 (0.95) | 14.82 (1.16) |
| WHOQOL Physical | 63.08 (3.40) | 63.07 (4.13) | .998 | 65.95 (2.63) | 75.00 (3.20) |
| WHOQOL Psychological | 52.64 (4.11) | 59.99 (4.99) | .266 | 47.05 (2.45) | 50.65 (2.98) |
| WHOQOL Social | 50.57 (4.27) | 55.41 (5.19) | .482 | 59.71 (3.56) | 57.86 (4.35) |
| WHOQOL Environmental | 73.04 (3.24) | 79.39 (3.96) | .231 | 72.14 (4.28) | 67.59 (5.20) |

4.3.3 Edinburgh Postnatal Depression Scale

Postpartum depression outcomes were measured using the EPDS. No significant differences were found between flavonoid and control conditions at baseline (Table 7). Also at baseline, 42.1% of mothers scored above the clinical cut off (score of 10) for the EPDS, indicating postpartum depression. Furthermore, 23.68% of mothers responded to 'Yes, quite often' or 'Sometimes' when asked '*The thought of harming myself has occurred to me'* on the EPDS signifying some prevalence of depression and thoughts of self-harm in this sample. A significant Condition *Time interaction ($F_{[1,37]}$=10.38, $p$=.003), revealed that mothers in the flavonoid condition reported significantly lower postpartum depression at the end of the two week intervention compared to baseline ($p$=.002), which was not evident in the control group ($p$=.276). There were no significant main effects of Condition or Time or any covariate in the model ($p$>0.05) (Appendix A; Figure 4).

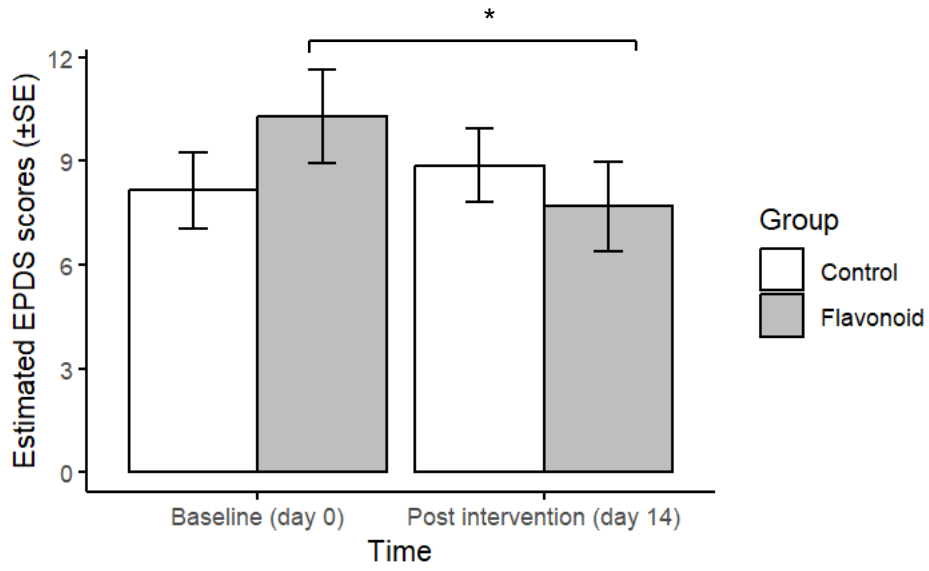


*Figure 4. Linear mixed models with subjective sleep, maternal age, and baseline habitual flavonoid intake as covariates, revealed that mean (SEM) postpartum depression (EPDS) was significantly lower for mothers in the flavonoid group (n=15) at 2-weeks compared to baseline (significant Condition*Time interaction $F_{[1,37]}$=10.38, p=.003). Bonferroni corrected post-hoc analysis indicated a significant reduction in depression in the intervention group (*p=.002) which was not reported in the control group (n=23).*

4.3.4 Positive and Negative Affect Schedule (Positive Affect)

Positive affect was measured with the PANAS, no significant differences were found at baseline between control and flavonoid conditions. A significant Condition*Time interaction ($F_{[1,37]}$=5.13, $p$=.029) was also found for positive affect where mothers in the flavonoid group had significantly higher positive affect scores at Week-2 compared to baseline ($p$=.006) which was not evident in the control group ($p$=.971) (Figure 5). Additionally, results revealed a significant main effect of Time, where positive affect was greater at follow up regardless of condition (Appendix A). Interestingly, Mothers age was a significant covariate ($F_{[1,37]}$=4.62, $p$=.038), where older mothers was associated with lower positive affect, though age was not significant when accounted for in further models.

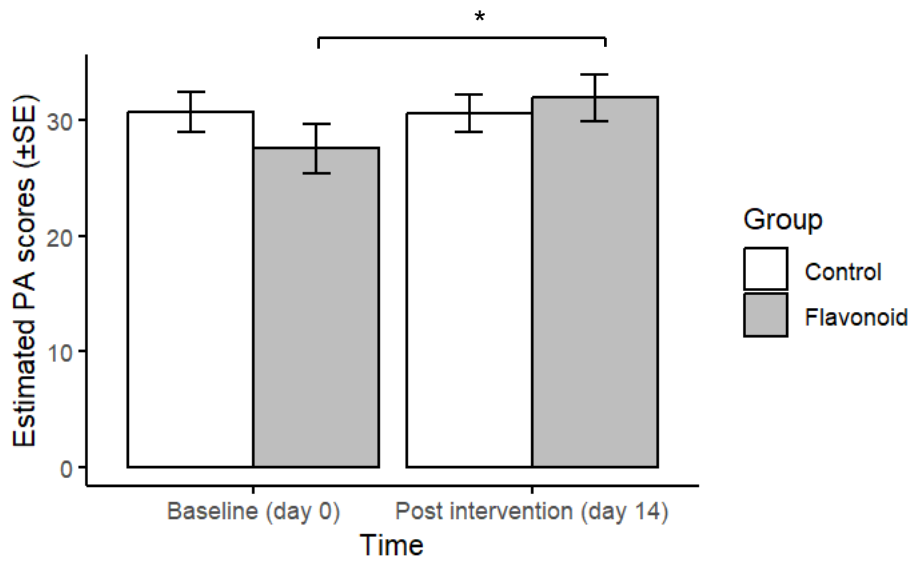


*Figure 5. Linear mixed models with subjective sleep, maternal age, and baseline habitual flavonoid intake as covariates, revealed that mean (SEM) positive affect (PANAS) was significantly higher for mothers in the flavonoid group (n=15) at 2-weeks compared to baseline which was not seen in the control (n=23) with a significant main effect of Time $F_{[1,37]}$=4.92, p=.033 and significant Condition*Time interaction $F_{[1,37]}$=5.13, p=.029). Bonferroni corrected post-hoc analysis indicated a significant reduction in depression in the intervention group (*p=.006) which was not reported in the control group (n=23).*

4.3.5 State-trait anxiety inventory

State anxiety was assessed with the STAI. No significant differences were found between flavonoid and control conditions at baseline (Table 7). At baseline, 60.5% mothers scored above the cut off for anxiety (score of 34) on the STAI, highlighting anxiety for the sample was high at baseline. Time was a significant main effect ($F_{(1,37)}$=4.10, $p$=.05) such that anxiety was lower at follow-up. Additionally, there were no significant effects of any covariate in the model ($p$>.05) (Appendix A; Appendix K.1).

4.3.6 Positive and Negative Affect Schedule (Negative Affect)

Negative affect was also measured with the PANAS, no significant differences were found at baseline between control and flavonoid conditions. Linear mixed models with covariates revealed a significant main effect of Time ($F_{(1, 37)}$=4.78, $p$=.035) but no significant interaction effect, effect of condition and no significant covariates (Appendix A; Appendix K.2).

4.3.7 Postpartum anxiety

Postpartum anxiety was measured with the PSAS-RSF-C, no significant differences were found at baseline between control and flavonoid conditions. At baseline, 21.1% of mothers were above the clinical cut-off for postpartum anxiety. Linear mixed models with covariates showed a significant main effect of Time ($F_{(1, 37)}$=12.46, $p$=.001) with no other significant other interaction, Condition or covariate effects (Appendix A; Appendix K.3).

4.3.8 Quality of life- Physical

Physical health quality of life was assessed with the WHOQOL physical health domain, no significant differences were found at baseline between control and flavonoid conditions. Linear mixed models

with covariates revealed a significant main effect of Time ($F_{(1, 37)}$=5.07, $p$=.029) with no other significant Interaction, Condition or covariate effects (Appendix A).

4.3.9. Quality of life- Psychological

Psychological quality of life was assessed with the WHOQOL psychological domain, no significant differences were found at baseline between control and flavonoid conditions, linear mixed models with covariates showed no significant interaction or main effects ($p$>.05) (Appendix A).

4.3.10. Quality of life- Social

Social quality of life was assessed with the WHOQOL social domain, no significant differences were found at baseline between control and flavonoid conditions. Linear mixed models showed no significant interaction or main effects were found ($p$>.05) (Appendix A).

4.3.11. Quality of life- Environmental

Environmental quality of life was assessed with the WHOQOL environmental domain, no significant differences were found at baseline between control and flavonoid conditions. Linear mixed models showed no significant interaction or main effects were found ($p$>.05) (Appendix A).

4.3.12 Habitual diet

Regarding habitual diet, analysis of data from EPIC-Norfolk showed no significant differences between flavonoid and control conditions at baseline (Table 8). Both control ($p$<.001) and flavonoid ($p$<.001) conditions had a higher flavonoid intake post intervention compared to baseline ($F_{[1,37]}$=63.09, $p$<.001, see Table 7). Additionally, one sample t-tests were conducted to explore differences between mean nutrient intake at baseline and the recommended dietary allowance (RDA) for mothers in the postpartum period. Significant differences were observed for all nutrients, (Table 8), whereby mothers were under-achieving RDA's for most macronutrient groups, except for iron which was higher than the respective RDA (Table 8).

*Table 8. Mean (SD) FETA-derived dietary intake estimates and interaction effects from the EPIC-Norfolk FFQ for mothers in the flavonoid and control groups at baseline and 2 weeks post-intervention.*

| Nutrient | RDA | One sample t-test comparing baseline intake with RDA's | Baseline | | Between groups *p* value | Post-intervention | | Condition*time interaction |
|---|---|---|---|---|---|---|---|---|
| | | | Flavonoid (n=15) | Control (n=23) | | Flavonoid (n=15) | Control (n=23) | |
| | | | M (SE) | M (SE) | | M (SE) | M (SE) | |
| Flavonoid ( mg) | 428 mg[1] | $t_{(35)}$= 2.25, *p*<.030 | 494.08 (144.79) | 770.86 (119.44) | .149 | 1606.860 (143.61) | 1519.12 (115.98) | $F_{(1, 38)}$= 2.42, *p*=.128 |
| Calories (kcal) | 2500kcal[2] | $t_{(35)}$= -9.43, *p*<.001 | 1618.31 (217.95) | 1756.08 (176.01) | .626 | 1606.85 (143.61) | 1519.12 (115.98) | $F_{(1, 38)}$ =.55, *p*=.461 |
| Protein (g) | 71g [2] | $t_{(35)}$= -2.01, *p*<.026 | 60.41 (10.13) | 76.34 (8.35) | .233 | 64.92 (6.60) | 61.82 (5.33) | $F_{(1, 38)}$ =1.95, *p*=.170 |
| Fat (g) | 90g[2] | $t_{(35)}$= -5.62, *p*<.001 | 64.71 (8.48) | 72.76 (6.99) | .469 | 65.28 (7.44) | 60.45 (6.01) | $F_{(1, 38)}$=1.01, *p*=.320 |
| Carbohydrates (g) | 300g[2] | $t_{(35)}$= -7.72, *p*<.001 | 208.24 (26.89) | 232.18 (22.17) | .496 | 199.43 (17.30) | 191.57 (13.97) | $F_{(1, 38)}$=.794, *p*=.379 |
| Fruit (g) | 400g[2] | $t_{(35)}$= -7.78, *p*<.001 | 200.01 (125.92) | 351.31 (103.96) | .360 | 198.27 (39.04) | 218.62 (31.52) | $F_{(1, 38)}$=.613, *p*=.439 |
| Vegetables (g) | 400g[2] | $t_{(35)}$= -7.20, *p*<.001 | 261.55 (229.59) | 489.31 (189.55) | .449 | 396.44 (113.86) | 204.72 (91.95) | $F_{(1, 38)}$= 1.71, *p*=.199 |
| Iron ( mg) | 9 mg[2] | $t_{(35)}$= 1.68, *p*=1.00 | 10.11 (3.47) | 10.22 (2.22) | .912 | 9.03 (3.43) | 8.83 (2.56) | $F_{(1, 38)}$= 2.02, *p*=.163 |
| Folate (mcg) | 500mcg[2] | $t_{(35)}$= -19.46, *p*<.001 | 227.51 (90.37) | 234.61 (67.85) | .792 | 190.18 (87.13) | 199.90 (61.39) | $F_{(1, 38)}$= 1.23, *p*=.274 |

[1] Vogiatzoglou et al. (2015); [2] U.S. Department of Agriculture. (2020)

Linear mixed models with covariates showed no other significant outputs from the EPIC-Norfolk including alcohol, fibre, calcium, vitamin C and D, B6 and B12, zinc and iodine had no significant effect of Time or Condition between Baseline and Post-intervention ($p$>.05).

#### 4.3.13 Qualitative data

A total of 25 mothers provided responses regarding their health experiences during pregnancy. Among these, 18 (72%) mothers acknowledged facing pregnancy challenges. In relation to birth complications, 20 mothers shared their experiences, with all of them highlighting difficulties during childbirth (100%). Elaboration of the birth experience was given by all 38 participants, where 21 (55%) participants described their experiences as more positive, and 17 (44%) more negative. For breastfeeding, 27 mothers responded, all of which indicated encountering difficulties (100%).

### 4.4. Discussion

The current study recruited both mothers and fathers with infants under six months old with the aim to investigate whether a two-week dietary flavonoid intervention would improve parents' mental health in the 6-month postpartum period. Mothers who consumed two additional flavonoid-rich foods per day over two weeks had a significant reduction in postpartum depression scores and a significant increase in positive affect post intervention relative to baseline. No such differences occurred in the control group. These results suggest that regular consumption of flavonoid-rich foods in the habitual diet during the first 6-months postpartum may alleviate symptoms of postpartum depression and improve transient mood in the postpartum population. Due to lack of compliance with the intervention and outcome measures, fathers' data were not analysed, suggesting potential barriers to engagement in this sample. Overall, findings provide evidence to further support the idea that flavonoid-rich foods are an accessible and cost-effective option to promote mental health in mothers in the immediate postpartum period, where risk of mood disturbance is higher than that of the general population.

The overall improvement in positive affect for the flavonoid group aligns with findings from Khalid et al. (2017) who found higher positive affect following acute blueberry intervention across separate samples of children and young adults. Considering that low positive affect is linked to depression and high negative affect is linked with anxiety (Watson, Clark, & Carey., 1988) it could be argued that acute and chronic affective states associated with depressive disorders are more sensitive to flavonoid interventions compared with those associated with anxiety, as both negative affect and anxiety measures did not significantly change as a result of the flavonoid intervention. Conversely, studies have found changes in anxiety symptoms following flavonoid consumption (Barfoot. et al., 2021; Garrido et al., 2012; Sinclair et al., 2022). Comparing mean STAI scores between Barfoot et al. (2021) and the present study reveals no major differences in baseline anxiety, making it unclear why their observed anxiolytic effects were not replicated. However, one possible explanation is the difference in postpartum stage: Barfoot et al. studied mothers up to 12 months postpartum, whereas the current sample included mothers up to 6 months postpartum. This may therefore reflect that changes in anxiety are more responsive to flavonoids in the later postpartum period, though further evidence is needed to confirm this effect.

Sensitivity of a flavonoid effect on chronic depressive symptomology may also depend on the specificity of the measure used. Barfoot et al (2021) found no flavonoid-related outcomes on the PHQ-8, a measure of depression designed for the general population. However, the current study found significantly reduced depression following 2 weeks of dietary flavonoids using the EPDS, a tool specifically designed to capture PPD in a postpartum population. In comparison with the PHQ, the EPDS includes more questions focused on the unique emotional and psychological experiences of motherhood, such as feelings of being overwhelmed by caregiving and the pressure of adjusting to a new role. These factors may be particularly sensitive to dietary interventions, especially those aimed at improving overall mood and well-being. Additionally, the timing of the assessments may play a role in the observed differences. The PHQ-8 measures depressive symptoms over the past two weeks,

while the EPDS captures symptoms over the past week. This shorter time frame in the EPDS may make it more sensitive to more recent mood changes, It is plausible that meaningful changes in mood may emerge after the first week of dietary intervention. If so, averaging across the entire two-week period, as the PHQ-8 does, could mask early effects that only become evident later. Therefore, the higher sensitivity of the EPDS in this context may reflect both its focus on postpartum-specific mood symptoms and its ability to detect more immediate changes in emotional state, which might be more easily influenced by recent dietary improvements. This highlights importance of careful consideration of the outcome measures.

At baseline, postnatal depression and postpartum anxiety scores (as assessed by EPDS and PSAS respectively) were noticeably higher than the number of recorded mental health diagnoses in the sample (postnatal depression n=1, postnatal anxiety n=1, postnatal anxiety and depression n=1 anxiety n=1) whereby 42% of mothers scored over the clinical cut-off for PPD and 60% were above cut-off for PPA. This exceeds respective global population estimates (PPD: 10-15%, Halbreich & Karkun., 2006; postpartum anxiety: 13-40%, Field., 2018), further underscoring the clinical vulnerability of the current sample. This highlights the importance of investigating postpartum mental health within the wider context where risk of missed diagnoses may be high. Furthermore, the qualitative data indicated that the percentage of women reporting a negative birth experience (44%) was also higher than previously recorded prevalence, ranging from 7-21% (Waldenström et al., 2004; Henriksen et al., 2017). It is unclear why this might be, and future research should investigate the factors that might affect mothers' interpretation of birth experience and relation to mood. This data may highlight that the sample were more clinically vulnerable than the general postpartum population. However, the significant reduction in mean postpartum depression scores in the flavonoid group from 'possible depression' at baseline to 'little or no depression' at 2-weeks (-2.6 scoring points) highlights the potential for a flavonoid-rich diet to alleviate some symptoms of clinical depression in this cohort.

The EPIC FFQ was utilised to assess baseline habitual diet and to monitor stability of participants' diets over the 2-week intervention period. Flavonoid intake estimates were derived using the FETA software, which has been validated for macronutrient, micronutrient, and key food group intake (Bingham et al., 1997; McKeown et al., 2001), it has not been formally validated specifically for flavonoid intake. Consequently, flavonoid estimates in Table 8 should be interpreted as indicative rather than precise measures of intake. The only outcome from the EPIC FFQ to significantly change over the two-week intervention was flavonoid content, where flavonoid intake significantly increased from baseline to post-intervention in both groups. Flavonoids were not explicitly mentioned in study advertisements, rather diet was highlighted as the variable of interest, so this effect in the control group is unlikely to be explained by participants specifically focusing on flavonoids. Rather, this finding in the control group may have been an effect of food diary completion leading to increased awareness of diet over the intervention period whereby participants inadvertently consumed a healthier diet which included greater consumption of flavonoid-rich foods. Reassuringly, the mean change between pre and post was higher for the flavonoid group compared to the control (Table 8). Given that the control group also increased flavonoid intake, the observed differences in mood outcomes cannot be unequivocally attributed solely to flavonoid consumption. Therefore, while improvements in postpartum depression and positive affect were larger in the flavonoid group, these results should be interpreted with caution.

As no significant differences as a result of the intervention were found in other EPIC items such as fruit and vegetable intake, it's likely participants consumed other flavonoid-rich foods and beverages such as cocoa and tea which contributed to the significant change in flavonoid consumption in both groups. However, these specific items were not captured in the EPIC analysis, making it difficult to ascertain the main sources of flavonoids in the participant's diet. It is also important to emphasise here that the food diaries did not provide enough data to accurately estimate flavonoid or other nutrient intake, and the main purpose, as previously described, was to identify the intervention food items, to assess and encourage compliance, and to match procedures across the two groups. It would be interesting to explore this in future studies using dietary measures which may better capture intake of

high flavonoid foods, for example 24-hr food recalls (Peterson et al., 2015) or a more comprehensive collection of flavonoid-rich items in current dietary questionnaires.

At baseline, there were differences between the RDA several macro and micronutrients, where mothers were significantly reporting underconsumption of these macro and micronutrients. Also, in regard to RDA, at baseline, differences can be seen for fruit, vegetable and flavonoid, intake. These slight differences at baseline could partly drive the results, whereby the flavonoid intervention group have lower intakes of these items and therefore could have greater benefits of the dietary intervention, as seen in Conner et al. (2017) and Velichkov et al. (2024). However, importantly, there are no significant differences between groups for any nutrients, which suggests that these baseline variations may not be a major confounder in the overall interpretation of the findings.

Food diaries in the current study did accurately capture the two daily flavonoid-rich items participants added to their diet over the 2-week intervention period. Berry fruits, orange juice and dark chocolate were the most consumed intervention food by mothers (22%, 18% and 17% consumed over the two-week period respectively). Analysis of the food diaries further indicated patterns in the types of flavonoid-rich items consumed. Mothers tended to frequently consume certain items such as berry fruits, orange juice, and dark chocolate, while less frequently consuming other flavonoid-rich foods, suggesting that participants primarily added the same items to their diet rather than broadly diversifying flavonoid sources over the two-week period. These results are in keeping with previous experimental and epidemiological studies demonstrating antidepressant effects of a high flavonoid, berry-rich diets (Khalid et al., 2017; Fisk et al., 2020; Chang et al., 2016). Regarding potential mechanisms, berry fruits are rich in anthocyanins, and as outlined in Chapters 1.7.2, and 3.6, have been hypothesised to have regulatory abilities for mood by crossing the blood brain barrier (BBB) acting as a monoamine oxidase (MAO) inhibitor (Youdim, Shukitt-Hale and Joseph., 2004; Dreiseitel et al., 2009). Elevated MAO has been observed in the immediate postpartum period (4-6 days after birth) (Sacher et al., 2010) which was later positively associated with postpartum depressive symptoms (Sacher et al., 2015), suggesting the MAO hypothesis for depression may extend to the postpartum. Collectively, this evidence could explain why depressive mood and positive affect were improved in the present study following an increased consumption of berry fruits which was not found in Barfoot et al. (2021) though more research is warranted.

As discussed, fathers' data was not analysed due to lack of engagement with the study materials and intervention. This continues to be an area of research interest due to the significant risk of poor mental health and PPD in the immediate postpartum for fathers and male caregivers. Additionally, there was a large attrition rate (Figure 3), where fathers seemed less motivated than mothers to participate in a nutrition and mood study. Further research should explore engagement of fathers in nutritional interventions and paternal mental health, to evaluate whether certain study methodologies (e.g. online testing) or other factors around motivation for involvement or completion of the research affect engagement. Mitchell et al (2007) stress the difficulty in recruiting and retaining fathers in research, highlighting that high attrition rates in paternal research is common. Under engagement in research has also been associated with lower socio-economic status (Unger et al., 2013). The father's sample had a slightly lower household income than the UK average at £32,300 (Office for National Statistics, 2022) and also compared to the mothers sample, which may partly explain the lack of engagement in the trial. Additionally, the majority of fathers (n=18) did not have a partner also taking part in the trial which may have resulted in a lack of shared motivation and social support which perhaps could be a barrier for fathers engaging in nutritional interventions. Another major barrier to paternal research is recruitment, which is primarily conducted via their partners (Tokhi et al., 2018). Recent research suggests that studies seeking to recruit fathers for parenting research should prioritise using advertisements specifically tailored to fathers; for example 79% of participants recruited through father-targeted advertisements were male, while only 14% of participants recruited through advertisements targeting parents in general were male (Yaremych and Persky., 2002). Collectively, this highlights a growing need to explore paternal involvement with research generally and applying these methods to nutritional research. In addition, the structure of families within the UK is as varied as it has ever been, with only 44% of families in a traditional nuclear structure of a biological mother,

father and child(ren) cohabiting (Office for National Statistics, 2023), therefore is important to acknowledge that prevalences in parental mental health may vary depending on changing family structures. Furthermore, same sex couples have been found to have higher rates of postnatal depression than heterosexual couples (Ross et al., 2007) with research suggesting perinatal mental health may be poorer in Lesbian, Gay, Bisexual, Transgender, Queer or Questioning, Two spirit and additional sexual orientations and gender identity (LGBTQ2S+) couples (Kirubarajan et al., 2022). Exploring the mental health of parents and caregivers inside and outside the heteronormative realm is critical to supporting and treating PPD at population level.

Future research should continue to explore the potential benefits of dietary interventions for improving mood and well-being in the postpartum period. Given the differences in findings and the aspects of mood between Barfoot et al. (2021) and this study, the timing of the intervention may play a crucial role in its effectiveness. Additionally, the dosage of flavonoids requires further investigation, as varying quantities may have different impacts on specific facets of mood. The dose used in this study appears feasible for new parents, particularly mothers in the 0-6 month postpartum period, but further research is needed to assess its feasibility and effectiveness at different stages of the postpartum period, in addition to observing if there continues to be a dose-response relationship for mood outcomes in this population. Furthermore, deeper exploration into the mechanisms underlying both postpartum mood changes and the specific actions of dietary flavonoids is essential for understanding how these interventions might work. As discussed in Chapters 3.2 and 1.5.3, mood changes may impair cognitive function, particularly in individuals during pregnancy and the postpartum period. Given the documented benefits of flavonoids for cognitive function (Cheng et al., 2022), this presents an intriguing area for future research to further explore and clarify the relationship between mood, cognitive function, and flavonoid interventions.

It's clear that measures and methodologies are crucial in dietary intervention trials, especially when determining flavonoid content in the habitual diet. As demonstrated by Ma et al. (2024), discrepancies between different dietary assessment tools, such as food frequency questionnaires (FFQs) and more direct measures like urinary polyphenol metabolites, can lead to different conclusions about the relationship between flavonoid intake and mood. This highlights the potential benefits of using more dynamic dietary assessment methods, such as 24-hour food recalls, in these types of studies. Unlike FFQs, which estimate habitual intake over long periods, 24-hour food recalls can capture more immediate dietary intake, providing a potentially more accurate representation of flavonoid consumption in relation to mood and well-being. Incorporating such tools, along with physiological measures like plasma and urinary metabolites, could offer more comprehensive insights into how dietary flavonoid intake impacts mental health outcomes, and to continue to investigate this relationship into the postpartum period. Lastly, investigation into paternal mental health remains crucial; however, this study highlights that recruiting parents and engaging them in dietary intervention trials can be complex. Future research should explore alternative recruitment strategies to better engage fathers in these studies, to explore whether dietary interventions may be of benefit to this sample.

In conclusion, this study provides evidence for the benefits of a dietary intervention for mood and mental health to mothers in the immediate postpartum. Specifically, this study demonstrated improvements in postpartum depression symptoms and positive affect following a 2-week flavonoid-rich diet in the 0–6-month postpartum. However, as the control group also increased their flavonoid intake, these findings cannot be attributed solely to the intervention diet. The results should therefore be interpreted cautiously, and further research is needed to clarify the specific contribution of flavonoids to postpartum mood changes. The research also observed that fathers in this critical period lacked adequate engagement, highlighting a need for further research into diet and paternal mental health.

# Chapter 5: Exploring the effects of a chronic 30-day dietary flavonoid intervention on mood and cognition in the immediate postpartum

## 5.1. Introduction

Given the promising findings from supplementing flavonoids during the postpartum period (Barfoot et al., 2021) and the potential benefits observed within the first 0-6 months postpartum (Chapter 4), there appears to be consistent evidence that flavonoid-rich foods may be beneficial for mood during this critical postpartum period. While this period is associated with increased risk of mood disorders, research suggests that the few days immediately following birth may be particularly important. This is thought to be due to the onset of the 'postpartum blues', also known as maternity blues or baby blues, which often manifests shortly after childbirth. This normal, transient psychological condition is characterised by mood swings, irritability, crying spells, and sadness (Ntaouti et al., 2020) and estimated to effect between 13-76% of new mothers (Rezaie-Keikhaie et al., 2020). Symptoms typically emerge between days 3 and 5 following delivery (Buttner et al., 2015; Henshaw et al., 2004; Pop et al., 2015), often subsiding before the $10^{th}$ day (Beck, 1991; Yalom et al., 1968). More severe and prolonged experiences of postpartum blues have been associated with an increased risk of developing postpartum depression, often with an earlier onset within the first year (Landman et al., 2024; O'Hara et al., 1991; Watanabe et al., 2008).

Several risk factors are associated with worse postpartum blues and later depression, including a history of previous mood disorders, lack of social support and low economic status (Henshaw et al., 2004; Manjunath & Venkatesh, 2011). As outlined in Chapter 3.1, hormonal changes are linked to mood alterations in the weeks following delivery, and these changes are most pronounced in the initial days after birth. For instance, Harris et al. (1994) found that a larger fall in progesterone following delivery was associated with higher postpartum blues scores, which peaked at day 5 postpartum. Furthermore, changes in oestrogen, prolactin and other circulating sex hormones have been associated with the postpartum blues and subsequent postpartum mood disorders (Nott et al., 1976; O'Hara et al., 1991). Considering the findings from Experiment 1, in conjunction with Barfoot et al. (2021) and similar evidence from Dowlati, Meyer and colleagues (Chapter 3.5), flavonoids may represent a suitable intervention to promote mood and wellbeing in the immediate days postpartum. Taking into account that the severity of postpartum mood states in the initial days following delivery may predict later postpartum prevalences and severity of mood disorders, supplementing with a dietary intervention during the immediate postpartum may provide benefits to the later postpartum, though this has not yet been investigated.

Cognitive changes are also pronounced during the postnatal period, with evidence indicating poorer cognition in the postpartum, particularly in areas such as executive functioning (Almanza-Sepulveda et al., 2018; Chico et al., 2014; Logan et al., 2014), processing speed (Anderson & Rutherford, 2012; Henry & Sherwin, 2012a), verbal memory (Buckwalter et al., 1999) (Henry & Sherwin, 2012a), working memory (Almanza-Sepulveda et al., 2018; Anderson & Rutherford, 2012; Pieters et al., 2021), and interestingly, subjective memory (Orchard et al., 2023). However, Orchard et al. (2023) note discrepancies in the extent of cognitive decrements during the postpartum, with some studies being limited by the lack of appropriate control groups (Pieters et al., 2021), often using non-pregnant control groups which introduces levels of variability in the findings due to differences in hormonal profiles, sleep patterns and lifestyle factors unrelated to the postpartum period. In light of the evidence base for improvements to cognition following flavonoid interventions (e.g. see meta-analysis Cheng at al., 2022 and Chapter 1.5 for reviews), alongside the cognitive changes observed during the postpartum, there is potential for flavonoid supplementation to benefit cognition in a postpartum sample. Additionally, there is consistency between the cognitive domains affected by the postpartum and those which appear to be most sensitive to flavonoid interventions (e.g. executive functioning, working memory, processing speed and verbal memory, as outlined in Chapter 1.5), this further supports the potential utility of flavonoid supplementation for enhancing postpartum cognition.

In addition to mood and cognitive outcomes, it is pertinent to examine flavonoid-related physiological change to ascertain potential mechanistic pathways. As outlined in Chapter 1.7.4, consumption of

flavonoid-rich food such as berries and cocoa have been found to improve flow-mediated dilation (Rodriguez-Mateos et al., 2013) and cerebral blood flow (Keane et al., 2016a; Lamport et al., 2015). Specifically, flavanol-rich cocoa has been shown to improve endothelium dependant vasodilation via acting on nitric oxide pathways (Fisher et al., 2003; Heiss et al., 2003). These mechanisms can increase delivery of oxygenated blood and therefore nutrients to the brain which may be a plausible mechanism of mood and cognition improvement following flavonoid interventions. These responses have clear implications for the cardiovascular system, for example flavonoids have been shown to lead to improvements in blood pressure potentially via improved endothelial function and increased vasodilation (Hodgson & Croft, 2006; Keane et al., 2016a). Coincidently, blood pressure changes are seen throughout the postpartum, with increases in blood pressure immediately following delivery, returning to pre-pregnancy values in 2-weeks (Soma-Pillay et al., 2016), these initial changes also may lead to postpartum hypertension which may develop during this time even with non-hypertensive pregnancies (Bramham et al., 2013). Further to this, research has shown that women diagnosed with hypertension or preeclampsia have either a higher risk of onset or greater severity of depressive symptoms (Caropreso et al., 2020; Strapasson et al., 2018). Given that flavonoids can modulate these pathways through improvements in endothelial function and nitric oxide bioavailability, they may represent a dietary strategy to attenuate both cardiovascular and mood-related changes in postpartum women. Therefore, considering the nature of postpartum blood pressure regulation, it is of particular interest to monitor these changes alongside mood outcomes to better understand whether flavonoid-related cardiovascular benefits translate to psychological improvements during this vulnerable period.

Studies investigating postpartum changes benefit from longitudinal designs, allowing for the tracking of mood and cognitive fluctuations across a hormonally and psychologically complex period. Collecting data during pregnancy prior to birth is valuable to provide a pre-intervention baseline. In particular, measuring mood in the later stages of pregnancy enables meaningful comparisons with postpartum data. While there is limited evidence specifically tracking mood fluctuations across the third trimester, Field et al. (2006) report general mood stability between 20–32 weeks, whereas research suggests a U-shaped curve, with changes in mood and disorder symptomatology highest in the first and third trimesters (Bennett et al., 2004; Da Costa et al., 2000; Markon et al., 2021; Sedov & Tomfohr-Madsen, 2021). Therefore, assessing mood in late pregnancy, close to delivery, may provide a more appropriate comparator for postpartum outcomes. Practically, collecting data shortly before birth may also help to minimise attrition, as maintaining contact close to labour can improve participant engagement in early postpartum visits. Initiating an intervention within the first four days postpartum may be particularly important, as it would ensure flavonoid exposure occurs before the peak of postpartum blues, typically observed around day 5 (Sacher et al., 2010), when monoamine oxidase-A (MAO-A) density and mood symptoms are heightened. Given that flavonoids have been seen to inhibit MAO activity and improve mood (Chapter 1.7.2; Chapter 2), it is plausible that flavonoid mood-enhancing effects, as mediated by MAO activity, may also apply to the postpartum period. As previously mentioned, studies from Dowlati et al. (2017) and Meyer et al. (2024) suggest that a dose of flavonoid-rich blueberry, alongside a combination of tyrosine and tryptophan may result in resilience to depressed mood in the immediate postpartum period, via the MOA interaction. With regard to length of intervention, previous evidence demonstrates a period of 30-days may be optimal to show benefits of flavonoids to mood (for review, see Chapter 2). In example, Fisk et al. (2020) found decreased scores in the Mood and Feelings Questionnaire, a measure of depression, following 4-week blueberry intervention compared to placebo. Also, within this timeframe Abdelhalim (2021) found those who consumed 250 mg fresh peppermint 30 minutes before bedtime had reductions in the anxiety compared to those in their control group. Mechanistically, improvements in endothelial and cerebral blood flow, modulation of the HPA axis, and monoamine oxidase inhibition may exert cumulative effects over relatively short periods, producing measurable mood benefits within weeks rather than months (Chapter 1.7), suggesting a period of 30-days may be optimal to detect mood effects from a dietary flavonoid intervention.

Within this 30-day timeframe, including a 2-week timepoint would be ideal as is consistent with previous flavonoid-based interventions (Barfoot et al., 2021; Experiment 1), facilitating comparison. Including a 12-week postpartum follow-up timepoint would additionally be valuable within early

postpartum intervention research, in order to assess the longevity of any mood-related changes, as depressive symptoms often peak during this period , with symptom onset commonly occurring within the first three months postpartum (Monti et al., 2008). Notably, prevalence rates have been reported to be highest at 10 weeks postpartum, compared to 6, 12, and 18 months, as measured using the EPDS (Pellowski et al., 2019). Moreover, flavonoid studies rarely include follow-up assessments beyond the immediate post-intervention period, limiting understanding of sustained behavioural effects. A 12-week follow-up would therefore provide important insights into the degree of sustained mood change following daily flavonoid intake. As such, the present experiment investigated mood and cognition at pregnancy, 0-4 days postpartum, 2-weeks, 4-weeks and 12-weeks postpartum, introducing the dietary flavonoid intervention in the first 0-4 days following delivery for a period of 30-days. Crucially, this multi-timepoint design provides one of the most comprehensive assessments of mood and cognition across the early postpartum period to date. By combining a pre-emptive early intervention, initiated within the first four days postpartum, before the peak of postpartum blues with repeated assessments spanning to 12 weeks, this study uniquely captures both the short- and longer-term trajectory of psychological and cognitive changes. Such an approach not only strengthens the ecological validity of findings but also addresses a critical gap in the literature, where few nutritional intervention studies have examined mood and cognition across this complex window.

Trials investigating the relationship between a dietary flavonoid intervention and postpartum mood previously (Barfoot et al., 2021, and Experiment 1) found different facets of mood outcomes to benefit, potentially due to factors such as different sampling timeframes and postnatal specific questionnaires. However, the two trials also utilised two different doses of flavonoids, which may have potentially elicited different results, whereby Barfoot et al. (2021) found reductions in symptoms of anxiety with one portion, though when two portions were introduced in Experiment 1, reductions in depression and transient depressive states were found. Previous research has shown symptom reduction in a dose response manner following flavonoid supplementation, whereby consuming higher amounts of flavonoids, specifically anthocyanins and flavanones resulted in lower depressive symptoms (Chang et al., 2016; Godos et al., 2018), indicating that elevating levels of total flavonoids, as well as specific subclasses in the diet may have optimal benefits on different aspects of mood. Importantly, RCT evidence also supports a dose-response effect. For instance, Pase et al. (2013) utilised a parallel groups trial, finding significant increases in calmness and contentedness following highest dose of cocoa flavanols (500 mg) following 30-day supplementation, which was not seen following placebo drink or 250 mg drink, indicating a dose-response relationship. Such findings strengthen the argument that varying flavonoid doses can produce different mood outcomes and may help explain the discrepancies between Barfoot et al. (2021) and Experiment 1, though requires further investigation.

In addition to an early intervention in the postpartum period and comprehensive assessment of mood and cognition from pre-birth to 12-weeks postpartum, this study differs from the trial presented in Chapter 4 in terms of the focus on maternal outcomes only. Given the timepoints in this trial and the level of commitment required, it may be more challenging for partners to participate. However, this should not diminish the importance of exploring paternal mood and cognition in the postpartum period, an area with significant potential for further research. As a proxy for partner mood, the Edinburgh Postnatal Depression Scale-Partner (EPDS-Partner) was used to assess partner feelings from the mother's perspective. This approach provides a valid and reliable measure of partner mood, allowing for an exploration of the relationship between maternal and paternal well-being in the current study, while mitigating challenges related to recruitment and attrition in fathers.

The primary aim of this study was to investigate whether a 30-day high flavonoid dietary intervention could improve postpartum depression and anxiety, while secondary aims included measurement of cognitive function and blood pressure following a 30-day intervention, and assessment of all mood, cognitive an physiological outcomes at both 2 and 12 weeks postpartum. Building on findings from Barfoot et al. (2021) and Experiment 1, participants were randomised into one of three groups: control, low flavonoid (one flavonoid-rich food per day), and high flavonoid (two flavonoid-rich foods per day), enabling an exploration of potential dose-response effects. Crucially, this study extends previous work through its longitudinal design, capturing outcomes across five timepoints

from late pregnancy to 12 weeks postpartum. It was hypothesised that mothers in the high flavonoid group would show reductions in postnatal depression, state and postnatal anxiety, alongside improvements in mood, subjective cognition, working memory, executive function, processing speed, and verbal memory.

## 5.2 Methods

### 5.2.1. Design

The study employed a randomised, parallel groups-controlled design to explore the effects of a 30-day flavonoid intervention versus control on several mood and cognitive outcomes. Outcome measures were assessed at five timepoints (Figure 6); 1) Pregnancy (third trimester), 2) 0-4 days postpartum, 3) 2-weeks, 4) 4-weeks and 5) 12-weeks postpartum. The primary outcome measures for the study were depressive symptoms (Edinburgh Postnatal Depression Scale; EPDS) and state anxiety (State-Trait Anxiety Inventory-State scale; STAI-S). Secondary outcome measures included postpartum specific anxiety symptoms (Postpartum Specific Anxiety Scale; PSAS), current affect (Positive And Negative Affect Schedule; PANAS), partner depressive symptoms (Edinburgh Postnatal Depression Scale-Partner; EPDS-P), subjective prospective and retrospective memory (Prospective Retrospective Memory Questionnaire; PRMQ), verbal memory (Rey's Auditory Verbal Learning Test; RAVLT), sustained attention and executive functioning (Modified Attention Network Task; MANT), visuospatial working memory (Visuospatial N-Back), and resting systolic and diastolic blood pressure. Other measures taken included general diet (European Prospective Investigation of Cancer-Norfolk-Food Frequency Questionnaire; EPIC-FFQ), 24-hr dietary recall (Intake24) and subjective sleep (Pittsburgh Sleep Quality Index; PSQI).

Data reported in Experiment 1 showed non-significant, but considerable differences in baseline flavonoid intake between flavonoid and control groups. Considering that baseline flavonoid intake plays a key role in mood and cognitive outcomes (chapters 1.4.1 and 1.5.1), it was deemed appropriate to ensure even spread of flavonoid intake across conditions in the current study. As such participants were quasi-randomised according to their flavonoid intake, measured with the EPIC FFQ which was taken at the pregnancy timepoint. Based on average estimates of flavonoid intake, outlined in Chapter 1.3, participants were considered 'high' flavonoid consumers if total flavonoid consumption was >428 mg/day (Vogiatzoglou et al., 2015) (n=25), and low consumers if consuming less than this estimate (n=31). After categorising if participants were high or low consumers, a random number generator was used to randomly assign to either a 'low flavonoid', 'high flavonoid' or a control group.

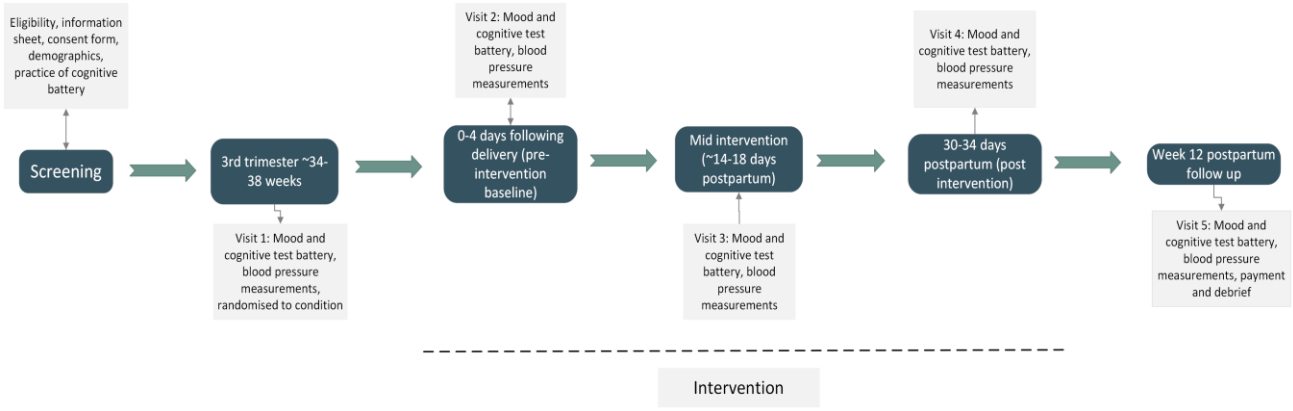


*Figure 6. Diagram of study deign*

### 5.2.2. Participants

Based on the findings from Experiment 1, which showed a large effect size (Cohen's f = 0.98) for the impact of flavonoids on EPDS scores in a 2x2 design, an a priori power analysis indicated that only 6 participants would be required to achieve 95% power at an alpha level of 0.05. To allow for adequate detection of smaller but meaningful effects in a more complex design involving three groups and five repeated measures in the immediate postpartum, a larger sample size was selected. A total of 60 participants (20 per group) was targeted, consistent with the sample sizes used in previous postpartum flavonoid intervention studies (Barfoot et al., 2021).

The inclusion criteria was that participants were over the age of 18, and were pregnant (reliant of mothers' self-reporting), were English speakers and resided within a 30 mile radius of Reading. Participants were excluded if they were beyond 38 weeks of their pregnancy (reliant on mother's self-reporting). No further exclusion criteria were applied, as recruitment feasibility was a priority considering the timepoints of the visits, meaning a broader inclusion was necessary.

### 5.2.3. Sample

One hundred and thirty-two responses to the online advertisements were received via mum and baby pages on social media and in-person mum and baby groups in Berkshire between March 2023 and April 2024. Of these, 14 were excluded due to being computerised bot responses or lost following screening (Figure 7). A total of 60 participants completed baseline data and 56 participants completed the intervention (See Figure 7).

Of the sample of 56, the average weeks gestation at screening was 31 (27-36 weeks). 85.7% were White or Caucasian, 7.1% Asian or Asian British, 1.7% Black/African/Caribbean/Black British and 5.3% reporting mixed race, with 85.7% reporting to be married or in a domestic partnership (10.7% single). Half the women had a bachelor's degree as their highest level of education (50%), with 25% holding a Master's degree and 5.3% holding a PhD or Doctorate degree. Considering employment status, 55.3% worked full time, with 75% having a household income over £51,000. For 28 (50%) women, this was their first child. In those who reported other children, the age of children ranged from 11 months to 14 years. Twelve women (21.42) reported a physical health diagnosis, with the most common being Asthma (10.7%). For psychological health, 14 participants (25%) reported a psychological diagnosis, of which, 4 women had anxiety, 2 had depression and 6 had comorbid anxiety and depression, 2 had obsessive compulsive disorder. Out of these 14 women, three were taking medication for their mental health. Finally, 19 (33.9%) women reported pregnancy complications such as gestational diabetes (3.5%) and hyperemesis gravidarum (3.5%). Other reported complications included pelvic pain, anaemia and premature rupture of membranes.

Participants were seen on average 3 days following delivery, the earliest gestational age at delivery was 36 weeks, though the majority of participants delivered at 39 weeks (35.7%). Majority of participants had a vaginal delivery (55.3%), followed by Caesarean section (26.7%) and assisted vaginal delivery (vacuum or forceps) (17.8%). A sample of participants reported birth complications (14%), with the most common complication being an emergency caesarean section (7.1%). Visual analogue scales (1-10) were given to participants to report their birth experience. On average, participants reported a more positive (scores above 5) birth experience of 7.19 (2.27). If participants had decided to breastfeed (30%), some (70.6%) reported difficulties such as pain and infant tongue ties. Finally, 10 (17.8%) reported not having adequate childcare support.

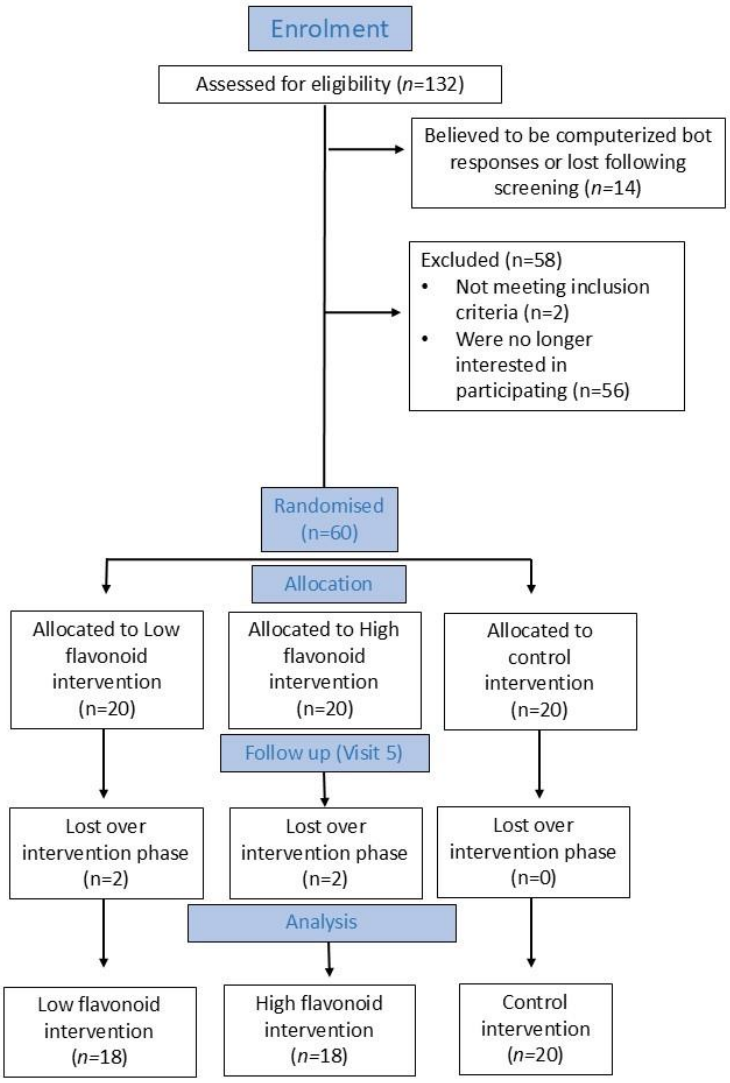


*Figure 7. Experiment 2 consort diagram of participant recruitment*

5.2.4. Intervention

Following a similar intervention to Barfoot et al. (2021) and Experiment 1, those in the flavonoid groups were asked to continue with their current diet, but to add either one or two (depending on condition) flavonoid food items per day into their current diet. Comparatively, controls were asked to continue with their usual diet for 30-days. Items were initially selected based from Barfoot et al. (2021) which were chosen based on their flavonoid content, likability, accessibility, affordability, and typical portion size. Portion sizes were chosen based on the flavonoid content alongside what was deemed reasonable for participants to consume based on the findings from Experiment 1, whereby an average of 219 mg flavonoids were consumed per day, following consumption of 2 portions of the foods. This method was chosen as 219 mg/day (high flavonoid group) and 109 mg/day (low flavonoid group) therefore represent achievable intake levels of flavonoid-rich foods for postpartum mothers. Furthermore, these quantities were previously associated with beneficial mood outcomes, as indicated by data from the previous experimental chapter and Barfoot et al. (2021).

The foods included in the present study were refined from the previous studies, whereby items that were not as rich in flavonoids, such as cabbage and coffee, were removed as participants would need to consume large quantities to obtain the 219 mg/day. Additionally, items which had greater

variations in flavonoid content such as tea (green and black) were removed, as these are affected by various factors in preparation, such as temperature of the water (Lakenbrink et al., 2000), which may have brought in additional variability within consumption of flavonoids. Red wine was also removed upon consideration of the wider health message this may have portrayed within the study (Haastrup et al., 2014; NHS, 2020). Furthermore, to more accurately calculate the flavonoid content in the foods, grouped items such as 'mixed berries' and 'leafy green vegetables' in Experiment 1 were separated into individual items, such as blueberries and spinach so participants could choose individual foods such that it could more accurately ascertain flavonoid content in the intervention groups.

Participants in both intervention groups were provided with the list of intervention foods in grams/mls to consume over the intervention period (Table 9). This list also included the quantity of food based on average portion sizes. Flavonoid content of items was calculated using USDA flavonoid content data (Bhagwat & Haytowitz, 2023). For example, to reach the 109 mg flavonoids in commercially available orange juice, the participant would be required to drink approximately 190mls, which approximated 1/3$^{rd}$ of a pint, this enabled freedom if the participant wished to measure/weigh the intervention or if they would rather count how many foods/visualise how much to drink. Participants were also asked to note down the included foods over the 30-day period, which enabled compliance to be observed (Appendix I.2).

### 5.2.5. Measures

#### *5.2.5.1 Demographics*

At screening, demographic data was collected on gestational weeks and baby due date. Specific diet was indicated by asking participants to note any dietary choices or restrictions e.g., Gluten free or Vegetarian. Participants were also asked if they had a psychological or physical health diagnosis by selecting 'yes', 'no' or 'prefer not to say', and if they were taking medication for such reasons. Additionally, participants were asked if they had any other children by indicating 'yes', 'no' or 'prefer not to say', and if so, to provide the number of children and their ages.

Visit 1 (0-4 days) included an additional demographic questionnaire collecting data on how old their baby was at the time of data collection, sex of baby indicated as 'Female', 'Male', 'Other', and 'Prefer not to say', infants gestational age at birth, mode of delivery where participants selected an option from multiple choice answers of either 'Vaginal delivery', 'assisted vaginal delivery (vacuum or forceps)', 'Caesarean section', 'Prefer not to say', 'Other', if participants selected 'other' they were provided with a box to specify their mode of delivery. Birth complications entered as 'yes', 'no', 'prefer not to say' where participants that selected 'yes' were asked if they wished to provide further detail, feelings toward their recent birth experience (entered as a visual scale from 1-10), with the option to provide additional comments regarding recent birth experience, breastfeeding complications and whether they had any access to nearby childcare support with 'Yes', 'No', and 'Prefer not to say' options.

#### *5.2.5.2 Repeated outcome measures*

The EPDS, STAI, PANAS and EPIC FFQ was utilised in this study, please refer to 4.2.6.2, 4.2.6.3, 4.2.6.4 and 4.2.6.7 for commentary on the validity and reliability of these measures.

#### *5.2.5.3 Postnatal Specific Anxiety Scale*

To measure postpartum anxiety, the Postnatal Specific Anxiety Scale; PSAS (Fallon et al., 2016) was used. This is a 51-item scale where responses are scored on 5-point Likert scales, with possible responses including 'Not at all; Sometimes; Often; Almost always; Not applicable'. After discounting any 'Not applicable' scores, responses are summed with a maximum score of 204. Higher scores indicate higher anxiety, with 112 being a clinical cut-off to detect postpartum anxiety.

*5.2.5.4 Edinburgh postpartum depression scale- partner*

This is a 10-item measure adapted from the EPDS developed by Moran and O'hara (2006). The EPDS-P is a revision of the EPDS to provide a proxy of the partners' symptoms of depression. In this study, the mothers will complete the EPDS-P to provide information about paternal depressive symptoms. The scale and scoring of the EPDS-P is the same as the EPDS, though there is no cut-off in the EPDS-P to indicate likelihood for depressive disorder.

*5.2.5.5. Prospective and retrospective memory questionnaire (subjective cognition)*

In order to measure subjective memory, the PRMQ (Crawford, 1996) was employed, a 16-item rating scale, designed to assess the frequency of different types of memory failures whereby higher scores indicate greater frequency of memory failures. Participants were asked to score questions on a 5-point scale 1 (never), 2 (rarely), 3 (sometimes), 4 (quite often), 5 (very often). Results were summed, giving an for an overall score of subjective memory. This measure is a reliable tool for exploring subjective memory (Crawford et al., 2003) and has previously been used in postnatal populations (Orchard et al., 2022).

*5.2.5.6. Pittsburgh Sleep Quality Index*

The PSQI (Buysse et al., 1989) is a 19-item questionnaire designed to measure sleep quality over the past month. The items are scored and form seven component scores: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction. The sum of scores for these seven components yields one global score (range 0-21) with higher global scores indicating poorer sleep quality. The PSQI has been found to be a valid and reliable measure for this population (Okun et al., 2018; Qiu et al., 2016).

*5.2.5.7. Blood pressure*

Resting systolic and diastolic blood pressure was taken with an ambulatory blood pressure monitor. Measurements were taken on participant's left arm and the mean of three consecutive measurements was calculated.

*5.2.5.8. Reys Auditory Verbal Learning Task (RAVLT)*

Participants were presented with an auditory recording containing 15 nouns (List A), which were read aloud at a rate of one per second. Following each presentation, they were asked to freely recall the items from this list, this was repeated for 5 recalls resulting in recalls labelled as A1 to A5. Subsequently, a new set of 15 nouns (List B) was introduced during the sixth trial, as an interference list, participants were instructed to recall this list only once (recall B) (Appendix J.1). Afterward, participants were tasked with recalling list A after short (2-minute) and long (15-minute) delays, leading to free recalls known as A6 and A7 respectively. Following the recall A7 phase, participants were visually presented with 60 nouns, comprising words from both lists A and B, along with an additional 30 nouns. Their task was to identify the words that belonged to list A, List B or whether the word was a new word.

To ensure balanced testing conditions, different versions of the word lists were used across the test sessions. In each test session, a set of measures were computed based on Lezak (2004) and prior research (Lamport et al., 2020), including: immediate word span (recall A1); words learned (recall A5–A1); final acquisition (recall A5); total acquisition (sum A1 through A5); proactive interference (recall A1–B); retroactive interference (recall A5–A6); delayed recall (A6).

Word recognition and source monitoring scores were also produced via the presentation of the 60 nouns. In line with previous literature on episodic memory following dietary interventions (Lamport et al., 2014), word recognition scores were referred as the count of correctly recognised words and source monitoring scores were represented as a percentage indicating the proportion of words accurately attributed to their original list (A or B), excluding new words. Reaction time data were also collected for source monitoring scores to investigate whether the intervention affected the time taken to identify the list to which each word belonged.

*5.2.5.9 Modified Attention Network Task (MANT)*

This task combines a cue-target and flanker task to assess vigilance, selective attention, and response interference across varying cognitive demands. Manipulations were made in stimuli load, duration, orientation, and cueing to modulate the cognitive demand of the task. Following Whyte et al. (2017) participants started with a practice block of 35 trials where the duration of the target decreased from 1000ms to 120ms over 16 trials, enabling participants to become accustomed to the required speed of response. Subsequently, participants undertook two target blocks in the MANT, each comprising 80 trials. Within the blocks, the target stimuli, represented by a single arrow pointing either "<" or ">", was then shown either above or below the fixation cross for a duration of 120ms (in one block) or 500ms (in one block). The target stimulus could appear in isolation or surrounded by pairs of flanker arrows, creating congruent (e.g., <<<<< or >>>>>) or incongruent (e.g., <<><< or >><>>) conditions with the surrounding arrows. Individual arrows represented low load, while congruent or incongruent trials represented medium load (one row of five arrows) or high load (two rows of five arrows). The arrangement of stimulus position, congruence, and load was randomised across trials, presented with equal probability. Participants' task was to press either the left or right arrow key on the keyboard based on the direction of the target stimulus arrow in each trial.

The outcome measures for the MANT encompassed accuracy (the count of correct hits) and reaction time for accurate targets (indicating response speed to targets). Reaction times less than 200ms were excluded, as these reaction times were likely to represent anticipatory or accidental responses rather than genuine responses.

*5.2.5.10 Visuospatial n-back*

This task measured visuospatial working memory and required participants to monitor a sequence of visual stimuli, presented as a series of grey rectangles that turned blue in different spatial locations. Participants were required to determine if the same rectangle had turned blue "n" steps back in the sequence. Participants were presented with a practice trial followed by 15 further trials, consisting of sequences displaying for 'n-1' to n-5' each 'n' presenting three times. The outcome measures for this task consisted of accuracy (the count of correct hits) and reaction time for accurate targets (indicating response speed to targets; with reaction times less than 200ms excluded).

*5.2.5.11 24-hr food recall*

Participants' habitual diet using 24-hr dietary recalls were measured with the software Intake24 (Rowland et al., 2018). This tool contacted participants via email, asking to provide details of all the foods consumed in the previous 24-hours. The participants were able to do this from their phone, laptop or tablet via weblink whereby they self-reported the food they consumed, time eaten, food portion sizes and preparation in addition to any dietary supplements. Over the course of the study, participants were contacted nine times for a 24-hr recall, three times during their pregnancy, three times during the intervention period and three times post-intervention. Three of these nine recalls were scheduled for a weekend and six for weekdays over the course of the study. Participants were unaware of the specific days they would be contacted to ensure unbiased and representative reporting of their typical dietary intake.

### 5.2.6. Procedure

Participants emailed the researcher expressing their interest in taking part. Interested participants were invited to an in-person screening session, during the session the study was explained by the researcher and the participant received the participant information sheet (Appendix F.2), eligible participants then signed the consent form (Appendix G). Participants were recruited at any stage of their pregnancy though screening did not take place until their third trimester (weeks 27+), to ensure more a more stable pregnancy baseline based on the evidence outlined in section 5.1 (Bennett et al., 2004; Glynn, 2010). It also ensured sufficient time for both a screening and baseline visit to be completed approximately one week apart, helping to minimise potential practice effects (Bell et al., 2018) and allowing flexibility should the infant be born prior to the expected due date.

Participants were invited to a study investigating diet, mood and cognition to not reveal the true aims of the study. Screening demographics were then completed via REDCap, followed by a practice of the cognitive tests. The study took place in person, at participant homes over the 6 time points; 1) a screening session, 2) Visit 1 (third trimester), 3) Visit 2 (after birth 0-4 days, pre intervention), 4) Visit 3 (mid-way through intervention ~15 days), 5) Visit 4 (post-intervention ~30-days) and 6) Visit 5 (follow up, 12 weeks postpartum). cut-off was also decided to not test participants for Visit 1 post 38 weeks gestation to ensure data could be collected should the participant deliver earlier than their expected due date. The rationale for 0-4 days postpartum was driven by the findings from flavonoid supplementation in the immediate postpartum, and to capture initial transient mood changes associated with the postpartum blues (Dowlati et al., 2017; Meyer et al., 2024).

At each of the timepoints, participants completed outcome measures and had their blood pressure taken. Each testing session took approximately 45-60 minutes. As outlined, following the pregnancy timepoint, eligible participants were allocated to one of three groups; a high flavonoid condition (consumption of 2 portions of flavonoid-rich food per day), low flavonoid condition (consumption of one portion of flavonoid-rich food per day) and a control (no change to diet). After informing the researcher they had delivered their infant, participants in the flavonoid intervention groups were notified by the researcher that they would need to include some additional foods in their diet, accompanied by a list of the intervention foods, and were asked to choose a food item which the researcher purchased and brought to the testing session. This ensured that participants could start the intervention after the testing session at time 1 without needing to visit a supermarket during this sensitive time. During this first postpartum session, participants were also asked some demographic questions about the infant and birth experience. After the outcome measures were taken, participants were again informed of their condition and instructed to begin the intervention. The two intervention groups were also asked to keep a food log of their selected intervention foods for the 30-day period. Participants were then seen a further 3 times over the course of the study at 2, 4 and 12-weeks postpartum. At the final timepoint, upon debrief (appendix H.2), all participants were provided with helplines and weblinks specific to parental mental health support and were encouraged to contact their GP should they wish to seek further support. All participants were reimbursed with a £50 Amazon voucher. Data was collected between March 2023 and December 2024 and the study was given a favourable ethical opinion for conduct by the University of Reading School of Clinical Language Sciences (2023-029-DL) and registered at ClinicalTrials.gov (NCT05890014).

### 5.2.7. Data analysis

Quantitative data was analysed using R (version 4.1.0) and various statistical packages such as ‘lme4’ for running linear mixed models and ‘ggplot’ for visualisation. Regression analysis was conducted on demographic variables to investigate whether variables such as age, sleep, baseline flavonoid intake, ethnicity, education, household income, marital status, other children, number or other children, delivery method, birth complications, birth experience and childcare support would be significant predictors to the primary outcome variables and therefore to be utilised as covariates in the models. Independent groups t-tests and Chi-squared tests were performed to assess potential group differences

in baseline demographic variables, such as maternal age, dietary preferences (e.g., vegetarian or vegan), presence of diagnosed psychological or physical health conditions, whether the participants had other children, sex of infant, delivery method, and infants gestational age at birth. For the measures PANAS-NOW, STAI-S, EPDS, EPDS-P, PSAS, PRMQ, MANT (RT and accuracy), N-BACK (RT and accuracy), AVLT (word span (recall A1); words learned (recall A5–A1); final acquisition (recall A5); total acquisition (sum A1 through A5); proactive interference (recall A1–B); retroactive interference (recall A5–A6); delayed recall (A6); word recognition and source monitoring (accuracy and RT)) data were analysed using separate linear mixed models, where Condition (high flavonoid, low flavonoid, control) and Time (baseline (Visit 2; 0-4 days postpartum- 12 weeks postpartum) were fixed effects, with covariates (sleep; PSQI scores), maternal age, habitual flavonoid intake (taken at pregnancy) and birth experience included. Visit 1 (pregnancy) was excluded from this model, as it was considered more appropriate to establish the baseline at postpartum and 'pre-intervention' to better assess changes over subsequent visits resulting from the flavonoid intervention. However, for exploratory purposes, repeated measures t-tests were performed to investigate potential changes in outcomes from pregnancy to postpartum. This analysis was conducted as a secondary step, following the primary investigation of the intervention's effects.

These covariates were selected due to their known association with mood and their potential impact on the results, see 4.2.9 for discussion. Birth experience was an additional covariate that was not utilised in the previous chapter. As discussed in 4.2.3, it is unsurprising that traumatic, and more negative birth experiences are associated with higher anxiety and depression symptoms in the postpartum (Ahmadpour et al., 2023). Birth experience was taken as an open-ended question in Experiment 1, whereby mothers reported having difficulties during childbirth, but still described their overall experience to be more positive. To better account for the nuance between difficulties and overall perception of their experience, in the current study, birth experience was captured as the same open ended question, but also a visual scale was also included to quantify perceived birth experience. This was used as a covariate in the model, while also keeping the qualitative measure to provide richer insights to birth experience, as in Experiment 1.

The same analytical model was applied to nutrients from the 24-hr food recalls (flavonoids, calories, carbohydrate, protein, fat, fruit, vegetables, iron, folate, fibre) to examine whether participation in the dietary study led to significant changes in habitual diet, macronutrient, and flavonoid intake. One-sample t-tests were also conducted to compare mean nutrient intake at baseline with the UK recommended dietary allowance (RDA) for postpartum mothers, to evaluate general diet quality in the sample and assess whether mothers met the RDAs at baseline.

At data analysis, data was screened for outliers, and values falling outside interquartile ranges were removed for the cognition and blood pressure outcomes, as they were found to significantly affect the results and model performance, leading to skewed estimates. However, outliers were not removed for the mood outcomes, as their presence did not notably influence the overall analysis or the robustness of the model, which also aided in the preservation of natural variation in mood data.

Due to the nature of the longitudinal design in this study, several data points are missing from the analysis out of the 280 possible data points. Specifically, 1 data point is missing from the mood data, 34 from the blood pressure data, 46 from the N-BACK, 30 from the RAVLT, and a total of 127 from the MANT. These missing data points arose for several reasons, with the majority resulting from participants being unable to complete blood pressure measurements and cognitive tasks due to the demands of the infant during the testing session. Due to an error in coding for the MANT, the 120ms block did not collect participant responses. This issue was identified and resolved within three months of starting the trial; however, resulted in missing data for this block. Specifically, the MANT 500ms block has 36 missing data points, while the 120ms block has 91. Given the proportion of missing data, the accuracy and reaction time data from these two blocks from the MANT was analysed separately to assess whether this missing data affected the overall scores. Despite missing data, as outlined in 4.2.8 a strength to linear mixed models is to handle unbalanced data effectively. Finally, regarding analysis

of the MANT task, models were run to include the effect of load and congruency as per Whyte et al. (2017).

As conducted in Experiment 1, a qualitative content analysis was conducted for the demographic questions related to participants' birth, breastfeeding experiences, and nearby childcare support. This analysis involved extracting key quotations from participants' responses, which were then grouped into themes. For example, difficulties during pregnancy were categorised into themes such as gestational hypertension, gestational diabetes, nausea and vomiting, pelvic pain, and anaemia. Similarly, birth complications were categorised based on the type of complication reported, such as emergency caesarean sections, retained placenta, postpartum haemorrhages, and inductions due to medical conditions. For the question, “Did you have any birth complications?”, 54 participants responded, with 12 (21%) providing further details on their experiences. The responses were categorised and expressed as percentages to give a clearer understanding of the proportion of participants who faced each complication. The same procedure was followed for the question, "Do you have any complications whilst breastfeeding?". Data from 47 participants were analysed, and common themes such as latch issues and infant tongue ties were identified. In cases where participants reported no milk production or challenges in breastfeeding, the data were also categorised, with participants’ responses indicating improvements over time or the ongoing absence of milk. Additionally, participants recorded their birth experience on a Likert scale from 1-10, with an option to provide additional elaboration. Of the 32 participants (57%) who offered further comments, their responses were grouped into three broad themes: positive, negative, and neutral/mixed experiences. These themes were quantified, with 16 (50%) participants reporting positive experiences, 9 (28.1%) reporting negative experiences, and 7 (21.9%) reporting neutral or mixed feelings. By categorising and quantifying these responses, the analysis provided valuable insight into the overall wellbeing of the sample and potential risk factors related to birth and breastfeeding.

## 5.3. Results

### 5.3.1. Compliance

For the low flavonoid group, compliance was 92%, compared with 79% for the high flavonoid group. For both conditions, orange juice was the most commonly consumed food item, followed by dark chocolate and blueberries (see Table 9).

Table 9. Flavonoid items recommended to the intervention groups and frequency of consumption

| Food item (amount suggested)[1] | N times consumed over 30-days | |
|---|---|---|
| | Low flavonoid (*n*=18) | High flavonoid (*n*=18) |
| Orange juice 190ml | 212 | 229 |
| Dark chocolate 64g | 70 | 150 |
| Blueberries 65g | 68 | 144 |
| Strawberries 157g | 62 | 59 |
| Spinach 109g | 28 | 102 |
| Grapefruit juice 170ml | 17 | 4 |
| Black olives 89g | 17 | 30 |
| Red/black grapes 142g | 13 | 59 |
| Cherries 182g | 8 | 15 |
| Oranges 247g | 7 | 17 |
| Blackberries 81g | 0 | 7 |
| Plums 90g | 0 | 23 |

[1] Portion sizes listed were selected to provide approximately 109 mg of flavonoids per item.

5.3.2. Demographics

There was only one significant difference between groups at postpartum baseline (Visit 2) in demographics, where sex of infant was different in each group, such as more Female infants observed in the low flavonoid group and more Male infants were in the high flavonoid group (Table 10).

*Table 10. Demographic data for both mothers in flavonoid intervention and control groups collected at screening and following delivery of infant (0-4 days postpartum; Visit 2)*

| Outcome | Low flavonoid (n=18) | High flavonoid (n=18) | Control (n=20) | Between groups *p*-value |
|---|---|---|---|---|
| Age (Mean (SD) | 33.79 (4.55) | 33:00 (3.96) | 33.16 (3.30) | 0.814 |
| Ethnicity[1] | 17:1:0:0:1 | 16:2:0:0:0 | 15:1:1:0:2 | 0.596 |
| Education[2] | 2:8:6:2:0:0:0:0:1 | 2:11:4:1:0:0:0:0:0 | 5:9:4:0:0:0:0:1:0 | 0.536 |
| Employment[3] | 10:5:4:0:0:0:0 | 11:3:1:1:1:0:1 | 10:6:3:0:0:0:0 | 0.538 |
| Household income[4] | 0:0:1:0:1:15:2 | 0:0:2:1:0:15:0 | 0:0:3:1:2:12:1 | 0.602 |
| Marital status[5] | 2:16:0:0:0:0:1 | 2:15:0:0:0:0:1 | 2:17:0:0:0:0:0 | 0.897 |
| Other children[6] | 8:11 | 11:7 | 8:11 | 0.413 |
| Sex of infant[7] | 15:4:0 | 4:14:0 | 9:10:0 | 0.002* |
| Mode of delivery[8] | 9:6:4 | 10:2:6 | 12:2:5 | 0.408 |
| Birth complications[9] | 5:14 | 3:15 | 7:12 | 0.382 |
| Childcare support[10] | 14:5 | 14:4 | 18:1 | 0.200 |

[1] Participants ethnicity (White or Caucasian; Asian or Asian British; Black/African/Caribbean/Black British: Latino or Hispanic: Mixed: Other): [2] Participants education (High school/college: Bachelor's degree: Master's degree: PhD or higher: Trade school: Still in education: Prefer not to say: Other): [3] Participant employment status (Employed full-time (40+ hours a week): Employed part-time (less than 40 hours a week): Self-employed: Unemployed: Student: Retired: Other): [4]Participant household income (£0 - £10,000: £11,000 - £20,000: £21,000 - £30,000: £31,000 - £40,000: £41,000 - £50,000: £51,000 +: Prefer not to say): [5] Participant marital status (Single: Married (or domestic partnership): Widowed: Divorced: Separated: Prefer not to say: Other): [6] Whether the participant has other children (Yes: No); [7] Sex of infant (Female: Male: Other): [8] Mode of delivery (Vaginal delivery: Assisted vaginal delivery (vacuum or forceps): Caesarean section: Prefer not to say: Other): [9] Birth complications (Yes: No): [10] Nearby childcare support (Yes: No).

*Table 11. Mean (SD) outcome variable data and interaction effects for participants in the flavonoid intervention and control groups at baseline (Visit 2; 0-4 days post intervention)*

| Outcome | Low flavonoid M (SD) (n=18) | High flavonoid M (SD) (n=18) | Control M (SD) (n=20) | Between groups *p* |
|---|---|---|---|---|
| EPDS | 8.63 (5.12) | 7.11 (4.48) | 6.631 (3.41) | 0.351 |
| STAI | 40.68 (13.08) | 37.88 (12.21) | 38.63 (11.45) | 0.772 |
| PA | 32.89 (8.93) | 33.22 (4.78) | 32.36 (7.51) | 0.938 |
| NA | 19.00 (6.87) | 16.11 (6.23) | 16.84 (5.25) | 0.337 |
| PSAS | 94.94 (20.13) | 89.66 (15.20) | 82.57(17.28) | 0.107 |
| EPDSP | 8.63 (5.12) | 7.11 (4.48) | 6.63 (3.41) | 0.351 |
| PSQI | 4.63 (2.40) | 3.94 (1.73) | 4.63 (1.49) | 0.463 |
| PRMQ | 54.31 (12.53) | 56.55 (8.47) | 54.63 (12.21) | 0.81 |
| Systolic BP | 116.79 (7.80) | 116.58 (10.43) | 118.15 (9.35) | 0.878 |
| Diastolic BP | 76.80 (7.10) | 75.89 (9.67) | 75.40 (6.01) | 0.879 |
| N-BACK overall accuracy | 10.36 (2.50) | 10.84 (1.86) | 10.63 (1.02) | 0.825 |
| N-BACK reaction time (s) | 506.35 (57.29) | 526.77 (99.03) | 525.47 (87.89) | 0.813 |
| MANT accuracy (blocks combined) | 13.42 (2.74) | 12.90 (2.89) | 13.07 (3.11) | 0.363 |
| MANT reaction time (blocks combined) (s) | 485.04 (65.42) | 483.14 (64.42) | 468.48 (57.21) | 0.107 |

| | | | | |
|---|---|---|---|---|
| MANT accuracy (500ms block) | 12.71 (3.61) | 12:00 (4.48) | 10.64 (5.20) | 0.343 |
| MANT reaction time (500ms block) (s) | 503.15 (78.00) | 491.03 (62.02) | 470.08 (57.71) | 0.214 |
| MANT accuracy (120ms block) | 12.45 (4.17) | 12.35 (3.10) | 12.97 (3.12) | 0.669 |
| MANT reaction time (120ms block) (s) | 473.80 (83.42) | 467.61 (75.55) | 459.62 (53.34) | 0.649 |
| RAVLT Word span | 5.72 (1.96) | 6.25 (1.98) | 6.40 (1.68) | 0.553 |
| RAVLT Final acquisition | 11.55 (2.25) | 12.61 (1.64) | 11.80 (2,48) | 0.313 |
| RAVLT Total acquisition | 47.50 (9.35) | 51.05 (8.04) | 48.33 (10.64) | 0.497 |
| RAVLT Words learned | 5.83 (2.35) | 6.50 (1.61) | 5.40 (2.29) | 0.324 |
| RAVLT Proactive Interference | 0.44 (2.20) | 1.00 (1.90) | 0.66 (1.83) | 0.713 |
| RAVLT Retroactive Interference | 1.88 (1.64) | 2.00 (2.11) | 1.71 (1.54) | 0.906 |
| RAVLT Delayed recall | 8.50 (3.89) | 10.17 (2.94) | 9.33 (2.52) | 0.314 |
| RAVLT Word recognition | 16.81 (5.40) | 21.11 (4.32) | 21.15 (3.80) | 0.015* |
| RAVLT Source monitoring accuracy | 64.07 (25.15) | 53.77 (14.06) | 45.27 (6.03) | 0.169 |
| RAVLT Source monitoring reaction time (s) | 2017.19 (223.80) | 2217.61 (233.85) | 2660.51 (272.93) | 0.369 |

*= $p<.05$

5.3.3. Edinburgh Postpartum Depressive Scale (EPDS)

Postpartum depression outcomes were measured using the EPDS. There were no significant differences between pre-baseline (pregnancy) and baseline (0-4 days postpartum) measures ($t_{(55)}$=0.66, $p$=.507) indicating no significant changes in depressive symptomatology from pregnancy to postpartum in this sample. At baseline, 17.86% of mothers scored above the clinical cut off (score of 10) for the EPDS, indicating postpartum depression. Furthermore, 1.79% of mothers responded to 'Yes, quite often' or 'Sometimes' when asked '*The thought of harming myself has occurred to me'* on the EPDS signifying some prevalence of thoughts about self-harm in this sample at 0-4 days postpartum. No significant differences were seen for Condition *Visit interaction, main effect of Condition, or main effect of Visit (Appendix B; Figure 8). Sleep and birth experience scores were significant predictors, where worse sleep and poorer birth experience predicted worse depression in the model ($F_{[1,193]}$=5.12, $p$=.024; $F_{[1,48]}$=4.73, $p$=.034 respectively).

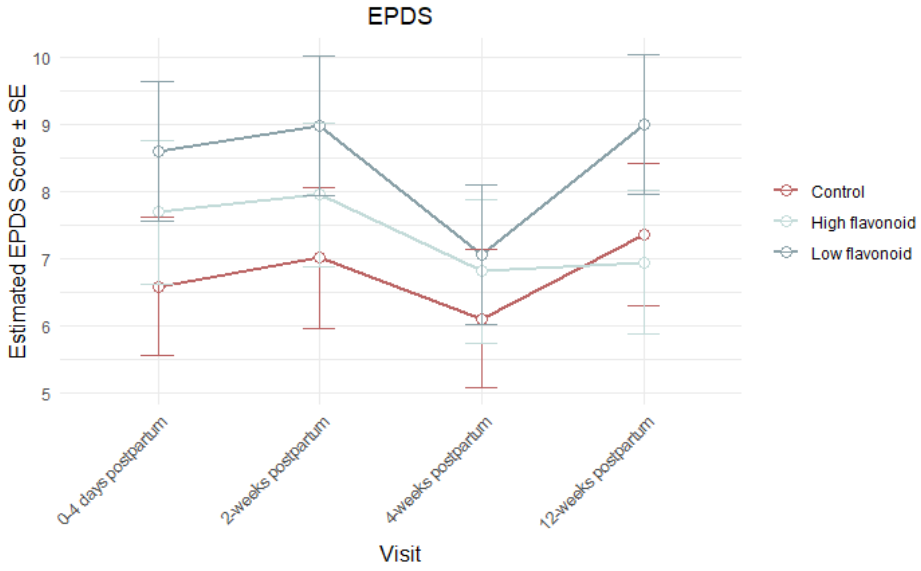


*Figure 8. Postpartum depression scores (EPDS) broken down by intervention group with LMMs showed no significant change in mean (±SEM) postpartum depression over time (p > .05). Models were controlled for sleep quality (PSQI), maternal age, habitual flavonoid intake, and birth experience as covariates.*

Exploratory analysis showed no further significant main effects or interactions when sleep was accounted as a factor in the model ($p$>0.05), defined as scores >5 indicating poor sleep (Buysse et al., 1989). Birth experience was then accounted for as a factor in the model, with scores under 5 reflecting poorer birth experience, and over 5 reflecting better experiences. In this model, a main effect of Visit was present ($F_{[3,148]}$= 3.89, $p$=.010), where pairwise comparisons showing a significant reduction in EPDS scores from 2-weeks ($M$=10.3, $SE$=0.99) to 4-weeks ($M$=7.25, $SE$=0.98) ($p$=.006) (Figure 9), which was largely driven by the mothers who had a poor birth experience who received the high flavonoid intervention.

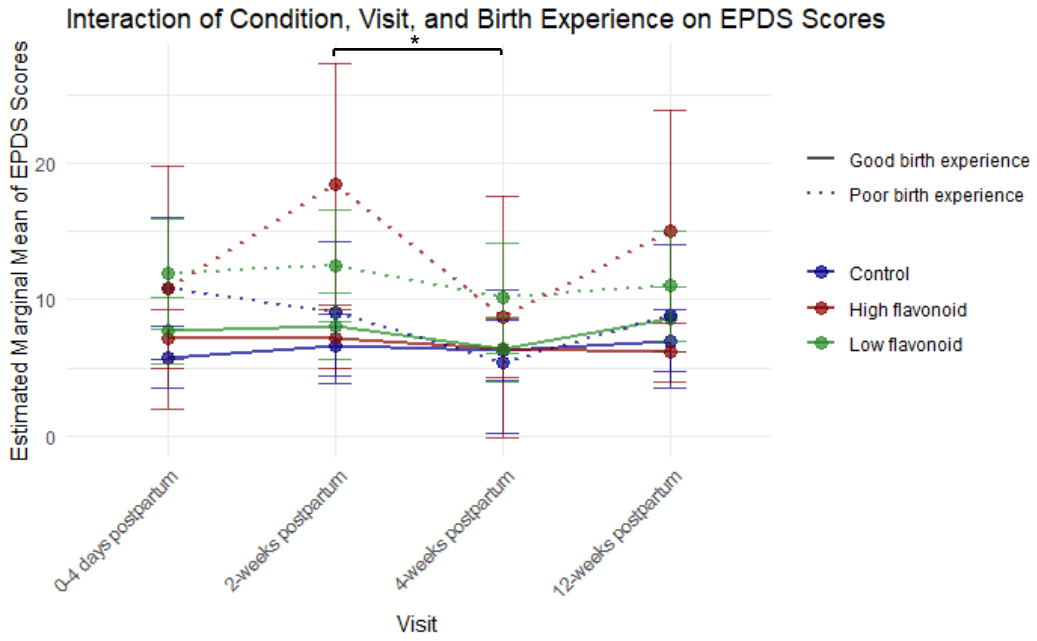


*Figure 9. Postpartum depression scores (EPDS) broken down by intervention group and birth experience with LMMs showed a significant decrease in mean (±SEM) EPDS scores over time (main effect of Visit, $F_{[3,148]} = 3.89$, $p = .010$). Bonferroni-corrected post hoc tests showed significant reductions in depressive symptoms between 2 and 4 weeks postpartum. Models included sleep quality (PSQI) and maternal age, and habitual flavonoid intake as covariates.*

5.3.4. State Trait Anxiety Inventory-State scale (STAI)

Anxiety outcomes were measured using the STAI. There were no significant differences between pre-baseline (pregnancy) and baseline (0-4 days postpartum) measures ($t_{(55)}$=-0.96, $p$=.336). Also at baseline (0-4 days postpartum), 64.29% of mothers scored above the clinical cut off (score of 34) for the STAI, indicating postpartum anxiety. No significant differences were seen for Condition *Visit interaction (Appendix B; Figure 10). Sleep scores were a significant predictor to the model, where worse sleep predicted higher anxiety ($F_{[1,202]}$=17.02, $p$<.001).

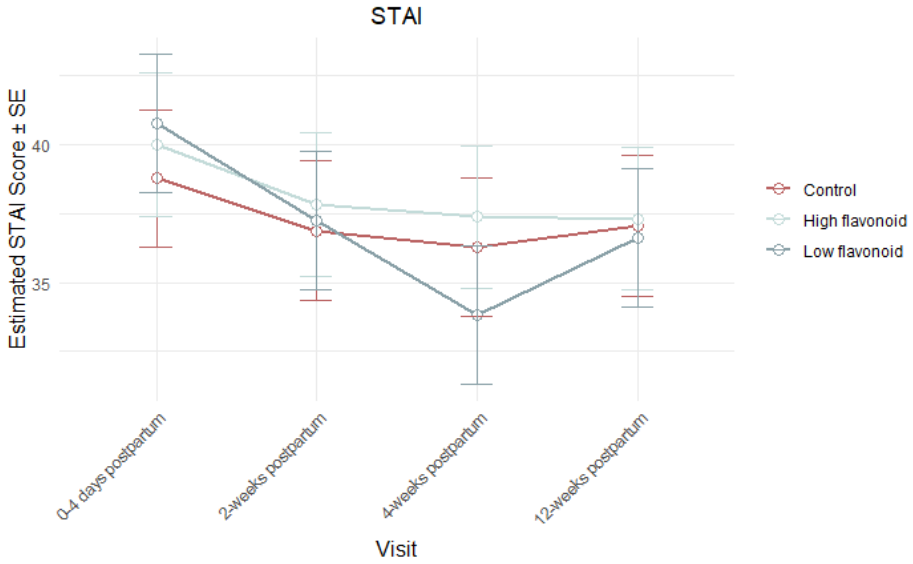

*Figure 10. Anxiety scores (STAI) broken down by intervention group with LMMs showed no significant change in mean (±SEM) anxiety over time (p > .05). Models were controlled for sleep quality (PSQI), maternal age, habitual flavonoid intake, and birth experience as covariates.*

Exploratory analysis showed a significant interaction between Condition*PSQI scores when sleep was accounted as a factor in the model ($F_{[2,176]}$=5.88, $p$=.003). Bonferroni corrected post hoc comparisons showed worse anxiety for 'Bad' sleepers ($M$=41.1.2, $SE$=2.25) compared to 'Good' sleepers ($M$=31.2, $SE$=2.54) in the control condition ($p$<.001) (Figure 11). This relationship was not observed for intervention groups indicating potential flavonoid-related protection from adverse sleep outcomes, specifically for 'Bad' sleepers.


*Figure 11. Anxiety scores (STAI) broken down by intervention groups and sleep quality (good vs poor sleepers) with LMMs showing a significant Condition*PSQI interaction ($F_{[2,176]}$ = 5.88, p = .003), with higher mean (±SEM) anxiety scores observed in the control group among participants with poor sleep compared to those with good sleep (p < .001). Models included maternal age, habitual flavonoid intake, and birth experience as covariates.*

5.3.5. Positive Affect (PA)

No significant main effects or interactions were found (Appendix B; Appendix B.1).

5.3.6. Negative Affect (NA)

No significant main effects or interactions were found (Appendix B; Appendix B.2).

5.3.7. Postpartum Specific anxiety Scale (PSAS)

This measure focused on postpartum anxiety, therefore was given from 0-4 days postpartum onwards. Subsequently, analysis between pregnancy and postpartum was not conducted for this measure. At baseline, 8.93% of mothers scored above the clinical cut off (score of 112) for the PSAS, indicating postpartum anxiety. No significant main effects or interactions were found (Appendix B; Appendix B.3).

5.3.8. Edinburgh Postpartum Depressive Scale-Partner (EPDSP)

At baseline, 5.36% of mothers reported their partners scored above the clinical cut off (score of 10) for the EPDSP, indicating postpartum depression. Furthermore, 0% of mothers responded to 'Yes, quite often', 'Sometimes' or 'Hardly ever' when asked 'He has been having thoughts of harming himself' on the EPDS signifying no prevalence of depression and thoughts of partner self-harm in this sample. It was hypothesised that if flavonoid supplementation improved maternal mood, it might also

have an indirect positive effect on partner mood; however, no significant main effects or interactions were found (Appendix B; Appendix B.4).

5.3.9. Prospective Retrospective Memory Questionnaire (PRMQ)

Subjective memory outcomes were measured using the PRMQ. No significant differences were observed between pregnancy and postpartum days 0-4 ($t_{[55]}$=1.76, $p$=.082), though this did show a trend towards better performance during pregnancy compared to 0-4 days postpartum. No significant differences were seen for Condition *Visit interaction, main effect of Condition, or main effect of Visit (Appendix B; Figure 12).

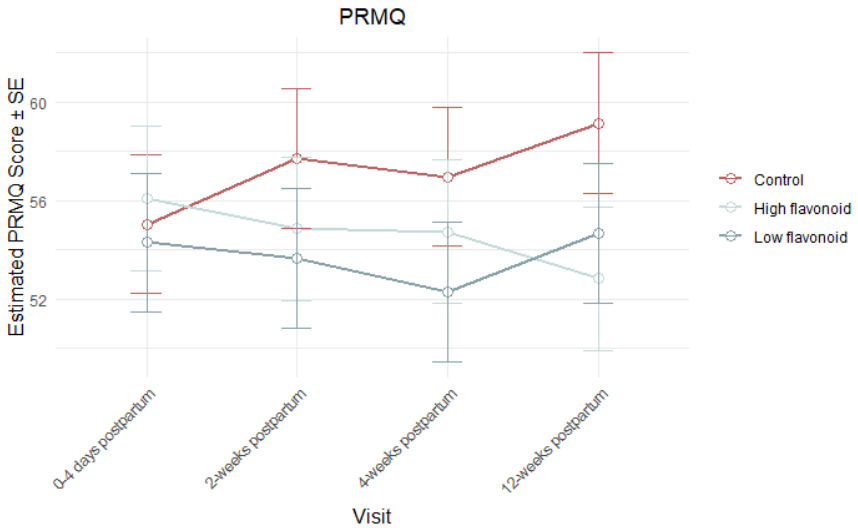


*Figure 12. Prospective memory (PRMQ) scores broken down by intervention group with LMMs showed no significant change in mean (±SEM) subjective memory over time (p > .05). Models were controlled for sleep quality (PSQI), maternal age, habitual flavonoid intake, and birth experience as covariates.*

None of the initial main effects or interactions were significant, however, hypothesis driven exploratory within groups analyses showed significant differences for Low and High flavonoid conditions ($F_{[3,46]}$= 9.47, $p$<.001; $F_{[3,42]}$= 5.41, $p$=.003 respectively), where pairwise comparisons showed significantly better (lower) PRMQ scores at 2-weeks ($p$=.021) and 4-weeks postpartum ($p$<.001) relative to 0-4 days, for the low flavonoid group. Similarly, better (lower) scores were observed at 12-weeks postpartum ($p$=.002) compared to 0-4 days for the high flavonoid group, indicating fewer subjective memory impairments. This was not emulated in the control group, where, significant worsening of cognition was seen ($F_{[3,38]}$= 3.65, $p$=.020), at 2-weeks ($p$=.045) and 12-weeks postpartum ($p$=.023) compared to 0-4 days. This suggests flavonoid groups may be beneficial for reducing subjective memory complaints compared to the control group.

Flavonoid intake was a significant covariate to the model ($F_{[1,50]}$=4.39, $p$=.041). Exploratory analysis showed a significant interaction for Condition*Visit *Baseline flavonoid intake (median values, 410.45 mg/day) ($F_{[6,148]}$= 2.50, $p$=.024), however pairwise comparisons revealed no significant differences ($p$>0.05) (Figure 13).

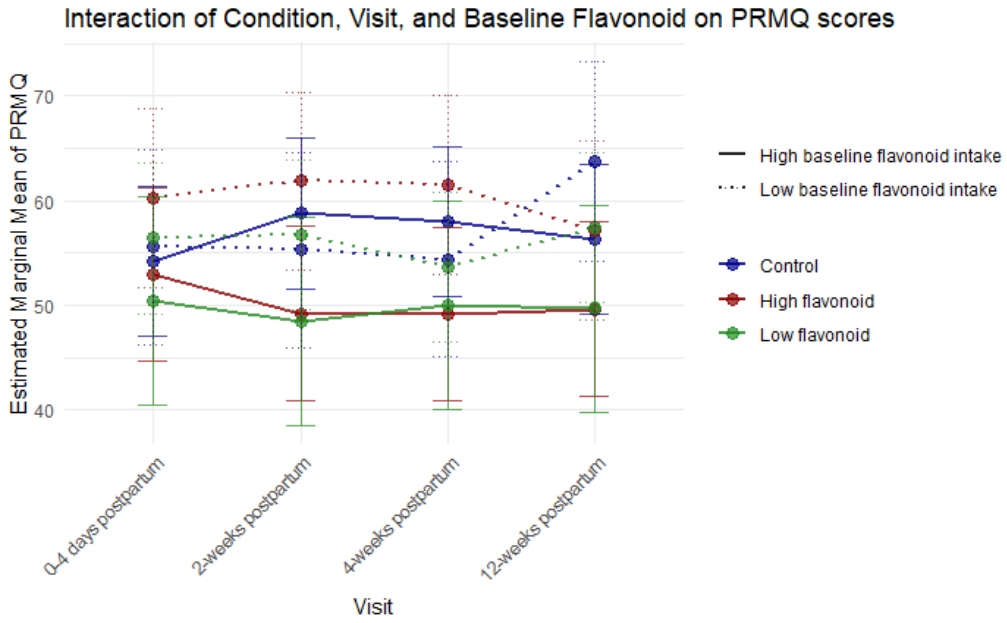


*Figure 13. Subjective Memory scores (PRMQ) broken down by intervention group and Habitual Flavonoid intake at baseline (High vs. Low). Linear mixed models revealed a significant Condition*Visit*Baseline flavonoid intake interaction on subjective memory scores ($F_{[6,148]}$ = 2.50, p = .024), indicating differences between high and low flavonoid intake groups over time. Models were controlled for sleep quality (PSQI), maternal age, and birth experience as covariates.*

5.3.10. Modified Attention Network Task (MANT)

*5.3.10.1 MANT overall*

*Accuracy*

Here, significant interactions were seen for Condition*Visit ($F_{[6, 1080]}$=2.97, $p$=.006), where pairwise comparisons showed significant improvements in the High flavonoid condition across Visits compared to 0-4 days postpartum (all $p$s < .005) and the Low flavonoid group between 0-4 days postpartum ($M$=12.5, $SE$=0.73) and 12-weeks ($M$=13.8, $SE$=0.72) ($p$<.0001). A main effect of Visit ($F_{[3, 1082]}$ = 14.58, $p$ < .001) indicated significant, incremental improvements in accuracy over time, particularly between baseline and each follow-up timepoint (all ps < .005; Figure 14). Accuracy did not differ significantly between 2–4 and 4–12 weeks postpartum ($p$ = .664 and $p$ = 1.00, respectively). Stimulus presentation was significant in the model ($F_{[1, 1082]}$=39.49, $p$<.001), where pairwise comparisons showed better accuracy for the 120ms presentation ($n$ trials 56, $M$=13.0, $SE$=0.46) ($p$<.001), compared with the 500ms presentation ($n$ trials 235, $M$=12.3, $SE$=0.46). In addition, significant differences were seen for load ($F_{[1, 1077]}$=5.68, $p$=.017), where high load trials had higher correct scores ($M$=12.8, $SE$=0.46) compared to medium load trials ($M$=12.5, $SE$=0.46) ($p$=.017). This effect was further explored where significant interactions were also found for Condition * Load ($F_{[2, 1077]}$=3.92, $p$=.019), with pairwise comparisons showing significantly better accuracy for High flavonoid, High Load trials ($M$=13.6, $SE$=0.83) than High flavonoid Medium Load trials ($M$=13.0, $SE$=0.82) ($p$=.004).

PSQI scores were a significant covariate in the model ($F_{[1, 1109]}$=8.41, $p$<.003), where exploratory analysis with PSQI as a factor in the model showed a significant Condition * Visit * Sleep quality interaction ($F_{[6, 1000]}$=5.34, $p$<.001). Pairwise comparisons showed participants who were 'Good sleepers' (PSQI scores <5) and were randomised to the High flavonoid condition had significantly higher scores over time compared to those in the same condition in those who were 'Poor sleepers' (Figure 15).

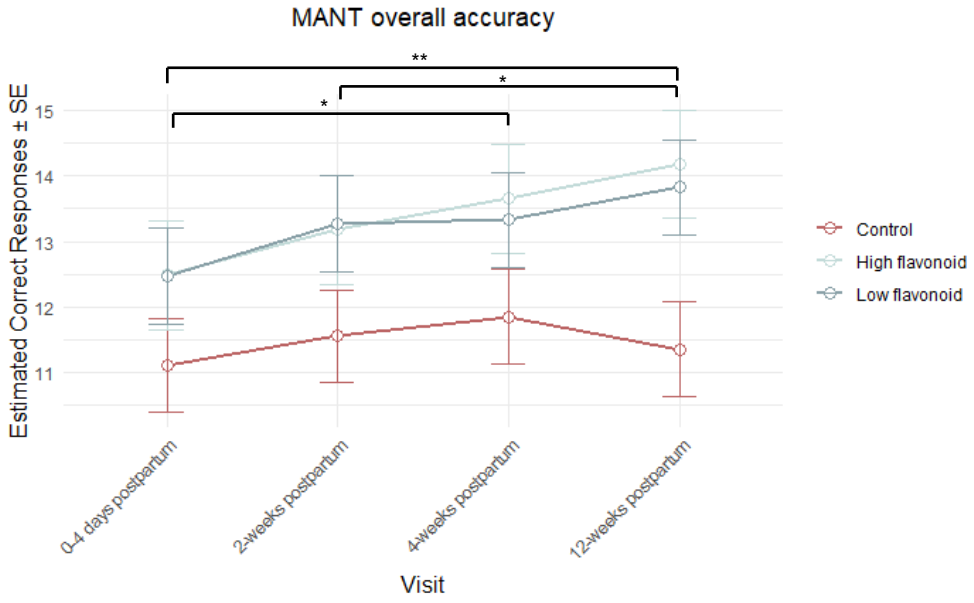


*Figure 14. MANT overall accuracy scores broken down by intervention groups with LMMs showed that mean (SEM) MANT accuracy was significantly higher for mothers in the Low flavonoid and High flavonoid intervention groups over Visits compared to baseline (significant Condition*Time interaction [$F_{[6, 1080]}$=2.97, p=.006]). Bonferroni corrected post-hoc analysis indicated a significant improvement in scores for the High flavonoid group at 4-weeks postpartum (p=.002), and 12-weeks postpartum (p <.0001) relative to 0-4 days, in addition to improvements in the low flavonoid group at 12-weeks postpartum compared to 0-4 days (p <.0001), and 2-weeks postpartum (p=.005) which was not reported in the control group at any Visit. Models were controlled for sleep quality (PSQI), maternal age, habitual flavonoid intake, and birth experience as covariates. (*=p<.05, **=p<.001).*

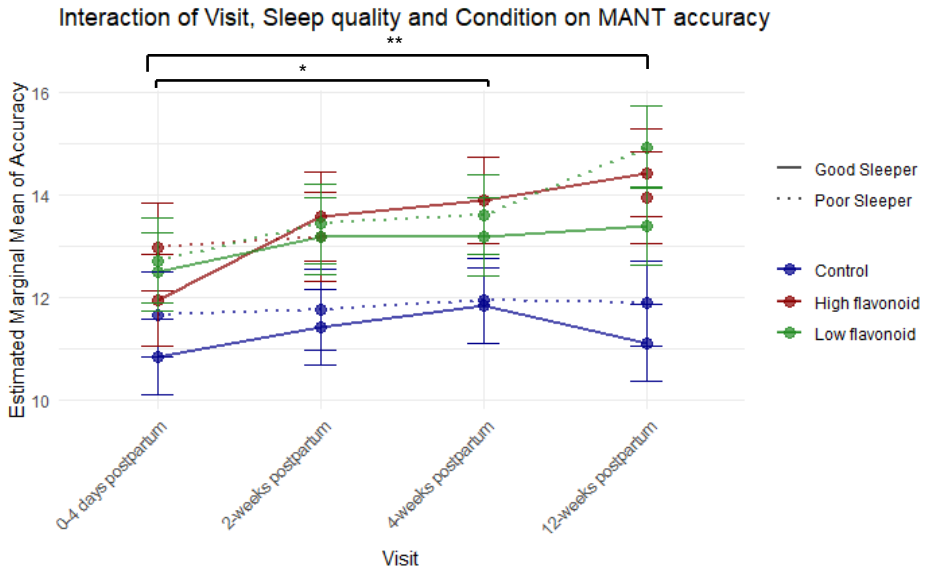


*Figure 15. MANT overall accuracy scores broken down by intervention groups and sleep quality (good vs bad sleeper), with LMMs showed that mean (SEM) MANT accuracy was significantly higher for mothers who were good sleepers (>5 PSQI score) in the High flavonoid intervention group compared to baseline (significant Condition*Time*Sleep interaction ($F_{[1, 1109]}$=8.41, p<.003). Bonferroni-corrected post-hoc analysis indicated that, in the High flavonoid group, good sleepers showed significantly better scores at 4-weeks (p = .010) and at 12-weeks postpartum (p < .0001) compared to 0–4 days, with the highest accuracy observed at 12-weeks, which was not reported in the*

*control group, and low flavonoid group for good sleepers in addition to any poor sleepers at any Visit. Models were controlled for maternal age, habitual flavonoid intake, and birth experience as covariates (*=p<.05, **=p<.001).*

*Reaction Time*

No significant main effects or interactions were found for RT (Appendix B; Apprendix B.5).

#### *5.3.10.2 MANT 500ms block*

*Accuracy*

The MANT task was further broken down into the 500ms and 120ms stimulus presentation block, due to the missing data in the 120ms block. Here, there was a significant Condition *Visit interaction ($F_{[6,626]}$=2.52, $p$=.020), where there was significantly better accuracy in the High flavonoid group at 12-weeks ($M$=13.64, $SE$=1.12) compared to 0-4 days ($M$=12.02, $SE$=1.10) ($p<.001$) and 2-weeks ($M$=12.29, $SE$=1.10; $p$=.005; Figure 16).

Further, a significant main effect was seen for Visit ($F_{[3,626]}$=8.44, $p<.001$), with pairwise comparisons showing significant differences between 0-4 days postpartum ($M$=11.17, $SE$= 0.57) and 12-weeks postpartum ($M$= 12.39, $SE$= 0.57) ($p$= <.0001) and 2 weeks postpartum ($M$= 11.65, $SE$= 0.57) and 12-weeks postpartum ($p$=.008).

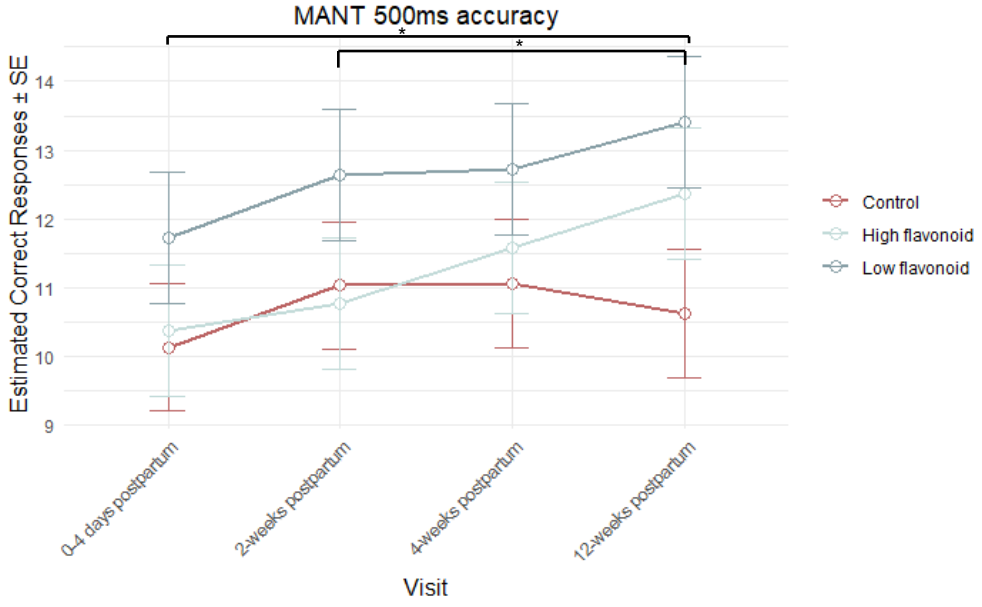


*Figure 16. MANT 500ms accuracy scores broken down by intervention groups with LMMs revealed that mean (SEM) MANT accuracy (500ms block) was significantly increased for participants over time as a result of the intervention (significant Condition*Visit interaction [$F_{[6,626]}$=2.52, p=.020]). Bonferroni corrected post-hoc analysis indicated a significant increase in accuracy for participants in the high flavonoid group between 0-4 days and 12-weeks (p<.001) in addition to 2-weeks and 12 weeks (p=.005). Models were controlled for sleep quality (PSQI), maternal age, habitual flavonoid intake, and birth experience as covariates (*=p<.05, **=p<.001).*

Finally, habitual flavonoid intake (categorised as 'high' and 'low' consumers calculated by median split) was a significant covariate to the model ($F_{[1,662]}$=4.98, $p$=.025), and a Condition*Visit*Flavonoid intake interaction was significant ($F_{[2, 590]}$=2.14, $p$=.047). Pairwise comparisons revealed that participants with low habitual flavonoid intake, who were randomised to the high flavonoid condition, showed significantly improved scores at 12-weeks postpartum (M =

12.96, SE = 1.08) compared to both 0–4 days (M = 9.76, SE = 1.10; p < .001) and 2-weeks postpartum (M = 10.20, SE = 1.11; *p* = .016) (Figure 17).

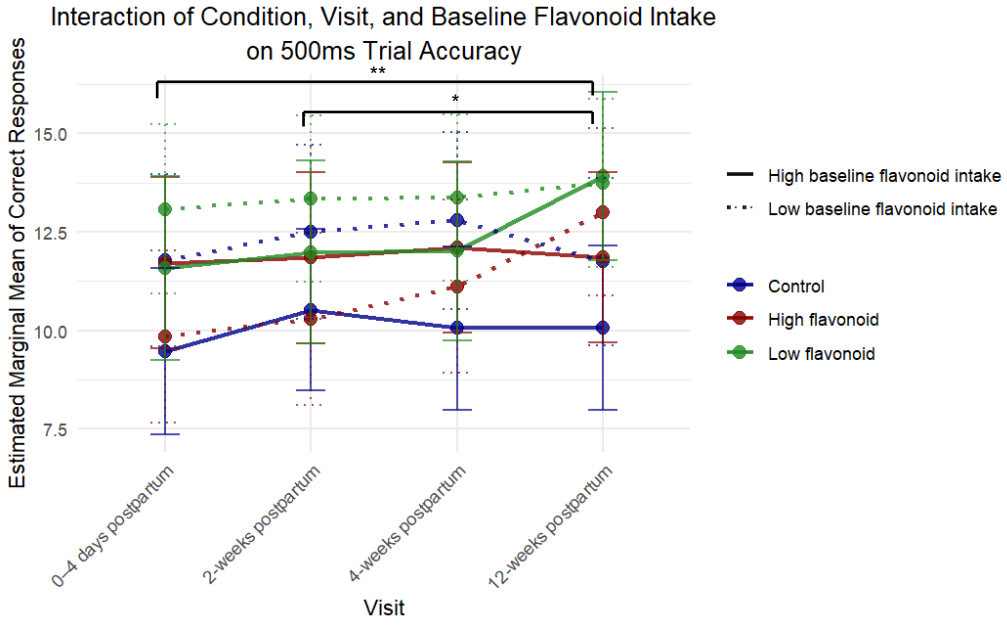


*Figure 17. MANT 500ms accuracy scores broken down by intervention groups and habitual flavonoid intake at baseline (High and Low) with LMMs showed that mean (SEM) MANT accuracy (500ms block) had a significant Condition*Visit*Flavonoid intake interaction ($F_{[2, 590]}$=2.14, p=.047), where low consumers of flavonoids at baseline had significant increases in accuracy between visits 0-4 days and 12-weeks (p<.001), and 2-weeks with 12-weeks (p=.016) following two portions of flavonoid foods. Models were controlled for sleep quality (PSQI), maternal age, and birth experience as covariates (*=p<.05, **=p<.001).*

*Reaction time 500ms block*

Reaction time data showed no significant Condition *Visit interactions, further, no significant main effects were seen for Visit or Condition (Appendix B). In regard to low load trials, for RT the Condition * Visit interaction was non-significant (Appendix B; Appendix B.6). There was, however, a significant main effect of Visit ($F_{[3,130]}$ = 5.79, p>.001), with pairwise comparisons indicating significant increases in RT from 0-4 days postpartum (M = 12.70, SE = .50) to 4-weeks postpartum (M = 13.85, SE = .50) (*p* = .011), and between 0-4 days and 12-weeks postpartum (M = 14.19, SE = .51) (*p*>.001).

For reaction time in the low load, none of the initial main effects and interactions were significant (*p*>.05).

*5.3.10.2 MANT 120ms block*

For the 120ms block, there was no significant Condition *Visit interaction ($F_{[6, 502]}$=1.15, *p*=.326), or Condition main effect ($F_{[2, 36]}$=0.33, *p*=.719), however, there was a significant main effect of Visit ($F_{[3, 504]}$=12.06, *p<.001*), where pairwise comparisons showed significantly better accuracy at 4-weeks postpartum (*M*=13.45, *SE*=0.44) compared to 0-4 days postpartum *(M*=11.87, *SE*=0.42*)* (*p*<.001), in addition to significantly better accuracy from 0-4 days to 12-weeks postpartum (*M*=13.23, *SE*=0.42*) (p<.001*), and 2-weeks postpartum (*M*=12.77, *SE*=0.41*)* to 4-weeks (*p*=.037), indicating improved performance for all groups over time (Figure 18).

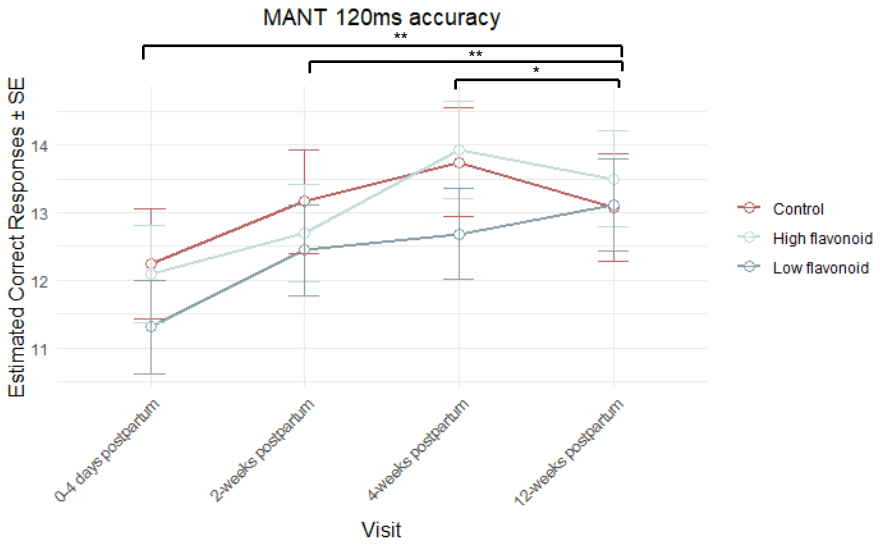


*Figure 18. MANT 120ms accuracy scores broken down by intervention groups with LMMs showed that mean (SEM) MANT accuracy (120ms block) significantly increased for participants over time (significant main effect of Visit ($F_{[3, 504]}$= 12.06, p<.001). Bonferroni corrected post-hoc analysis indicated a significant increase (improvement) in accuracy for participants between 0-4 days and 4-weeks (p<.001), 0-4 days and 12-weeks (p<.001), and finally 2-weeks to 4-weeks (p=.037). Models were controlled for sleep quality (PSQI), maternal age, habitual flavonoid intake and birth experience as covariates. (*=p<.05, **=p<.001).*

*Reaction time 120ms block*

For reaction time, the Condition * Visit interaction was significant ($F_{[6,494]}$ = 2.22, $p$ = .039), though there were no significant pairwise comparisons ($p$>.05). There was also a significant main effect of Visit ($F_{[3,496]}$= 4.57, $p$=.003) (Appendix B.7), with pairwise comparisons showing significant quickening in reaction time from 2-weeks ($M$=484.83, $SE$=8.69) to 12-weeks (M = 467.11, SE = 8.80) ($p$ = .006) and from 4-weeks (M = 481.14, SE = 8.87) to 12-weeks ($p$ = .047), suggesting performance was faster at 12-weeks relative to the 2 and 4 week timepoints. The main effect of Condition was not significant (Appendix B; Appendix B.7).

In regard to low load trials, accuracy data showed the Condition * Visit interaction was not significant, in addition to Condition. However, there was a significant main effect of Visit ($F_{[3,84]}$ = 2.85, $p$ = .042), however pairwise comparisons did not reveal significant differences between Visits. Significant covariate effects were observed for PSQI ($F_{[1,97]}$ = 8.75, p = .003), though further exploratory analysis did not reveal any further significant effects when PSQI scores were accounted for in the model ($p$>.05). Reaction time data for the low load trials showed no significant main effect or interaction.

### 5.3.11 N-BACK

#### *5.3.11.1 N-BACK overall*

No significant main effects or interactions were found for overall accuracy and RT (Appendix B; Appendix B.8), there were no significant covariates in this model.

#### *5.3.11.2 N-BACK n-1*

No significant main effects of interactions were found for accuracy (Appendix B; Appendix B.9) and RT (Appendix B; Appendix B.10).

#### *5.3.11.3 N-BACK n-2*

No significant main effects of interactions were found for accuracy (Appendix B; Appendix B.11) and RT (Appendix B; Appendix B.12)

*5.3.11.4 N-BACK n-3*

A main effect of Visit was present for accuracy, though no further main effects and interactions were significant for accuracy (Appendix B; Appendix B.13) and RT (Appendix B; Appendix B.14)

*5.3.11.5 N-BACK n-4*

A main effect of Visit was present for accuracy (Appendix B; Appendix B.15) and reaction time (Appendix B; Appendix B.16), though no further main effects and interactions were significant.

*5.3.11.6 N-BACK n-5*

No significant main effects of interactions were found for either accuracy (Appendix B; Appendix B.17) or RT (Appendix B; Appendix B.18).

5.3.12 RAVLT

*5.3.13.1. Word span*

Significant differences were seen at 4-weeks ($F_{[2, 40]}$=4.25, $p$=.021), where the High flavonoid group ($M$=6.25, $SE$=0.49) had higher word span compared to the Low flavonoid group ($M$=5.72, $SE$=0.45) ($p$=.043), indicating a higher number of initial words recalled, and therefore better verbal memory for those consuming a higher flavonoid dose. No other significant main effects or interactions were found (Appendix B; Figure 19).

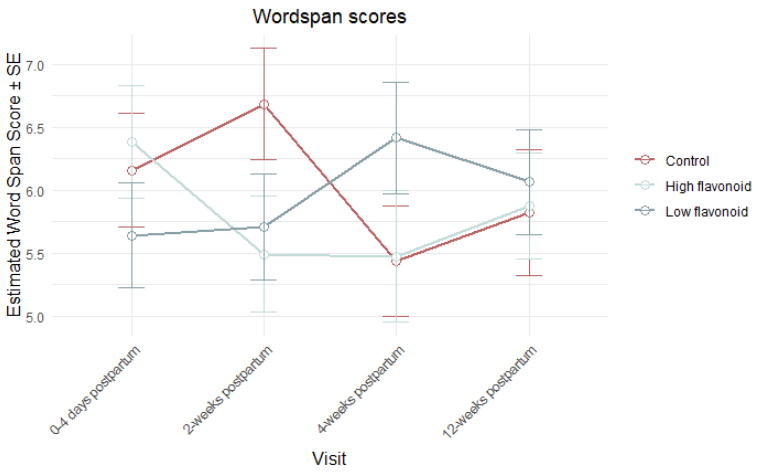


*Figure 19. Word span scores broken down by intervention group with LMMs, revealed that mean (SEM) a higher number of words were recalled for the High flavonoid group compared to the Low flavonoid group at 4-weeks postpartum. Models were controlled for sleep quality (PSQI), maternal age, habitual flavonoid intake and birth experience as covariates.*

*5.3.12.2. Final acquisition*

No significant main effects of interactions were found (Appendix B; Appendix B.19).

*5.3.12.3. Total acquisition*

No significant main effects of interactions were found (Appendix B; Appendix B.20).

*5.3.12.4. Words learned*

No significant main effects of interactions were found (Appendix B; Appendix B.21).

*5.3.12.5. Proactive Interference*

No significant main effects of interactions were found (Appendix B; Appendix B.22).

*5.3.12.6. Retroactive Interference*

No significant main effects of interactions were found (Appendix B; Appendix B.23).

*5.3.12.7. Delayed recall*

No significant main effects of interactions were found (Appendix B; Appendix B.24).

*5.3.12.8. Word recognition*

Word recognition scores were significantly different at baseline ($F(2,43) = 4.59$, $p = .016$) where post hoc Bonferroni corrections showed significantly lower scores for low flavonoid group versus control ($p = .046$) and high flavonoid groups ($p = .031$) (Figure 20). A significant effect was observed for Condition, but not for Visit or the Condition*Visit interaction. Given that baseline differences were observed between groups, a change from baseline analysis was conducted, however, no significant effects were observed.

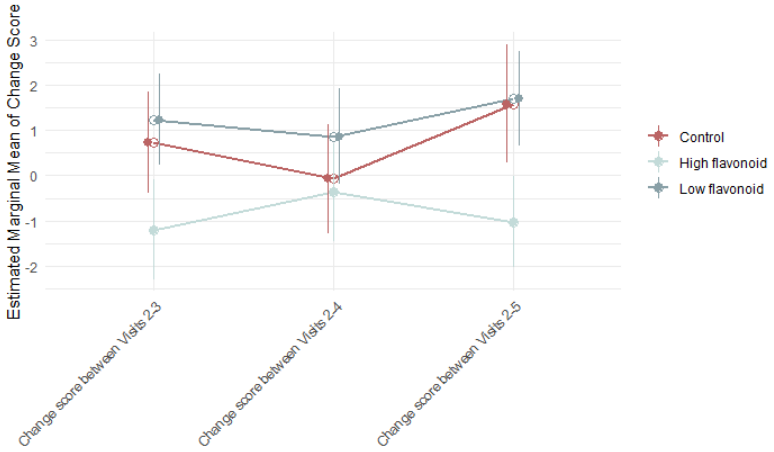


*Figure 20. Word recognition change scores broken down by intervention groups with LMMs revealed change from baseline for word recognition scores did not change over time as a result of the intervention (p>.05). Models were controlled for sleep quality (PSQI), maternal age, habitual flavonoid intake and birth experience as covariates.*

*5.3.12.9. Source monitoring accuracy*

A significant main effect of Condition was found, no pairwise comparisons showed significant effect, however further analysis showed a significant between groups differences at 0-4 days postpartum ($F_{[2, 39]} = 3.65$, $p = .035$), with Bonferroni corrected pairwise comparisons showing significantly higher source monitoring accuracy for the high low flavonoid group compared to the control group ($p=.033$). The same effect was found at 4-weeks postpartum, with significantly higher scores for the low flavonoid group compared to control ($p=.007$) and high flavonoid group ($p=.002$) (Figure 21). Given that baseline differences were observed between groups, a change from baseline analysis was conducted, showing a significant main effect of visit ($F_{[2, 80]} = 3.26$, $p = .043$) with Bonferroni corrected comparisons showing significantly higher change scores between 0-4 days to 12-weeks postpartum with 0-4 days and 2-weeks postpartum ($p= .042$), no other main effects or interaction effects were present.

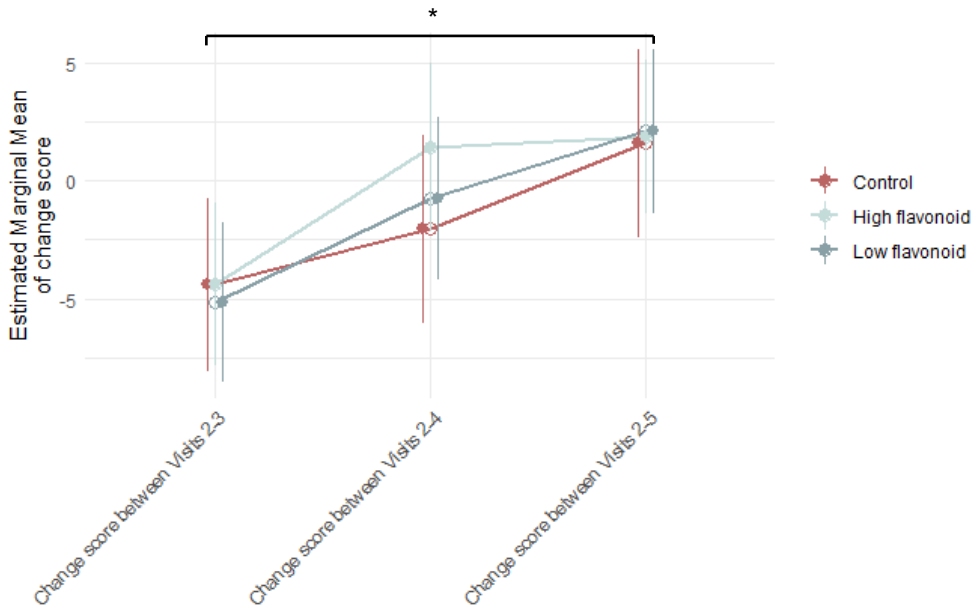


*Figure 21. Source monitoring accuracy change scores broken down by intervention groups with LMMs revealed change from baseline for source monitoring accuracy scores significantly improved over time ($F_{[2, 80]} = 3.26$, $p = .043$) (*=p<.005). Models were controlled for sleep quality (PSQI), maternal age, habitual flavonoid intake and birth experience as covariates.*

#### *5.3.12.10. Source monitoring reaction time (s)*

No significant main effects of interactions were found (Appendix B; Appendix B.26).

### 5.3.13 Blood pressure

#### *5.3.13.1 Systolic BP*

The Condition * Visit interaction and main effect of Condition were not significant. However, a main effect of Visit ($F_{[3,128]}$= 12.94, *p<.001*) was seen, with a significant increase in systolic blood pressure from 2-weeks (*M*=109.45, *SE*=1.39) to 4-weeks (*M*=110.30, *SE*=1.40) (*p*=.006), which appears to be driven by the control group and attenuated by flavonoid groups, though not statistically significant (Figure 22).

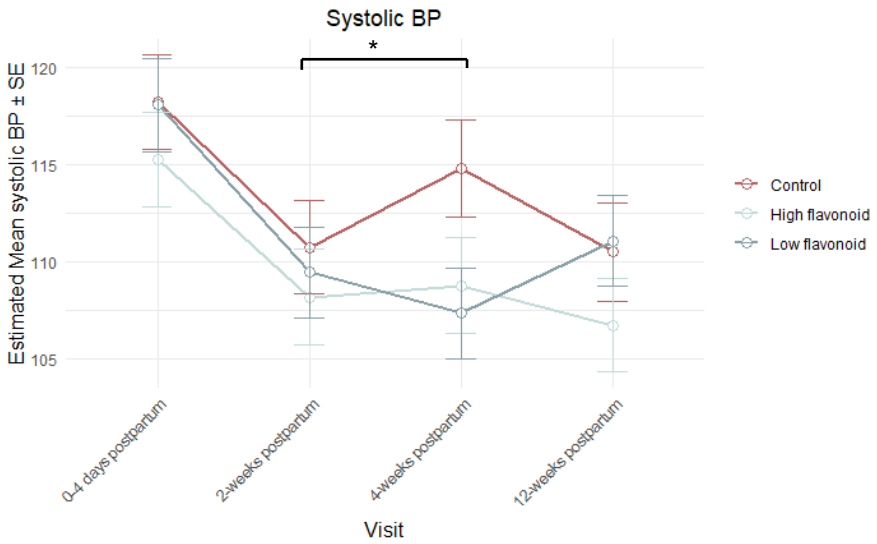

*Figure 22. Systolic blood pressure broken down by intervention with LMMs revealed that mean (SEM) systolic blood pressure significantly changed over time (*=p<.005). Models were controlled for sleep quality (PSQI), maternal age, habitual flavonoid intake and birth experience as covariates.*

Significant changes over time were found in the Low Flavonoid ($F_{[3, 45]} = 8.66$, $p < .001$), High Flavonoid ($F_{[3, 42]} = 5.41$, $p = .003$), and Control ($F_{[3, 37]} = 3.85$, $p = .016$) groups. Pairwise comparisons revealed significant decreases in blood pressure from 0-4 days to 2-weeks and from 0-4 days to 12-weeks across all groups. Notably, the Low Flavonoid group showed a marked drop in systolic BP from 0-4 days (M = 118, SE = 1.99) to 12-weeks (M = 110, SE = 1.99), $p < .001$. The most pronounced change occurred between 0-4 days and 4-weeks in the Low Flavonoid condition (M = 11.60, SE = 2.42, $t_{(45)} = 4.80$, $p < .001$), suggesting a particularly beneficial effect during this interval. This was greater than the changes observed between 0-4 days and 2-weeks in the same group (Mean change = 9.54, $p = .001$) and larger than corresponding changes in the High Flavonoid (M = 7.42, $p = .0263$) and Control groups (M = 7.46, $p = .043$).

5.3.13.2 Diastolic BP

No significant main effects of interactions were found (Appendix B; Figure 28), there were no significant covariates in this model.

5.3.14. Habitual diet

Regarding habitual diet, analysis of data from EPIC-Norfolk showed no significant differences between conditions at Visit 1 (pregnancy; pre-intervention baseline) (Table 12). Additionally, one sample t-tests were conducted to explore differences between mean nutrient intake at baseline and the UK recommended dietary allowance (RDA) for mothers in the third trimester of pregnancy. Significant differences were observed for most nutrients whereby mothers were under-achieving RDA's for most nutrient groups, except flavonoid, protein and fat intake where RDAs were met.

Participants were provided with nine 24hr food recalls over the trial, split into three in pregnancy, three during the intervention period and three during the 4-12 week postpartum follow up period. Overall compliance for the 24hr recalls was 62% with compliance dropping over time from 68%, 61% and 57% in the follow up period. No significant differences were seen between conditions for any nutrient, over the three time points ($p>.05$) (Table 13). Furthermore, LMMs revealed no significant effect of the intervention over visits for any nutrient ($p>.05$). Interestingly this was the case for reported flavonoid intake where no significant Condition * Time interactions were seen ($F(2, 85)= 1.09$, $p=.339$). These findings suggest that participants' nutrient and flavonoid intake remained consistent over time, regardless of group allocation, and that the intervention did not significantly alter dietary intake.

*Table 12. Mean (SE) raw data and interaction effects from the EPIC-Norfolk FFQ for participants in the intervention and control groups at pregnancy*

| Nutrient | Pregnancy RDA | One sample t-test comparing intake with RDA's | Intervention | | | Between groups *p* value |
|---|---|---|---|---|---|---|
| | | | Low flavonoid (n=18) | High flavonoid (n=18) | Control (n=20) | |
| | | | M(SE) | M(SE) | M(SE) | |
| Flavonoid ( mg) | 428 mg[1] | t(51)= 1.51, *p*=.135 | 488.33 (87.54) | 459.00 (83.51) | 540.39 (74.13) | .771 |
| Calories (kcal) | 2600kcal[2] | t(51)= -5.60, *p*<.001 | 1790.96 (169.64) | 1995.92 (249.41) | 1891.21 (155.25) | .761 |
| Protein (g) | 71g[2] | t(51)= 1.40, *p*=.166 | 76.95 (7.94) | 74.40 (7.06) | 78.80 (6.99) | .914 |
| Fat (g) | 90g[2] | t(51)= -1.57, *p*=.121 | 78.62 (7.92) | 85.18 (11.88) | 80.93 (8.72) | .890 |
| Carbohydrates (g) | 300g[2] | t(51)= -5.47, *p*<.001 | 206.84 (19.35) | 246.32 (33.59) | 225.99 (17.06) | .518 |
| Fruit (g) | 400g[2] | t(51)= -6.71, *p*<.001 | 208.91 (29.75) | 225.15 (52.19) | 308.08 (30.78) | .137 |
| Vegetables (g) | 400g[2] | t(51)= -4.30, *p*<.001 | 263.61 (34.53) | 273.98 (37.23) | 360.76 (42.06) | .145 |
| Iron ( mg) | 9 mg[2] | t(51)= 4.04, *p*<.001 | 10.33 (0.95) | 11.01 (1.11) | 11.87 (0.66) | .476 |
| Folate (mcg) | 500mcg[2] | t(51)= -15.68, *p<.001* | 260.63 (28.57) | 276.19 (29.44) | 300.22 (15.12) | .504 |
| Fibre (g) | 34g[2] | t(51)= -15.31, *p*<.001 | 16.56 (1.49) | 18.24 (2.50) | 19.97 (1.27) | .389 |

[1] Vogiatzoglou et al. (2015); [2] U.S. Department of Agriculture. (2020)

*Table 13. Mean (SE) raw data and interaction effects from the 24-hr recalls for participants in the intervention and control groups at pregnancy, throughout the intervention and follow up*

| Nutrient | Time | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pregnancy | | | | Intervention (0-4 days postpartum-4-weeks postpartum) | | | | Post intervention (4-12 weeks postpartum) | | | | |
| | Low flavonoid (n=18) | High flavonoid (n=18) | Control (n=20) | Between groups *p* value | Low flavonoid (n=18) | High flavonoid (n=18) | Control (n=20) | Between groups *p* value | Low flavonoid (n=18) | High flavonoid (n=18) | Control (n=20) | Between groups *p* value | Condition * Visit interaction |
| Flavonoid ( mg) | 274.17 (61.75) | 225.70 (45.10) | 248.17 (57.20) | .833 | 271.14 (79.61) | 280.95 (53.15) | 278.35 (58.85) | .994 | 195.88 (66.57) | 276.91 (53.19) | 295.69 (66.31) | .509 | F(2, 85)= 1.09, *p*=.339 |
| Calories (kcal) | 1746.09 (495.70) | 1205.03 (162.07) | 1203.49 (149.09) | .345 | 1230.84 (190.88) | 1324.78 (153.34) | 1259.99 (146.28) | .923 | 1239.19 (184.18 ) | 1353.12 (165.70) | 1266.02 (187.26) | .892 | F(2, 89)= 0.32, *p*=.726 |
| Protein (g) | 60.26 (11.85) | 44.12 (5.63) | 61.79 (16.69) | .560 | 57.54 (9.74) | 50.71 (5.49) | 45.72 (5.77) | .486 | 56.16 (8.74) | 53.54 (6.33) | 53.18 (7.79) | .957 | F(2, 90)= 0.93, *p*=.910 |
| Fat (g) | 65.80 (19.99) | 62.59 (14.62) | 105.54 (62.55) | .714 | 47.11 (9.30) | 52.75 (8.07) | 47.34 (6.56) | .853 | 53.68 (10.84) | 53.39 (6.88) | 49.81 (8.83) | .941 | F(2, 87)= 0.003, *p*=.997 |
| Carbohydrates (g) | 243.83 (75.15) | 155.55 (21.61) | 164.36 (20.64) | .315 | 152.43 (22.32) | 172.68 (20.93) | 173.79 (20.39) | .747 | 141.41 (21.17) | 172.96 (24.51) | 156.85 (22.80) | .636 | F(2, 88)= 0.78, *p*=.457 |
| Fruit (g) | 89.76 (23.78) | 86.83 (20.96) | 94.82 (16.40) | .958 | 101.15 (30.43) | 112.29 (28.40) | 134.20 (34.28) | .754 | 95.33 (22.21) | 72.23 (17.62) | 82.83 (23.72) | .745 | F(2, 87)= 0.20, *p*=.815 |
| Vegetables (g) | 135.39 (52.03) | 70.49 (20.88) | 104.93 (24.06) | .419 | 84.39 (35.4) | 73.83 (23.09) | 63.12 (15.82) | .819 | 69.45 (20.81) | 97.94 (30.18) | 87.79 (18.60) | .721 | F(2, 84)= 0.22, *p*=.798 |
| Iron ( mg) | 21.22 (7.78) | 42.93 (32.88) | 33.78 (17.92) | .797 | 14.60 (5.65) | 9.40 (1.71) | 28.57 (17.12) | .518 | 11.15 (2.90) | 11.92 (3.11) | 8.28 (1.50) | .586 | F(2, 80)= 0.60, *p*=.550 |
| Folate (mcg) | 337.95 (59.22) | 251.25 (74.25) | 343.73 (72.33) | .581 | 185.64 (35.89) | 207.08 (40.67) | 269.72 (57.45) | .445 | 238.48 (67.70) | 280.95 (77.99) | 168.46 (28.21) | .436 | F(2, 85)= 1.95, *p*=.148 |
| Fibre (g) | 13.06 (1.82) | 10.91 (1.31) | 11.99 (1.65) | .656 | 9.38 (1.37) | 11.96 (1.89) | 11.65 (1.50) | .510 | 9.03 (1.29) | 11.22 (2.22) | 10.00 (1.55) | .697 | F(2, 90)= 1.83, *p*=.165 |

## 5.4. Discussion

This study recruited mothers during the third trimester of pregnancy with the aim to explore whether a 30-day dietary flavonoid intervention in the first month postpartum would improve mothers' mental health, cognition and blood pressure.

Significant improvements in overall accuracy to executive functioning (MANT) were seen following consumption of both one and two flavonoid-rich food items over the postpartum, an effect which was sustained 2 months following the intervention. Increases in accuracy for participants consuming 2 flavonoid-rich foods were further magnified when cognitive load was higher, and when the participant reported better sleep. Interestingly, during longer stimulus presentation (500ms), participants who consumed fewer flavonoids at baseline and consumed two portions of additional flavonoid-rich foods over the intervention period had improved accuracy compared to baseline, which was not seen in the low flavonoid or control condition and was not replicated in high habitual flavonoid consumers. The effect of baseline diet is mirrored in subjective cognition scores, where participants that consumed fewer flavonoids in their habitual diet, and consumed an additional one or two portions of flavonoid-rich foods, reported fewer impairments in subjective cognition (PRMQ). Combined, this indicates the flavonoid-rich diet may improve subjective memory and objective executive function in this population, especially in habitually low consumers. Additionally, improvements in systolic blood pressure following delivery (0-4 days postpartum) were larger in magnitude following consumption of flavonoid-rich foods, suggesting flavonoids may modulate postpartum changes in blood pressure. Despite these benefits to cognitive function and blood pressure, no consistent mood or mental health outcomes were found following consumption of either one or two flavonoid-rich foods over the postpartum versus the control condition. However, inspection of Appendix B.2 suggests a slight reduction in positive affect (PA) at 2 weeks in the control group only, which may tentatively indicate some protective effect of flavonoid consumption. Additionally, interesting mental health covariates emerged. A more positive birth experience was associated with better depression outcomes over time, although this effect was independent of flavonoid condition. In contrast, for anxiety, an interaction between Condition and sleep quality was observed: poor sleepers in the control group reported significantly higher anxiety than good sleepers, a difference that was not evident in the flavonoid groups. This suggests that flavonoid intake may have moderated the negative impact of poor sleep on anxiety. While there is no evidence that sleep quality itself improved following the intervention, it is possible that those with poorer sleep had greater scope for benefit, resulting in reduced anxiety despite ongoing sleep difficulties. Overall, the current findings suggest that an early intervention of dietary flavonoids may support postpartum mood, cognitive function and blood pressure regulation, with effects persisting for cognitive function and blood pressure beyond the intervention period, and highlights the importance of considering relevant factors such as sleep when assessing the efficacy of a flavonoid intervention.

Following the benefits to postpartum depression and anxiety observed following the consumption of flavonoid-rich foods for mood in the later postpartum (Chapter 3.6.), it is surprising that no consistent mood benefits were observed in the present study as hypothesised based on previous flavonoid intervention studies and the wider literature linking flavonoid intake to improved mood. However, tentative patterns, such as possible protective effect on positive affect and flavonoid related attenuation of anxiety in poorer sleepers suggest that subtle mood-related effects may be present when considering other wellbeing risk factors. One explanation for the discrepancy between the present and previous studies could be baseline mood of the sample, as postnatal depression (EPDS scores) at baseline were generally lower (17% of mothers above clinical cut off) in the present study, especially in comparison to Barfoot et al. (2021) (64% above cut-off on Patient Health Questionnaire (Kroenke et al., 2009)) and Chapter 4 (23% above cut off). This was also seen in postpartum anxiety scores (PSAS), where 8% of the current sample reported clinical levels of postpartum anxiety 0-4 days postpartum, compared with 21% in Experiment 1. Therefore, it could be suggested that mood was better at these timepoints in the present

sample, potentially leaving less scope for improvement following consumption of flavonoids. EPDS scores, however, did decrease over the course of the trial when birth experience was accounted for. This suggests that birth experience is likely a protective factor when exploring depression during the immediate postpartum period, a finding that is in line with postpartum mental health literature. Future flavonoid trials could therefore benefit from stratifying participants by birth experience, as it may help to identify subgroups who are more likely to benefit from flavonoid supplementation.

Regarding the other primary outcome measure, state anxiety (STAI), the data reflected a large percentage of women experiencing clinical symptoms of anxiety at 0-4 days postpartum . The mean score in this sample was more consistent with the data seen in Barfoot et al. (2021) and data in Experiment 1, where higher anxiety was evident. This was an interesting finding, particularly when compared to the low levels of anxiety observed in the PSAS. This discrepancy may be due to differences in measurement focus: the STAI captures general state anxiety, whereas the PSAS targets perinatal-specific concerns. The PSAS may be less sensitive to transient changes in the immediate 0–4 days postpartum but better suited to capturing maternal anxieties that emerge later, highlighting the complexity of assessing postpartum anxiety. Nevertheless, scores for anxiety (STAI) did not change as a result of either intervention group, or over time. Interestingly, sleep was a protective measure for anxiety scores, where those who reported sleeping better had less anxiety. This was not seen in the control condition, which may suggest that those in the flavonoid groups did not experience changes in anxiety even when sleep was poor, potentially indicating that flavonoid intake may be just as protective as sleep on anxiety in the postpartum period. However, the overall lack of significant effects for anxiety indicates that in this sample under these conditions, the impact of a flavonoid intervention on anxiety may be limited. Further research should explore these effects using more targeted approaches, for instance incorporating objective measures of sleep, such as actigraphy, to better understand its role in postpartum anxiety. Consideration of additional factors, such as diet, birth experience, and the timing of assessments in the postpartum period, may also be important, as these nuances could help explain subtle differences in findings between studies, including those of Experiment 1 and Barfoot et al. (2021).

While the present data suggest the importance of measuring sleep in understanding postpartum mood, they also highlight the limitations of current measurement tools in this population. The current study utilised the PSQI, which has been validated in both pregnancy and postpartum populations and is widely accessible (Qiu et al., 2016; Zhong et al., 2015). However, certain questions in the PSQI may not be appropriate and may inaccurately pathologise non-typical sleep in this population. For example, question 5 asks, "How often have you had trouble sleeping because you wake up in the middle of the night or early in the morning?" This may be misleading for new mothers and for researchers' interpretations, as waking frequently to tend to infants' needs is a common and expected experience. This also highlights the lack of accessible, well-validated, and reliable postpartum sleep questionnaires. Sultan et al. (2021) suggested that the Bergen Insomnia Scale may be the best patient-reported measure of postpartum sleep. However, the PSQI has also been reported as a suitable measure, and given its association with postpartum mood disorders (McEvoy et al., 2019), it was deemed an appropriate measure for the present trial, building on the use of a single subjective sleep question utilised in Experiment 1. As discussed, incorporating objective sleep measures in future research may help clarify the relationship between sleep and postpartum wellbeing, alongside the development of a validated postpartum-specific sleep questionnaire.

It is also important to consider the timeframe for these mood measures, with the EPDS asking mothers to reflect on their feelings over the past two weeks whilst the anxiety questionnaires reflected the previous week. As the baseline visit occurred within the first 0-4 days postpartum, the mothers' responses on these scales may not fully capture the progression or onset of symptoms that might develop later in the postpartum period. However, transient mood changes were captured using the PANAS, which provided insight into immediate mood fluctuations during this sensitive timeframe, something that tools like the EPDS, STAI, and PSAS may not fully capture. Additionally, baseline scores for the EPDS and PSAS were higher in this sample compared to those in previous trials, suggesting that the participants may have

started with a more positive mood, leaving less room for change following the dietary flavonoid intervention. Despite this, positive affect and negative affect did not significantly change over time as a result of the intervention, despite some protection for positive affect following flavonoid consumption at 2-weeks, which was not emulated in the control group. These findings, along with the other mood outcomes, suggest that the intervention may be less effective during the immediate postpartum period compared to previous studies examining the effects of flavonoid-rich foods in the 0-6 month (Experiment 1) and 0-12 month (Barfoot et al., 2021) postpartum periods, or that perhaps the measures used such as the STAI and PSAS are not as sensitive in the immediate postpartum to detect such changes, compared to the later postpartum. This underscores the importance of timing in interventions aimed at promoting mood and potentially reducing the prevalence of mood disorders. While Dowlati et al. (2017) and Meyer et al. (2024) observed mood changes in the immediate postpartum period following a single dose of flavonoid, studies focusing on interventions targeting mood and/or cognition in the early postpartum period are relatively rare. These trials may have found effects due to the sensitivity of the measures used, such as Visual Analogue Scales following the sad mood induction procedure, alongside supplementation with tryptophan and tyrosine, which may potentially explain why results were seen in the previous trials compared to this experiment. This highlights the need for further research to explore the potential of early interventions during this sensitive time, with appropriate measures capable of detecting such effects. Some evidence suggests that early postpartum interventions (within the first month postpartum) can improve mood outcomes, as seen in Qin et al. (2022), who gave 112 participants app-based cognitive behavioural therapy, versus wait-list control, immediately following delivery for 4-weeks. Participants showed significant reductions in EPDS scores following the intervention, which was not emulated in the control group. This supports the possibility of beneficial effects from early interventions like the one in this trial. However, it may be that dietary interventions may be less effective during this stage compared to other approaches, such as cognitive behavioural therapy.

In contrast, cognitive function may be particularly sensitive to consumption of flavonoids within this timeframe. Benefits over time were seen for subjective cognition scores (PRMQ) in the intervention groups, signifying improvements in participants' perception of their own cognitive abilities, such as memory and attention, with fewer impairments in subjective cognition between post-intervention and follow-up. Flavonoid-related improvements were seen particularly in those with lower flavonoid intake at baseline. As previously mentioned, higher dietary intake of flavonoids has been linked to fewer cognitive subjective complaints (Yeh et al., 2021), and previous research has shown changes in subjective cognition during pregnancy and the postpartum period without corresponding objective changes (Orchard et al., 2022). This indicates that subjective reports may capture a sensitive area of cognition which responds to flavonoids, that is not captured by objective computerised tests. Factors such as mood and age may contribute to this discrepancy (Marino et al., 2009; Srisurapanont et al., 2017), but Orchard et al. (2022) propose that increased self-awareness and attentional monitoring of memory performance during motherhood play a key role (Anderson & Rutherford, 2012). The postpartum period involves substantial behavioural adaptation and a markedly increased daily cognitive load, which raises the likelihood of memory lapses. This heightened cognitive demand may increase mothers' sensitivity to minor forgetfulness, leading to more frequent subjective reports of cognitive difficulties despite unchanged objective function. Furthermore, physiological changes such as increased cerebral blood flow (Chapter 1.7) may lead to increased alertness, and reduced cognitive fatigue as demonstrated in other flavonoid studies (Alharbi et al., 2016; Scholey et al., 2010; Watson et al., 2015) which may subsequently influence how individuals perceive their own cognitive abilities, but may not translate immediately into enhanced task performance. Future research should explore psychological pathways, especially ones relevant to the postpartum such as maternal self-awareness, alongside physiological mechanisms to better understand how flavonoids influence cognitive experience in the postpartum period, even in the absence of objective performance gains.

In this experiment, mothers that consumed both one and two flavonoid-rich foods in addition to their normal diet, had improved accuracy in the MANT over the course of the intervention, with significant improvements for the high flavonoid condition across all visits, and low flavonoid condition across 0-4 days to 12 weeks postpartum, compared with the control group. This highlights the potential for flavonoid consumption to support maternal executive functioning during the postpartum period. However, the absence of significant differences between the low and high flavonoid groups overall suggests that greater flavonoid intake does not necessarily lead to proportionally greater benefits in executive function, challenging the straightforward dose-response relationship as proposed in previous literature (Chapter 1.5). When MANT task performance was analysed by cognitive load, a significant interaction emerged between condition and load. Participants in the high flavonoid group demonstrated greater accuracy on high-load trials compared to medium-load trials, a counterintuitive finding, as medium-load conditions typically result in higher accuracy due to lower cognitive demand following flavonoids as evidenced in Barfoot et al. (2019); Whyte at al. (2016) and Whyte et al. (2017). This may suggest that consuming two portions of flavonoid-rich foods enhances executive functioning specifically under conditions of higher cognitive demand during the postpartum period. Additionally, there was a significant interaction for the 120ms reaction time data, though significant pairwise comparisons were not evident, inspecting Appendix B.7 shows the high flavonoid group demonstrated faster RT by 2-weeks which was not evident in control and low flavonoid groups, indicating a potential earlier benefit of the higher dose. Interestingly, across all conditions, accuracy was unexpectedly higher in the 120ms stimulus duration block. This finding again contradicts prior research indicating that shorter stimulus durations typically increase cognitive load and reduce accuracy, effects that have previously been shown to improve with flavonoid supplementation (Whyte et al., 2016; Whyte et al., 2017). Interestingly, the significant decreases in reaction time in the 120ms block may also be supported by the improvements in accuracy by observing Figures 18 and Appendix B.7, possibly explaining more efficient processing of stimuli following the high flavonoid intervention, though this was not confirmed by pairwise comparisons. However, as discussed, these findings may have been affected by the lower trial numbers in the 120ms condition. Together, these findings highlight the complexity of cognitive responses to flavonoid intake in the postpartum period.

Furthermore, this benefit was only observed at 12 week follow up in participants with lower habitual flavonoid intake. This suggests that the cognitive benefits of flavonoids may persist even after the intervention has ended. It also points to a possible sensitive period for intervention, with lasting effects most evident for demanding tasks in those who may plausibly have the most to gain from a flavonoid intervention, i.e. low flavonoid consumers. While one possibility is that participants continued to increase their flavonoid intake beyond the intervention period, potentially contributing to the sustained effect, this was not reflected in the 24-hour dietary recall data. Although compliance with dietary reporting declined to 57% by 12 weeks, reported intake remained stable, consistent with findings from Experiment 1. This supports the idea that the observed cognitive improvements are unlikely to be driven by ongoing dietary changes, but rather may represent a genuine lasting effect of the intervention in low habitual consumers.

Further analysis of overall MANT accuracy scores highlighted the crucial role of sleep in maternal executive functioning whereby the high flavonoid condition showed improvements in accuracy over time, but only among those with PSQI scores <5, indicating ‘good sleepers.’ This suggests that while flavonoids may enhance executive functioning, their benefits may be contingent on adequate sleep. The relationship between sleep and executive function is well-established, with poorer sleep having significant effects on performance (Nilsson et al., 2005; Tucker et al., 2010). This finding is particularly pertinent in the postpartum, where Swain et al. (1997) reports dysphoric mood and impaired cognitive functioning during the first 3-weeks postpartum due to changes in sleep. Subsequently, this finding is notable as it implies that dietary interventions may only be effective when sufficient rest is achieved, highlighting the interplay between nutrition and sleep in cognitive recovery postpartum. This finding is consistent with the anxiety data, where sleep quality moderated the effects of flavonoid intake, highlighting a consistent role of sleep shaping the efficacy of flavonoid interventions across mood and cognitive outcomes. Future

research could further explore this potential synergy through intervention studies that manipulate both sleep quality and flavonoid intake, or by stratifying participants based on objective sleep metrics, for example, as aforementioned, actigraphy may be beneficial for capturing this data, rather than subjective questionnaires to examine interactive effects on cognitive performance.

Executive functioning is a core component of cognition, making the observed benefits of flavonoid supplementation in some of the executive function tasks within this population a promising finding. However, executive functioning is influenced by multiple factors, including baseline diet and sleep, as discussed, as well as stress (Alexander et al., 2007; Shields et al., 2016). The transition to the postpartum period is widely recognised as a stressful time (Hung, 2007) and is frequently associated with the onset of postpartum mood disorders (Hung, 2004; Schalla & Stengel, 2024). Given the well-established links between stress, executive functioning, and mood (Walters & Hines-Martin, 2018), it is essential to consider how these variables interact. Beyond maternal stress, infant irritability is another key factor, as it has been shown to have a bidirectional relationship with maternal mood (Britton, 2011; Wiggins et al., 2014). Considering these complex relationships, future research should account for postpartum stress and infant irritability as potential moderators in the investigation of postpartum mood and cognition. Understanding these influences may help clarify the extent to which flavonoid supplementation benefits executive functioning and whether its effects are contingent on maternal psychological and environmental factors.

It is important to note that whilst compliance with the intervention itself was good, as recorded via participant diaries, with 92% adherence in the low flavonoid group and 79% in the high flavonoid group. Compliance with the 24-hour dietary recalls was considerably poorer. As shown in Table 13, these data indicated no significant changes in flavonoid intake between groups over the intervention period, which presents some challenges in interpreting the findings. It is possible that participants substituted their usual sources of dietary flavonoids with the foods provided as part of the intervention, rather than adding these to their habitual intake. While this may partly explain the lack of change observed in the recall data, it cannot be confirmed with the information collected. More importantly, the 24-hour recalls had limited completion (overall compliance 62%, which dropped over the intervention period, as reported in 5.3.14) and were only administered on three occasions during the 4-week intervention period. This was intended to minimise participant burden during the postnatal period while still capturing an overview of dietary intake; however, it likely contributed to poor overall compliance and reduced the reliability of these data as an indicator of habitual diet. Therefore, the results of this trial should be interpreted with caution, as it cannot be confidently concluded that the observed effects were driven by increases in flavonoid intake, given the lack of significant dietary changes reported in the recall data.

In contrast to the improvements observed on the MANT, no significant effects of the intervention were found on the N-Back task or any RAVLT outcomes. This suggests that the cognitive domains assessed by these tasks may be less sensitive to flavonoid supplementation in a postpartum population. Previous research has also reported null effects on these measures following flavonoid interventions (Boespflug et al., 2018; Nathan et al., 2004), suggesting consistency within the literature and may help to explain why such effects were not detected in this experiment. Alternatively, it is possible that the postpartum population is less responsive to supplementation in certain cognitive domains. As highlighted by Orchard (2022), subjective perceptions of cognitive decline are common during the postpartum period, even in the absence of consistent objective deficits. This may help explain the lack of significant change across visits and the absence of clear intervention effects on the RAVLT and N-Back tasks. However, one potential explanation is that the cognitive demands of the N-Back and RAVLT tasks were insufficient to reveal subtle effects, particularly when compared to more challenging tasks like the MANT. As discussed in Chapter 3.2, previous studies employing executive function tasks such as the Go/No-Go may also have lacked sufficient cognitive load to detect performance differences in maternal samples. The observed improvements on the MANT following flavonoid supplementation may therefore reflect a unique interaction between high task demand and postpartum cognitive sensitivity, enabling the detection of

subtle enhancements in performance. These benefits may be further amplified by flavonoid intake, which has been shown to support cognitive performance under conditions of increased cognitive load (Chapter 1.5.2). Similar patterns have been observed in the broader nutritional psychology literature, where cognitive benefits from interventions such as probiotics (Eastwood et al., 2025), flavonoid-rich blueberries (Barfoot et al., 2019; Whyte et al., 2016), and cocoa (Massee et al., 2015; Scholey et al., 2010) tend to emerge most clearly during cognitively demanding tasks designed to induce mental fatigue

Furthermore, one key factor possibly influencing the outcomes in this study is the transition of mood and cognitive states from pregnancy to postpartum where changes were observed in negative affect, retroactive interference, and word span, reflecting poorer cognitive performance and increased negative affect transitioning into the postpartum. These findings suggest that these specific cognitive and emotional outcomes may be particularly sensitive to the hormonal fluctuations that occur during this period (Glynn, 2010; Grattan & Ladyman, 2020). Declines in verbal memory performance have also been widely reported postpartum (Henry & Sherwin, 2012; Eidelman et al., 1993), making these observed changes consistent with prior research. Notably, fluctuations in key hormones such as oestrogen and progesterone have been shown to differentially affect subregions of the hippocampus (Barha & Galea, 2010), potentially accounting for the selective impact on specific memory functions. This could explain why only certain aspects of verbal memory, such as retroactive interference in the RAVLT were affected, while others remained stable. Future research should further investigate the extent of these alterations across the peripartum period and explore how they relate to underlying neurobiological mechanisms, particularly region-specific hormonal sensitivity in the hippocampus.

Another notable physiological change from pregnancy to postpartum was the increase in both systolic and diastolic blood pressure following delivery. This shift is consistent with well-documented postpartum adjustments as the cardiovascular system readjusts after pregnancy. The finding of reduced blood pressure in the later postpartum period following flavonoid supplementation is particularly promising. This trial captured the expected peak in blood pressure after delivery, commonly referred to as postpartum hypertension. As outlined by Powles (2017), factors such as pain, medication use, and the restoration of vascular tone likely contribute to this transient increase. Additionally, postpartum preeclampsia can emerge de novo, and persistently elevated blood pressure beyond six weeks postpartum, especially following hypertensive pregnancies, has been linked to an increased risk of hypertension later in life (Lazdam et al., 2012). Although no data was collected on whether participants had hypertensive pregnancies, and no participants reported preeclampsia, the observed benefits of flavonoid supplementation suggest a potential cardiovascular advantage for this population, which is underpinned by the well documented role of flavonoids in supporting vascular health and lowering blood pressure both in RCTs and longitudinal research (Hodgson, 2006; Clark et al., 2015).

In regards to birth experience being highlighted in this data as a protective factor, Bell and Andersson (2016) outline that birth experience is intrinsically linked with postpartum depressive symptoms, however, it is a complex construct, making it challenging to assess. There is no generally accepted gold standard measure. In this trial, birth experience was measured with a simple Likert scale form 1-10, with 10 indicating a more positive birth experience, this was followed by the option for mothers to comment on their recent birth experience, however this may not have been sufficient to grasp the full extent to understand the underlying themes of the mothers experience (Bell et al., 2016). However, considering the multitude of measures used in this trial, collecting more in depth data for this measure may have distracted from the overall aim, though does stand out as an area for future research and the need for validated and reliable measures. It should also be noted that there are relatively few studies exploring the effects of birth experience on anxiety symptoms (Bell & Andersson, 2016; Giakoumaki et al., 2009). While Giakoumaki et al. (2009) found that negative birth experiences were associated with state anxiety symptoms, this was not reflected in the current trial, where birth experience did not emerge as a relevant covariate for STAI or PSAS scores. This may suggest that birth experience plays a limited role in postpartum anxiety; however, given that some evidence points to a possible association, further research

is warranted to clarify under what circumstances, if any, birth experience might influence postpartum anxiety.

It is important to note that paternal mood and cognition were not directly assessed in this trial due to compliance challenges, as outlined in Experiment 1. Instead, to gain insight into partner mood postpartum, the EPDS-Partner was used, allowing mothers to rate their partners' depressive symptoms. This approach helped circumvent the recruitment and compliance issues encountered in the previous experimental trial. Given that paternal depression often co-occurs with maternal depression (Cameron, 2016), it was hypothesised that if flavonoid supplementation improved maternal mood, it might also have an indirect positive effect on partner mood. However, since no significant improvements were observed in maternal mood symptoms, it is perhaps not surprising that no corresponding changes were detected in partner mood. While it may be overly assumptive to expect dietary supplementation in one parent to influence the mood of the other, the interconnected nature of parental mental health in the postpartum period suggests that this warrants further investigation. Future research could explore whether such effects emerge later in the postpartum period when more pronounced maternal mental health improvements following flavonoid intake are observed.

In this trial, it was interesting that among the intervention foods, orange juice was the most frequently consumed (5.3.1), which may have played a key mechanistic role in the observed cognitive effects. While flavanone-rich orange juice has been demonstrated to elicit cognitive benefits in previous research (Alharbi et al., 2016; Kean et al., 2015), it may not be as effective for mood outcomes within the given timeframe. In order to observe mood-related benefits of flavonoids, particularly flavanones, a longer duration of intervention or higher intake levels may be required, as suggested (Park et al., 2020) who showed mood benefits only after 8 weeks (Chapter 2.3.5.6). Future research should explore whether the timeframe of mood related effects of flavonoid-rich foods is influenced by the flavonoid source. For example, berries were the most consumed item in Experiment 1 (where effects for mood were seen) which is consistent with the systematic review findings from Chapter 2. Additionally, dark chocolate was another commonly consumed intervention food in this study, which is known for its beneficial effects on blood pressure. This could represent another underlying mechanism contributing to the observed benefits for blood pressure here. Notably, the variety of flavonoid-rich foods consumed was somewhat limited, as mothers tended to select more convenient, accessible, likable and cost-effective options such as orange juice, and chocolate. While flavonoid-rich foods are known to support cognitive and cardiovascular health, and greater dietary diversity is generally associated with improved health outcomes (Chapter 1.3; Del Bo et al., 2021), this pattern of food choice was not reflected in the current findings. In contrast, Experiment 1 showed mood-related benefits, despite a narrower range of flavonoid sources consumed more consistently (e.g., berries, juice, and dark chocolate). This suggests that the specific types of flavonoids may be influential to outcomes. However, the evidence linking flavonoid diversity specifically to mood and cognition is still limited, and future research is needed to better understand how variety and intake patterns influence psychological outcomes.

Regarding limitations of the trial, as discussed, a proportion of data was missing from the MANT task. This may have limited the findings, and despite the analytical steps taken to account for this, it remains a notable limitation. Postpartum cognitive changes appear evident during this period and may be influenced by dietary flavonoid intervention. Future research should aim to minimise missing data to more accurately determine the true effects of this relationship. Furthermore, the intervention was implemented within the first 0–4 days postpartum to begin flavonoid supplementation as early as possible, prior to the peak of postpartum blues symptoms. Given this timing, it may have been beneficial to include a postpartum blues scale, such as the Stein Maternity Blues Scale (Stein, 1980) to better track transient mood changes during this sensitive window, especially since such measures have shown sensitivity to dietary interventions in previous research (Meyer et al., 2024). Although this study included transient mood measures like the PANAS alongside maternal-specific questionnaires such as the PSAS and EPDS, none detected flavonoid-related mood effects during this time. An additional limitation stems from the sample being

predominantly from a higher socioeconomic status, well-educated, and majority White-British population, which limits the generalisability of the findings and underscores the need to investigate postpartum mood and flavonoid effects in more diverse populations. Finally, use of measures to detect postpartum sleep, subjective birth experience, and dietary changes within the study serves as a limitation, given that the sleep questionnaire was not specific to the postpartum period, the birth experience was assessed only via a simple visual analogue scale, and dietary compliance data were limited, reducing the sensitivity and comprehensiveness of these assessments. Future research could benefit from development of appropriate and reliable measures for use within the postpartum to better capture how these may influence results of similar dietary intervention trials.

The findings of cognitive benefits from flavonoid supplementation carry meaningful practical implications for postpartum women, who often face sustained high cognitive demands, including caring for infants and other children, alongside potential early return to work. The observed improvements in executive function and subjective cognition suggest that incorporating flavonoid-rich foods into the diet may offer a feasible, cost effective and accessible strategy to support cognitive health during this demanding period. This is especially important given the well-documented sleep disruptions common in the postpartum, which can worsen cognitive difficulties and emotional distress. Notably, flavonoids may also provide a protective effect by reducing anxiety in those experiencing poor sleep during this time. For healthcare providers, these results highlight a non-pharmacological, nutrition-based approach that could complement traditional postpartum care. Furthermore, for women returning to work early postpartum, dietary flavonoids may help alleviate cognitive fatigue and enhance daily functioning, underscoring the potential real-world benefits of such dietary interventions.

This experiment is one of the first to examine the effect of a nutritional intervention from the immediate to several months postpartum, whilst also capturing outcomes in pregnancy. This offers a comprehensive picture of the dynamic changes in mood, cognition and physiology over this transition period, whilst also exploring the effects of dietary flavonoids during this sensitive time. Overall, results of this trial highlight the potential cognitive benefits of 30-day flavonoid supplementation in the early postpartum period. These cognitive improvements were observed following the consumption of either one or two flavonoid-rich foods in addition to participants' regular diet, and notably, these benefits persisted for up to two months after the supplementation period. Significant improvements in accuracy on the Modified Attention Network Task (MANT) were seen in both intervention groups, with the most pronounced effect in mothers consuming two portions, suggesting a relationship that is more apparent under higher cognitive demand. Additionally, mothers reported improvements in subjective cognitive function, particularly when considering baseline flavonoid intake. Protective factors such as birth experiences and sleep also appeared to influence these outcomes, indicating the need for further research to better understand their roles in postpartum mood and cognition, as well as how flavonoids may interact with these factors. Contrary to previous literature, no improvements in mood were observed following the intervention. Nonetheless, tentative trends, such as a possible protective effect on positive affect and flavonoid-related attenuation of anxiety in poorer sleepers suggest subtle mood-related benefits that warrant further investigation. This may suggest that the timing of dietary interventions is crucial, with later interventions potentially being more effective in improving depressive and anxious symptoms. However, mood during the immediate postpartum period is highly complex and influenced by a range of biological, psychological, and environmental factors. As such, the high variability in mood across individuals may have limited the ability to detect changes resulting from a relatively short intervention. Importantly, the lack of significant changes in flavonoid intake reported in the 24-hour food recalls indicates that observed effects cannot be confidently attributed to increases in flavonoid consumption and should therefore be interpreted with caution. Given the poor compliance with these dietary recalls, but relatively good adherence to the intervention foods as recorded in participant diaries, the intervention effects may still reflect the intended flavonoid exposure, albeit with some uncertainty. Future research should explore whether the cognitive benefits of flavonoid supplementation are sustained in both parents, and whether effects can be found

under acute time periods and with specific flavonoid-rich foods which may work in combination with the underlying physiological changes throughout this time.

# Chapter 6: The acute effects of Blueberries on Cognition And Mood in the Postpartum (BLUCAMP)

## 61. Introduction

Results from Experiment 1 showed mothers in the 0-6 months postpartum, who consumed two portions of flavonoid-rich foods daily for 14-days, had significant reductions in EPDS scores and improvements in positive affect. These results suggest flavonoid interventions during the 0-6 month postpartum period may offer benefits for maternal mood. In contrast, Experiment 2, which examined a similar intervention, did not find significant mood effects when supplementation was initiated in the first few days postpartum. However, cardiovascular and cognitive improvements were observed following flavonoid consumption at 4-weeks, which were maintained by the 12-week postpartum follow up point. Together, these findings suggest that implementing flavonoid interventions slightly later in the postpartum period, such as up to 6-months postpartum, may be more effective for improving mood outcomes.

As previously discussed, the precise timing of postpartum depression (PPD) and other mood disorders onset is still debated, but it is generally agreed that the highest prevalence occurs between 3-6 months postpartum (O'hara & Swain, 1996). Therefore, as emphasised throughout this thesis, interventions during this period may help reduce the prevalence of mood disorders or alleviate symptoms when mood is most labile, but not significantly influenced by the rapid physiological changes of the immediate postpartum weeks (Munk-Olsen et al., 2006; Nott et al., 1976; O'hara & Swain, 1996). Additionally, since cognitive outcomes were not assessed in Experiment 1, but significant cognitive improvements were found following flavonoid consumption in the immediate postpartum in Experiment 2, further investigation into effects on cognitive function later in the postpartum period is important.

A theme throughout this thesis emerges when considering specific flavonoid-rich foods that may be most optimal for mood and cognition, for instance, the evidence reviewed in Chapter 2 supporting cocoa and blueberries, and the improvements in mood observed in Experiment 1 following berry fruit consumption. Blueberries (and other berries) are an excellent source of flavonoids, specifically anthocyanins, which possess both anti-inflammatory and antioxidant capabilities, which have the potential to improve brain health and function (Kalt et al., 2020). Habitual berry intake has been associated with reduced risk of depression in adults (Sun et al., 2021). This association extends to cognitive function, as evidenced by Devore et al. (2012) who found that increased blueberry consumption was related to slower cognitive decline in the Nurses' Health Study, which included 16,010 women. As mentioned in Chapter 2, anthocyanin-rich interventions may have benefits for mood. For example, Khalid et al. (2017) found improvements in positive affect in both children and young adults following a 30g (253 mg anthocyanin) wild blueberry (WBB) intervention. Similarly, Fisk et al. (2020) reported reductions in self-reported depressive symptoms following a 4-week WBB intervention in healthy 12-17-year-olds, using the same dose of WBB as Khalid et al. (2017). Collectively, these findings suggest that even short-term supplementation with anthocyanin-rich blueberries may positively influence mood in young and healthy populations, highlighting their potential as a practical and accessible dietary strategy for emotional well-being.

Recent findings by Curtis et al. (2024) further support the acute benefits of blueberries, showing that a 26g (364 mg anthocyanin) dose improved postprandial self-reported calmness (using the BL-VAS) 24 hours after ingestion in individuals with metabolic syndrome. However, their lower dose of 13g (182 mg anthocyanin) dose did not significantly affect mood within this timeframe, nor did 6 months of daily consumption show any improvements in mood in either dose. These results suggest that acute blueberry supplementation may be more effective for calmness than chronic intake, particularly in non-clinical populations. In line with these findings, Velichkov et al. (2024) supplemented emerging adults (mean age 20) with 22g freeze-dried WBB (121 mg anthocyanins) and observed acute improvements in positive affect, though no changes in mood outcomes were found after 6 weeks. Notably, participants in this study

reported depressive symptoms at baseline, highlighting the potential for acute mood improvements in clinical and sub-clinical populations, as well as healthy populations. Additionally, Velichkov et al. (2024) observed improvements in executive functioning 1.5 hours after WBB consumption, coinciding with improvements in positive affect. As outlined in previous chapters, executive functioning is closely tied to mood disorders, with numerous studies showing that individuals with depression often experience deficits in this domain (Fossati et al., 2002). These difficulties are also commonly observed in the postpartum period, where cognitive disruptions, including impairments in executive function, are frequently reported (Chapter 3.2). A meta-analysis by Snyder (2013) supports this link, demonstrating that major depressive disorder is associated with reduced performance on executive function tasks, an effect that tends to worsen with increasing symptom severity and the use of psychotropic medications.

The effects on cognition seen in Velichkov et al (2024) are consistent with those seen in Barfoot et al. (2019), who found that acute administration of 30g WBB improved verbal memory in children, compared to a placebo group. A 12-week supplementation study by Bowtell et al. (2017) reported improvements in working memory in healthy older adults who consumed 24g of blueberries per day (19.2 mg/g anthocyanins). In another study, Miller et al. (2018) found improved verbal memory and reduced cost on the Task Switching Test, a measure of executive function, in older adults. Furthermore, Whyte et al. (2016) demonstrated acute (2-hour) improvements in executive function on a modified flanker task in 7-10-year-olds following consumption of 30g (253 mg anthocyanins) of WBB. Collectively, these studies suggest that a dose of 253 mg anthocyanins may be optimal for eliciting changes in mood and cognition within an acute timeframe. However, further research is needed to assess whether these effects extend to clinical or at-risk populations.

Although the exact flavonoid content was not reported, trials by Dowlati et al. (2017) and Meyer et al. (2024) suggest that short periods of supplementation with blueberry flavonoids, combined with tyrosine and tryptophan, in the early postpartum days (up to 5 days postpartum) can have positive effects on mood. In these studies, the blueberry intervention involved either an active extract or placebo mixed with blueberry juice. However, considering that several trials have successfully supplemented participants with 253 mg of anthocyanins from freeze-dried wild blueberries (e.g., Whyte et al., 2016; Barfoot et al., 2019 and Khalid et al., 2017), this dosage may be optimal for applying a blueberry intervention for mood and cognition in the postpartum period.

Investigating the acute effects of flavonoids on mood and cognition could be particularly beneficial for parents with young infants. New parents often report mood fluctuations, with acute and transient mood changes being especially significant (Li et al., 2020; Miller et al., 2017). Therefore, supplements that may enhance mood over a short time frame could provide substantial benefits in this context, such as potentially reducing stress, alleviating low mood, and supporting emotional resilience during demanding periods. Additionally, many parents experience subjective cognitive changes, along with objective cognitive shifts, as outlined in Chapter 3. Therefore, any potential acute improvements in these areas following flavonoid supplementation could be of great interest, as they may help address both perceived and objective cognitive challenges. Participants in Experiment 1 reported improvements in mood, which coincided with increased consumption of berry fruits within the intervention. In contrast, those in Experiment 2, who consumed orange juice, did not report similar mood-related benefits. This suggests that specific flavonoid-rich foods or subclasses, such as anthocyanins found in berries, may be driving these changes in mood and/or cognition. Acute improvements associated with blueberry consumption, as demonstrated in studies by Khalid et al. (2017) and Barfoot et al. (2019), are likely underpinned by distinct physiological mechanisms. Indeed, acute reductions in systolic BP have been observed within 1–3 hours of flavonoid-rich interventions (Keane et al., 2016; Whyte., 2018), a timeframe which has also been paired with observed improved endothelial function and increased circulating metabolites just two hours after wild blueberry (WBB) consumption (Rodriguez-Mateos et al., 2013) Therefore, it would be of benefit to explore acute effects of flavonoid-rich foods on blood pressure as provides a feasible and non-

invasive insight into potential vascular contributions to any observed behavioural or mood effects. Additionally, blueberry intake has been shown to inhibit monoamine oxidase (MAO) activity in the early postpartum period (Dowlati et al., 2017), a time when MAO levels are typically elevated (Sacher et al., 2010). While this mechanism is specific to the immediate days following birth, broader mechanisms discussed in Chapters 1.7.5 and 3.6 suggest that flavonoids, particularly anthocyanins may offer unique benefits during the postpartum period. Future research should further explore both behavioural outcomes and the physiological pathways through which these effects occur.

An important aspect when considering execution of acute interventions is trial design. In this context, crossover designs offer significant advantages, particularly for flavonoid studies. By allowing each participant to act as their own control, crossover trials reduce between-subject variability. When combined with baseline and post-intervention outcome measures within each condition, this design also helps to account for day-to-day fluctuations in mood, cognition, and physiology that may vary both within and between individuals, which are especially relevant in the postpartum period and may also be influenced by the intervention itself. These fluctuations have been previously highlighted in Experiments 1 and 2, where factors such as birth experience, maternal age, and sleep significantly influence postpartum outcomes. Stress, for example, is known to increase during the postpartum period (Hung, 2007; Hung & Chung, 2001) and is frequently associated with the onset of postpartum mood disorders (Hung, 2004; Schalla & Stengel, 2024). As stress levels can fluctuate daily, controlling for this variability is crucial in trial design. Another key factor is infant temperament, which has a well-established bidirectional relationship with maternal mood (Britton, 2011; Wiggins et al., 2014). This acute study will therefore capture and account for such variables to better control for potential confounds in the postpartum context.

Despite low engagement and compliance among fathers in Experiment 1, the potential cognitive and mood-related benefits of flavonoids in postpartum populations justify further exploration among new fathers. As discussed in Section 4.4, paternal research often faces high attrition rates. One strategy to improve engagement may be to adopt father-specific recruitment approaches, such as using the term “Father” rather than the more generic “Parent” in advertisements, which has shown to be more effective (Yaremych & Persky, 2002). The shorter duration of paternity leave compared to maternity leave may also contribute to reduced availability for study participation. In Experiment 1, the continuous supplementation model may have posed an additional burden. However, shorter, acute intervention trials may be more appealing to this demographic, warranting including fathers in addition to mothers in this trial. Additionally, typical healthy populations have been seen to benefit from acute WBB supplementation (see Chapter 2), therefore, fathers, regardless of postpartum status, may also experience similar benefits. Furthermore, previous acute intervention trials such as Khalid et al. (2017) took place in a controlled environment, in testing cubicles, at the University's Nutrition Cognition and Health Lab. While some parents may find attending this location ideal, others may perceive it as a barrier. Therefore, to enhance accessibility and flexibility, participants in this study were given the option to complete the trial either at home or in the lab. This design also aimed to accommodate fathers by offering morning testing sessions prior to work, in either location, further supporting broader participation.

The primary aim of this study was to examine the acute (2-hour) effects of a wild blueberry intervention on mood in mothers and fathers within the first six months postpartum. Secondary outcomes included assessing effects on blood pressure, executive function, working memory, and verbal memory. It was hypothesised that participants would show improvements across several mood and cognitive domains, and a reduction in blood pressure following WBB consumption, but not following the placebo intervention.

## 6.2. Methods

### 6.2.1. Design

The study employed a randomised, double-blind crossover design to explore the acute effects of a WBB drink versus placebo drink on several mood and cognition outcomes. The primary outcome measure for the study was current affect (Positive And Negative Affect Schedule; PANAS). Secondary outcome measures included state anxiety (State-Trait Anxiety Inventory-State scale; STAI-S), transient mood (Immediate Mood Scaler; IMS), subjective feelings (Bond Lader-Visual Analogue Scale; BL:VAS), Resting systolic and diastolic blood pressure, verbal memory (Rey's Auditory Verbal Learning Test; RAVLT), visuospatial working memory (Visuospatial N-Back), sustained attention and executive functioning (Modified Attention Network Task; MANT). Other outcome measures taken at baseline included postnatal depression (Edinburgh Postnatal Depression Scale; EPDS), postpartum specific anxiety symptoms for the mothers sample only (Postpartum Specific Anxiety Scale; PSAS), trait anxiety in the fathers sample only (State-Trait Anxiety Inventory-Trait scale; STAI-T), subjective prospective and retrospective memory (Prospective Retrospective Memory Questionnaire; PRMQ), general diet (European Prospective Investigation of Cancer- Norfolk-Food Frequency Questionnaire; EPIC-FFQ). Outcome measures were assessed at baseline (0hr) and post intervention (2 hours). The order of drink administration was randomised using a random number generator (18 participants received WBB drink first).

### 6.2.2. Participants

Based on prior research using the same intervention and dose in an adult population (Khalid et al., 2017), a priori-power analysis with GPower (3.1) was conducted based on positive affect scores, showing a total sample of 30 participants per sample (mothers and fathers) was needed to achieve a power of 0.95 and alpha level of 0.05.

#### *6.2.2.1. Mothers sample*

One hundred and five responses from online advertisements were received via mum and baby pages on social media and in-person mum and baby groups in Berkshire between April-December 2024. Of these, 77 were excluded due to being computerised bot responses, did not wish to participate or lost following screening (Figure 23).

The sample was predominantly white, middle-class, and of moderate to high socioeconomic status. Of the 28, 86% were White or Caucasian, 10% Asian or Asian British, 4% reporting Black/African/Caribbean/Black British, with 82% reporting to be married or in a domestic partnership, (18% single). Nearly half of mothers had a bachelor's degree as their highest level of education (44%), with 17% holding a Master's degree and 39% reporting other. Considering employment status, 51% worked full time, with 68% having a household income over £51,000. For 55% women, this was their first child. In those who reported other children, the age of children ranged from 2-9 years. Some women (41%) reported a physical health diagnosis, with the most common being Asthma. For psychological health, 22% participants reported a psychological diagnosis, such as depression, anxiety, post-traumatic stress disorder and obsessive compulsive disorder.

Infant age ranged between 0-6 months, with an average of 3 months old, and an average gestational age of 39 weeks ± 1.36 . Majority of participants reported a vaginal delivery (55%), followed by Caesarean section (24%) and assisted vaginal delivery (vacuum or forceps) (21%). Several participants reported birth complications (41%), reporting emergency caesarean sections (*n=2*) and postpartum haemorrhage's (*n=2*). Visual analogue scales (1-10) were given to participants to report their birth experience, on average, participants reported a more positive than neutral birth experience of 6.00 (SD=2.48). Most participants reported they breastfed (89%), and finally, 27% reported not having adequate childcare support.

*6.2.2.2. Fathers sample*

Forty-six responses from online advertisements were received from social media, in-person father and baby groups and partners of mothers enrolled in the trial, between April-December 2024. Of these, 36 were excluded due to being either computerised bot responses, did not wish to participate or were lost following screening. Nine of these participants were in a couple with participants in the mothers sample (Figure 23).

Of the sample of 10, 75% were White or Caucasian, 16% Asian or Asian British, 8% reporting mixed race, with 90% reporting to be married or in a domestic partnership (10% single). Half the fathers had a bachelor's degree as their highest level of education (58%), with 25% holding a Master's degree and 8.3% reporting other. Considering employment status, 83.3% worked full time, with 83.3% having a household income over £51,000. For 66.6% men, this was their first child. In those who reported other children, the age of children ranged from 2-9 years. Some, (27%) reported a physical health diagnosis, with the most common being Asthma. For psychological health, 2 participants reported a psychological diagnosis, of which, one man reported obsessive compulsive disorder, and the other reported autism.

Infant age ranged between 0-6 months, with an average of 3 months old, with an average gestational age of 39 weeks ± 1.35. Majority of participants reported their partners had a vaginal delivery (72%), followed by Caesarean section (14%) and assisted vaginal delivery (vacuum or forceps) (14%). One participant reported birth complications, reporting their partner had a c-section. Visual analogue scales (1-10) were given to participants to report their own personal birth experience (as opposed to their perception of the mothers experience). On average, participants reported a more positive than neutral birth experience of 6.42 (SD=2.61). Finally, 54% reported not having adequate childcare support.

6.2.3. Intervention

Participants consumed a drink prepared by mixing 46g freeze-dried wild lowbush blueberries (*Vaccinium angustifolium*) with 250ml water or a blueberry-flavoured placebo drink matched for carbohydrates and fibre (see Nieman et al. (2020) for detailed chemical composition of the placebo powder). The dose of 46g is equivalent to 240g of fresh blueberries, aligning with previous literature from the Nutrition Cognition lab (Barfoot et al., 2021; Barfoot et al., 2019; Fisk et al., 2020; Whyte & Williams, 2012). The blueberry powder contained 253 mg anthocyanins (mostly delphinidin), 114.28 mg chlorogenic acid, and 17.88 mg flavonols (mostly quercetin) per 46g dry weight serving, as quantified by liquid chromatography–mass spectrometry. All drinks were administered in opaque shaker bottles and straw to ensure that double blinding was maintained. All interventions were prepared on site, for participants who were tested in their homes, the intervention was kept in a freezer bag with ice packs until consumption, all interventions were consumed within 1 hour from preparation for both home and lab visits.

6.2.4. Measures

*6.2.4.1. Demographics*

At screening, demographic data was collected on participant age, ethnicity, highest level of education and marital status. Specific diet was indicated by asking participants to note any dietary choices or restrictions e.g., Gluten free or Vegetarian. Participants were also asked if they had a psychological or physical health diagnosis by selecting 'yes', 'no' or 'prefer not to say', and if they were taking medication for such reasons. Additionally, participants were asked if they had any other children by indicating 'yes', 'no' or 'prefer not to say', and if so, to provide the number of children and their ages. Additional demographic data was also collected on how old their baby was at the time of data collection, sex of baby indicated as 'Female', 'Male', 'Other', and 'Prefer not to say', infants gestational age at birth, mode of delivery where participants selected an option from multiple choice answers of either 'Vaginal delivery', 'assisted vaginal delivery (vacuum or forceps)', 'Cesarean section', 'Prefer not to say', 'Other', if participants selected 'other' they were provided with a box to specify their mode of delivery. Birth complications entered as 'yes', 'no', 'prefer not to say' where participants that selected 'yes' were asked if they wished to provide

further detail, feelings toward their recent birth experience (entered as a visual scale from 1-10), with the option to provide additional comments regarding recent birth experience, current feeding status and a question asking if the participant breastfed their baby were included with the option to describe any complications with breastfeeding finishing with a question asking whether they had any access to nearby childcare support with 'Yes', 'No', and 'Prefer not to say' options.

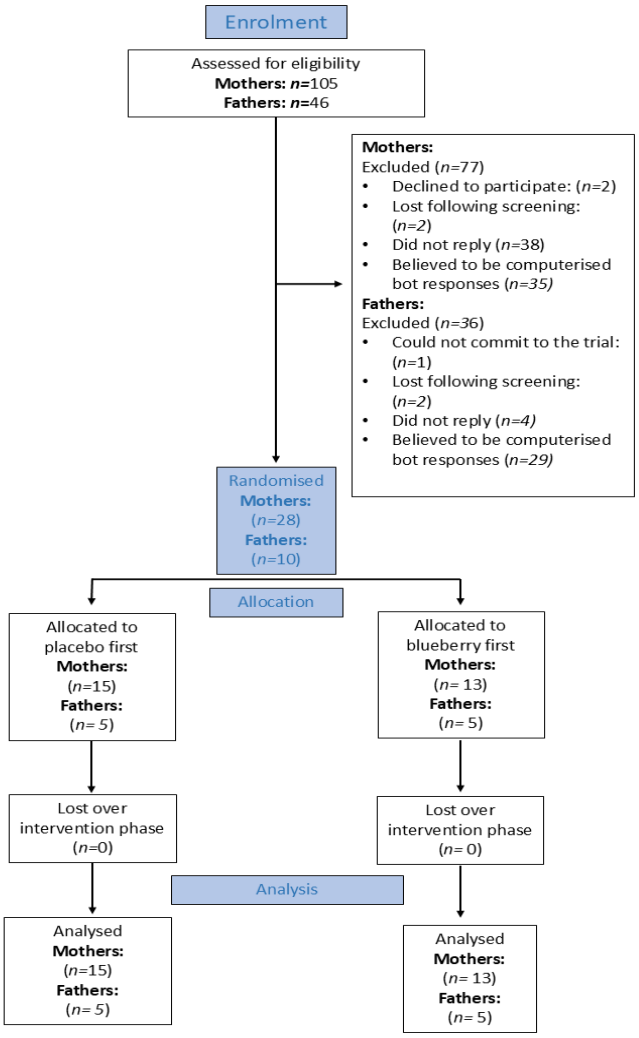


*Figure 23. Experiment 3 consort diagram of participant recruitment*

*6.2.5.2. Repeated outcome measures*

The EPDS, STAI, PANAS, PSAS, PRMQ, PSQI, Blood pressure, RAVLT, MANT, Visuospatial n-back and EPIC FFQ was utilised in this study, please refer to 4.2.6.2, 4.2.6.3, 4.2.6.4, 4.2.6.7, 5.2.5.3, 5.2.5.5, 5.2.5.6, 5.2.5.7, 5.2.5.8, 5.2.5.9 and 5.2.5.10 for commentary on the validity and reliability of these measures.

*6.2.5.3. Immediate Mood Scaler (IMS)*

This questionnaire contains 22 items developed to assess dynamic components of mood. Participants were asked to rate their current mood state on a continuum using 7-point Likert scales (e.g., happy-sad,

distracted-focused, sleepy-alert). For each item, an integer score between 1 and 7 is derived. Scores are then summed and inversed, where higher scores reflect more negative mood states.

*6.2.5.4. Bond-Lader Visual Analogue Scale (BL-VAS)*
These consist of 16 dimensions of mood: Slow-Quick Witted, Tense-Relaxed, Attentive-Dreamy, Incompetent-Proficient, Happy-Sad, Antagonistic-Friendly, Interested-Bored, Withdrawn-Social. The participant was required to mark, on a line to what extent the described state is appropriate to them at that moment in time. The individual responses from the 16 mood scales were combined to make three affective dimensions of alertness, contentment, and calmness. Items were reverse scored where relevant and then all items for each factor were summed and divided by the number of relevant factors, giving scores for alertness, calmness and contentedness, higher scores represent greater alertness, calmness, and contentedness.

*6.2.6.5 State-trait anxiety inventory (STAI-T)*
This questionnaire is a measure of state and trait anxiety containing 40 items in total (20 for trait; 20 for state). Participants were asked to agree or disagree with anxiety-related statements on a scale of 1-4. The trait measure (STAI-T) measure was taken at the screening timepoint and assessed paternal anxiety, as the PSAS had not yet been validated for use in fathers at the time of data collection. This approach ensures reliable assessment of baseline anxiety levels for fathers.

*6.2.5.6 Perceived Stress Scale (PSS)*
The PSS is a 10-item questionnaire designed to measure stress in the last month. Participants were asked to rate their feelings on a continuum using 5-point Likert scales from 0 (never) to 4 (very often). The total score for this questionnaire is 40 and is validated for use in the postpartum for both mothers and fathers and was used at baseline timepoints only. Higher scores on this measure indicate higher levels of stress.

*6.2.5.7. Infant temperament- Mother and Baby Scales- Overall impressions subscale*
This questionnaire explores early infant temperament and asks parents to rate their infants temperament in the last 7 days (Wolke & James-Roberts, 1987). For the purpose of this study, only the 'Overall impressions and experiences subscale' was used which explores 'Easiness of baby' and 'Global confidence'. This particular subscale consists of seven questions which were rated on seven-point scales from '-3' to '+3', with -3 signifying 'very difficult' behaviours and +3 'very easy' ones (e.g. -3 = 'very irritable'/ +3 = 'very calm'). The total score was taken, with lower scores representing a more irritable infant. The Overall impressions and experiences subscale was used at screening; however at each baseline visit, only the first question "How irritable is your baby" was administered to capture the infants temperament specifically on the day of testing.

*6.2.5.8. Drink rating*
Participants were asked to rate eight palatability-related questions immediately following consumption of both the WBB and placebo drinks. Each question was rated on a Likert scale from 0 (not at all) to 9 (extremely). Items included: 'How sweet did you find the drink?', 'How bland did you find the drink?', 'How tasty did you find the drink?', 'How pleasant did you find the drink?', 'How sour did you find the drink?', 'How satisfying did you find the drink?', 'How much more of this drink do you think you could consume?', and 'How easy did you find it to consume the drink? Higher scores indicated stronger agreement with each statement (Table 18).

6.2.6 Procedure
Participants emailed the researcher expressing their interest in taking part. Eligible participants were invited to a study investigating the effects of a fruit drink on mood and cognition in order to not let the participant know about the true aims of the study.

Recruitment for fathers was again less successful compared with recruitment for mothers, somewhat mirroring Experiment 1. One key incentive was for the trial to take place wherever the participant wished, either in their homes or at the University Nutrition Cognition lab space, to encourage flexible participation, yet to control for extraneous measures, such as noise. Therefore, the study took place in person, in participant homes or the University of Reading Nutrition-Cognition lab over three Visits; a screening, and two test days. For the fathers, an equal number of Visits took place at the lab and home (5:5 respectively) for mothers this was more biased towards home Visits but still well distributed (12:16 respectively). The locations were kept consistent within participant for all Visits.

Interested participants were invited to an in-person screening session where the study was explained by the researcher and the participant received the information sheet, eligible participants then completed the consent form. Screening demographics were completed via REDCap, following a practice of the cognitive tests. On the test days, the participant arrived at the lab or the researcher visited their homes between 8-10am, in order to ensure consistency in testing windows across participants, and also to accommodate parents routines with young infants and work schedules. Height and weight were taken if the participant visited the lab or if in their homes, the researcher asked the participant what their last known height and weight was, to determine BMI. The participant completed baseline measures (PSS-10, PSQI, MABS, IMS, STAI-S, PANAS, BL-VAS) via REDCap then completed the cognitive tests on the Gorilla platform, via the researcher's laptop. This was followed by measures of the participants blood pressure and consumption of the intervention alongside the drink rating scale. Participants then had a 2-hr break during which they were instructed to only consume water, to prevent any potential effects from other foods or drinks. Upon return, this was confirmed verbally by the participant. Those who visited the lab stayed in the waiting room, while home participants reported resting until the follow-up timepoint. Once returned, participants completed the mood outcomes (IMS, STAI-S, PANAS, BL-VAS), cognitive tests and blood pressure measurements, each session took between 45-60 minutes. Participants returned after a washout period (mean washout period 7-days) and completed the same procedure, consuming the alternate intervention. Participants were then debriefed and all participants were provided with helplines and weblinks to specific parental mental health support and to contact their GP should they wish to seek further support. All participants were reimbursed with a £30 Amazon voucher. Data was collected between April 2024 and January 2025 and the study was given a favourable ethical opinion for conduct by the University of Reading School of Psychology and Clinical Language Sciences Ethics Committee (2023-234-DL) and is registered at ClinicalTrials.gov (NCT06402916).

### 6.2.7. Data analysis

Quantitative data was analysed using R (version 4.1.0) and various statistical packages such as 'lme4' for running linear mixed models and 'ggplot' for visualisation. Regression analysis was conducted on demographic variables to investigate whether variables such as household income were significant predictors to the primary outcome variables and therefore to be utilised as covariates in the models. Independent groups t-tests and Chi-squared tests were performed to assess any differences between mothers and fathers in baseline demographic variables, such as age, dietary preferences (e.g., vegetarian or vegan), presence of diagnosed psychological or physical health conditions, whether the participants had other children, sex of infant, delivery method, and infants gestational age at birth. For the measures IMS, STAI-S, PANAS-NOW (Positive affect; Negative affect), Bond-Lader Alert, Bond-Lader Calm, Bond-Lader Contentedness, MANT (RT and accuracy), N-BACK (RT and accuracy), AVLT (word span (recall A1); words learned (recall A5–A1); final acquisition (recall A5); total acquisition (sum A1 through A5); proactive interference (recall A1–B); retroactive interference (recall A5–A6); delayed recall (A6); word recognition and source monitoring (accuracy and RT)) data were analysed using separate linear mixed models, where Condition (WBB, placebo), Time (baseline-2hours) and Drink order (Placebo-WBB; WBB-Placebo) were fixed effects, with covariates (baseline sleep (PSQI scores), age, habitual flavonoid intake (taken at screening) birth experience, baseline stress (PSS-10), baseline infant

temperament (MABS) and study location (Home or Lab) included. These covariates were selected due to their known association with mood and their potential impact on the results, as reported in previous chapters. Furthermore, sleep, stress and infant temperament were recorded at baseline, due to their known effects on mood and cognitive function. Study location was included as a covariate in the primary outcome measures (PA and NA) to explore whether this significantly affected outcomes. Meaningful effects are reported in the results section, whilst additional effects are reported in the Appendices and Tables 15-16.

One-sample t-tests were also conducted to compare mean nutrient intake at baseline with the recommended dietary allowance (RDA) for postpartum parents (USDA., 2020), to evaluate general diet quality in the sample and assess whether either sample met the RDAs at baseline. Additionally, Pearson correlations were performed to explore the relationship between baseline nutrient intake and mood outcomes. In the initial analysis, mothers and fathers were included in one model to get a better understanding of the overall impact of acute WBB on mood and cognition in new parents. Subsequently, a separate LMM was also conducted for each sample. During data analysis, data was screened for outliers, and values falling outside interquartile ranges were removed. However, outliers were not removed for the mood outcomes, as their presence did not notably influence the overall analysis or the robustness of the model, which also aided in the preservation of natural variation in mood data.

As conducted in Chapter 4.2.9 and 5.2.7, a qualitative content analysis was conducted for the demographic questions related to participants' birth experiences. This analysis involved extracting key quotations from participants' responses, which were then grouped into themes. For the question, “Did you have any birth complications?”, 12 participants (combined mothers and fathers sample) responded, with 11 providing further details on their experiences. The responses were categorised and expressed as percentages to give a clearer understanding of the proportion of participants who faced each complication. Additionally, participants recorded their birth experience on a Likert scale from 1-10, with an option to provide additional elaboration. Of the 20 participants who offered further comments, their responses were grouped into three broad themes: positive, negative, and neutral/mixed experiences. These themes were quantified, with 9 (45%) participants reporting positive experiences, 5 (25%) reporting negative experiences, and 6 (30%) reporting neutral or mixed feelings. By categorising and quantifying these responses, the analysis provided valuable insight into the overall wellbeing of the sample and potential risk factors related to birth and breastfeeding.

6.3. Results

6.3.1. Demographics

*Table 14. Demographic data for both mothers and fathers, collected at screening, with between-groups p-values representing comparisons between mother and father samples.*

| Measures | Mothers (*n*=28) | Fathers (*n*=10) |
|---|---|---|
| Age of parent (M(SD)years) | 32.17 (4.83) | 35.80 (6.54) |
| Age of infant (M(SD)months) | 3.67 (1.86) | 3.00 (2.71) |
| Ethnicity[1] | 24:3:1:0:0 | 7:2:0:0:1 |
| Education[2] | 8:13:4:2:0:0:0:1 | 1:6:2:0:0:0:0:1 |
| Employment[3] | 15:7:2:1:0:0:3 | 9:0:1:0:0:0:0 |
| Household income[4] | 1:0:3:1:2:20:1 | 0:1:0:0:1:8:0 |
| Marital status[5] | 5:22:0:0:0:0:1 | 1:8:0:0:0:0:1 |
| Other children[6] | 13:15 | 4:6 |
| Sex of infant[7] | 15:13 | 1:9 |
| Mode of delivery[8] | 15:6:7 | 7:1:2 |
| Birth complications[9] | 12:15:0 | 1:7:2 |
| Childcare support[10] | 21:7 | 6:4 |
| EPDS (Mean (SE))[11] | 8.78 (4.66) | 7.9 (4.69) |
| TAI (Mean (SE))[12] | N/A | 35.00 (8.17) |
| PSAS (Mean (SE))[13] | 101.53 (20.30) | N/A |
| PRMQ (Mean (SE))[14] | 51.64 (10.79) | 60.60 (7.63) |
| BMI (Mean (SE))[15] | 28.84 (7.03) | 27.81 (2.74) |
| MABS (Mean(SE))[16] | 7.67 (4.68) | 6.90 (4.71) |

[1] Participants ethnicity (White or Caucasian; Asian or Asian British; Black/African/Caribbean/Black British: Latino or Hispanic: Mixed: Other): [2] Participants education (High school/college: Bachelor's degree: Master's degree: PhD or higher: Trade school: Still in education: Prefer not to say: Other): [3] Participant employment status (Employed full-time (40+ hours a week): Employed part-time (less than 40 hours a week): Self-employed: Unemployed: Student: Retired: Other): [4]Participant household income (£0 - £10,000: £11,000 - £20,000: £21,000 - £30,000: £31,000 - £40,000: £41,000 - £50,000: £51,000 +: Prefer not to say): [5] Participant marital status (Single: Married (or domestic partnership): Widowed: Divorced: Separated: Prefer not to say: Other): [6] Whether the participant has other children (Yes: No); [7] Sex of infant (Female: Male: Other): [8] Mode of delivery (Vaginal delivery: Assisted vaginal delivery (vacuum or forceps): Caesarean section: Prefer not to say: Other): [9] Birth complications (Yes: No: Prefer not to say): [10] Nearby childcare support (Yes: No).

Table 15. Mean (SE) outcome variable data and interaction effects in combined data for WBB and placebo conditions at baseline and post intervention

| Outcomes | Combined data (*n*= 38) | | | | | |
|---|---|---|---|---|---|---|
| | Baseline | | Between groups | Post | | Interaction *p* |
| | WBB | Placebo | *p*- value | WBB | Placebo | value |
| | M (SE) | M (SE) | | M (SE) | M (SE) | |
| PSS-10 | 19.52 (3.21) | 19.65 (3.26) | .860 | N/A | N/A | N/A |
| MABS (acute) | 0.73 (1.78) | 1.21 (1.49) | .217 | N/A | N/A | N/A |
| PSQI | 4.23 (1.97) | 4.23 (2.18) | .860 | N/A | N/A | N/A |
| Positive affect | 31.55 (1.22) | 30.68 (1.22) | .753 | 31.79 (1.22) | 32.26 (1.22) | .420 |
| Negative affect | 16.74 (0.81) | 16.75 (0.81) | .904 | 15.47 (0.81) | 16.74 (0.81) | .992 |
| Immediate Mood Scaler | 74.61 (2.89) | 73.99 (2.89) | .845 | 64.82 (2.89) | 64.49 (2.90) | .933 |
| State anxiety | 39.83 (1.50) | 38.52 (1.50) | .953 | 35.87 (1.51) | 36.19 (1.50) | .538 |
| Bond-Lader Alertness | 42.61 (2.29) | 41.89 (2.29) | .813 | 37.44 (2.29) | 38.68 (2.29) | .466 |
| Bond-Lader Calmness | 43.15 (2.69) | 41.94 (2.69) | .662 | 40.41 (2.69) | 38.11 (2.70) | .798 |
| Bond-Lader Contentedness | 35.57 (2.34) | 36.10 (2.33) | .894 | 32.17 (2.33) | 32.35 (2.34) | .899 |
| Systolic BP | 109.14 (2.02) | 107.16 (2.02) | .430 | 107.94 (2.02) | 108.69 (2.03) | .195 |
| Diastolic BP | 73.98 (1.58) | 74.91 (1.58) | .422 | 74.91 (1.60) | 74.62 (1.59) | .389 |
| RAVLT Wordspan | 6.15 (0.29) | 6.22 (0.29) | .844 | 5.67 (0.29) | 5.90 (0.29) | .728 |
| RAVLT Final Acquisition | 12.80 (0.36) | 12.11 (0.36) | .446 | 12.02 (0.36) | 11.73 (0.37) | .239 |
| RAVLT Total Acquisition | 49.34 (1.59) | 48.31 (1.59) | .688 | 46.86 (1.59) | 47.40 (1.60) | .345 |
| RAVLT Words Learned | 5.65 (0.30) | 6.08 (0.32) | .140 | 6.72 (0.31) | 5.81 (0.31) | .030* |
| RAVLT Proactive Interference | 0.82 (0.39) | -0.13 (0.41) | .046* | -0.22 (0.40) | 0.26 (0.40) | .072 |

| | | | | | | |
|---|---|---|---|---|---|---|
| RAVLT Retroactive Interference | 2.50 (0.33) | 2.34 (0.35) | .761 | 2.40 (0.37) | 2.52 (0.36) | .637 |
| RAVLT Delayed Recall | 8.89 (0.50) | 8.89 (0.50) | .428 | 8.64 (0.50) | 8.37 (0.51) | .358 |
| RAVLT Word Recognition | 21.63 (0.67) | 22.04 (0.66) | .330 | 21.34 (0.65) | 21.18 (0.65) | .586 |
| RAVLT Source monitoring accuracy | 89.94 (1.92) | 90.18 (1.89) | .903 | 84.70 (1.85) | 84.60 (1.84) | .908 |
| RAVLT source monitoring RT | 1833.97 (78.49) | 1857.31 (76.28) | .941 | 1930.92 (76.68) | 1857.31 (76.28) | .140 |
| N-BACK overall accuracy | 10.65 (0.27) | 10.90 (0.28) | .630 | 11.14 (0.28) | 10.85 (0.27) | .229 |
| N-BACK overall RT | 506.86 (8.99) | 529.01 (8.89) | .127 | 513.93 (8.80) | 522.02 (8.90) | .277 |
| MANT accuracy | 12.70 (0.54) | 11.47 (0.55) | .137 | 12.51 (0.63) | 13.09 (0.65) | .966 |
| MANT RT | 498.38 (15.19) | 499.05 (15.16) | .832 | 494.79 (15.02) | 489.23 (15.06) | .945 |

*Table 16. Mean (SE) outcome variable data and interaction effects in mothers and fathers-only data for WBB and placebo conditions at baseline and post intervention*

| Outcomes | Mothers data ($n$= 38) | | | | | | Fathers data ($n$= 10) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Baseline | | Between groups $p$ value | Post | | Interaction $p$ value | Baseline | | Between groups $p$ value | Post | | Interaction $p$ value |
| | WBB M(SE) | Placebo M(SE) | | WBB M(SE) | Placebo M(SE) | | WBB M(SE) | Placebo M(SE) | | WBB M(SE) | Placebo M(SE) | |
| PSS-10 | 20.07 (0.64) | 19.79 (0.65) | .755 | N/A | N/A | N/A | 18.00 (0.75) | 19.30 (0.92) | .287 | N/A | N/A | N/A |
| MABS (acute) | 0.68 (0.35) | 1.39 (0.28) | .116 | N/A | N/A | N/A | 0.90 (0.57) | 0.70 (0.47) | .790 | N/A | N/A | N/A |
| PSQI | 4.75 (0.35) | 4.64 (0.40) | .841 | N/A | N/A | N/A | 2.80 (0.53) | 3.10 (0.67) | .731 | N/A | N/A | N/A |
| Positive affect | 30.43 (1.44) | 29.74 (1.46) | .855 | 31.52 (1.44) | 30.83(1.46) | .997 | 34.90 (2.81) | 33.46 (2.79) | .260 | 32.53 (2.81) | 36.19 (2.80) | .031* |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Negative affect | 17.22 (1.00) | 17.63 (1.01) | .777 | 15.31 (1.00) | 16.21 (1.01) | .729 | 15.34 (1.42) | 15.40 (1.41) | .762 | 16.00 (1.42) | 15.85 (1.41) | .553 |
| Immediate Mood Scaler | 66.42 (3.58) | 77.28 (3.57) | .925 | 75.30 (3.54) | 64.64 (3.54) | .964 | 67.69 (6.52) | 71.90 (6.55) | .807 | 65.09 (6.54) | 62.49 (6.52) | .656 |
| State anxiety | 37.69 (1.16) | 36.79 (1.20) | .967 | 41.88 (1.17) | 40.38 (1.16) | .773 | 35.86 (3.47) | 34.28 (3.45) | .850 | 33.16 (3.46) | 33.88 (3.45) | .141 |
| Bond-Lader Alert | 42.36 (2.75) | 42.64 (2.77) | .854 | 36.43 (2.75) | 39.15 (2.78) | .474 | 41.64 (9.77) | 40.78 (9.74) | .878 | 39.45 (9.76) | 39.36 (9.75) | .804 |
| Bond-Lader Calmness | 41.01 (3.05) | 43.14 (3.05) | .996 | 36.58 (3.05) | 37.15 (3.06) | .721 | 47.86 (6.77) | 44.88 (6.72) | .329 | 48.66 (6.77) | 46.03 (6.72) | .969 |
| Bond-Lader Contentedness | 35.26 (2.62) | 38.76 (2.64) | .685 | 30.79 (2.62) | 33.58 (2.65) | .833 | 35.17 (6.42) | 31.81 (6.38) | .672 | 35.39 (6.40) | 32.81 (6.39) | .841 |
| Systolic BP | 106.09 (2.30) | 104.70 (2.32) | .562 | 104.60 (2.31) | 106.09 (2.34) | .247 | 118.64 (2.43) | 116.24 (2.43) | .440 | 117.48 (2.43) | 117.65 (2.43) | .583 |
| Diastolic BP | 74.21 (1.81) | 74.62 (1.82) | .984 | 75.00 (1.81) | 74.61 (1.83) | .689 | 75.57 (1.75) | 80.47 (1.75) | .131 | 73.71 (1.74) | 75.57 (1.75) | .097 |
| RAVLT Wordspan | 6.25 (0.34) | 6.05 (0.33) | .939 | 5.84 (0.34) | 5.86 (0.34) | .730 | 6.32 (0.65) | 6.24 (0.64) | .806 | 5.24 (0.65) | 6.16 (0.64) | .276 |
| RAVLT Final Acquisition | 11.97 (0.43) | 12.15 (0.43) | .568 | 11.91 (0.43) | 12.00 (0.43) | .881 | 11.5 (0.80) | 11.8 (0.78) | .614 | 12.5 (0.80) | 10.8 (0.79) | .024* |
| RAVLT Total Acquisition | 49.81 (1.92) | 48.40 (1.93) | .676 | 47.39 (1.92) | 47.65 (1.95) | .417 | 48.08 (3.65) | 47.23 (3.62) | .946 | 45.82 (3.63) | 45.82 (3.63) | .710 |
| RAVLT Words Learned | 5.92 (0.36) | 6.11 (0.37) | .452 | 6.64 (0.38) | 6.00 (0.37) | .253 | 5.07 (0.56) | 5.69 (0.63) | .128 | 7.08 (0.56) | 4.92 (0.57) | .008* |
| RAVLT Proactive Interference | 0.82 (0.39) | -0.13 (0.40) | .140 | -0.22 (0.40) | 0.26 (0.40) | .476 | 1.33 (0.85) | -0.67 (0.90) | .194 | -039 (0.77) | 1.64 (0.84) | .022* |
| RAVLT Retroactive Interference | 2.58 (0.40) | 2.57 (0.44) | .952 | 2.01 (0.44) | 2.56 (0.45) | .437 | 2.36 (0.70) | 1.69 (0.66) | .392 | 3.36 (0.79) | 2.16 (0.67) | .610 |
| RAVLT Delayed Recall | 9.31 (0.56) | 9.15 (0.57) | .868 | 9.29 (0.57) | 8.87 (0.57) | .723 | 7.99 (0.77) | 9.51 (0.81) | .155 | 7.32 (0.77) | 7.04 (0.84) | .222 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RAVLT Word Recognition | 21.94 (0.81) | 22.75 (0.79) | .204 | 21.90 (0.78) | 21.90 (0.77) | .546 | 20.80 (1.37) | 20.03 (1.36) | .634 | 20.11 (1.37) | 19.42 (1.40) | .969 |
| RAVLT Source monitoring accuracy | 90.91 (2.15) | 90.75 (2.11) | .793 | 85.75 (2.05) | 85.25 (2.05) | .920 | 87.38 (3.95) | 86.47 (3.88) | .556 | 82.28 (3.68) | 82.84 (3.78) | .831 |
| RAVLT source monitoring RT | 1777.60 (98.27) | 1888.96 (100.48) | .974 | 1871.39 (96.83) | 1824.06 (95.10) | .290 | 2051.67 (126.91) | 2125.54 (123.33) | .616 | 2120.11 (111.00) | 1935.25 (125.86) | .279 |
| N-BACK overall accuracy | 10.42 (0.32) | 10.97 (0.32) | .331 | 11.11 (0.32) | 10.95 (0.32) | .153 | 11.11 (0.49) | 10.62 (0.49) | .514 | 11.10 (0.49) | 10.62 (0.49) | .999 |
| N-BACK overall RT | 504.74 (11.49) | 520.13 (11.47) | .391 | 514.92 (11.24) | 514.04 (11.46) | .260 | 521.03 (13.63) | 544.08 (14.84) | .135 | 517.31 (13.61) | 540.37 (13.63) | .999 |
| MANT accuracy | 11.77 (0.48) | 11.76 (0.48) | .871 | 12.47 (0.48) | 11.88 (0.49) | .347 | 12.59 (0.49) | 12.19 (0.50) | .420 | 12.53 (0.49) | 12.58 (0.52) | .195 |
| MANT RT | 492 (17.6) | 500 (17.8) | .884 | 490 (17.6) | 485 (17.8) | .658 | 514.01 (33.33) | 499.65 (33.06) | .698 | 512.73 (33.27) | 508.68 (33.15) | .715 |

6.3.2. Positive Affect

In the combined analysis, there were no significant main effects or interactions (Appendix C). Baseline flavonoid intake remained a significant covariate in the model, where higher baseline flavonoid intake was associated with higher PA ($F_{(1, 31)} = 6.65$, $p = .015$). However, when flavonoid intake was entered as a factor in further analysis, no overall changes to the model were observed ($p > .05$). Further, no significant main effects or interactions were observed for mothers data (Appendix D).

A significant Condition*Time interaction was observed for fathers' positive affect scores ($F_{(1, 18)} = 5.38$, $p = .032$), suggesting differential changes across groups. However, Bonferroni-adjusted pairwise comparisons were non-significant, indicating no clear group differences at specific timepoints. No other significant effects were found (Appendix E, Figure 24).

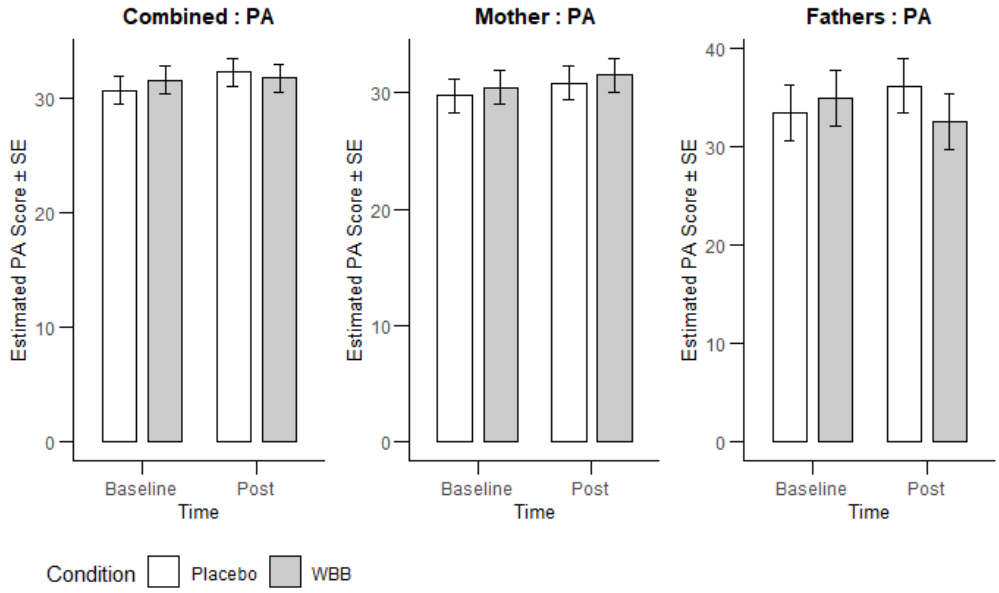


*Figure 24. Positive affect scores (PA) broken down by intervention group with LMM's showed a Condition * Time interaction for the fathers sample ($F_{(1, 18)} = 5.38$, $p = .032$), though Bonferroni corrected pairwise comparisons did not show any significant differences between any condition at any timepoint. No significant changes were seen for combined or mothers data (p>.05). Models were controlled for sleep (PSQI), maternal age, habitual flavonoid intake, birth experience, infant temperament, location and stress (PSS-10) as covariates.*

6.3.3. Negative Affect

In the combined analysis, there were no differences at baseline (Table 15), furthermore, no significant Condition*Time interaction or main effect of Condition. However, there was a significant main effect of Time (Appendix C) where negative affect lessened after 2 hours, regardless of intervention, suggesting some improvement to mood in both samples over the 2- hours. Stress (PSS-10) was a significant covariate ($F_{(1,114)} = 18.51$, $p < .001$) where higher stress lead to higher NA scores, though entering it as a factor did not meaningfully change the overall model ($p > .05$). This effect was likely driven by mothers as the same pattern emerged in the mothers data, showing a significant main effect of Time and stress as a covariate (Appendix D) in the same pattern as the combined analysis. However, for the fathers sample, there were no significant main effects or interactions (Appendix E, Figure 25).

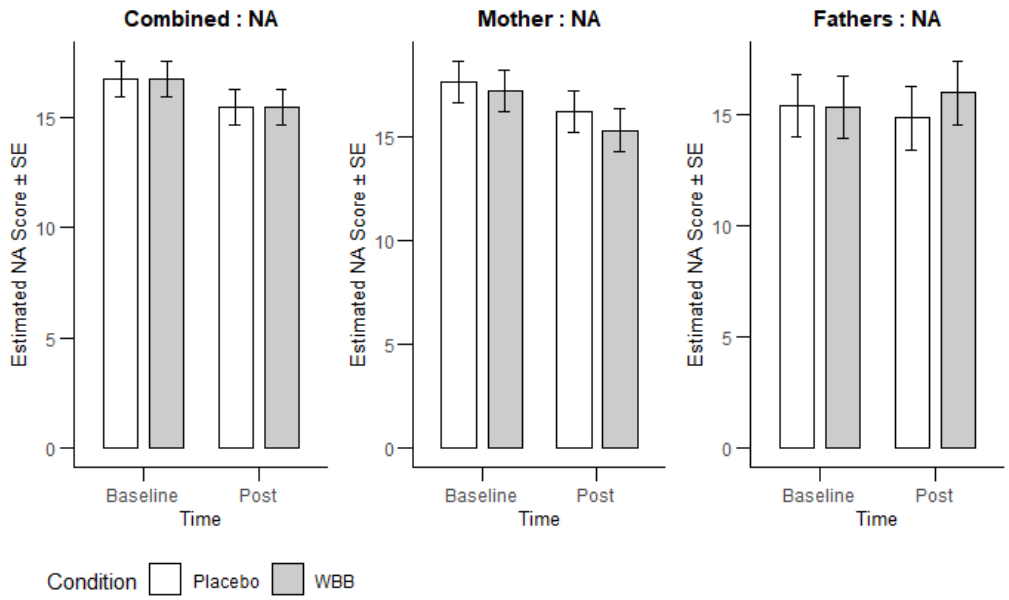


*Figure 25. Negative affect (NA) scores broken down by intervention group with LMMs showed no significant change in mean (±SEM) negative affect over time for the fathers sample and combined data (p>.05). However, a Time effect was seen for the combined ($F_{(1,106)}$ = 4.41, p = .037) and mothers sample ($F_{[1,80]}$= 4.21, p=.043), with lower mean scores at follow-up compared to baseline. Models were controlled for sleep (PSQI), maternal age, habitual flavonoid intake, birth experience, infant temperament, location and stress (PSS-10) as covariates.*

6.3.4. IMS

For combined data, a main effect of Time was present for IMS, where lower scores were seen post intervention compared to baseline for both samples, indicating lower levels of positive mood. Though no further main effects and interactions were significant (Appendix C, Appendix L.1). Stress was a significant covariate in the model ($F_{[1, 137]}$= 14.73, $p$<.001) where higher stress indicated higher IMS scores (worse mood), and when this was entered as a factor for further analysis, the original main effect of Time was not apparent (new Time effect ($F_{[1,101]}$= 3.64, $p$=.059)), though no other main effects were seen. Infant temperament was additionally a significant covariate ($F_{[1, 134]}$= 8.72, $p$=.003) where easier temperament predicted lower IMS scores (better mood), though when accounted for in further exploratory analysis did not significantly affect overall main effects and interactions ($p$>.05). Lastly, habitual flavonoid intake was a significant covariate ($F_{[1, 30]}$= 11.81, $p$=.001), where lower intake predicted higher scores (worse mood). Further exploratory analysis, where median baseline flavonoid intake was accounted for, did not show significant changes to main effect of Time, Condition or their interaction but did highlight a Condition*flavonoid intake interaction ($F_{[1, 110]}$= 10.66, $p$=.001), though pairwise comparisons did not show further significant differences between groups at this level ($p$>.05).

For the mothers and fathers-only data, a main effect of Time was present for IMS in the same direction as the combined data, though no further main effects and interactions were significant (Appendix D, E, L.1).

6.3.5. STAI-S

Regarding the combined analysis and mothers only data, a main effect of Time was present, though no further main effects and interactions were significant. Regarding fathers data, no main effects and interactions were significant (Appendices C, D, E, L.2).

### 6.3.6. Bond-Lader scales

#### *6.3.7.1. Alert*

Regarding the combined analysis, a main effect of Time was present, though no further main effects and interactions were significant (Appendix C, Figure 40). Higher stress significantly predicted higher alertness, when this was added a factor into the model, the main effect of Time was no longer present ($F_{[1, 101]}$= 0.14, $p$=.705), indicating stress to play a significant role in outcomes above time effects. For the mothers data, a main effect of Time was present, where alertness decreased over time, though no further main effects and interactions were significant (Appendix D, Appendix L.3). In the fathers data, no significant interaction or main effects were observed (Appendix E).

#### *6.3.7.2. Calm*

For the combined analysis and fathers only, no main effects and interactions were significant. For mothers data, calmness significantly decreased over time though no further main effects and interactions were significant (Appendix D, Appendix L.3).

#### *6.3.7.3. Contentedness*

Regarding the combined analysis and mothers only, contentedness significantly decreased over time, though no further main effects and interactions were significant. Regarding fathers data, no main effects and interactions were significant (Appendices C, D, E, L.4).

### 6.3.7. RAVLT

#### *6.3.7.1. Wordspan*

Regarding the combined, mothers and fathers only analysis, no main effects and interactions were significant (Appendices C, D, E).

#### *6.3.7.2. Final Acquisition*

Regarding the combined, and mothers only analysis, no main effects and interactions were significant (Appendices C, D, E, Figure 26). In the fathers sample, a significant Condition*Time interaction was found ($F_{(1, 20)}$ = 5.89, $p$ = .024), suggesting a differential change in acquisition performance over time between groups. Here, scores showed a slight decrease for the placebo group from baseline to post-intervention, while the WBB group showed an increase from baseline to post-intervention, though pairwise comparisons did not show further significant differences. Neither the main effect of Condition, Time or any other main effect, interaction or covariate reached significance.

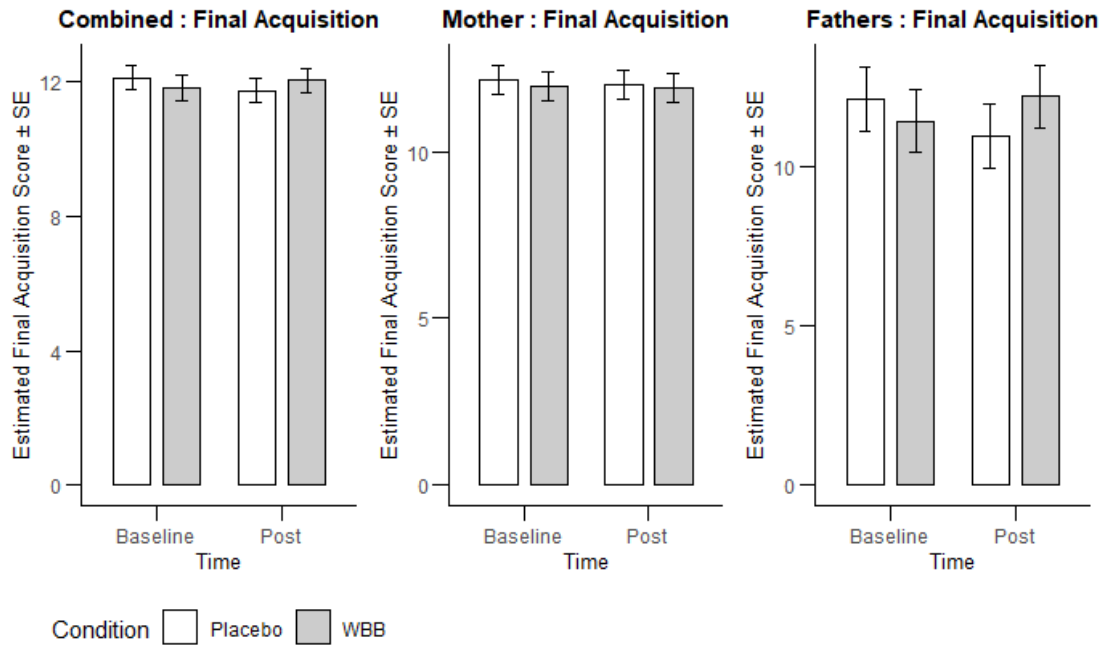


*Figure 26. Final Acquisition scores broken down by intervention group with LMMs showed no significant change in mean scores over time for mothers and combined datasets over time. However, Condition*Time effect was seen for fathers-only datasets, with higher mean scores at follow-up compared to baseline for the WBB group. Models were controlled for sleep (PSQI), maternal age, habitual flavonoid intake, birth experience, infant temperament, location and stress (PSS-10) as covariates.*

*6.3.9.3. Total Acquisition*

Regarding the combined, mothers and fathers only analysis, no main effects and interactions were significant (Appendices C, D, E).

*6.3.7.4. Words learned*

In the combined analysis, WBB was associated with an increase in the number of words learned, with just over one more word recalled post-intervention compared to baseline (see Figure 44), whereas no change was observed in the placebo group. This pattern was supported by a significant Condition*Time interaction ($F_{(1, 103)} = 4.82$, $p = .030$), however post-hoc comparisons adjusted using Bonferroni corrections did not reach significance (WBB baseline vs post, $p = .084$). There were no further significant main effects, interactions or covariates (Appendices C, D, E).

Regarding the mothers only analysis, no main effects and 2-way interactions were significant. However, a significant Time*Condition*Order interaction was observed ($F_{(1, 74)} = 6.44$, $p = .013$), pairwise comparisons did not show any significant differences between groups, however there was a trend for the WBB group where a higher amount of words were learned at 2 hours compared to baseline, only when WBB was consumed at the 2nd visit ($t_{(75)} = –3.14$, $p = .064$) (Figure 27).

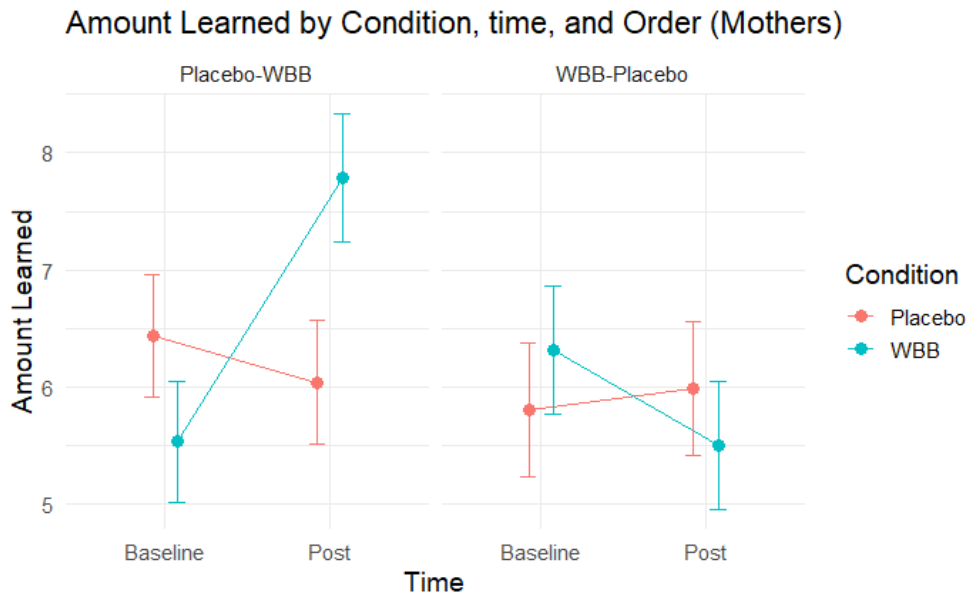


*Figure 27. Amount Learned scores broken down by intervention group and drink order with LMMs revealed a significant Condition*Time*Order interaction ($F_{(1, 74)}$ = 6.44, p = .013) for the mothers only dataset. This showed higher scores post intervention following WBB consumption compared to baseline, when the placebo drink was consumed first (# p=0.06). Models were controlled for sleep (PSQI), maternal age, habitual flavonoid intake, birth experience, infant temperament, location and stress (PSS-10) as covariates.*

For fathers, WBB was associated with an increase in the number of words learned, with fathers recalling approximately two more words post-intervention compared to baseline. In contrast, no improvement was observed in the placebo group (see Figure 28). This pattern was supported by a significant Condition*Time interaction ($F_{(1, 18)}$ = 8.62, p = .008). Pairwise comparisons confirmed that the increase in the WBB group was significant: WBB Baseline vs. WBB Post ($t_{(18)}$ = –2.01, $p$ = .028), as was the comparison between Placebo Post and WBB Post ($t_{(19)}$ = –3.14, $p$ = .031). No other comparisons and covariates reached significance.

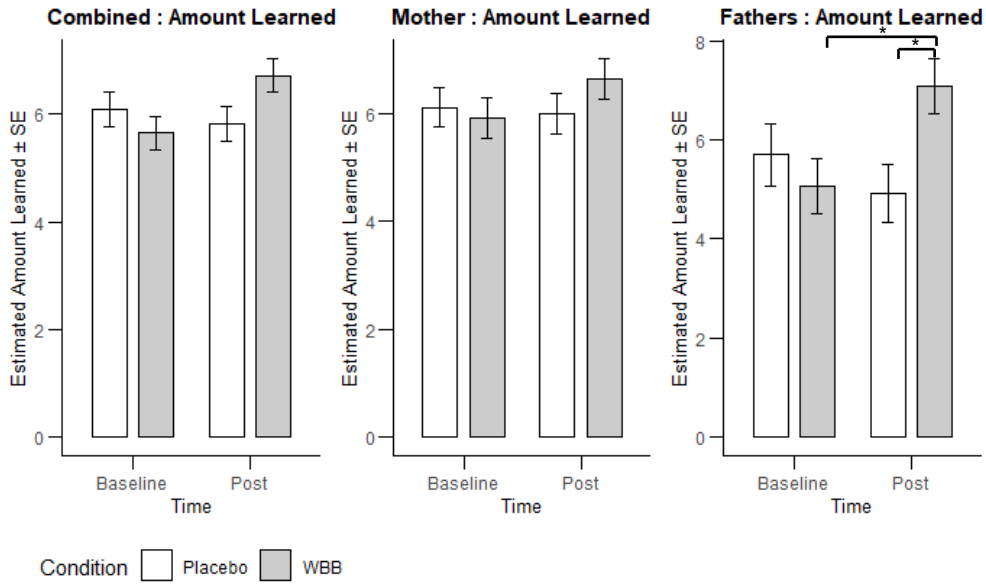


*Figure 28. Amount learned scores broken down by intervention group with LMMs revealed a significant Condition*Time interaction for combined ($F_{(1, 103)}$ = 4.82, p = .030) and fathers-only datasets ($F_{(1, 18)}$ = 8.62, p = .008), where pairwise comparisons revealed significantly higher scores*

*following WBB consumption from baseline to post, which was not emulated following placebo consumption. Models were controlled for sleep (PSQI), maternal age, habitual flavonoid intake, birth experience, infant temperament, location and stress (PSS-10) as covariates.*

*6.3.7.5. Proactive Interference*

Significant differences were observed between the placebo and WBB groups at baseline for proactive interference scores in the combined sample (Table 15), though not for mothers and fathers only data (Table 16). Regarding the combined and mothers only analysis, no main effects and interactions were significant (Appendices C, D, E, Figure 29). No main effects were present for the fathers only data, however there was a significant Condition * Time interaction ($F_{(1, 18)} = 6.18$, $p = .022$, Figure 29) indicating higher proactive interference for the placebo from baseline to post, though this was not supported by Bonferroni corrections. However, this was not replicated in the WBB group indicating a protection from interference.

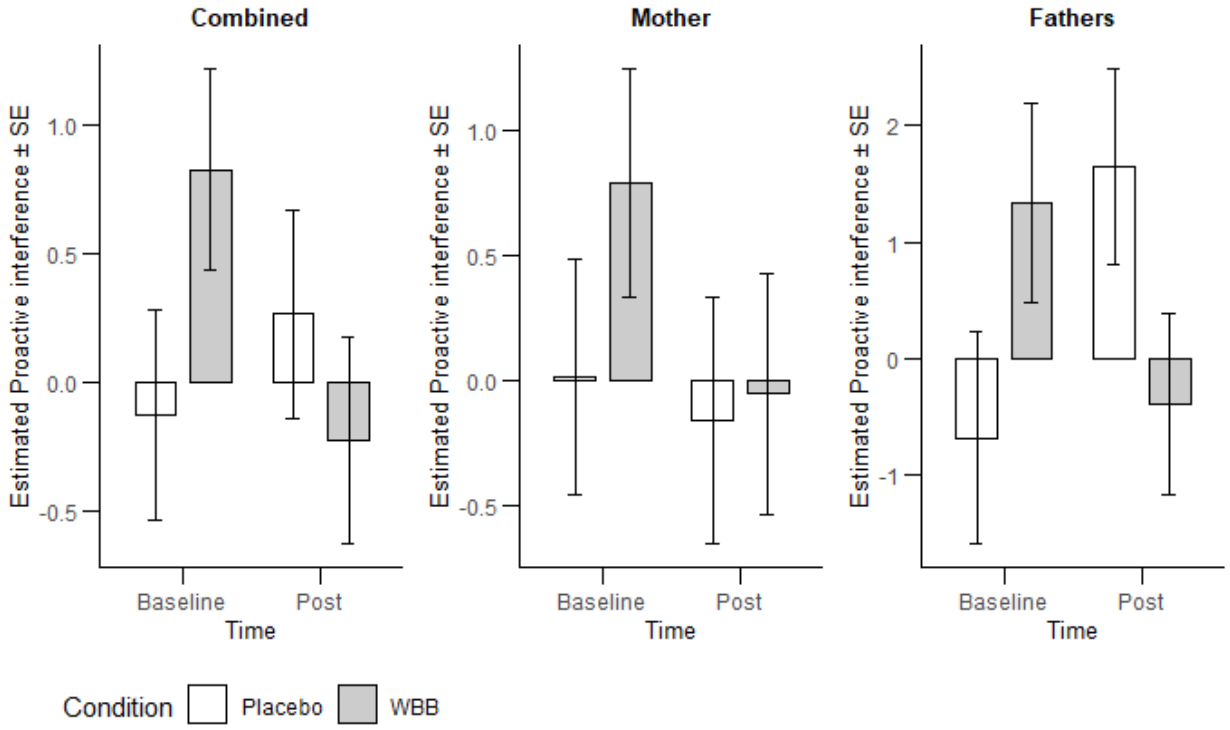


*Figure 29. Proactive Interference scores broken down by intervention group with LMMs showed a significant Condition*Time interaction for fathers-only ($F_{(1, 18)} = 6.18$, $p = .022$), though pairwise comparisons did not support further significant group specific differences. No significant changes over time were seen for mothers and combined datasets. Models were controlled for sleep (PSQI), maternal age, habitual flavonoid intake, birth experience, infant temperament, location and stress (PSS-10) as covariates*

*6.3.7.6. Retroactive Interference*

Regarding the combined, mothers and fathers only analysis, no main effects and interactions were significant (Appendices C, D, E).

*6.3.7.7. Delayed Recall*

Regarding the combined, mothers and fathers only analysis, no main effects and interactions were significant (Appendices C, D, E).

*6.3.7.8. Word recognition*

the combined, mothers and fathers only analysis, no main effects and interactions were significant (Appendices C, D, E).

*6.3.7.8. Source monitoring accuracy*

Regarding the combined and mothers only data, a significant main effect of Time emerged, however no further main effects and interactions were significant. For the fathers only analysis, no main effects or interactions were present in the data (Appendices C, D, E).

*6.3.7.9. Source monitoring reaction time*

Regarding the combined, mothers and fathers only analysis, no main effects and interactions were significant (Appendices C, D, E).

6.3.8. MANT

*6.3.8.1. Accuracy*

For accuracy data, performance significantly improved over time for combined and mothers-only analysis (Appendix C, D, E, L.6) but no significant main effect of Condition or Condition * Time interaction. Further, main effects of congruency and stimulus presentation were seen for all datasets where congruent trials had increased accuracy compared to incongruent, in addition to higher accuracy for 500ms presentation. An additional main effect of Load was seen for the combined and mothers-only analysis, but not fathers ($F_{(1, 1018)} = 7.06$, $p = .007$; $F_{(1, 710)} = 4.19$, $p = .040$, respectively). Here, higher accuracy scores were seen for medium load and 500ms trials. In the mothers analysis, there were no effect of Condition, Time or Interaction. There were no further main effects or interactions in the fathers data. Regarding low load trials, a main effect of Time was present for both combined and mothers-only data (Appendices C, D), but no further effects of Time or the Condition*Time interaction was observed all data sets.

*6.3.8.3. Reaction Time*

For RT data, no main effects of Condition, Time, or Condition*Time interaction was present for any dataset. However, a main effect of stimulus presentation was present for the combined, mothers and fathers-only data and congruency were present in a similar pattern to accuracy data, where quicker reaction times were seen for 500ms and congruent trials.

For low load trials, no main effects were seen for Condition, Time and interaction for Condition*Time for any dataset (Appendices C, D, E). However, for fathers-only data a significant interaction was seen for Condition*Time*Order ($F_{(1, 52)} = 5.67$, $p$=.020; Figure 30). Here, none of the pairwise comparisons reached statistical significance after Bonferroni adjustment, although there was a trend ($p$ = .053) suggesting that fathers in the Placebo condition at Post (when Placebo was given first, followed by WBB) had slower reaction times on Low Load trials compared to their own Baseline performance (Mean difference = 57.95, SE = 17.7). Reaction times in this condition also appeared slower than during the WBB condition at Post in the same order group (Mean difference = 53.93, SE = 19.1, $p$ = .187), suggesting a potential benefit of WBB relative to Placebo at the same timepoint, though this was not significant.

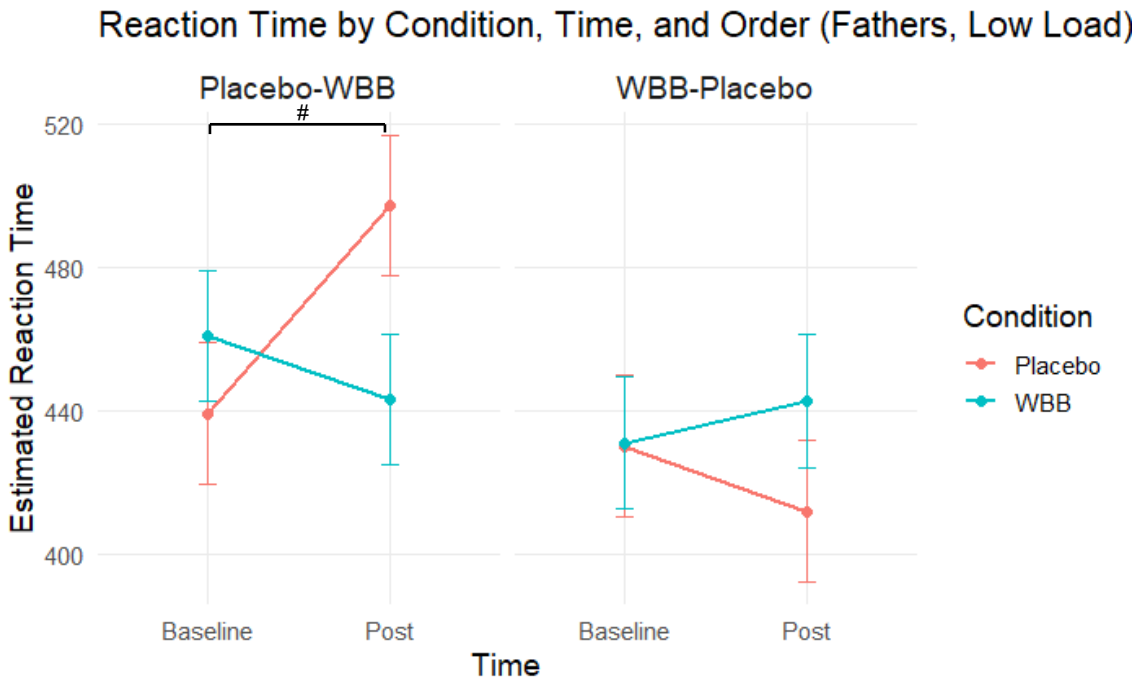


*Figure 30. MANT RT broken down by intervention group and drink order with LMMs revealed a significant Condition*Time*Order interaction ($F_{(1, 52)}$ = 5.67, p=.020) for the fathers only, where a trend emerged showing faster RT at post intervention compared to baseline for the placebo group when the order was Placebo-WBB (p = .053), (# p= .053). Models were controlled for sleep (PSQI), maternal age, habitual flavonoid intake, birth experience, infant temperament, location and stress (PSS-10) as covariates.*

6.3.9. N-BACK

*6.3.9.1 N-BACK overall accuracy*

No significant differences were seen between placebo and WBB groups as baseline for mothers and fathers data, in addition to combined data (Table 15, Table 16). Regarding the combined, mothers and fathers only analysis, no main effects and Condition*Time interactions were significant (Appendices C, D, E).

*6.3.11.2. N-BACK overall reaction time*

No significant differences were observed between the placebo and WBB groups at baseline (Table 15, Table 16). Regarding the combined data, a significant main effect of Condition emerged, where faster RT's were seen in the WBB group. There were no further significant main effects or interactions. Among covariates, age was a significant predictor ($F_{(1, 31)}$ = 6.15, $p$ = .018), indicating that older participants tended to have slower reaction times. When age was accounted for in additional models, there was a significant Condition * Time interaction ($F_{(1, 90)}$ = 4.16, $p$ = .044), where pairwise comparisons showed significantly slower RTs at baseline for placebo (M=538.09, SE= 9.22) compared to WBB (M=503.79, SE=9.33) ($p$=.002) though no further pairwise comparisons were significant. For the mothers and fathers only data, no significant main effects or interactions were present significant (Appendices C, D, E).

*6.3.9.3. N-1*

For the combined data, in regards to accuracy, a, significant Condition*Time interaction ($F_{(1, 105)}$ = 4.15, $p$ = .043), where in the Placebo condition, participants had higher accuracy at Baseline to Post. In contrast, for the WBB condition, accuracy was higher at Post compared to Baseline. This difference

between the conditions at baseline was not significant (*p=.174)* and pairwise comparisons, revealed no further significant differences. There were no additional significant main effects of Time or Condition. Furthermore, for both the mothers and fathers only data, there was no significant main effect or interaction.
For reaction time data, no significant differences were observed between the placebo and WBB groups at baseline (Table 15, Table 16). No significant main effects or interactions were seen across any analysis groups (Appendices C, D, E, Figure 31).

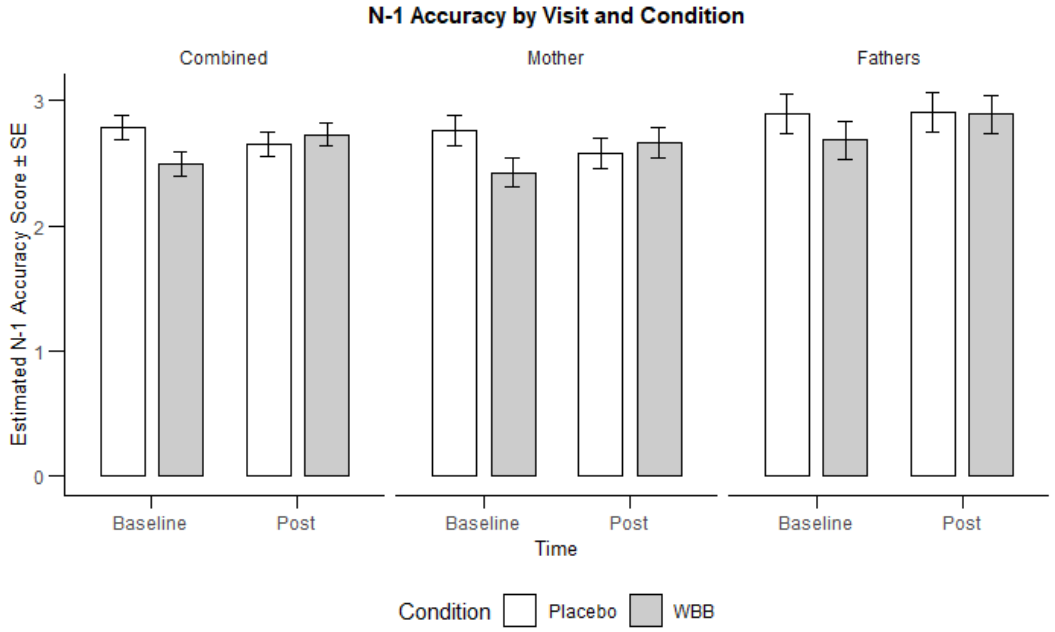


*Figure 31. N-BACK n-1 scores broken down by intervention group with LMMs showed a significant Condition*Time interaction for mean (SEM) n-1 accuracy interaction ($F_{(1, 105)}$ = 4.15, p = .043), though pairwise comparisons did not reveal further significant group specific effects. Models were controlled for sleep (PSQI), maternal age, habitual flavonoid intake, birth experience, infant temperament, location and stress (PSS-10) as covariates.*

*6.3.9.4. N-2*
No significant main effects or interactions were seen across combined and mothers groups. A main effect of Time was seen for the fathers-only analysis where increased accuracy was seen at baseline compared to post-intervention.

For RT, the combined data showed a significant main effect of Condition and Time, with reduced RT in the WBB group and faster RT seen post intervention. There was no significant Condition * Time interaction. However, a significant three-way interaction between Condition, Time, and Order ($F_{(1, 103)}$ = 4.23, *p* = .042) suggested that the pattern of change over time differed by treatment order. Follow-up comparisons showed a significant difference between participants in the placebo-first group at baseline and those in the WBB-first group post-intervention, though no further significant effects.

For the mothers only data, there were no significant differences between conditions, though there was a main effect of Time and Condition * Time interaction ($F_{(1, 65)}$ = 4.96, *p* = .029) where pairwise comparisons showed significantly faster RT between the placebo group at baseline compared to post (*p*=.004), in addition to significantly faster reaction times between placebo group at baseline and WBB group at post intervention (*p*=.015). There was a Condition*Time*Order interaction ($F_{(1, 65)}$ = 4.41, *p* = .039; Figure 32), where significant differences were seen between placebo and WBB groups at baseline when placebo was given first ($t_{(69)}$=3.34, *p*=.037), in addition to significant differences between placebo and WBB conditions between baseline and post, with differences between the order

of treatment ($t_{(44)}$=3.65, $p$=.015). Lastly, for the mothers, there was a significant covariate of Location, though there were no further effects when location was accounted for in further models.
However, for fathers there were no significant main effects or interactions within the data set (Appendices C, D, E).

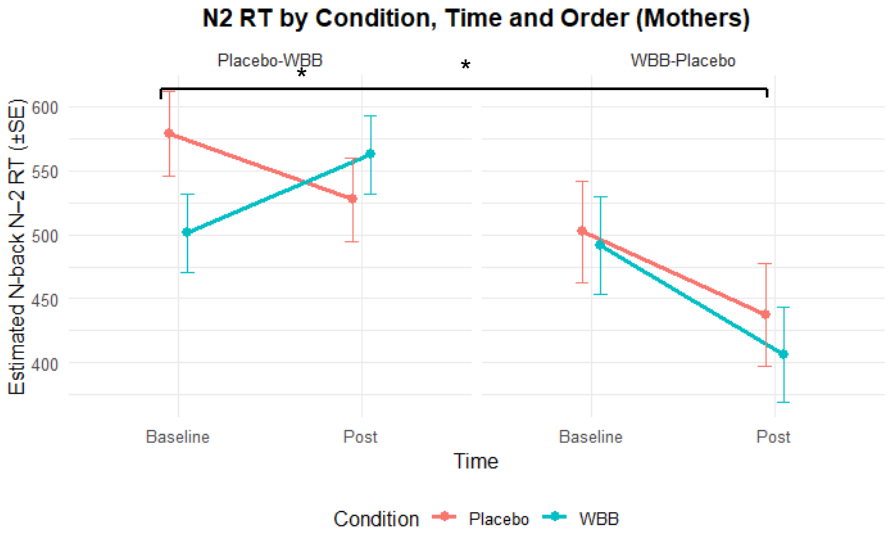


*Figure 32. N-BACK n-2 broken down by intervention group and drink order with LMMs revealed a significant Condition*Time*Order interaction ($F_{(1, 65)}$ = 4.41, p = .039) for the mothers only dataset, (* p<.05). Models were controlled for sleep (PSQI), maternal age, habitual flavonoid intake, birth experience, infant temperament, location and stress (PSS-10) as covariates.*

*6.3.9.5. N-3*

For accuracy data, regarding the combined analysis, mothers and fathers only, no main effects and interactions were significant. However, a main effect of condition was seen for reaction time data for the combined analysis and fathers-only data, in addition to a main effect of Time for mothers only data. No other main effects and interactions were present for this outcome (Appendices C, D, E).

*6.3.9.6. N-4*

Further, for both accuracy and reaction time data, regarding the combined analysis, mothers and fathers only, no main effects and interactions were significant (Appendices C, D, E).

*6.3.9.7. N-5*

For accuracy data, regarding the combined analysis, mothers and fathers only, no main effects and interactions were significant (Appendices C, D, E). However, a main effect of condition was seen for reaction time data for the combined analysis and mothers-only data.

### 6.3.10 Blood pressure

*6.3.10.1. Systolic blood pressure*

Regarding the combined analysis, mothers only and fathers only data, no main effects and interactions were significant (Appendices C, D, E).

*6.3.10.2. Diastolic blood pressure*

For the combined analysis, no main effects and interactions were significant (Appendices C, D, E).

For the mothers only data, no main effects and interactions were significant (Appendix D). However, the effect of location was significant ($F_{(1, 21)}$ =5.44, $p$ = .029). When accounted for in further models, a Location*Time interaction ($F_{(1, 68)}$ =4.11, p = .046), where pairwise comparisons revealed a significant difference at the 2-hr timepoint between Home (M=70.14, SE= 2.26) and Lab (M=80.50, SE=2.78) locations, where diastolic blood pressure was higher when the Time took place in the lab.

In the fathers only model, there was a significant main effect of Condition, though no further main effect of Time or interaction was significant (Appendix E). Further, Location was significant covariate ($F_{(1, 25)}$ = 4.41, $p$ = .045), though did not have further effects when accounted for in additional models.

6.3.11. Habitual diet

Mothers' intake of flavonoids and iron met or exceeded postpartum RDAs, while fathers consumed significantly less flavonoids. Both groups' caloric and protein intakes were generally adequate, with no significant differences compared to RDAs. Fathers showed borderline lower fat intake compared to their RDA. Both mothers and fathers consumed less fruit, vegetables, folate, and fibre than recommended, with fathers having significantly lower vegetable and fibre intake than mothers. Overall, mothers tended to have higher nutrient intakes closer to or above RDAs, while fathers showed some shortfalls, particularly in flavonoids, vegetables, and fibre (Table 17).

*Table 17. Mean (SE) raw data from the EPIC-Norfolk FFQ for participants at baseline*

| Nutrient | Postpartum RDA (mothers) | P-values from one sample t-test comparing intake with RDA's (mothers) | RDA (fathers) | One sample t-test comparing intake with RDA's (fathers) | Sample | | | Between groups *p* value (mothers vs. fathers) |
|---|---|---|---|---|---|---|---|---|
| | | | | | Combined | Mothers | Fathers | |
| | | | | | M(SE) | M(SE) | M(SE) | |
| Flavonoid ( mg)[1] | 428 mg | .434 | 428 mg | .045 * | 434.60 (67.02) | 494.93 (84.32) | 259.63 (72.42) | .042* |
| Calories (kcal)[2] | 2,400kcal | .606 | 2,200kcal | .049* | 2139.44 (200.84) | 2264.65 (259.95) | 1776.31 (186.62) | .136 |
| Protein (g)[2] | 71g | .156 | 56g | .099 | 81.23 (7.45) | 85.01 (9.63) | 70.28 (7.77) | .242 |
| Fat (g)[2] | 90g | .406 | 90g | .051 | 94.31 (10.24) | 101.29 (13.38) | 74.08 (7.08) | .081 |
| Carbohydrates (g)[2] | 210g | .606 | 130g | .001* | 253.86 (22.97) | 267.19 (29.25) | 215.20 (27.25) | .204 |
| Fruit (g)[2] | 400g | .001* | 400g | .001* | 204.99 (32.60) | 216.94 (40.89) | 170.34 (47.26) | .463 |
| Vegetables (g)[2] | 400g | .033* | 400g | .001* | 270.04 (33.94) | 302.66 (43.50) | 175.44 (23.60) | .014* |
| Iron ( mg)[2] | 9 mg | .013* | 8g | .694 | 11.42 (0.92) | 12.11 (1.17) | 9.42 (1.04) | .097 |
| Folate (mcg)[2] | 500mcg | .001* | 400mcg | .001* | 273.14 (25.10) | 293.31 (32.23) | 214.67 (22.11) | .052 |
| Fibre (g) [2] | 34g | .001* | 34g | .001* | 17.54 (1.67) | 18.99 (2.16) | 13.32 (1.22) | .028* |

[1] Vogiatzoglou et al. (2015); [2] U.S. Department of Agriculture. (2020); * $p<.05$

6.3.12. Intervention likability

For the combined sample, a significant difference was seen between 'Pleasant' ratings of the drinks, where the WBB drink was rated significantly more pleasant than the placebo. All other outcomes were non-significant (Table 18, Figure 33).

*Table 18. Mean (SD) raw data and between groups p-value for WBB and placebo drink likability measures*

| *Likability measure* | Placebo<br>*M (SD)* | WBB<br>*M (SD)* | Between groups p-value |
|---|---|---|---|
| Sweet | *5.89 (1.97)* | *5.24 (2.15)* | 0.143 |
| Bland | *3.50 (2.19)* | *3.68 (1.83)* | 0.642 |
| Tasty | *4.79 (2.66)* | *5.71 (2.19)* | 0.077 |
| Pleasant | *4.82 (2.62)* | *6.05 (2.40)* | 0.046* |
| Sour | *2.68 (1.95)* | *3.16 (1.92)* | 0.191 |
| Satisfying | *4.66 (2.70)* | *5.61 (2.37)* | 0.103 |
| Could drink more | *4.61 (2.95)* | *5.42 (2.66)* | 0.153 |
| Easy | *6.50 (2.41)* | *6.34 (2.26)* | 0.750 |

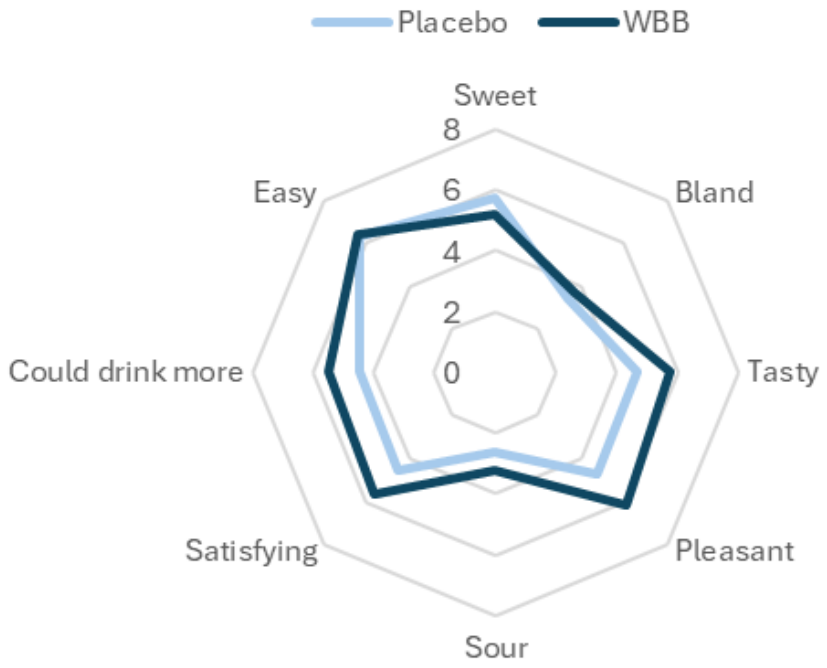


*Figure 33. Spider diagram representing WBB and placebo drink likability*

6.4. Discussion

This study recruited parents in the 0-6 month postpartum with the aim to explore whether a single dose of flavonoid-rich WBB would improve parameters of mood, cognition and blood pressure over 2- hours compared to a placebo. Improvements to verbal learning were seen in the Words Learned outcome of the RAVLT following consumption of the WBB drink in the combined, mothers and fathers dataset. Additionally, for the combined dataset, improvements in working memory accuracy were seen following consumption of the WBB drink, on the least cognitively demanding trial of the N-BACK (*n-1*). No improvements were seen for mood as a result of the intervention across both groups. Comparatively, several other facets of verbal learning improved following the WBB intervention in the fathers dataset, such as increased Final Acquisition, and protection from proactive Interference, where benefits were seen following consumption of the WBB drink which were not emulated following the placebo drink, suggesting fathers may have the potential for distinct benefits during this sensitive time.

Words Learned is the difference in the number of words recalled between the first and final word lists in the RAVLT, providing a measure of how much information the participant was able to learn over repeated exposures. Improvements in this measure for the combined datasets suggest enhanced ability to encode and retain new verbal material over time. Therefore, finding acute improvements in this measure following consumption of a flavonoid-rich wild blueberry intervention suggests that flavonoids may support memory encoding learning processes. As highlighted in Chapter 1.2, such improvements have been documented following the same dose of WBB (253 mg anthocyanins) in children (Barfoot et al., 2019; Whyte and Williams., 2015) and adults (Whyte et al., 2021). Therefore, this study adds to the evidence base, supporting that blueberry flavonoids are beneficial to cognitive function, specifically verbal memory across the lifespan, even during especially sensitive periods for mood and cognitive change, such as the postpartum. The more words learnt reflect better ability to encode and retain new verbal information over repeated exposures, suggesting that flavonoid consumption may facilitate encoding efficiency, capacity for learning or deeper cognitive processing. These processes have been linked to hippocampal function (Fernández et al., 1998; Greicius et al., 2003; Karlsgodt et al., 2005), which is a region in which flavonoids have been shown to enhance neuronal survival and plasticity in rodents (Williams et al., 2008). Although the exact neurocognitive pathway in humans remains unclear, the aforementioned collective evidence from both children and adults consuming this dosage of WBB, suggests that flavonoids can acutely improve cognitive performance. While benefits were seen in the combined dataset, there is some indication that these effects may have been more pronounced in the fathers-only sample, potentially driving results in the combined dataset.

Specifically, improvements were seen following WBB consumption over the 2-hr time period, which were not observed following the placebo or in the mothers-only cohort. These benefits were largely seen in the RAVLT outcomes, such as proactive interference, where less interferences were seen following consumption of the WBB, though greater interference was seen following placebo, an effect not replicated in the mothers-only dataset, further suggesting improvements to verbal memory may be more prominent in fathers. Alternatively, the fathers sample may simply reflect a typical healthy adult population, where we have seen cognitive benefits of flavonoids (Cheng et al., 2022), while the cognitive effects may have been less pronounced in the mothers sample, who are perhaps undergoing physiological and psychological change to a greater degree than the fathers. As discussed throughout this thesis, pregnancy and the postpartum period involve unique physiological changes, such as increased monoamine oxidase activity and changes in blood flow that are specific to individuals who have carried a child. This was illustrated in Experiment 2, where notable changes in both systolic and diastolic blood pressure were observed during the early postpartum weeks. These biological processes are not experienced by fathers, suggesting that around six months postpartum, sex-specific differences within the parent cohort may have influenced the observed outcomes in mood and cognition. For example, mothers may still be experiencing the effects of postpartum physiological changes, as well as ongoing psychosocial and environmental demands, and if they are the primary caregiver, additional psychosocial and environmental demands may further influence cognitive and mood outcomes, while fathers may respond differently to dietary interventions due to a relative lack of such changes, and are

therefore reflective of a typical population. These sex-specific contexts could therefore play a mediating role in the effectiveness of nutritional strategies and help explain the differential cognitive benefits observed. However, an important limitation to consider is the small sample of fathers which was below the target sample size. As such, while the results are promising, they should be interpreted with caution and require replication. Nevertheless, the findings raises the question of whether there are sex differences during this period which may mediate the effects of flavonoids on cognitive function

In addition to Words Learned, a benefit following the WBB intervention was seen in the N-BACK task, specifically in the n-1 trials when performance was collapsed across different forms of the task, indicating improved working memory accuracy under lower cognitive load conditions. This effect was seen in the combined sample, indicating a potential benefit to parents during the 6-month postpartum. Interestingly, improvements under lower cognitive demand contrasts with findings from previous research suggesting flavonoids may be most beneficial during high-demand tasks (Whyte et al., 2016; Whyte et al., 2017). However, this aligns with findings from Experiment 2, where improvements were observed during the marginally less demanding 500ms trials of the MANT task, but not during the more challenging 120ms trials. Taken together, these results may indicate that in highly resource depleted populations such as new parents, flavonoids support performance more effectively under moderate rather than maximal cognitive load, as it is possible that the already elevated baseline cognitive and emotional demands of the postpartum period limit the capacity for enhancement during more difficult tasks. As discussed in Chapter 3, postpartum cognitive deficits, particularly in processing speed and working memory, are often subtle and may depend on task demands. Thus, it is plausible that some cognitive tasks are too easy and fail to reveal meaningful deficits or improvements (Anderson and Rutherford, 2012), while overly challenging tasks may overwhelm participants already experiencing heightened baseline cognitive load, masking potential benefits. This emphasises the need for further exploration into cognition at different stages of the postpartum, comparing against non-pregnant controls, identifying a cognitive threshold and evaluating whether dietary flavonoids may provide further benefit.

That being said, as verbal learning and working memory was seen to benefit from WBB consumption in the postpartum, it was surprising to not see replication of the benefits in the MANT, considering the positive findings in Experiment 2. Comparison of the combined data in this chapter, with the data in Experiment 2 shows slightly better accuracy and faster RT at baseline in Experiment 2, though this difference is marginal, so does not explain why effects were found in the immediate postpartum and not reflected in the 0-6 month. However, closer inspection suggests this may relate to task difficulty and participant performance. In the current trial, mean MANT accuracy was noticeably lower than in Experiment 2, alongside generally slower reaction times. These findings point to the possibility that the MANT may have been too cognitively demanding for this group to exhibit measurable acute benefits from the intervention, suggesting chronic interventions might be more appropriate to produce meaningful cognitive improvement following flavonoids. Although previous studies have demonstrated cognitive improvements following acute WBB supplementation (Barfoot et al., 2019; Whyte et al., 2016; Whyte et al., 2017), the findings in this trial do not align with those earlier results. Therefore, despite evidence supporting the hypothesis that WBB supplementation may benefit executive function tasks, the timing of testing within this specific population may be a critical factor. For example, variables such as stress and sleep quality may have differed between the two experiments, potentially contributing to differences in cognitive outcomes. Importantly, stress, parental leave, and infant irritability were not measured in the previous trial, limiting direct comparisons between the datasets to explain these discrepancies. However, when comparing measures such as EPDS, PSAS, PRMQ, MANT accuracy and reaction time, as well as retroactive interference and delayed recall, the current dataset shows generally poorer scores than those presented in Experiment 2. This finding is somewhat surprising given that the current sample consists predominantly of individuals with moderate to high socioeconomic status and higher education levels, factors typically associated with greater cognitive reserve and resilience to mood disturbances (Duncan & Magnuson, 2012; Muntaner et al., 2004). This highlights the non-discriminatory nature of postpartum mood and cognitive challenges, emphasising that these difficulties can affect parents

across diverse backgrounds, regardless of protective socioeconomic factors. However, the relative homogeneity of the sample may also limit the generalisability of these findings, as it remains unclear whether similar patterns would emerge in more socioeconomically or educationally diverse populations. Notably, there is clear evidence that postpartum mental health outcomes are often poorer in Black, Asian, and minority ethnic (BAME) communities, as well as in socioeconomically disadvantaged groups (Clare & Yeh, 2012; Garapati et al., 2023; Maxwell et al., 2019). If mood and cognitive challenges are evident even within a relatively protected sample, it is likely that such difficulties may be more pronounced in less advantaged populations. This underscores the potential value of accessible nutritional interventions in supporting maternal mental health more broadly

Interestingly, the present trial did not find effects on mood, an effect which is not consistent with previous evidence such as Velichkov et al. (2024) who found acute changes in mood in a population with self-reported mild to moderate depressive symptoms. The sample in the present trial were not classed as a clinical population in this sense, however the high risk of mood disorders, with both parents reporting mild depression according to the EPDS (Table 14), suggesting potential for improvements following the WBB drink. However, the lack of findings may be due to the aforementioned complex interplay of extraneous factors like sleep disruption, elevated stress, and variable infant temperament, all of which are known to significantly influence mood in the postpartum period. While there is potential for mood improvement in this population, a single acute dose may not be sufficient. Building on evidence from previous trials, it may be that anthocyanins, in particular, show stronger effects on mood when administered chronically. For instance, studies such as Barfoot et al. (2021) and Experiment 1, which involved higher anthocyanin content and longer intervention periods, did observe mood-related benefits. This suggests that for at-risk populations, chronic anthocyanin intake may be more appropriate for achieving meaningful mood improvements. Interestingly, a significant increase in positive affect was seen following consumption of the placebo drink in the fathers-only dataset, this is a surprising finding and was not affected by other factors such as location and drink order, and this may reflect a Type I error, or additional extraneous variables that were not captured in the experiment. While the study employed a double-blind, crossover design, it is unlikely that demand characteristics would only affect the placebo drink. Closer inspection of the data suggests that this result may reflect a combination of a slight increase in PA following the placebo and a slight decrease following WBB, rather than a meaningful treatment effect. Therefore, this pattern may be better interpreted as a statistical artefact rather than evidence of a true psychological response.

The present results additionally suggest that the order in which these treatments were given influenced some of the outcomes, signifying a potential limitation of the design and, highlighting the importance of considering potential carryover effects Interestingly, in the mothers-only analysis of the word learning task, participants who received the WBB drink second (after placebo) showed improved learning scores from baseline to post-intervention. This pattern may reflect an acute effect of WBB rather than a carryover effect, as the benefit emerged only when WBB was consumed in the second session and did not appear to persist across sessions. A similar complexity was observed in the N-back task, particularly in reaction times for N2 trials. Although the interaction suggests that order influenced performance, the pattern does not clearly indicate a classic carryover effect. Instead, the differences likely reflect a combination of baseline variability and short-term treatment effects. However, these findings reinforce the need for caution when interpreting crossover designs. As discussed earlier in this thesis, carry-over effects have been previously demonstrated in the flavonoid literature, where Keane et al. (2015) found cognitive function to maintain after a 4-week washout period, following consumption of flavanone-rich orange juice for 8-weeks. A period of 7 days was utilised as a washout between study visits, based on previous research (Whyte et al., 2015; 2016; 2017; Khalid et al., 2017). However, these studies did not account for drink order in their analyses, and it remains uncertain whether a one-week washout is sufficient to fully eliminate the effects of WBB consumption. Research suggests that anthocyanins and their metabolites may persist in the body for 48-hours (Kalt et al., 2008; Wu et al., 2011). Therefore, it is unlikely that physiological carryover alone accounts for the observed performance differences among participants who received WBB first. However, in the absence of plasma or urinary metabolite data, subtle or indirect carryover effects cannot be entirely ruled out. Future crossover studies should consider incorporating objective

flavonoid metabolite measures and enforcing a low-flavonoid diet during the washout period to more precisely determine the clearance timeline and reduce potential residual effects.

Regarding baseline diet, there was a large difference in flavonoid consumption, with fathers consuming significantly fewer flavonoids, in addition to vegetables and fibre compared to mothers. These dietary components are crucial for overall health, including important influences on factors such as composition and function of the gut microbiota and other food bioactives. Given this pattern, fathers, or men more generally, may represent an important target group for dietary health interventions aimed at improving nutritional status and related health outcomes. This may reflect the greater improvements seen in fathers after WBB consumption, as their poorer baseline diet offers more room for benefit compared to mothers, whose diets already contain adequate flavonoids (Velichkov et al., 2024; Sloan et al., 2021).

Furthermore, location was included as a covariate in the trial, as having flexible study locations was thought to encourage less attrition, especially in the father cohort. Location did occur as a significant covariate on few occasions, such as blood pressure, where higher blood pressure was evident when participants were seen in the lab compared to their homes. This could be interpreted as a limitation of the experiment, though is not an unknown observation, where Mancia et al. (1995) reports similar findings of reduced blood pressure at home versus in a clinic setting. Although prior research has documented that location may affect mood outcomes in the postpartum, with contrasting findings from Myer et al. (2024) versus Dowlati et al. (2017) in either home or hospital locations. In this trial, when accounted for in further models, wherever location did occur as a significant covariate, it had no further effects on the overall model, potentially complimenting the feasibility of this trial on parents who may have preferences on study location, and therefore encouraging wider participation.

Although no effects of WBB consumption were found on blood pressure, it is important to note that participants' baseline blood pressure values were within the normal range. This likely limited the potential for detecting further reductions, as flavonoid-related improvements in vascular outcomes are typically more pronounced in individuals with elevated or borderline blood pressure. In agreement with Rees et al. (2018), who outlined that several trials have reported significant reductions in blood pressure mainly in at-risk or hypertensive populations, but little to no effect in healthy adults, the absence of change in this study should therefore be interpreted in light of the healthy baseline status of the sample rather than as absence of a physiological effect.

Recruitment of sufficient fathers of 0-6 month olds in the current study represented a significant challenge, as was the case in Experiment 1. Efforts were made to pursue different recruitment strategies, including targeting the partners of the existing mothers taking part, however this was not sufficient to recruit the target sample size for fathers. This once again highlights a need to explore ways to encourage fathers to participate in research. It should also be highlighted that the baseline data reflects fathers reporting significantly higher subjective cognition (PRMQ) scores, indicating greater subjective cognitive complaints. This may reflect the added challenges of balancing returning to work and childcare demands, or potentially differences in how men perceive and report their cognitive function. Further investigation into these factors is warranted, especially considering the prevalence and broader impact of paternal mental health (Fisher et al., 2016; Maleki et al., 2018).

To conclude, this study reinforces the complex interaction between mood, cognition, and dietary supplementation during the early postpartum period. The data presented in this chapter suggest that an acute dose of wild blueberry (WBB) may enhance aspects of cognitive performance, specifically verbal learning and working memory in both mothers and fathers. Fathers appeared to benefit particularly, showing improvements across a broader range of RAVLT domains compared to the mothers-only cohort. However, greater beneficial effect in fathers may be affected by lower habitual flavonoid intake, and these findings must be interpreted cautiously due to the small sample size ($n$ = 10), underlining the need for replication in larger samples. No changes in mood were detected following acute WBB, in contrast with previous findings. Given the variability and challenges of the postpartum period including factors such as disrupted sleep, infant care demands, and return to work, mood outcomes may be especially difficult to change or capture with an acute dose of flavonoids. The findings from the present work, alongside previous chapters and the study by Barfoot et al. (2021),

suggest that chronic flavonoid interventions may be more effective than acute approaches for detecting meaningful mood changes in this population. The study also identified drink order as a significant factor in several analyses, suggesting potential carryover effects of WBB. This highlights the importance of considering treatment order and the possibility of residual bioactive or drink taste effects, particularly in crossover designs. Future research would benefit from including physiological markers (e.g. plasma metabolites) to track carry over effects and also to explore possible underlying mechanisms of how flavonoids may benefit outcomes acutely. Overall, these findings align with the broader pattern observed in Experiments 1 and 2, supporting the view that the 0–6 month postpartum period is a sensitive window during which cognitive function may be particularly responsive to flavonoid interventions.

# Chapter 7. General Discussion

## Aims of the thesis

The aims of this thesis were 1) to systematically review the existing literature exploring whether flavonoid-rich food supplementation may benefit mood and mental health in healthy populations throughout the lifespan 2) assess whether chronic dietary flavonoid supplementation benefits mood and cognition in the postpartum, and 3) explore whether an acute dose of WBB can improve parents' mood, cognitive function and blood pressure in the 0-6 month postpartum period.

## 7.1. Overview of the thesis

### 7.1.1. Systematic review

It is evidenced that diets rich in flavonoids may play a beneficial role in the development and treatment of mental health disorders throughout the lifespan. In the last decade, numerous trials have explored this relationship, with a variety of methodologies such as duration of the intervention, type of flavonoid-rich food, tools utilised in measuring symptom severity and populations that may be of particular benefit. Previous reviews have explored this mood relationship (Ali et al., 2021; Jia et al., 2023; Pizarro Melendez et al., 2024), suggesting that flavonoids are likely to benefit. However, these reviews fail to incorporate a range of mental health considerations within one review, and often focus on both flavonoid-rich whole foods and flavonoid extracts, which may have differential effects due to interactions within the food matrix.

Therefore, the first aim of this thesis was to evaluate the current evidence by providing an updated systematic review focused exclusively on flavonoid-rich whole foods. This focus reflects typical dietary habits and offers greater ecological validity compared with extract-based interventions that often involve inaccessible, high-dose products with limited real-world relevance. This approach may also strengthen public health guidance by generating evidence that is directly translatable to everyday dietary patterns. A total of 35 studies were included in the review, with the overall consensus suggesting that flavonoid-rich foods, including berries, cocoa, and citrus, can confer mood benefits in both acute and chronic supplementation designs. These benefits appear to be moderated by a range of factors, including the food source, dose, intervention length, and characteristics of the population.

A key finding of the review was that chronic supplementation tended to produce more consistent effects on mood than acute dosing, particularly in interventions involving cocoa. However, acute benefits have been observed in studies using anthocyanin-rich interventions, likely due to the rapid absorption and bioavailability of these compounds. This distinction between flavonoid subclasses and their time-sensitive effects underscores the need for more mechanistic studies to determine optimal dosing windows, particularly in relation to peak metabolite levels for acute dosing, and changes in gut microbiota, and neuronal change following chronic intervention. Additionally, findings suggest that flavonoid interventions may be especially beneficial during periods of heightened psychological stress, such as academic examinations or mental stress tasks. This highlights flavonoid-rich foods as potentially useful for targeted, time-sensitive interventions aimed at mood enhancement in real-world settings. Furthermore, the evidence base points to differential responses across age groups, with younger adults generally responding more robustly than older adults. This may reflect age-related differences in emotion regulation or baseline mood, offering further nuance to future intervention targeting.

Importantly, the review also identified substantial heterogeneity in outcome measures, with tools such as the STAI, PANAS, and BL-VAS appearing most sensitive to detecting change. By contrast, measures like the POMS and GDS showed fewer significant findings. This suggests that careful consideration of outcome measures is essential in future flavonoid trials, particularly those assessing subtle changes in mood. While promising, the evidence base remains limited by inconsistent methodological quality, variation in flavonoid dosage, and a lack of transparency in study procedures such as randomisation and handling of withdrawals. Moreover, the absence of a meta-analysis in the current review limits the ability to quantify the magnitude of effects. Nonetheless, as summarised

above, the narrative synthesis offered a rich contextual understanding of where and for whom flavonoid interventions may be most beneficial.

These findings also provided a strong rationale for the subsequent empirical studies presented in this thesis. Given that the postpartum period is a time of increased vulnerability to mood disturbances, and that the biological mechanisms underlying these disturbances may overlap with those influenced by flavonoids, this period may represent an ideal window for dietary flavonoid interventions.

#### 7.1.2. Experiment 1 (Chapter 4)

This study investigated the effects of a two-week dietary flavonoid intervention on mental health in parents with infants under six months old. Both mothers and fathers were recruited, and after collecting baseline mood and diet questionnaires, were asked to consume an additional two flavonoid-rich foods to their normal diet, or just to continue with their diet over a period of 14-days. Participants were asked to record a food diary and outcome measures were then recorded post-intervention.

While both mothers and fathers were recruited, only mothers' data were analysed due to low paternal compliance. Mothers in the flavonoid intervention group, who consumed two additional flavonoid-rich foods per day, showed a significant reduction in postpartum depression scores and an increase in positive affect compared to baseline, with no such changes in the control group. These findings suggest that incorporating flavonoid-rich foods into the diet may alleviate symptoms of postpartum depression and improve mood in the early postpartum period.

The intervention's effects on depression aligned with prior research showing benefits of flavonoids for positive affect, although no changes were observed in anxiety measures, which contrasts with earlier studies. Differences in outcome sensitivity may relate to the use of the EPDS being specific to postpartum depression, as opposed to general tools like the PHQ-8. This is a key finding when relating results back to the systematic review, where specific measures found subtle changes in mood outcomes. Notably, the review highlighted that tools such as the STAI, PANAS, and BL-VAS were more sensitive to detecting mood changes, while broader or less targeted scales like the POMS and GDS yielded fewer significant effects, emphasising the importance of aligning outcome measures with the specific affective domain and population of interest. Though this trial did not find effects in the STAI, despite Barfoot et al. (2021) finding effects, the lack of change here may partly reflect slightly better baseline STAI scores in the cohort, leaving less room for improvement. Nonetheless, scores did change over time, indicating some degree of sensitivity of the measure in this population. Furthermore, the inclusion of the PSAS-RSF-C alongside the STAI allows for a comparison between the two measures, which indeed correlated, facilitating the detection of anxiety changes within this specific population. This approach also enables an exploration of whether either measure is more sensitive to changes resulting from dietary interventions, helping to determine which tool may be more effective for assessing anxiety in postpartum dietary studies. Interestingly, both the PSAS-RSF-C and STAI scores changed over time in this dataset, indicating that both measures are suitable for use in a postpartum population. However, the PSAS-RSF-C may have limited sensitivity for detecting subtle dietary effects, as several items assess concerns (e.g., fears around the baby's safety) that are unlikely to be influenced by nutritional interventions. In contrast, the STAI has shown sensitivity to flavonoid supplementation in previous work (Barfoot et al., 2021), suggesting it may be more responsive under the right conditions.

Maternal age was explored as a potential moderator of intervention effects. Although the trend suggested that older mothers reported lower levels of positive affect, though this association did not reach statistical significance. Interestingly, other factors hypothesised to influence outcomes, such as baseline flavonoid intake and subjective sleep quality also failed to emerge as significant predictors. This lack of effect was somewhat unexpected, given the established links between both nutrition and sleep with mood and psychological wellbeing, particularly in the sensitive postpartum period (Ross et al., 2005; Franzen & Buysse, 2008; Park et al. 2021). These findings suggest that the mechanisms underlying the observed mood changes may be more complex than anticipated, potentially involving other variables such as stress and other subjective measures of sleep, which were therefore included in following experimental studies.

At baseline, a high proportion of mothers reported experiencing depressive or anxious symptoms, despite low rates of formal diagnosis. This discrepancy highlights the presence of a potentially clinically vulnerable sample, where psychological distress may be under-recognised or under-treated. Such baseline vulnerability may help explain the observed changes in EPDS and positive affect (PA) scores, as individuals experiencing subclinical or undiagnosed symptoms may have greater capacity for improvement in response to dietary interventions. This is consistent with previous findings, where both clinically diagnosed populations and those reporting low mood have shown significant symptom improvement following nutritional interventions (Velichkov et al., 2024; Jacka et al., 2017). The present findings suggest that increasing dietary flavonoid intake could offer a particularly meaningful benefit in populations at risk, even in the absence of a formal clinical diagnosis. Given that the postpartum period is a time of heightened vulnerability to mood disorders for all women, these results support the potential for broader application of nutritional education and intervention. Integrating such approaches into routine postnatal care through antenatal classes, primary care services, or public health campaigns may offer an accessible, preventative strategy to support maternal mental health.

Food diaries confirmed good compliance with the intervention, with berry fruits, orange juice, and dark chocolate emerging as the most frequently consumed flavonoid-rich items. While both the intervention and control groups demonstrated an overall increase in flavonoid intake possibly reflecting heightened dietary awareness due to study participation greater improvements in mood outcomes were observed in the intervention group. Notably, the high consumption of berry fruits and cocoa rich dark chocolate may suggest mechanism-specific effects, as these sources are particularly rich in anthocyanins and flavanols, respectively. This aligns with the findings reviewed in Chapter 2, where berry-derived anthocyanins and cocoa flavanols showed the strongest and most consistent associations with mood enhancement and emotional wellbeing. These patterns lend support to the notion that not all flavonoids confer equal benefits and that specific subclasses may exert more pronounced effects to mood and mental health.

As discussed, a significant limitation in this experiment was the lack of reliable data from fathers due to attrition and lack of compliance. This highlights that differential methodology may be required for this specific sample, such as different ‘father-specific’ recruitment posters, or in-person testing may be necessary to explore this relationship further. As such, this was employed in future experimental trials conducted in this thesis.

Overall, the findings support the feasibility and potential of flavonoid-rich diets as a low-cost, accessible strategy to support maternal mental health in the postpartum period, warranting further research into mechanisms and long-term effects.

#### 7.1.3. Experiment 2 (Chapter 5)

This study investigated whether a 30-day dietary flavonoid intervention during the early postpartum period could support maternal mental health, cognitive function, and blood pressure regulation. This was investigated using a parallel groups, participant blind design with 60 participants. Participants were seen six times between their third trimester of pregnancy and 12-weeks postpartum, where they were randomised to an intervention group at 0-4 days postpartum and asked to consume either 1 or 2 flavonoid-rich food items from a selected list on top of their normal diet, or to continue their normal diet over a period of 30-days.

Notable cognitive and vascular benefits emerged following flavonoid intervention in this experiment. Both low and high flavonoid groups demonstrated improved accuracy on an executive function task (MANT), with effects persisting up to two months post-intervention (12-weeks postpartum). These benefits were most pronounced under high cognitive load and among participants who reported better sleep quality, highlighting the interaction between sleep and cognitive performance. Subjective cognitive improvements, as measured by the Prospective and Retrospective Memory Questionnaire (PRMQ), were also more evident in individuals with low habitual flavonoid intake, aligning with prior evidence linking flavonoid consumption to reduced subjective cognitive complaints.

Mood-related outcomes, including depression (EPDS), anxiety (STAI), and maternal specific anxieties (PSAS) did not show significant intervention effects. This may be due to generally low

baseline symptom severity, limiting the potential for observable improvement, in contrast to findings from Experiment 1. However, when controlling for birth experience, EPDS scores improved regardless of intervention group, suggesting a potential moderating or protective effect of birth experience on postpartum mental health. Additionally, a slight reduction in positive affect (PA) at 2 weeks in the control group was observed, which may tentatively indicate some protective effect of flavonoid consumption. Furthermore, while anxiety scores (STAI) remained stable across groups, sleep quality was found to moderate anxiety levels in the control group but not in the flavonoid groups, implying a possible buffering role of flavonoids under conditions of poor sleep, though these effects need to be investigated further.

Blood pressure findings were particularly compelling. Participants in the flavonoid groups exhibited greater reductions in both systolic and diastolic blood pressure compared to controls. These effects are consistent with the established vascular benefits of flavonoids, which include enhanced endothelial function, reduced arterial stiffness, and improved nitric oxide bioavailability (Kay et al., 2012; Rodriguez-Mateos et al., 2013; Brickman et al., 2014). Such mechanisms may be especially relevant during the postpartum period, when cardiovascular regulation undergoes significant changes, where peaks are seen shortly after delivery, with a return to individuals baseline over the postpartum months (Bramham et al., 2013). These findings suggest that dietary flavonoids could play a beneficial role in supporting cardiovascular health during this vulnerable time.

Several limitations warrant consideration. The use of general measures of sleep (PSQI) may have limited sensitivity to postpartum-specific sleep changes. Additionally, the timing of assessments may not have fully captured the trajectory of symptom emergence or resolution, compared to Barfoot et al. (2021) and Experiment 1, where participants were in the 0-6 month postpartum. However this may indicate that the later postpartum, up to 6 months, may be more optimal to introduce a dietary flavonoid intervention in comparison to the immediate when evaluating its effects on mood. Furthermore, in this experiment, the Stein Maternity Blues scale, which captures specific baby blues symptoms, seen in Meyer et al. (2024) and Dowlati et al. (2017) was not utilised. This could be a limitation of the present study, as it restricts direct comparison of findings with previous trials that employed this measure. However, given the focus on tracking mood from pregnancy through to 12-weeks postpartum, the Stein scale may be less relevant at this later timepoint due to postpartum blues typically resolving around 14 days after delivery. Therefore, the PANAS was utilised to capture transient mood changes over a broader postpartum period. Nonetheless, including the Stein scale in future research could be valuable for assessing dietary-related mood changes during the immediate postpartum period.

A significant takeaway from this study is that the types of flavonoid-rich foods consumed may have influenced the outcomes. The frequent intake of orange juice may have influenced the observed cognitive effects. While flavanone-rich orange juice appears to support cognitive performance, its impact on mood may require longer exposure or higher doses. The limited diversity of consumed foods, often favouring convenient options like orange juice, berries, and dark chocolate, may also have shaped the outcomes. This may be a prominent finding when compared to Barfoot et al. (2021) and Experiment 1, where anthocyanin rich berry fruits were the most consumed food items. Future research should explore whether specific flavonoid subclasses or more varied diets yield different cognitive and mood-related benefits in the postpartum period.

Covariates such as sleep, age, birth experience, and baseline flavonoid intake were significant throughout the models in the dataset. This suggests that individual differences may influence postpartum outcomes, indicating that maternal experiences, lifestyle factors, and pre-existing dietary habits can affect how individuals respond to dietary interventions. Including a broader range of psychosocial and physiological covariates in future studies would therefore provide a more comprehensive understanding of the factors that influence postpartum wellbeing and may help clarify the indirect mechanisms through which flavonoid intake relates to mood outcomes.

Overall, findings suggest that flavonoid intake during the early postpartum period may support cognitive performance and blood pressure regulation, particularly among individuals with low habitual intake. In contrast, mood-related effects were less consistent, indicating that factors such as

intervention timing, baseline mental health status, and dosage may be critical to the efficacy of dietary interventions in this context. Notably, cognitive benefits were limited to the 500ms condition and were most pronounced in participants with lower baseline flavonoid intake, highlighting potential dose- and baseline-dependent effects. No significant changes were observed for other cognitive measures (N-BACK, RAVLT), suggesting that flavonoid related cognitive benefits may be task-specific and more detectable under higher cognitive demand.

Finally, it is important to consider that the early postpartum period is a highly sensitive time, characterised by complex physiological, emotional, and environmental changes. These factors may have attenuated the immediate impact of the dietary intervention, underscoring the need for future research to examine longer-term effects, optimise timing, and explore personalised approaches to postpartum nutrition.

#### 7.1.4. Experiment 3 (Chapter 6)

This study investigated the acute effects of a flavonoid-rich wild blueberry (WBB) drink on cognition, mood, and blood pressure in parents during the 0–6 month postpartum period. A crossover, double blind study was conducted in a sample of both mothers and fathers in the 0-6 month postpartum period. Participants were tested in either their own homes or the Nutrition Cognition lab at the University, baseline outcome measures were taken followed by consumption of either a WBB drink (253 mg anthocyanins) or placebo matched control. Two hours following consumption, outcome measures were repeated.

In this experiment, significant improvements following the WBB drink were found for the amount learned domain and least cognitively demanding trials of the n-back task (n-1) when mothers and fathers samples were combined. This suggests improved verbal and working memory following the flavonoid-rich drink, at higher sampling power. Additionally, several other facets of the RAVLT were found to improve 2- hours following consumption of the WBB drink, in the fathers-only sample. This is the first trial to investigate acute effects of flavonoids on behavioural outcomes in parents, adding to the evidence base to support flavonoids role in aiding learning and memory, in addition to highlighting that parents, in particular, fathers may have the potential for distinct benefits during this time.

No reliable effects of the WBB intervention were observed on mood outcomes, suggesting that a single dose may be insufficient to influence affect in this population. This aligns with a broader theme discussed throughout the thesis, that chronic flavonoid supplementation may be more effective than acute dosing for modulating mood in this cohort. These findings contrast with previous studies, such as those by Khalid et al. (2017) and Velichkov et al. (2024), the latter of which reported mood improvements in individuals with mild to moderate depressive symptoms. However, as discussed, factors unique to the postpartum period such as stress, disrupted sleep, and physiological changes may underlie the absence of mood effects, and a single dose of WBB flavonoids may not be adequate to address these complex influences.

Order effects were evident in this trial, a pattern that has been documented in prior research, such as Keane et al. (2015), although their study involved an 8-week crossover design using flavanone-rich orange juice, where carryover effects are more plausible due to sustained exposure. In this experiment, a one-week washout period was used, and given that anthocyanin metabolites typically do not persist beyond 48 hours, a physiological carryover effect is unlikely. However, sensory aspects of the intervention, such as taste, may have played a role. Although the WBB drink was not significantly preferred over the placebo, it was rated slightly more favourably, which may have influenced participants' expectations or responses. A more pleasant-tasting intervention may lead to more positive mood associations, particularly when experienced first, and could subtly shape responses in subsequent sessions. This highlights the importance of considering order effects in acute trials.

When examining mothers and fathers separately, interesting differences emerged in the effects of the WBB intervention. Fathers appeared to experience greater benefits in aspects of verbal memory compared to mothers. Moreover, baseline diet seemed to influence outcomes more strongly in the mothers-only and combined datasets than in the fathers-only group. These findings are exploratory,

given the small sample size in the fathers-only dataset, and further research is required to determine whether either parent group may differentially benefit from flavonoid interventions, as well as to investigate the mechanisms driving these effects.

It was hypothesised that blood pressure would decrease at 2 hours post-WBB consumption, in line with prior findings and the known peak of circulating anthocyanin metabolites at this timepoint (Rodriguez-Mateos et al., 2013). Similar short-term reductions in systolic blood pressure have been observed following cherry juice consumption (Keane et al., 2016). These blood pressure changes are thought to enhance cerebral blood flow and nutrient delivery, potentially supporting cognitive function. Under this mechanism, improvements in mood outcomes might also be expected, as in Khalid et al. (2017); however, such effects in mood and BP were not observed in this study. One possible explanation may relate to the testing environment. Unlike previous trials of blood pressure and flavonoids, conducted under more controlled lab settings, participants in this study were often accompanied by their infant during testing, potentially contributing to a heightened and sustained state of arousal which may be less likely to change as a result of an acute dietary intervention. Importantly, baseline BP in this sample was within the normal range, suggesting there may have been less physiological scope for reduction. Future studies should consider the influence of testing context and parental stress, as well as the potential role of stress hormones, which may counteract the vascular or mood-related benefits of flavonoid interventions. However, the overall reasons for lack of effects for blood pressure remains unclear, highlighting the need for further research with larger samples and additional mechanistic exploration.

Despite these limitations, the current study contributes to a growing body of evidence suggesting that flavonoids may confer cognitive benefits during a period of significant mental and physical demand, such as early parenthood. These findings support the rationale for further trials with larger sample sizes, chronic intervention designs, and extended washout periods to better elucidate the potential of flavonoids in supporting parental health and wellbeing.

### 7.2. Overview of experimental findings

Across the three experiments, the effects of flavonoid-rich dietary interventions on mood, cognition, and physiological outcomes in postpartum individuals was explored. While each experiment varied in duration, flavonoid source, and outcome, several common patterns and meaningful distinctions emerged.

In Experiment 1, a two-week high-flavonoid diet led to clear improvements in mood, particularly reduced depressive symptoms and increased positive affect. These effects were most pronounced in participants with poorer baseline mood symptoms, aligning with and extending previous findings by Velichkov et al. (2024), and suggesting that flavonoids may confer particular benefits for individuals at heightened risk of postpartum mental health disorders. Experiment 2 extended the intervention to 30-days starting 0-4 days postpartum and introduced objective cognitive and cardiovascular measures. While mood outcomes did not significantly differ between groups, likely due to slightly better mood at baseline compared to Experiment 1 and Barfoot et al. (2021), the flavonoid group showed improved executive function under high cognitive load and greater reductions in blood pressure, particularly among those with better sleep or low baseline flavonoid intake. This indicates a potential shift in beneficial flavonoid effects from mood to cognitive and vascular domains when baseline mood symptoms are minimal. Such effects may be particularly valuable in the postpartum period where diets are often suboptimal (Shah et al., 2010) and where a general decline in dietary quality is observed over the first six months (Lebrun et al., 2019), suggesting that even the simple addition of one or two flavonoid-rich foods could help support these outcomes in mothers not meeting adequate nutritional intake. In contrast, Experiment 3 investigated the acute effects of a single dose of an anthocyanin-rich wild blueberry drink in parents during the 0-6 month postpartum period. Two hours after consumption, participants showed improvements in verbal and working memory. These effects were more prominent in fathers and were not accompanied by consistent mood changes. In fact, no mood benefits were observed, suggesting that acute dosing may not be sufficient to influence affect in this population. This builds on previous literature demonstrating the acute cognitive benefits of WBB, while extending these findings to an at-risk postpartum population who may particularly benefit from

acute supplementation. In such contexts, where parents are experiencing heightened stress, disrupted sleep, or suboptimal diet, and where longer-term interventions may not be immediately practical, flavonoid interventions capable of enhancing mood over a short time frame in areas such as verbal and working memory may help parents manage daily tasks more effectively, support decision-making under fatigue, and maintain mental clarity during the demanding early months of parenthood.

Differences in the types of flavonoid-rich foods consumed between Experiments 1 and 2 could partly explain the contrasting effects observed. As highlighted in the systematic review, it may be that anthocyanin-rich foods elicit more optimal effects for mood. However, while acute anthocyanin-rich interventions remain a healthy dietary choice, they may not have strong efficacy for improving mood in this population, as no mood effects were observed in Experiment 3.This underscores the importance of study duration, where chronic trials may be more effective in eliciting meaningful changes in mood outcomes in this at-risk population. Such results may be due to specific chronic mechanisms of action, such as changes in cerebral blood flow and neuronal changes, which may result in more persistent changes in mood during sensitive periods. Despite the lack of mood effects, cognitive improvements were observed following both 30-day consumption of flavonoid-rich foods and a single acute dose. This suggests that cognition may be particularly sensitive to changes in flavonoid intake in postpartum parents, with detectable benefits emerging even within a two-hour window.

Together, the findings indicate that flavonoid effects are multifaceted and context dependent. Mood improvements appeared more likely with chronic supplementation and when baseline symptoms were elevated (Experiments 1 and 2), whereas cognitive enhancements could occur acutely, as shown in Experiment 3. These outcomes underscore the importance of tailoring intervention strategies to the specific needs and contexts of the target population. Additionally, while improvements in blood pressure were observed with chronic supplementation, such effects were not reliably seen following acute dosing. This highlights a need for further investigation into the underlying mechanisms of action, including vascular, neuroplasticity and monoamine oxidase pathways, particularly within the context of postpartum physiology.

Importantly, this thesis presents the first known set of studies to investigate the effects of flavonoid supplementation, both acute and chronic, on cognitive function and mood in new parents. While previous research has demonstrated the cognitive and mood enhancing potential of flavonoids in other populations, few studies to date have focused specifically on individuals in the postpartum period a time characterised by significant physiological, emotional, and neurological change. By targeting this unique group, the thesis contributes novel insights into the potential for flavonoids to support parental functioning and wellbeing. The findings also extend the literature by demonstrating both acute and chronic effects across multiple cognitive domains, including verbal and working memory, which are areas of the brain known to undergo structural and functional changes during the perinatal period (Chapter 3.2). Collectively, these studies provide a novel contribution to the evidence of how nutritional strategies can support cognitive and emotional health in new parents, and lay important groundwork for future research. Specifically, these findings may have important real world implications. Nutritional interventions using flavonoid-rich foods could offer an accessible, non-stigmatising strategy to support emotional and cognitive wellbeing during the postpartum period. This has potential benefits not only for the individuals, but also for families and wider support networks, given the wider impact of parental mental health on the family system and infant development. Such evidence could be translated into dietary guidance offered by healthcare professionals, integrated into postnatal care pathways, or used to inform public health messaging around maternal nutrition.

## 7.3. Limitations of the work

### 7.3.1. Attrition and engagement

One of the most significant limitations of this thesis relates to the low engagement and high attrition among fathers, which limited the robustness and generalisability of findings for this group. In Experiment 1, data from fathers were ultimately excluded due to poor adherence to the intervention protocol and minimal engagement with study materials. This was a disappointing outcome, given the original aim to assess whether flavonoid supplementation could benefit mood outcomes in both

mothers and fathers during the postpartum period. The underrepresentation of fathers in this study echoes broader challenges in the literature, where paternal engagement in psychological and nutritional research remains limited (Mitchell et al., 2007).

Although efforts were made to improve father participation including partner-based recruitment, flexible online testing, and reminders, retention remained low. As shown in Experiment 1, attrition and engagement among fathers far exceeded that of mothers, suggesting differences in motivation or perceived relevance of the study. As discussed in Chapter 4.4 one potential explanation relates to socioeconomic status, where the fathers' sample reported a slightly lower average household income than the UK national average and compared to the mothers' sample. Research shows that lower socioeconomic status is associated with lower research engagement (Unger et al., 2013), which may have partially contributed to these patterns. Additionally, only a minority of fathers had a partner also taking part in the study. Without this shared motivation or social reinforcement, individual engagement may have been more difficult to sustain.

Another key challenge is the method of recruitment itself, where advertisements aimed more broadly at "parents" tend to skew heavily toward maternal participation. Yaremych and Persky (2002) found that 79% of participants recruited through father-specific advertisements were male, compared to only 14% recruited through gender neutral "parent" advertisements. This was taken into account in Experiment 3, however recruitment still presented a significant barrier. Therefore, future studies are needed to explore this mechanism further, in an effort to explore how to better engage fathers in research more generally. In the meantime, studies seeking to engage fathers should develop tailored recruitment strategies that appeal directly to male caregivers, with attention to language, design, and study relevance.

Experiment 3 did include a small sample of fathers, allowing for preliminary analysis of acute cognitive effects following flavonoid supplementation. A strength of this experiment was the ability to ensure intervention consumption, which was deemed particularly important for fathers, where engagement and compliance had previously been low, such as in Experiment 1. In this case, the intervention was administered by the researcher, reducing perceived effort and likely improving adherence. Therefore, this hands on approach may represent a more effective method of engaging with this demographic. However, the limited sample size constrained statistical power and therefore replication is needed. Nonetheless, mean scores were broadly comparable to those of the mothers, who, in addition to being part of a larger sample, demonstrated greater engagement and adherence across Experiments 1 and 2. Although some cognitive improvements were observed in fathers' following WBB consumption and not replicated with placebo, these effects should be interpreted with caution. Notably, certain improvements in the fathers' group were not mirrored in the mothers' cohort, despite a larger sample size in the latter. This discrepancy raises the possibility that the observed findings in fathers could reflect sampling variability rather than true intervention effects. Replication in a larger, more representative cohort of fathers is therefore essential to determine the validity and generalisability of these initial results.

Interestingly, baseline data suggested that fathers reported significantly higher PRMQ scores than mothers, indicating greater perceived cognitive difficulties. This may reflect the challenges of navigating return to work, managing new childcare responsibilities, and the strain of disrupted sleep, all of which can impact cognitive function. These factors could also contribute to reduced capacity or willingness to engage in research. Understanding these barriers is critical, particularly given the growing recognition of paternal postnatal depression and its effects on family wellbeing (Fisher et al., 2016; Maleki et al., 2018). Taken together, these limitations highlight a clear need for research that not only investigates the mental health and cognitive functioning of fathers in the postnatal period, but also actively addresses the barriers to their participation.

### 7.3.2 Cognitive tasks

Another important limitation concerns the interpretation of the cognitive findings. While the tasks used in this thesis targeted specific cognitive domains such as memory, attention, and learning they represent controlled, laboratory based measures that may not fully capture real-world or clinically

meaningful cognitive functioning. Performance on individual cognitive tasks is often influenced by factors such as task novelty, motivation, and testing environment, and may not reflect broader, day-to-day cognitive abilities or functional outcomes relevant to parenting, work, or emotional regulation. It could therefore be interesting to investigate these effects in an ecologically valid way, to capture parental specific cognition following flavonoid intervention. For example, using parental and baby specific nouns in the RAVLT, or adding infant crying noise into the MANT to replicate previous trials from Barfoot et al. (2019), who implemented playground noises in the background of MANT trials with 7-10 year old participants. Furthermore, considering the maternal 'rewiring' occurring in the postpartum, it would be worth investigating cognitive tasks that are more reflective for the mother, such as social and emotional cognitive processing. Therefore, while improvements observed on these tasks suggest potential cognitive benefits of flavonoid supplementation, caution is warranted when generalising these results to real-world cognitive functioning

Furthermore, testing location can influence study outcomes, particularly due to differences in environment. In Experiment 3, comparing home and lab testing showed no significant differences in mood or cognitive measures, suggesting that remote assessment can be reliable under suitable conditions. Experiment 2, by contrast, involved only home testing. Prior work (Meyer et al., 2024) indicates that at-home testing may introduce distractions that could reduce observed effects compared to more controlled lab environments. However, more research is needed to fully understand how testing location impacts cognitive and mood outcomes, especially in the context of flavonoid interventions. Another factor to consider is that the necessity of home testing in these experiments required using the Gorilla platform for the cognitive battery, a web-based tool optimised for remote administration. This contrasts with many previous flavonoid cognition studies that used E-Prime, a locally run laboratory software. E-Prime offers precise timing and response recording by running on dedicated PCs within controlled environments. In comparison, Gorilla's timing accuracy can be influenced by personal devices, internet speed, and browser variability, which may introduce some noise, particularly affecting reaction time data. Despite these limitations, Gorilla has been validated for a wide range of cognitive tasks (Anwyl-Irvine et al., 2020) and provides practical advantages for remote testing, making it well suited for the experimental trials in this thesis. Overall, while home testing and web-based platforms may add some variability, these factors appear manageable and do not undermine the validity of the findings presented here.

### 7.3.3 Improvements in diet

The improvement in diet observed within the control group in Experiment 1 represents another limitation. While the extent of this change was relatively modest, it nonetheless introduces the possibility that observed effects may have been partially influenced by broader lifestyle or dietary changes, rather than the intervention alone. Similar improvements were also evident in Experiment 2, suggesting that participants across both groups may have made general positive changes to their diet during the study period, potentially influenced by their engagement with the research process itself.

Importantly, despite the intended manipulation of flavonoid intake through the intervention in Experiment 2, no significant differences in total flavonoid intake were detected between the control and intervention groups, as reported by participants 24-hour dietary recalls. This finding complicates the interpretation of the results, as improvements in mood and cognitive outcomes cannot be confidently attributed solely to increased flavonoid consumption. It is possible that participants substituted their usual sources of dietary flavonoids with the foods and drinks provided as part of the intervention, rather than adding these to their habitual intake. Such substitution effects could have masked any true increases in total flavonoid intake, leading to an underestimation of the intervention's impact. Alternatively, the behavioural and psychological benefits observed may have been influenced by other aspects of study participation, for example, increased dietary awareness, improved self-monitoring, or general lifestyle modifications associated with taking part in a structured intervention. These factors could have contributed to the improvements observed across both groups.

Interestingly, compliance with the 24-hour dietary recalls in Experiment 2 was low (overall 62%) and declined over the intervention period. As these recalls were administered on only three occasions during the 4-week study, their sensitivity to detect subtle but meaningful dietary changes was limited.

Although this approach was designed to minimise participant burden during the postnatal period, it likely reduced the reliability of these data as a measure of habitual intake. Consequently, the limited frequency and low level of compliance mean that these dietary data cannot be relied upon to confirm that the observed effects were unrelated to flavonoid exposure. Further research with more comprehensive and consistent dietary monitoring is therefore required to clarify the relationship between flavonoid intake and the outcomes observed.

Overall, given these limitations, the absence of significant group differences in flavonoid intake suggests that the observed improvements in cognitive and mood outcomes may not have been driven solely by changes in flavonoid consumption. Future research would benefit from incorporating more objective or continuous dietary tracking methods, such as photo-based food logging or biomarker analyses to enhance accuracy and compliance. Such approaches would provide a more robust basis for determining whether the psychological and cognitive benefits observed are directly attributable to increased flavonoid intake or are instead influenced by broader lifestyle factors.

### 7.4. Future work

Future research ought to first, understand and address the barriers to father participation, and second, assessing the specific impact of flavonoids on paternal wellbeing. These insights could then inform targeted recruitment strategies, for example, designing father-specific outreach materials, tailoring language and framing. Once more robust engagement occurs, flavonoid interventions can be tested in larger paternal cohorts. Although preliminary findings from Experiment 3 hinted at possible benefits unique to fathers, these results require replication with adequate statistical power.

Future research should continue to refine and validate food intake measures, particularly those targeting polyphenol-rich foods. This is an active area of development, with recent progress in polyphenol-specific food frequency questionnaires (Li et al., 2024). However, a key limitation is the time burden these detailed questionnaires place on participants particularly in the postpartum period, where time and cognitive resources are limited. In Experiment 2, 24-hour food frequency questionnaires were employed to reduce burden, but this led to reduced compliance in the later postpartum weeks. Therefore, future research should prioritise the development of concise, targeted, and user friendly dietary assessment tools that balance accuracy with participant feasibility, especially in sensitive populations such as new parents.

A promising area for future research lies in the exploration of dietary diversity within flavonoid interventions, particularly in relation to the gut–brain axis (Chapter 1.7.2). In Experiment 2, many participants selected a limited range of foods, notably orange juice, as their primary source of flavonoids. However, evidence suggests that diversity in plant-based and flavonoid-rich food consumption may be a critical factor in driving beneficial health outcomes, including those related to cognition and mood (Ye et al., 2013; Del Bo et al., 2021; Parmenter et al., 2025). While the current studies did not assess adherence to broader dietary patterns such as the Mediterranean diet, general diet quality and flavonoid intake at baseline were considered. Given this, future studies could examine whether parents with higher adherence to healthy dietary patterns, alongside greater diversity in flavonoid-rich food consumption experience enhanced benefits in mood and cognitive outcomes. Moreover, integrating measures of gut microbiota composition and metabolites into such interventions could provide mechanistic insights into how diet and dietary diversity drives psychological and neurological outcomes.

In addition, future research could investigate the presence and role of flavonoids in breastmilk. Flavonoids have been detected in breastmilk following maternal dietary interventions (Codoñer-Franch et al., 2013; Jochum et al., 2017), yet it remains unclear whether these compounds can be transferred in physiologically meaningful amounts to the infant, where they may also confer health benefits. Supporting this possibility, maternal flavonoid-rich diets have been associated with detectable flavonoid levels in infant plasma and urine (Romaszko et al., 2014; Xu et al., 2019). Examining the relationship between maternal flavonoid intake, breastmilk composition, and infant health outcomes could therefore provide valuable insights into intergenerational pathways linking diet, cognition, and mood.

Baseline flavonoid intake emerged as a significant covariate across several models in Experiments 2 and 3. Further analysis showed that participants with lower baseline flavonoid consumption who received the intervention in Experiment 2 demonstrated significantly better accuracy in the executive function task and fewer subjective cognitive impairments. Further, as discussed in Sections 1.4.1, 1.4.2, and Chapter 2, individuals with poorer baseline mood or clinical symptoms may be more responsive to dietary interventions. Although mood at baseline in Experiment 2 was generally better than in Experiments 1, 3, and Barfoot et al. (2021), none represented a particularly low mood cohort. Future research could thus focus on flavonoid-rich interventions for parents with clinically low mood, low baseline flavonoid intake, or generally poorer diets, as these groups may have greater potential for improvement. Mechanisms of action specific to the postpartum population remain unexplored. While monoamine oxidase activity is known to peak in the initial days postpartum (Sacher et al., 2010; Tosto et al., 2023), it is unclear how it interacts with flavonoids during this time. Studies such as Dowlati et al. (2017) indicate that blueberry flavonoids may inhibit MOA activity in the initial days postpartum, this was in combination with tryptophan and tyrosine, therefore it is unknown whether an isolated flavonoid-rich food may replicate these mechanisms which may have mood promoting effects. Additionally, the postpartum involves significant structural and functional brain changes, particularly changes in hippocampal grey matter as shown by Hoekzema et al. (2017), which align with memory deficits observed during this period (Glynn, 2010; Silber et al., 1990; see Chapter 3.2). Experiment 2 demonstrated that flavonoid intake modulated blood pressure, suggesting that improvements in blood flow, a key mechanism of flavonoids detailed in Chapter 1.7.4, may contribute to mood and cognitive benefits postpartum. Given the unique vascular and neurochemical changes occurring postpartum, investigating flavonoid effects on cerebral blood flow within this population could provide valuable insights and complement existing postnatal research on mood and cognition. Future studies should prioritise these mechanisms alongside exploring broader flavonoid pathways promoting mental health and cognitive function.

Another important area for future research is the inclusion of non-pregnant control groups, particularly when investigating cognitive outcomes in the postpartum period. It is debated whether cognitive functioning is significantly impaired during the postpartum, with some studies suggesting discrepancies between subjective reports of cognitive difficulties and objective performance (Orchard et al., 2023). In this thesis, improvements in executive function, working memory, and verbal memory were observed across two experimental trials, suggesting that flavonoid interventions may confer cognitive benefits during this period. However, without a non-pregnant comparison group, it is difficult to determine whether these benefits observed following flavonoid supplementation are unique to the postpartum population specifically, or they mirror the effects we see in healthy adult populations (Cheng et al., 2023). Including non-pregnant controls in future studies would help clarify whether the cognitive changes observed are unique to the postpartum population, and whether flavonoids offer specific support to individuals navigating the cognitive demands of new parenthood.

Finally, it was unsurprising to see the role of sleep being a significant covariate to outcomes in Experiments 2 and 3, however a limitation of measuring sleep in the postpartum is the lack of appropriate measures. The PSQI was utilised as a valid and reliable measure of sleep during both pregnancy and postpartum, making it an appropriate measure to capture this risk factor over the timeframes of the experiments. However, the PSQI does not account for specific sleep disturbances commonly experienced by mothers during this period, such as waking during the night to care for a newborn or discomfort related to pregnancy and postpartum recovery. A purpose-built, well-validated, and reliable sleep questionnaire tailored to the perinatal period is therefore essential to more accurately capture maternal sleep patterns and better understand their influence on mood and cognitive outcomes.

## 7.5. Conclusions

This thesis provides novel insights into the role of dietary flavonoids in supporting mood and cognitive function during the postpartum period. The findings suggest that mood outcomes may be more sensitive to the timing and duration of the intervention, as highlighted in both the systematic review and experimental studies. In contrast, cognitive benefits were observed following an acute and

chronic dose of flavonoids, from 0-4 days postpartum, extending to 6-months. These findings point to a potential window where cognition in new parents may be particularly sensitive to a dietary flavonoid intervention. A significant barrier identified in this research was the limited engagement of fathers, which restricted the generalisability of findings to this group. Nonetheless, preliminary results suggest that fathers may uniquely benefit from such interventions, underscoring the need for future research that focuses on improving paternal recruitment and retention. Importantly, this thesis is the first to evaluate the effects of flavonoid supplementation on mood and cognitive outcomes across the postpartum period. It builds upon prior work, extending the understanding of whether and when such interventions can provide meaningful clinical and practical benefits. While more research is needed with the most appropriate intervention duration for this particular sample, as well as exploring postpartum specific mechanisms of action and appropriate comparison groups, these findings offer a promising foundation.

References


Abd El Mohsen, M. M., Kuhnle, G., Rechner, A. R., Schroeter, H., Rose, S., Jenner, P., & Rice-Evans, C. A. (2002). Uptake and metabolism of epicatechin and its access to the brain after oral ingestion. *Free Radical Biology and Medicine*, *33*(12), 1693-1702.

Abdelhalim, A. R. (2021). The effect of Mentha piperita L. on the mental health issues of university students: A pilot study. *J. Pharm. Pharmacogn. Res*, *9*, 49-57.

Abou-Saleh, M. T., Ghubash, R., Karim, L., Krymski, M., & Bhai, I. (1998). Hormonal aspects of postpartum depression. *Psychoneuroendocrinology*, *23*(5), 465-475.

Achour, M., Ben Salem, I., Ferdousi, F., Nouira, M., Ben Fredj, M., Mtiraoui, A., Isoda, H., & Saguem, S. (2022). Rosemary tea consumption alters peripheral anxiety and depression biomarkers: a pilot study in limited healthy volunteers. *Journal of the American Nutrition Association*, *41*(3), 240-249.

Ahles, S., Joris, P. J., & Plat, J. (2021). Effects of Berry Anthocyanins on Cognitive Performance, Vascular Function and Cardiometabolic Risk Markers: A Systematic Review of Randomized Placebo-Controlled Intervention Studies in Humans. *International Journal of Molecular Sciences*, *22*(12), 6482. https://www.mdpi.com/1422-0067/22/12/6482

Ahmadpour, P., Faroughi, F., & Mirghafourvand, M. (2023). The relationship of childbirth experience with postpartum depression and anxiety: a cross-sectional study. *BMC Psychology*, *11*(1), 58. https://doi.org/10.1186/s40359-023-01105-6

Alder, E. M., & Cox, J. L. (1983). Breast feeding and post-natal depression. *Journal of Psychosomatic Research*, *27*(2), 139-144.

Alexander, J. K., Hillier, A., Smith, R. M., Tivarus, M. E., & Beversdorf, D. Q. (2007). Beta-adrenergic Modulation of Cognitive Flexibility during Stress. *Journal of Cognitive Neuroscience*, *19*(3), 468-478. https://doi.org/10.1162/jocn.2007.19.3.468

Alharbi, M. H., Lamport, D. J., Dodd, G. F., Saunders, C., Harkness, L., Butler, L. T., & Spencer, J. P. (2016). Flavonoid-rich orange juice is associated with acute improvements in cognitive function in healthy middle-aged males. *Eur J Nutr*, *55*(6), 2021-2029. https://doi.org/10.1007/s00394-015-1016-9

Ali, E. (2018). Women's experiences with postpartum anxiety disorders: a narrative literature review. *International Journal of Women's Health*, *10*(null), 237-249. https://doi.org/10.2147/IJWH.S158621

Ali, S., Corbi, G., Maes, M., Scapagnini, G., & Davinelli, S. (2021). Exploring the impact of flavonoids on symptoms of depression: A systematic review and meta-analysis. *Antioxidants*, *10*(11), 1644.

Aliev, G., Palacios, H. H., Lipsitt, A. E., Fischbach, K., Lamb, B. T., Obrenovich, M. E., Morales, L., Gasimov, E., & Bragin, V. (2009). Nitric oxide as an initiator of brain lesions during the development of Alzheimer disease. *Neurotoxicity research*, *16*, 293-305.

Almanza-Sepulveda, M. L., Chico, E., Gonzalez, A., Hall, G. B., Steiner, M., & Fleming, A. S. (2018). Executive function in teen and adult women: Association with maternal status and early adversity. *Developmental Psychobiology*, *60*(7), 849-861. https://doi.org/https://doi.org/10.1002/dev.21766

American Psychiatric Association, D., & Association, A. P. . (2013). Diagnostic and statistical manual of mental disorders: DSM-5 (Vol. 5). . *American psychiatric association Washington, DC.* .

Aminoff, E. M., Kveraga, K., & Bar, M. (2013). The role of the parahippocampal cortex in cognition. *Trends in Cognitive Sciences*, *17*(8), 379-390.

Ammar, A., Trabelsi, K., Boukhris, O., Bouaziz, B., Mueller, P., M Glenn, J., Bott, N. T., Mueller, N., Chtourou, H., & Driss, T. (2020). Effects of polyphenol-rich interventions on cognition and brain health in healthy young and middle-aged adults: systematic review and meta-analysis. *Journal of Clinical Medicine*, *9*(5), 1598.

Anderson, & Rutherford. (2012). Cognitive reorganization during pregnancy and the postpartum period: an evolutionary perspective. *Evolutionary Psychology*, *10*(4), 147470491201000402.

Ansari, N. S., Shah, J., Dennis, C.-L., & Shah, P. S. (2021). Risk factors for postpartum depressive symptoms among fathers: A systematic review and meta-analysis. *Acta Obstetricia et Gynecologica Scandinavica*, *100*(7), 1186-1199. https://doi.org/https://doi.org/10.1111/aogs.14109

Anwyl-Irvine, A. L., Massonnié, J., Flitton, A., Kirkham, N., & Evershed, J. K. (2020). Gorilla in our midst: An online behavioral experiment builder. *Behavior Research Methods*, *52*(1), 388-407.

Areias, M., Kumar, R., Barros, H., & Figueiredo, E. (1996). Correlates of postnatal depression in mothers and fathers. *The British Journal of Psychiatry*, *169*(1), 36-41.

Bannbers, E., Gingnell, M., Engman, J., Morell, A., Sylvén, S., Skalkidou, A., Kask, K., Bäckström, T., Wikström, J., & Poromaa, I. S. (2013). Prefrontal activity during response inhibition decreases over time in the postpartum period. *Behavioural Brain Research*, *241*, 132-138. https://doi.org/https://doi.org/10.1016/j.bbr.2012.12.003

Barba-Müller, E., Craddock, S., Carmona, S., & Hoekzema, E. (2019). Brain plasticity in pregnancy and the postpartum period: links to maternal caregiving and mental health. *Archives of women's mental health*, *22*(2), 289-299. https://doi.org/10.1007/s00737-018-0889-z

Barfoot, Istas, G., Feliciano, R. P., Lamport, D. J., Riddell, P., Rodriguez-Mateos, A., & Williams, C. M. (2021). Effects of daily consumption of wild blueberry on cognition and urinary metabolites in school-aged children: a pilot study. *European journal of nutrition*, *60*(8), 4263-4278. https://doi.org/10.1007/s00394-021-02588-y

Barfoot, May, Lamport, Ricketts, Riddell, & Williams. (2019). The effects of acute wild blueberry supplementation on the cognition of 7–10-year-old schoolchildren. *European journal of nutrition*, *58*(7), 2911-2920. https://doi.org/10.1007/s00394-018-1843-6

Barfoot., Forster, & Lamport. (2021). Mental Health in New Mothers: A Randomised Controlled Study into the Effects of Dietary Flavonoids on Mood and Perceived Quality of Life. *Nutrients*, *13*(7). https://doi.org/10.3390/nu13072383

Barha, C. K., & Galea, L. A. (2017). The maternal'baby brain'revisited. *Nature neuroscience*, *20*(2), 134-135.

Barha, C. K., & Galea, L. A. M. (2010). Influence of different estrogens on neuroplasticity and cognition in the hippocampus. *Biochimica et Biophysica Acta (BBA) - General Subjects*, *1800*(10), 1056-1067. https://doi.org/https://doi.org/10.1016/j.bbagen.2010.01.006

Barker, D. J. P. (2004). The developmental origins of adult disease. *Journal of the American College of Nutrition*, *23*(sup6), 588S-595S.

Baskin, R., Hill, B., Jacka, F. N., O'Neil, A., & Skouteris, H. (2015). The association between diet quality and mental health during the perinatal period. A systematic review. *Appetite*, *91*, 41-47. https://doi.org/https://doi.org/10.1016/j.appet.2015.03.017

Bauer, S. R., Ding, E. L., & Smit, L. A. (2011). Cocoa Consumption, Cocoa Flavonoids, and Effects on Cardiovascular Risk Factors: An Evidence-Based Review. *Current Cardiovascular Risk Reports*, *5*(2), 120-127. https://doi.org/10.1007/s12170-011-0157-5

Baynham, R., Veldhuijzen van Zanten, J. J., Johns, P. W., Pham, Q. S., & Rendeiro, C. (2021). Cocoa flavanols improve vascular responses to acute mental stress in young healthy adults. *Nutrients*, *13*(4), 1103.

Beck, C. T. (1991). Maternity blues research: A critical review. *Issues in mental health nursing*, *12*(3), 291-300.

Bei, B., Coo, S., & Trinder, J. (2015). Sleep and mood during pregnancy and the postpartum period. *Sleep Medicine Clinics*, *10*(1), 25-33.

Beking, K., & Vieira, A. (2011). An assessment of dietary flavonoid intake in the UK and Ireland. *International Journal of Food Sciences and Nutrition*, *62*(1), 17-19. https://doi.org/10.3109/09637486.2010.511165

Bekinschtein, P., Cammarota, M., Igaz, L. M., Bevilaqua, L. R., Izquierdo, I., & Medina, J. H. (2007). Persistence of long-term memory storage requires a late protein synthesis- and BDNF- dependent phase in the hippocampus. *Neuron*, *53*(2), 261-277. https://doi.org/10.1016/j.neuron.2006.11.025

Bell, A. F., & Andersson, E. (2016). The birth experience and women's postnatal depression: a systematic review. *Midwifery*, *39*, 112-123.

Bell, L., Lamport, D. J., Butler, L. T., & Williams, C. M. (2015). A review of the cognitive effects observed in humans following acute supplementation with flavonoids, and their associated mechanisms of action. *Nutrients*, *7*(12), 10290-10306.

Bell, L., & Williams, C. M. (2019). A pilot dose–response study of the acute effects of haskap berry extract (Lonicera caerulea L.) on cognition, mood, and blood pressure in older adults. *European journal of nutrition*, *58*(8), 3325-3334. https://doi.org/10.1007/s00394-018-1877-9

Bennett, H. A., Einarson, A., Taddio, A., Koren, G., & Einarson, T. R. (2004). Prevalence of depression during pregnancy: systematic review. *Obstetrics & Gynecology*, *103*(4), 698-709.

Best, J. R., & Miller, P. H. (2010). A developmental perspective on executive function. *Child development*, *81*(6), 1641-1660.

Bhagwat, S., & Haytowitz, D. B. (2023). USDA Database for the Flavonoid Content of Selected Foods, Release 3.3 (March 2018). In: Nutrient Data Laboratory, Beltsville Human Nutrition Research Center, ARS, USDA.

Bingham, S. A., Gill, C., Welch, A., Cassidy, A., Runswick, S. A., Oakes, S., Lubin, R., Thurnham, D. I., Key, T. J., Roe, L., Khaw, K. T., & Day, N. E. (1997). Validation of dietary assessment methods in the UK arm of EPIC using weighed records, and 24-hour urinary nitrogen and potassium and serum vitamin C and carotenoids as biomarkers. *International journal of epidemiology*, *26 Suppl 1*, S137–S151. https://doi.org/10.1093/ije/26.suppl_1.s137

Blakemore, S.-J., & Choudhury, S. (2006). Development of the adolescent brain: implications for executive function and social cognition. *Journal of Child Psychology and Psychiatry*, *47*(3-4), 296-312. https://doi.org/https://doi.org/10.1111/j.1469-7610.2006.01611.x

Boespflug, E. L., Eliassen, J. C., Dudley, J. A., Shidler, M. D., Kalt, W., Summer, S. S., Stein, A. L., Stover, A. N., & Krikorian, R. (2018). Enhanced neural activation with blueberry supplementation in mild cognitive impairment. *Nutritional neuroscience*, *21*(4), 297-305.

Boisgueheneuc, F. d., Levy, R., Volle, E., Seassau, M., Duffau, H., Kinkingnehun, S., Samson, Y., Zhang, S., & Dubois, B. (2006). Functions of the left superior frontal gyrus in humans: a lesion study. *Brain*, *129*(12), 3315-3328.

Bondonno, C. P., Downey, L. A., Croft, K. D., Scholey, A., Stough, C., Yang, X., Considine, M. J., Ward, N. C., Puddey, I. B., & Swinny, E. (2014). The acute effect of flavonoid-

rich apples and nitrate-rich spinach on cognitive performance and mood in healthy men and women. *Food & function*, *5*(5), 849-858.
Bondonno, N. P., Bondonno, C. P., Blekkenhorst, L. C., Considine, M. J., Maghzal, G., Stocker, R., Woodman, R. J., Ward, N. C., Hodgson, J. M., & Croft, K. D. (2018). Flavonoid-Rich Apple Improves Endothelial Function in Individuals at Risk for Cardiovascular Disease: A Randomized Controlled Clinical Trial. *Molecular Nutrition & Food Research*, *62*(3), 1700674. https://doi.org/https://doi.org/10.1002/mnfr.201700674
Bondonno, N. P., Bondonno, C. P., Ward, N. C., Hodgson, J. M., & Croft, K. D. (2017). The cardiovascular health benefits of apples: Whole fruit vs. isolated compounds. *Trends in Food Science & Technology*, *69*, 243-256. https://doi.org/https://doi.org/10.1016/j.tifs.2017.04.012
Bondonno, N. P., Liu, Y. L., Zheng, Y., Ivey, K., Willett, W. C., Stampfer, M. J., Rimm, E. B., & Cassidy, A. (2023). Change in habitual intakes of flavonoid-rich foods and mortality in US males and females. *BMC Medicine*, *21*(1), 181.
Bonnar, J., Franklin, M., Nott, P., & McNeilly, A. S. (1975). Effect of breast-feeding on pituitary-ovarian function after childbirth. *Br Med J*, *4*(5988), 82-84.
Boolani, A., Lindheimer, J. B., Loy, B. D., Crozier, S., & O'Connor, P. J. (2017). Acute effects of brewed cocoa consumption on attention, motivation to perform cognitive work and feelings of anxiety, energy and fatigue: a randomized, placebo-controlled crossover experiment. *BMC Nutrition*, *3*, 1-11.
Bowtell, J. L., Aboo-Bakkar, Z., Conway, M. E., Adlam, A.-L. R., & Fulford, J. (2017). Enhanced task-related brain activation and resting perfusion in healthy older adults after chronic blueberry supplementation. *Applied Physiology, Nutrition, and Metabolism*, *42*(7), 773-779. https://doi.org/10.1139/apnm-2016-0550
Bramham, K., Nelson-Piercy, C., Brown, M. J., & Chappell, L. C. (2013). Postpartum management of hypertension. *Bmj*, *346*.
Breitkopf, C. R., Primeau, L. A., Levine, R. E., Olson, G. L., Wu, Z. H., & Berenson, A. B. (2006). Anxiety symptoms during pregnancy and postpartum. *Journal of Psychosomatic Obstetrics & Gynecology*, *27*(3), 157-162. https://doi.org/10.1080/01674820500523521
Brickman, A. M., Khan, U. A., Provenzano, F. A., Yeung, L.-K., Suzuki, W., Schroeter, H., Wall, M., Sloan, R. P., & Small, S. A. (2014). Enhancing dentate gyrus function with dietary flavanols improves cognition in older adults. *Nature neuroscience*, *17*(12), 1798-1803. https://doi.org/10.1038/nn.3850
Britton, J. R. (2011). Infant temperament and maternal anxiety and depressed mood in the early postpartum period. *Women & health*, *51*(1), 55-71.
Buckwalter, Stanczyk, F. Z., McCleary, C. A., Bluestein, B. W., Buckwalter, D. K., Rankin, K. P., Chang, L., & Goodwin, T. M. (1999). Pregnancy, the postpartum, and steroid hormones: effects on cognition and mood. *Psychoneuroendocrinology*, *24*(1), 69-84.
Buttner, M. M., Brock, R. L., & O'Hara, M. W. (2015). Patterns of women′s mood after delivery: A growth curve analysis. *Journal of Affective Disorders*, *174*, 201-208. https://doi.org/https://doi.org/10.1016/j.jad.2014.11.022
Buysse, D. J., Reynolds III, C. F., Monk, T. H., Berman, S. R., & Kupfer, D. J. (1989). The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry research*, *28*(2), 193-213.
Caffieri, A., Gómez-Gómez, I., Barquero-Jimenez, C., De-Juan-Iglesias, P., Margherita, G., & Motrico, E. (2024). Global prevalence of perinatal depression and anxiety during the COVID-19 pandemic: An umbrella review and meta-analytic synthesis.

*Acta Obstetricia et Gynecologica Scandinavica*, *103*(2), 210-224. https://doi.org/https://doi.org/10.1111/aogs.14740

Calderon-Garciduenas, L., Mora-Tiscareño, A., Franco-Lira, M., Cross, J. V., Engle, R., Gómez-Garza, G., Jewells, V., Weili, L., Medina-Cortina, H., Solorio, E., Chao, C.-k., Zhu, H., Mukherjee, P. S., Ferreira-Azevedo, L., Torres-Jardón, R., & D'Angiulli, A. (2013). Flavonol-rich dark cocoa significantly decreases plasma endothelin-1 and improves cognition in urban children [Original Research]. *Frontiers in pharmacology*, *4*. https://www.frontiersin.org/journals/pharmacology/articles/10.3389/fphar.2013.00104

Cameron, E. E., Sedov, I. D., & Tomfohr-Madsen, L. M. (2016). Prevalence of paternal depression in pregnancy and the postpartum: an updated meta-analysis. *Journal of Affective Disorders*, *206*, 189-203.

Camfield, D. A., Scholey, A., Pipingas, A., Silberstein, R., Kras, M., Nolidin, K., Wesnes, K., Pase, M., & Stough, C. (2012). Steady state visually evoked potential (SSVEP) topography changes associated with cocoa flavanol consumption. *Physiology & Behavior*, *105*(4), 948-957. https://doi.org/https://doi.org/10.1016/j.physbeh.2011.11.013

Caropreso, L., de Azevedo Cardoso, T., Eltayebani, M., & Frey, B. N. (2020). Preeclampsia as a risk factor for postpartum depression and psychosis: a systematic review and meta-analysis. *Archives of women's mental health*, *23*, 493-505.

Chang, S.-C., Cassidy, A., Willett, W. C., Rimm, E. B., O'Reilly, E. J., & Okereke, O. I. (2016). Dietary flavonoid intake and risk of incident depression in midlife and older women. *The American journal of clinical nutrition*, *104*(3), 704-714.

Chatzi, L., Melaki, V., Sarri, K., Apostolaki, I., Roumeliotaki, T., Georgiou, V., Vassilaki, M., Koutis, A., Bitsios, P., & Kogevinas, M. (2011). Dietary patterns during pregnancy and the risk of postpartum depression: the mother–child 'Rhea' cohort in Crete, Greece. *Public Health Nutrition*, *14*(9), 1663-1670. https://doi.org/10.1017/S1368980010003629

Chen, Jiang, C. Q., Zhang, W. S., Zhu, F., Jin, Y. L., Cheng, K. K., Lam, T. H., & Xu, L. (2022). Habitual tea consumption was associated with lower levels of depressive symptoms among older Chinese: Guangzhou Biobank Cohort Study. *Nutrition Research*, *103*, 59-67.

Chen, W.-l., & Zhao, J. (2023). Association between dietary anthocyanidins intake and depression among US adults: a cross-sectional study (NHANES, 2007–2010 and 2017–2018). *BMC psychiatry*, *23*(1), 525.

Chen., Li, W., Xiong, J., & Zheng, X. (2022). Prevalence and Risk Factors Associated with Postpartum Depression during the COVID-19 Pandemic: A Literature Review and Meta-Analysis. *International Journal of Environmental Research and Public Health*, *19*(4), 2219. https://www.mdpi.com/1660-4601/19/4/2219

Cheng, C.-Y., Chou, Y.-H., Chang, C.-H., & Liou, S.-R. (2021). Trends of Perinatal Stress, Anxiety, and Depression and Their Prediction on Postpartum Depression. *International Journal of Environmental Research and Public Health*, *18*(17), 9307. https://www.mdpi.com/1660-4601/18/17/9307

Cheng, N., Barfoot, K. L., Le Cozannet, R., Fança-Berthon, P., Lamport, D. J., & Williams, C. M. (2024). Wild Blueberry Extract Intervention in Healthy Older Adults: A Multi-Study, Randomised, Controlled Investigation of Acute Cognitive and Cardiovascular Effects. *Nutrients*, *16*(8), 1180. https://www.mdpi.com/2072-6643/16/8/1180

Cheng, N., Bell, L., Lamport, D. J., & Williams, C. M. (2022). Dietary Flavonoids and Human Cognition: A Meta-Analysis. *Molecular Nutrition & Food Research*, *66*(21), 2100976. https://doi.org/https://doi.org/10.1002/mnfr.202100976

Chia, A.-R., Chen, L.-W., Lai, J. S., Wong, C. H., Neelakantan, N., van Dam, R. M., & Chong, M. F.-F. (2019). Maternal Dietary Patterns and Birth Outcomes: A Systematic Review and Meta-Analysis. *Advances in Nutrition*, *10*(4), 685-695. https://doi.org/https://doi.org/10.1093/advances/nmy123

Chico, E., Gonzalez, A., Ali, N., Steiner, M., & Fleming, A. S. (2014). Executive function and mothering: Challenges faced by teenage mothers. *Developmental Psychobiology*, *56*(5), 1027-1035.

Chiochetta, M., Ferreira, E. J., Moreira, I. T. d. S., Avila, R. C. S. d., Oliveira, A. A. d., Busnello, F. M., Braganhol, E., & Barschak, A. G. (2018). Green juice in human metabolism: a randomized trial. *Journal of the American College of Nutrition*, *37*(8), 670-676.

Choi, J., Kim, J.-H., Park, M., & Lee, H.-J. (2023). Effects of Flavonoid-Rich Orange Juice Intervention on Major Depressive Disorder in Young Adults: A Randomized Controlled Trial. *Nutrients*, *15*(1), 145. https://www.mdpi.com/2072-6643/15/1/145

Chong, M. F., George, T. W., Alimbetov, D., Jin, Y., Weech, M., Macready, A. L., Spencer, J. P., Kennedy, O. B., Minihane, A.-M., & Gordon, M. H. (2013). Impact of the quantity and flavonoid content of fruits and vegetables on markers of intake in adults with an increased risk of cardiovascular disease: the FLAVURS trial. *European journal of nutrition*, *52*, 361-378.

Clare, C. A., & Yeh, J. (2012). Postpartum Depression in Special Populations: A Review. *Obstetrical & Gynecological Survey*, *67*(5), 313-323. https://doi.org/10.1097/OGX.0b013e318259cb52

Coates, A. M., Morgillo, S., Yandell, C., Scholey, A., Buckley, J. D., Dyer, K. A., & Hill, A. M. (2020). Effect of a 12-week almond-enriched diet on biomarkers of cognitive performance, mood, and cardiometabolic health in older overweight adults. *Nutrients*, *12*(4), 1180.

Codoñer-Franch, P., Hernández-Aguilar, M. T., Navarro-Ruiz, A., López-Jaén, A. B., Borja-Herrero, C., & Valls-Bellés, V. (2013). Diet supplementation during early lactation with non-alcoholic beer increases the antioxidant properties of breastmilk and decreases the oxidative damage in breastfeeding mothers. *Breastfeed Med*, *8*, 164-169. https://doi.org/10.1089/bfm.2012.0059

Colombage, R. L., Holden, S., Lamport, D. J., & Barfoot, K. L. (2024). The effects of flavonoid supplementation on the mental health of postpartum parents [Clinical Trial]. *Frontiers in Global Women's Health*, *5*. https://www.frontiersin.org/journals/global-womens-health/articles/10.3389/fgwh.2024.1345353

Conner, T. S., Brookie, K. L., Carr, A. C., Mainvil, L. A., & Vissers, M. C. (2017). Let them eat fruit! The effect of fruit and vegetable consumption on psychological well-being in young adults: A randomized controlled trial. *PLoS One*, *12*(2), e0171206.

Courtney, S. M., Petit, L., Maisog, J. M., Ungerleider, L. G., & Haxby, J. V. (1998). An area specialized for spatial working memory in human frontal cortex. *Science*, *279*(5355), 1347-1351.

Cox, J. L., Holden, J. M., & Sagovsky, R. (1987). Detection of postnatal depression: development of the 10-item Edinburgh Postnatal Depression Scale. *The British Journal of Psychiatry*, *150*(6), 782-786.

Crawford, J., Smith, G., Maylor, E., Della Sala, S., & Logie, R. (2003). The Prospective and Retrospective Memory Questionnaire (PRMQ): Normative data and latent structure in a large non-clinical sample. *Memory*, *11*(3), 261-275.

Crawford, J. R., & Smith, G. R. (1996). The Prospective and Retrospective Memory Questionnaire (PRMQ): A new measure of memory for everyday events. *Journal of*

*clinical and experimental neuropsychology*, *18*(6), 341-350. https://doi.org/https://doi.org/10.1080/13803399608402702

Crews, W. D., Harrison, D. W., Griffin, M. L., Addison, K., Yount, A. M., Giovenco, M. A., & Hazell, J. (2005). A double-blinded, placebo-controlled, randomized trial of the neuropsychologic efficacy of cranberry juice in a sample of cognitively intact older adults: pilot study findings. *Journal of Alternative & Complementary Medicine*, *11*(2), 305-309.

Cruz-Rodríguez, J., Díaz-López, A., Canals-Sans, J., & Arija, V. (2023). Maternal vitamin B12 status during pregnancy and early infant neurodevelopment: The ECLIPSES study. *Nutrients*, *15*(6), 1529.

Cuervo, M., Sayon-Orea, C., Santiago, S., & Martínez, J. A. (2014). Dietary and Health Profiles of Spanish Women in Preconception, Pregnancy and Lactation. *Nutrients*, *6*(10), 4434-4451. https://www.mdpi.com/2072-6643/6/10/4434

Cui, Birru, R. L., Snitz, B. E., Ihara, M., Kakuta, C., Lopresti, B. J., Aizenstein, H. J., Lopez, O. L., Mathis, C. A., & Miyamoto, Y. (2020). Effects of soy isoflavones on cognitive function: a systematic review and meta-analysis of randomized controlled trials. *Nutrition reviews*, *78*(2), 134-144.

Cui, Huang, C., Momma, H., Niu, K., & Nagatomi, R. (2020). Daily dietary isoflavone intake in relation to lowered risk of depressive symptoms among men. *Journal of Affective Disorders*, *261*, 121-125.

Curtis, P. J., van der Velpen, V., Berends, L., Jennings, A., Haag, L., Minihane, A.-M., Chandra, P., Kay, C. D., Rimm, E. B., & Cassidy, A. (2024). Chronic and postprandial effect of blueberries on cognitive function, alertness, and mood in participants with metabolic syndrome – results from a six-month, double-blind, randomized controlled trial. *The American journal of clinical nutrition*, *119*(3), 658-668. https://doi.org/https://doi.org/10.1016/j.ajcnut.2023.12.006

Da Costa, D., Larouche, J., Dritsa, M., & Brender, W. (2000). Psychosocial correlates of prepartum and postpartum depressed mood. *Journal of Affective Disorders*, *59*(1), 31-40.

Daneman, R., & Prat, A. (2015). The blood–brain barrier. *Cold Spring Harbor perspectives in biology*, *7*(1), a020412.

Davey, H. L., Tough, S. C., Adair, C. E., & Benzies, K. M. (2011). Risk factors for sub-clinical and major postpartum depression among a community cohort of Canadian women. *Maternal and Child Health Journal*, *15*, 866-875.

Davies, S. J., Lum, J. A., Skouteris, H., Byrne, L. K., & Hayden, M. J. (2018). Cognitive impairment during pregnancy: a meta-analysis. *Medical Journal of Australia*, *208*(1), 35-40.

Day, N., Oakes, S., Luben, R., Khaw, K., Bingham, S. a., Welch, A., & Wareham, N. (1999). EPIC-Norfolk: study design and characteristics of the cohort. European Prospective Investigation of Cancer.

De Amicis, R., Mambrini, S. P., Pellizzari, M., Foppiani, A., Bertoli, S., Battezzati, A., & Leone, A. (2022). Systematic Review on the Potential Effect of Berry Intake in the Cognitive Functions of Healthy People. *Nutrients*, *14*(14), 2977. https://www.mdpi.com/2072-6643/14/14/2977

de la Torre, R., de Sola, S., Hernandez, G., Farré, M., Pujol, J., Rodriguez, J., Espadaler, J. M., Langohr, K., Cuenca-Royo, A., Principe, A., Xicota, L., Janel, N., Catuara-Solarz, S., Sanchez-Benavides, G., Bléhaut, H., Dueñas-Espín, I., del Hoyo, L., Benejam, B., Blanco-Hinojo, L., . . . Dierssen, M. (2016). Safety and efficacy of cognitive training plus epigallocatechin-3-gallate in young adults with Down's syndrome (TESDAD): a

double-blind, randomised, placebo-controlled, phase 2 trial. *The Lancet Neurology*, *15*(8), 801-810. https://doi.org/10.1016/S1474-4422(16)30034-5
Deater-Deckard, K., Pickering, K., Dunn, J. F., Golding, J., Pregnancy, T. A. L. S. o., & Team, C. S. (1998). Family structure and depressive symptoms in men preceding and following the birth of a child. *American Journal of Psychiatry*, *155*(6), 818-823.
Del Bo, C., Bernardi, S., Cherubini, A., Porrini, M., Gargari, G., Hidalgo-Liberona, N., González-Domínguez, R., Zamora-Ros, R., Peron, G., Marino, M., Gigliotti, L., Winterbone, M. S., Kirkup, B., Kroon, P. A., Andres-Lacueva, C., Guglielmetti, S., & Riso, P. (2021). A polyphenol-rich dietary pattern improves intestinal permeability, evaluated as serum zonulin levels, in older subjects: The MaPLE randomised controlled trial. *Clinical Nutrition*, *40*(5), 3006-3018. https://doi.org/https://doi.org/10.1016/j.clnu.2020.12.014
Dennis, C.-L., & Chung-Lee, L. (2006). Postpartum Depression Help-Seeking Barriers and Maternal Treatment Preferences: A Qualitative Systematic Review. *Birth*, *33*(4), 323-331. https://doi.org/https://doi.org/10.1111/j.1523-536X.2006.00130.x
Devore, Kang, J. H., Breteler, M. M., & Grodstein, F. (2012). Dietary intakes of berries and flavonoids in relation to cognitive decline. *Ann Neurol*, *72*(1), 135-143. https://doi.org/10.1002/ana.23594
Diamond, A. (2013). Executive functions. *Annu Rev Psychol*, *64*, 135-168. https://doi.org/10.1146/annurev-psych-113011-143750
Dodd, G. F., Williams, C. M., Butler, L. T., & Spencer, J. P. E. (2019). Acute effects of flavonoid-rich blueberry on cognitive and vascular function in healthy older adults. *Nutrition and healthy aging*, *5*, 119-132. https://doi.org/10.3233/NHA-180056
Dowlati, Y., Ravindran, A. V., Segal, Z. V., Stewart, D. E., Steiner, M., & Meyer, J. H. (2017). Selective dietary supplementation in early postpartum is associated with high resilience against depressed mood. *Proceedings of the National Academy of Sciences*, *114*(13), 3509-3514.
Dreiseitel, A., Korte, G., Schreier, P., Oehme, A., Locher, S., Domani, M., Hajak, G., & Sand, P. G. (2009). Berry anthocyanins and their aglycons inhibit monoamine oxidases A and B. *Pharmacological Research*, *59*(5), 306-311.
Duffy, R., Wiseman, H., & File, S. E. (2003). Improved cognitive function in postmenopausal women after 12 weeks of consumption of a soya extract containing isoflavones. *Pharmacology Biochemistry and Behavior*, *75*(3), 721-729. https://doi.org/https://doi.org/10.1016/S0091-3057(03)00116-3
Dukic, J., & Ehlert, U. (2023). Longitudinal Course of Sex Steroids From Pregnancy to Postpartum. *Endocrinology*, *164*(8). https://doi.org/10.1210/endocr/bqad108
Dukic, J., Johann, A., Henninger, M., & Ehlert, U. (2024). Estradiol and progesterone from pregnancy to postpartum: a longitudinal latent class analysis [Original Research]. *Frontiers in Global Women's Health*, *5*. https://doi.org/10.3389/fgwh.2024.1428494
Duncan, G. J., & Magnuson, K. (2012). Socioeconomic status and cognitive functioning: moving from correlation to causation. *WIREs Cognitive Science*, *3*(3), 377-386. https://doi.org/https://doi.org/10.1002/wcs.1176
Eastwood, J., van Hemert, S., Stolaki, M., Williams, C., Walton, G., & Lamport, D. (2025). Exploring the acute and chronic effects of a multistrain probiotic supplement on cognitive function and mood in healthy older adults: a randomized controlled trial. *The American journal of clinical nutrition*, *121*(6), 1268-1280. https://doi.org/https://doi.org/10.1016/j.ajcnut.2025.04.002
Eidelman, A., Hoffmann, N. W., & Kaitz, M. (1993). Cognitive deficits in women after childbirth. *Obstetrics and gynecology*, *81*(5 (Pt 1)), 764-767.

Evans, M., Antony, J., Guthrie, N., Landes, B., & Aruoma, O. I. (2018). A randomized double-blind, placebo controlled, four-arm parallel study investigating the effect of a broad-spectrum wellness beverage on mood state in healthy, moderately stressed adults. *Journal of the American College of Nutrition*, *37*(3), 234-242.

Falah-Hassani, K., Shiri, R., & Dennis, C.-L. (2016). Prevalence and risk factors for comorbid postpartum depressive symptomatology and anxiety. *Journal of Affective Disorders*, *198*, 142-147.

Fallon, V., Halford, J. C. G., Bennett, K. M., & Harrold, J. A. (2016). The postpartum specific anxiety scale: development and preliminary validation. *Archives of women's mental health*, *19*(6), 1079-1090.

Farr, S. L., Dietz, P. M., O'Hara, M. W., Burley, K., & Ko, J. Y. (2014). Postpartum anxiety and comorbid depression in a population-based sample of women. *Journal of Women's Health*, *23*(2), 120-128.

Fernández, G., Weyerts, H., Schrader-Bölsche, M., Tendolkar, I., Smid, H. G. O. M., Tempelmann, C., Hinrichs, H., Scheich, H., Elger, C. E., Mangun, G. R., & Heinze, H.-J. (1998). Successful Verbal Encoding into Episodic Memory Engages the Posterior Hippocampus: A Parametrically Analyzed Functional Magnetic Resonance Imaging Study. *The Journal of Neuroscience*, *18*(5), 1841-1847. https://doi.org/10.1523/jneurosci.18-05-01841.1998

Field, A. (2024). *Discovering statistics using IBM SPSS statistics*. Sage publications limited.

Field, T., Hernandez-Reif, M., Diego, M., Schanberg, S., & Kuhn, C. (2006). Stability of mood states and biochemistry across pregnancy. *Infant Behavior and Development*, *29*(2), 262-267. https://doi.org/https://doi.org/10.1016/j.infbeh.2005.12.009

File, S. E., Hartley, D. E., Elsabagh, S., Duffy, R., & Wiseman, H. (2005). Cognitive improvement after 6 weeks of soy supplements in postmenopausal women is limited to frontal lobe function. *Menopause*, *12*(2), 193-201. https://journals.lww.com/menopausejournal/fulltext/2005/12020/cognitive_improvement_after_6_weeks_of_soy.14.aspx

File, S. E., Jarrett, N., Fluck, E., Duffy, R., Casey, K., & Wiseman, H. (2001). Eating soya improves human memory. *Psychopharmacology*, *157*(4), 430-436. https://doi.org/10.1007/s002130100845

Firth, J., Gangwisch, J. E., Borsini, A., Wootton, R. E., & Mayer, E. A. (2020). Food and mood: how do diet and nutrition affect mental wellbeing? *Bmj*, *369*, m2382. https://doi.org/10.1136/bmj.m2382

Fisher, N. D., Hughes, M., Gerhard-Herman, M., & Hollenberg, N. K. (2003). Flavanol-rich cocoa induces nitric-oxide-dependent vasodilation in healthy humans. *J Hypertens*, *21*(12), 2281-2286. https://doi.org/10.1097/00004872-200312000-00016

Fisher, S. D., Wisner, K. L., Clark, C. T., Sit, D. K., Luther, J. F., & Wisniewski, S. (2016). Factors associated with onset timing, symptoms, and severity of depression identified in the postpartum period. *Journal of Affective Disorders*, *203*, 111-120.

Fisk, J., Khalid, S., Reynolds, S. A., & Williams, C. M. (2020). Effect of 4 weeks daily wild blueberry supplementation on symptoms of depression in adolescents. *British Journal of Nutrition*, *124*(2), 181-188.

Fossati, P., Ergis, A.-M., & Allilaire, J. (2002). Executive functioning in unipolar depression: a review. *L'Encephale*, *28*(2), 97-107.

Francis, H. M., Stevenson, R. J., Chambers, J. R., Gupta, D., Newey, B., & Lim, C. K. (2019). A brief diet intervention can reduce symptoms of depression in young adults – A randomised controlled trial. *PLoS One*, *14*(10), e0222768. https://doi.org/10.1371/journal.pone.0222768

Francis, S., Head, K., Morris, P., & Macdonald, I. (2006). The effect of flavanol-rich cocoa on the fMRI response to a cognitive task in healthy young people. *Journal of cardiovascular pharmacology*, *47*, S215-S220.

Gao, S., Su, S., Zhang, E., Liu, R., Zhang, Y., Wang, C., Liu, J., Xie, S., Yin, C., & Yue, W. (2022). Psychological health status in postpartum women during COVID-19 pandemic: A systematic review and meta-analysis. *Journal of Affective Disorders*, *319*, 99-111. https://doi.org/https://doi.org/10.1016/j.jad.2022.08.107

Garapati, J., Jajoo, S., Aradhya, D., Reddy, L. S., Dahiphale, S. M., Patel, D. J., Jyotsna, G., Deeksha, H., srivani Reddy, L., & Dahiphale, S. (2023). Postpartum mood disorders: insights into diagnosis, prevention, and treatment. *Cureus*, *15*(7).

Garcia-Yu, I. A., Garcia-Ortiz, L., Gomez-Marcos, M. A., Rodriguez-Sanchez, E., Mora-Simon, S., Maderuelo-Fernandez, J. A., & Recio-Rodriguez, J. I. (2022). Effects of cocoa-rich chocolate on cognitive performance in postmenopausal women. A randomised clinical trial. *Nutritional neuroscience*, *25*(6), 1147-1158. https://doi.org/10.1080/1028415X.2020.1840119

Garrido, M., Espino, J., González-Gómez, D., Lozano, M., Barriga, C., Paredes, S. D., & Rodríguez, A. B. (2012). The consumption of a Jerte Valley cherry product in humans enhances mood, and increases 5-hydroxyindoleacetic acid but reduces cortisol levels in urine. *Experimental Gerontology*, *47*(8), 573-580.

Gavin, N. I., Gaynes, B. N., Lohr, K. N., Meltzer-Brody, S., Gartlehner, G., & Swinson, T. (2005). Perinatal depression: a systematic review of prevalence and incidence. *Obstetrics & Gynecology*, *106*(5 Part 1), 1071-1083.

Gaynes, B. N., Gavin, N., Meltzer-Brody, S., Lohr, K. N., Swinson, T., Gartlehner, G., Brody, S., & Miller, W. C. (2005). Perinatal depression: Prevalence, screening accuracy, and screening outcomes: Summary. *AHRQ evidence report summaries*.

George, G. C., Milani, T. J., Hanss-Nuss, H., & Freeland-Graves, J. H. (2005). Compliance with Dietary Guidelines and Relationship to Psychosocial Factors in Low-Income Women in Late Postpartum. *Journal of the American Dietetic Association*, *105*(6), 916-926. https://doi.org/https://doi.org/10.1016/j.jada.2005.03.009

German-Ponciano, L. J., Rosas-Sánchez, G. U., Cueto-Escobedo, J., Fernández-Demeneghi, R., Guillén-Ruiz, G., Soria-Fregozo, C., Herrera-Huerta, E. V., & Rodríguez-Landa, J. F. (2022). Participation of the serotonergic system and brain-derived neurotrophic factor in the antidepressant-like effect of flavonoids. *International Journal of Molecular Sciences*, *23*(18), 10896.

Giakoumaki, O., Vasilaki, K., Lili, L., Skouroliakou, M., & Liosis, G. (2009). The role of maternal anxiety in the early postpartum period: Screening for anxiety and depressive symptomatology in Greece [Article]. *Journal of Psychosomatic Obstetrics and Gynecology*, *30*(1), 21-28. https://doi.org/10.1080/01674820802604839

Giardinelli, L., Innocenti, A., Benni, L., Stefanini, M., Lino, G., Lunardi, C., Svelto, V., Afshar, S., Bovani, R., & Castellini, G. (2012). Depression and anxiety in perinatal period: prevalence and risk factors in an Italian sample. *Archives of women's mental health*, *15*, 21-30.

Gibson, N., Baker, D., Sharples, A., & Braakhuis, A. (2020). Improving mental performance in an athletic population with the use of Ārepa®, a blackcurrant based nootropic drink: A randomized control trial. *Antioxidants*, *9*(4), 316.

Gladwin, M. T., Crawford, J. H., & Patel, R. P. (2004). The biochemistry of nitric oxide, nitrite, and hemoglobin: role in blood flow regulation. *Free Radical Biology and Medicine*, *36*(6), 707-717. https://doi.org/https://doi.org/10.1016/j.freeradbiomed.2003.11.032

Gleason, C. E., Fischer, B. L., Dowling, N. M., Setchell, K. D. R., Atwood, C. S., Carlsson, C. M., & Asthana, S. (2015). Cognitive Effects of Soy Isoflavones in Patients with Alzheimer's Disease. *Journal of Alzheimer's Disease*, *47*, 1009-1019. https://doi.org/10.3233/JAD-142958

Glynn, L. M. (2010). Giving birth to a new brain: Hormone exposures of pregnancy influence human memory. *Psychoneuroendocrinology*, *35*(8), 1148-1155. https://doi.org/https://doi.org/10.1016/j.psyneuen.2010.01.015

Godos, J., Castellano, S., Ray, S., Grosso, G., & Galvano, F. (2018). Dietary Polyphenol Intake and Depression: Results from the Mediterranean Healthy Eating, Lifestyle and Aging (MEAL) Study. *Molecules*, *23*(5). https://doi.org/10.3390/molecules23050999

Godos, J., Micek, A., Mena, P., Del Rio, D., Galvano, F., Castellano, S., & Grosso, G. (2024). Dietary (Poly)phenols and Cognitive Decline: A Systematic Review and Meta-Analysis of Observational Studies. *Molecular Nutrition & Food Research*, *68*(1), 2300472. https://doi.org/https://doi.org/10.1002/mnfr.202300472

Goethe, J. W., Woolley, S. B., Cardoni, A. A., Woznicki, B. A., & Piez, D. A. (2007). Selective serotonin reuptake inhibitor discontinuation: side effects and other factors that influence medication adherence. *Journal of clinical psychopharmacology*, *27*(5), 451-458.

Gould, J. F., Best, K., & Makrides, M. (2017). Perinatal nutrition interventions and post-partum depressive symptoms. *Journal of Affective Disorders*, *224*, 2-9. https://doi.org/https://doi.org/10.1016/j.jad.2016.12.014

Gow, M. L., Lam, Y. W. I., Jebeile, H., Craig, M. E., Susic, D., & Henry, A. (2023). Antenatal diet quality and perinatal depression: the Microbiome Understanding in Maternity Study (MUMS) cohort. *Journal of Human Nutrition and Dietetics*, *36*(3), 754-762. https://doi.org/https://doi.org/10.1111/jhn.13081

Grassi, D., Necozione, S., Lippi, C., Croce, G., Valeri, L., Pasqualetti, P., Desideri, G., Blumberg, J. B., & Ferri, C. (2005). Cocoa Reduces Blood Pressure and Insulin Resistance and Improves Endothelium-Dependent Vasodilation in Hypertensives. *Hypertension*, *46*(2), 398-405. https://doi.org/doi:10.1161/01.HYP.0000174990.46027.70

Grattan, D. R., & Ladyman, S. R. (2020). Chapter 2 - Neurophysiological and cognitive changes in pregnancy. In E. A. P. Steegers, M. J. Cipolla, & E. C. Miller (Eds.), *Handbook of Clinical Neurology* (Vol. 171, pp. 25-55). Elsevier. https://doi.org/https://doi.org/10.1016/B978-0-444-64239-4.00002-3

Gregoire, A., Kumar, R., Everitt, B., & Studd, J. (1996). Transdermal oestrogen for treatment of severe postnatal depression. *The Lancet*, *347*(9006), 930-933.

Greicius, M. D., Krasnow, B., Boyett-Anderson, J. M., Eliez, S., Schatzberg, A. F., Reiss, A. L., & Menon, V. (2003). Regional analysis of hippocampal activation during memory encoding and retrieval: fMRI study. *Hippocampus*, *13*(1), 164-174. https://doi.org/https://doi.org/10.1002/hipo.10064

Grosso, G., Godos, J., Lamuela-Raventos, R., Ray, S., Micek, A., Pajak, A., Sciacca, S., D'Orazio, N., Del Rio, D., & Galvano, F. (2017). A comprehensive meta-analysis on dietary flavonoid and lignan intake and cancer risk: Level of evidence and limitations. *Molecular Nutrition & Food Research*, *61*(4), 1600930. https://doi.org/https://doi.org/10.1002/mnfr.201600930

Guenther, P. M., Dodd, K. W., Reedy, J., & Krebs-Smith, S. M. (2006). Most Americans Eat Much Less than Recommended Amounts of Fruits and Vegetables. *Journal of the American Dietetic Association*, *106*(9), 1371-1379. https://doi.org/https://doi.org/10.1016/j.jada.2006.06.002

Haastrup, M. B., Pottegård, A., & Damkier, P. (2014). Alcohol and Breastfeeding. *Basic & Clinical Pharmacology & Toxicology*, *114*(2), 168-173. https://doi.org/https://doi.org/10.1111/bcpt.12149

Hahn-Holbrook, J., Cornwell-Hinrichs, T., & Anaya, I. (2018). Economic and Health Predictors of National Postpartum Depression Prevalence: A Systematic Review, Meta-analysis, and Meta-Regression of 291 Studies from 56 Countries [Systematic Review]. *Frontiers in Psychiatry*, *8*. https://doi.org/10.3389/fpsyt.2017.00248

Halbreich, U., & Karkun, S. (2006). Cross-cultural and social diversity of prevalence of postpartum depression and depressive symptoms. *Journal of Affective Disorders*, *91*(2-3), 97-111.

Hampson, E., Phillips, S.-D., Duff-Canning, S. J., Evans, K. L., Merrill, M., Pinsonneault, J. K., Sadée, W., Soares, C. N., & Steiner, M. (2015). Working memory in pregnant women: Relation to estrogen and antepartum depression. *Hormones and behavior*, *74*, 218-227.

Hansotte, E., Payne, S. I., & Babich, S. M. (2017). Positive postpartum depression screening practices and subsequent mental health treatment for low-income women in Western countries: a systematic literature review. *Public Health Reviews*, *38*(1), 3. https://doi.org/10.1186/s40985-017-0050-y

Harris, Lovett, Newcombe, Read, Walker, & Riad-Fahmy. (1994). Maternity blues and major endocrine changes: Cardiff puerperal mood and hormone study II. *Bmj*, *308*(6934), 949-953. https://doi.org/10.1136/bmj.308.6934.949

Hashimoto, K., Shimizu, E., & Iyo, M. (2004). Critical role of brain-derived neurotrophic factor in mood disorders. *Brain research reviews*, *45*(2), 104-114.

Haskell-Ramsay, C., Stuart, R., Okello, E., & Watson, A. (2017). Cognitive and mood improvements following acute supplementation with purple grape juice in healthy young adults. *European journal of nutrition*, *56*, 2621-2631.

Hein, S., Wood, E., Abhayaratne, N., Mesnage, R., Fernandes, F., Williams, C., & Rodriguez-Mateos, A. (2021). Effects of Daily Wild Blueberry Consumption on Cognitive and Vascular Function in Healthy Older Individuals: A Randomized Double Blind Controlled Trial (the Bluflow Study). *Current Developments in Nutrition*, *5*, 318. https://doi.org/https://doi.org/10.1093/cdn/nzab037_028

Heiss, C., Dejam, A., Kleinbongard, P., Schewe, T., Sies, H., & Kelm, M. (2003). Vascular effects of cocoa rich in flavan-3-ols. *JAMA*, *290*(8), 1030-1031.

Hendrick, V., Altshuler, L. L., & Suri, R. (1998). Hormonal changes in the postpartum and implications for postpartum depression. *Psychosomatics*, *39*(2), 93-101.

Henry, & Rendell. (2007). A review of the impact of pregnancy on memory function. *Journal of clinical and experimental neuropsychology*, *29*(8), 793-803.

Henry, & Sherwin. (2012a). Hormones and cognitive functioning during late pregnancy and postpartum: A longitudinal study. *Behavioral Neuroscience*, *126*(1), 73-85. https://doi.org/10.1037/a0025540

Henry, & Sherwin. (2012b). Hormones and cognitive functioning during late pregnancy and postpartum: a longitudinal study. *Behav Neurosci*, *126*(1), 73-85. https://doi.org/10.1037/a0025540

Henshaw, C., Foreman, D., & Cox, J. (2004). Postnatal blues: a risk factor for postnatal depression. *Journal of Psychosomatic Obstetrics & Gynecology*, *25*(3-4), 267-272.

Hepsomali, P., Greyling, A., Scholey, A., & Vauzour, D. (2021). Acute Effects of Polyphenols on Human Attentional Processes: A Systematic Review and Meta-Analysis [Systematic Review]. *Frontiers in Neuroscience*, *15*. https://doi.org/10.3389/fnins.2021.678769

Heron, J., O'Connor, T. G., Evans, J., Golding, J., Glover, V., & Team, A. S. (2004). The course of anxiety and depression through pregnancy and the postpartum in a community sample. *Journal of Affective Disorders*, *80*(1), 65-73.
Herrschaft, H., Nacu, A., Likhachev, S., Sholomov, I., Hoerr, R., & Schlaefke, S. (2012). Ginkgo biloba extract EGb 761® in dementia with neuropsychiatric features: A randomised, placebo-controlled trial to confirm the efficacy and safety of a daily dose of 240 mg. *Journal of psychiatric research*, *46*(6), 716-723. https://doi.org/https://doi.org/10.1016/j.jpsychires.2012.03.003
Herselman, M. F., Bailey, S., Deo, P., Zhou, X.-F., Gunn, K. M., & Bobrovskaya, L. (2022). The effects of walnuts and academic stress on mental health, general well-being and the gut microbiota in a sample of university students: A randomised clinical trial. *Nutrients*, *14*(22), 4776.
Ho, S. C., Chan, A. S. Y., Ho, Y. P., So, E. K. F., Sham, A., Zee, B., & Woo, J. L. F. (2007). Effects of soy isoflavone supplementation on cognitive function in Chinese postmenopausal women: a double-blind, randomized, controlled trial. *Menopause*, *14*(3), 489-499. https://doi.org/10.1097/gme.0b013e31802c4f4f
Hodgson, J. M., & Croft, K. D. (2006). Dietary flavonoids: effects on endothelial function and blood pressure. *Journal of the Science of Food and Agriculture*, *86*(15), 2492-2498. https://doi.org/https://doi.org/10.1002/jsfa.2675
Hoekzema, E., Barba-Müller, E., Pozzobon, C., Picado, M., Lucco, F., García-García, D., Soliva, J. C., Tobeña, A., Desco, M., & Crone, E. A. (2017). Pregnancy leads to long-lasting changes in human brain structure. *Nature neuroscience*, *20*(2), 287-296.
Hoffman, C., Dunn, D. M., & Njoroge, W. F. M. (2017). Impact of Postpartum Mental Illness Upon Infant Development. *Current Psychiatry Reports*, *19*(12), 100. https://doi.org/10.1007/s11920-017-0857-8
Hoffman, L., & Rovine, M. J. (2007). Multilevel models for the experimental psychologist: Foundations and illustrative examples. *Behavior Research Methods*, *39*(1), 101-117. https://doi.org/10.3758/BF03192848
Holland, T. M., Agarwal, P., Wang, Y., Dhana, K., Leurgans, S. E., Shea, K., Booth, S. L., Rajan, K. B., Schneider, J. A., & Barnes, L. L. (2023). Association of dietary intake of flavonols with changes in global cognition and several cognitive abilities. *Neurology*, *100*(7), e694-e702.
Horasan Sagbasan, B., Williams, C. M., Bell, L., Barfoot, K. L., Poveda, C., & Walton, G. E. (2024). Inulin and Freeze-Dried Blueberry Intervention Lead to Changes in the Microbiota and Metabolites within In Vitro Studies and in Cognitive Function within a Small Pilot Trial on Healthy Children. *Microorganisms*, *12*(7), 1501. https://www.mdpi.com/2076-2607/12/7/1501
Hossain, Z., Field, T., Gonzalez, J., Malphurs, J., Valle, C. D., & Pickens, J. (1994). Infants of "depressed" mothers interact better with their nondepressed fathers. *Infant Mental Health Journal*, *15*(4), 348-357.
Howell, D. C. (1992). *Statistical methods for psychology*. PWS-Kent Publishing Co.
Howes, J. B., Bray, K., Lorenz, L., Smerdely, P., & Howes, L. G. (2004). The effects of dietary supplementation with isoflavones from red clover on cognitive function in postmenopausal women. *Climacteric*, *7*(1), 70-77. https://doi.org/10.1080/13697130310001651490
Hozawa, A., Kuriyama, S., Nakaya, N., Ohmori-Matsuda, K., Kakizaki, M., Sone, T., Nagai, M., Sugawara, Y., Nitta, A., & Tomata, Y. (2009). Green tea consumption is associated with lower psychological distress in a general population: the Ohsaki Cohort 2006 Study. *The American journal of clinical nutrition*, *90*(5), 1390-1396.
Huck, S. W. (2012). Reading statistics and research. *Boston, USA*, *4*, 103-112.

Hung, C.-H. (2007). Postpartum stress as a predictor of women's minor psychiatric morbidity. *Community mental health journal*, *43*, 1-12.
Hung, C. H. (2004). Predictors of postpartum women's health status. *Journal of nursing scholarship*, *36*(4), 345-351.
Hung, C. H., & Chung, H. H. (2001). The effects of postpartum stress and social support on postpartum women's health status. *Journal of advanced nursing*, *36*(5), 676-684.
Igwe, E. O., Charlton, K. E., Roodenrys, S., Kent, K., Fanning, K., & Netzel, M. E. (2017). Anthocyanin-rich plum juice reduces ambulatory blood pressure but not acute cognitive function in younger and older adults: a pilot crossover dose-timing study. *Nutrition Research*, *47*, 28-43. https://doi.org/https://doi.org/10.1016/j.nutres.2017.08.006
Ihl, R., Bachinskaya, N., Korczyn, A. D., Vakhapova, V., Tribanek, M., Hoerr, R., & Napryeyenko, O. (2011). Efficacy and safety of a once-daily formulation of Ginkgo biloba extract EGb 761 in dementia with neuropsychiatric features: a randomized controlled trial. *International Journal of Geriatric Psychiatry*, *26*(11), 1186-1194. https://doi.org/https://doi.org/10.1002/gps.2662
Iwata, H., Mori, E., Sakajo, A., Aoki, K., Maehara, K., & Tamakoshi, K. (2016). Prevalence of postpartum depressive symptoms during the first 6 months postpartum: association with maternal age and parity. *Journal of Affective Disorders*, *203*, 227-232.
Jacka, F. N., O'Neil, A., Opie, R., Itsiopoulos, C., Cotton, S., Mohebbi, M., Castle, D., Dash, S., Mihalopoulos, C., Chatterton, M. L., Brazionis, L., Dean, O. M., Hodge, A. M., & Berk, M. (2017). A randomised controlled trial of dietary improvement for adults with major depression (the 'SMILES' trial). *BMC Medicine*, *15*(1), 23. https://doi.org/10.1186/s12916-017-0791-y
Jackson, S. E., Smith, L., Firth, J., Grabovac, I., Soysal, P., Koyanagi, A., Hu, L., Stubbs, B., Demurtas, J., Veronese, N., Zhu, X., & Yang, L. (2019). Is there a relationship between chocolate consumption and symptoms of depression? A cross-sectional survey of 13,626 US adults. *Depression and anxiety*, *36*(10), 987-995. https://doi.org/https://doi.org/10.1002/da.22950
Jäger, A. K., & Saaby, L. (2011). Flavonoids and the CNS. *Molecules*, *16*(2), 1471-1485.
Jakobek, L. (2015). Interactions of polyphenols with carbohydrates, lipids and proteins. *Food Chemistry*, *175*, 556-567.
Jardí, C., Aparicio, E., Bedmar, C., Aranda, N., Abajo, S., March, G., Basora, J., Arija, V., & Study Group, t. E. (2019). Food Consumption during Pregnancy and Post-Partum. ECLIPSES Study. *Nutrients*, *11*(10), 2447. https://www.mdpi.com/2072-6643/11/10/2447
Jarrard, L. E. (1993). On the role of the hippocampus in learning and memory in the rat. *Behavioral and neural biology*, *60*(1), 9-26.
Jenkins, T. A., Nguyen, J. C., Polglaze, K. E., & Bertrand, P. P. (2016). Influence of Tryptophan and Serotonin on Mood and Cognition with a Possible Role of the Gut-Brain Axis. *Nutrients*, *8*(1). https://doi.org/10.3390/nu8010056
Jennings, A., Steves, C. J., Macgregor, A., Spector, T., & Cassidy, A. (2021). Increased habitual flavonoid intake predicts attenuation of cognitive ageing in twins. *BMC Medicine*, *19*, 1-12.
Jia, S., Hou, Y., Wang, D., & Zhao, X. (2023). Flavonoids for depression and anxiety: a systematic review and meta-analysis. *Critical Reviews in Food Science and Nutrition*, *63*(27), 8839-8849.
Jiang, W., Mo, M., Li, M., Wang, S., Muyiduli, X., Shao, B., Jiang, S., & Yu, Y. (2018). The relationship of dietary diversity score with depression and anxiety among prenatal and

post-partum women. *Journal of Obstetrics and Gynaecology Research*, *44*(10), 1929-1936.
Jochum, F., Alteheld, B., Meinardus, P., Dahlinger, N., Nomayo, A., & Stehle, P. (2017). Mothers' Consumption of Soy Drink But Not Black Tea Increases the Flavonoid Content of Term Breast Milk: A Pilot Randomized, Controlled Intervention Study. *Ann Nutr Metab*, *70*(2), 147-153. https://doi.org/10.1159/000471857
Johnson, A. J., Vangay, P., Al-Ghalith, G. A., Hillmann, B. M., Ward, T. L., Shields-Cutler, R. R., Kim, A. D., Shmagel, A. K., Syed, A. N., & Walter, J. (2019). Daily sampling reveals personalized diet-microbiome associations in humans. *Cell host & microbe*, *25*(6), 789-802. e785.
Jorm, A. F., Patten, S. B., Brugha, T. S., & Mojtabai, R. (2017). Has increased provision of treatment reduced the prevalence of common mental disorders? Review of the evidence from four countries. *World Psychiatry*, *16*(1), 90-99.
Jover, M., Colomer, J., Carot, J. M., Larsson, C., Bobes, M. T., Ivorra, J. L., Martín-Brufau, R., & Sanjuan, J. (2014). Maternal Anxiety following Delivery, Early Infant Temperament and Mother´s Confidence in Caregiving. *The Spanish journal of psychology*, *17*, E95, Article E95. https://doi.org/10.1017/sjp.2014.87
Kalt, W., Blumberg, J. B., McDonald, J. E., Vinqvist-Tymchuk, M. R., Fillmore, S. A., Graf, B. A., O'Leary, J. M., & Milbury, P. E. (2008). Identification of anthocyanins in the liver, eye, and brain of blueberry-fed pigs. *Journal of Agricultural and Food Chemistry*, *56*(3), 705-712.
Kalt, W., Cassidy, A., Howard, L. R., Krikorian, R., Stull, A. J., Tremblay, F., & Zamora-Ros, R. (2020). Recent Research on the Health Benefits of Blueberries and Their Anthocyanins. *Advances in Nutrition*, *11*(2), 224-236. https://doi.org/https://doi.org/10.1093/advances/nmz065
Kamiloglu, S., Tomas, M., Ozdal, T., & Capanoglu, E. (2021). Effect of food matrix on the content and bioavailability of flavonoids. *Trends in Food Science & Technology*, *117*, 15-33. https://doi.org/https://doi.org/10.1016/j.tifs.2020.10.030
Karlsgodt, K. H., Shirinyan, D., van Erp, T. G. M., Cohen, M. S., & Cannon, T. D. (2005). Hippocampal activations during encoding and retrieval in a verbal working memory paradigm. *NeuroImage*, *25*(4), 1224-1231. https://doi.org/https://doi.org/10.1016/j.neuroimage.2005.01.038
Kay, C. D., Hooper, L., Kroon, P. A., Rimm, E. B., & Cassidy, A. (2012). Relative impact of flavonoid composition, dose and structure on vascular function: A systematic review of randomised controlled trials of flavonoid-rich food products. *Molecular Nutrition & Food Research*, *56*(11), 1605-1616. https://doi.org/https://doi.org/10.1002/mnfr.201200363
Kean, R. J., Lamport, D. J., Dodd, G. F., Freeman, J. E., Williams, C. M., Ellis, J. A., Butler, L. T., & Spencer, J. P. (2015). Chronic consumption of flavanone-rich orange juice is associated with cognitive benefits: an 8-wk, randomized, double-blind, placebo-controlled trial in healthy older adults. *The American journal of clinical nutrition*, *101*(3), 506-514.
Keane, Haskell-Ramsay, C., Veasey, R., & Howatson, G. (2016a). Montmorency Tart cherries (Prunus cerasus L.) modulate vascular function acutely, in the absence of improvement in cognitive performance. *British Journal of Nutrition*, *116*(11), 1935-1944.
Keane, Haskell-Ramsay, C. F., Veasey, R. C., & Howatson, G. (2016b). Montmorency Tart cherries (Prunus cerasus L.) modulate vascular function acutely, in the absence of improvement in cognitive performance. *British Journal of Nutrition*, *116*(11), 1935-1944. https://doi.org/10.1017/S0007114516004177

Kent, K., Charlton, K. E., Lee, S., Mond, J., Russell, J., Mitchell, P., & Flood, V. M. (2018). Dietary flavonoid intake in older adults: how many days of dietary assessment are required and what is the impact of seasonality? *Nutrition journal*, *17*, 1-9.

Kesner, R. P. (2013). An analysis of the dentate gyrus function. *Behavioural Brain Research*, *254*, 1-7. https://doi.org/https://doi.org/10.1016/j.bbr.2013.01.012

Kesse-Guyot, E., Fezeu, L., Andreeva, V. A., Touvier, M., Scalbert, A., Hercberg, S., & Galan, P. (2012). Total and Specific Polyphenol Intakes in Midlife Are Associated with Cognitive Function Measured 13 Years Later1-23. *The Journal of Nutrition*, *142*(1), 76-83. https://doi.org/https://doi.org/10.3945/jn.111.144428

Khalid, S., Barfoot, K. L., May, G., Lamport, D. J., Reynolds, S. A., & Williams, C. M. (2017). Effects of acute blueberry flavonoids on mood in children and young adults. *Nutrients*, *9*(2), 158.

Kim, P., & Swain, J. E. (2007). Sad dads: paternal postpartum depression. *Psychiatry (Edgmont)*, *4*(2), 35-47.

Kimble, R., Keane, K. M., Lodge, J. K., Cheung, W., Haskell-Ramsay, C. F., & Howatson, G. (2022). Polyphenol-rich tart cherries (Prunus Cerasus, cv Montmorency) improve sustained attention, feelings of alertness and mental fatigue and influence the plasma metabolome in middle-aged adults: a randomised, placebo-controlled trial. *British Journal of Nutrition*, *128*(12), 2409-2420.

Kimura, D. (2002). Sex hormones influence human cognitive pattern. *Neuroendocrinology Letters*, *23*(4), 67-77.

Kirubarajan, A., Barker, L. C., Leung, S., Ross, L. E., Zaheer, J., Park, B., Abramovich, A., Yudin, M. H., & Lam, J. S. H. (2022). LGBTQ2S+ childbearing individuals and perinatal mental health: a systematic review. *BJOG: An International Journal of Obstetrics & Gynaecology*, *129*(10), 1630-1643.

Knief, U., & Forstmeier, W. (2021). Violating the normality assumption may be the lesser of two evils. *Behav Res Methods*, *53*(6), 2576-2590. https://doi.org/10.3758/s13428-021-01587-5

Ko, Y.-H., Kim, S.-K., Lee, S.-Y., & Jang, C.-G. (2020). Flavonoids as therapeutic candidates for emotional disorders such as anxiety and depression. *Archives of Pharmacal Research*, *43*(11), 1128-1143. https://doi.org/10.1007/s12272-020-01292-5

Kok, L., Kreijkamp-Kaspers, S., Grobbee, D. E., Lampe, J. W., & van der Schouw, Y. T. (2005). A randomized, placebo-controlled trial on the effects of soy protein containing isoflavones on quality of life in postmenopausal women. *Menopause*, *12*(1), 56-62.

Kontogianni, M. D., Vijayakumar, A., Rooney, C., Noad, R. L., Appleton, K. M., McCarthy, D., Donnelly, M., Young, I. S., McKinley, M. C., & McKeown, P. P. (2020). A high polyphenol diet improves psychological well-being: The polyphenol intervention trial (pphit). *Nutrients*, *12*(8), 2445.

Korczak, D. J., Perruzza, S., Chandrapalan, M., Cost, K., Cleverley, K., Birken, C. S., & McCrindle, B. M. (2022). The association of diet and depression: an analysis of dietary measures in depressed, non-depressed, and healthy youth. *Nutritional neuroscience*, *25*(9), 1948-1955. https://doi.org/10.1080/1028415X.2021.1918981

Kountanis, J. A., Muzik, M., Chang, T., Langen, E., Cassidy, R., Mashour, G. A., & Bauer, M. E. (2020). Relationship between postpartum mood disorder and birth experience: a prospective observational study. *International Journal of Obstetric Anesthesia*, *44*, 90-99. https://doi.org/https://doi.org/10.1016/j.ijoa.2020.07.008

Kreijkamp-Kaspers, S., Kok, L., Grobbee, D. E., de Haan, E. H. F., Aleman, A., Lampe, J. W., & van der Schouw, Y. T. (2004). Effect of Soy Protein Containing Isoflavones on

Cognitive Function, Bone Mineral Density, and Plasma Lipids in Postmenopausal WomenA Randomized Controlled Trial. *JAMA*, *292*(1), 65-74. https://doi.org/10.1001/jama.292.1.65

Krikorian, R., Boespflug, E. L., Fleck, D. E., Stein, A. L., Wightman, J. D., Shidler, M. D., & Sadat-Hossieny, S. (2012). Concord grape juice supplementation and neurocognitive function in human aging. *J Agric Food Chem*, *60*(23), 5736-5742. https://doi.org/10.1021/jf300277g

Krikorian, R., Shidler, M. D., Nash, T. A., Kalt, W., Vinqvist-Tymchuk, M. R., Shukitt-Hale, B., & Joseph, J. A. (2010). Blueberry Supplementation Improves Memory in Older Adults. *Journal of Agricultural and Food Chemistry*, *58*(7), 3996-4000. https://doi.org/10.1021/jf9029332

Krikorian, R., Skelton, M. R., Summer, S. S., Shidler, M. D., & Sullivan, P. G. (2022). Blueberry Supplementation in Midlife for Dementia Risk Reduction. *Nutrients*, *14*(8).

Kritz-Silverstein, D., Von Mühlen, D., Barrett-Connor, E., & Bressel, M. A. B. (2003). Isoflavones and cognitive function in older women: the SOy and Postmenopausal Health In Aging (SOPHIA) Study. *Menopause*, *10*(3). https://journals.lww.com/menopausejournal/fulltext/2003/10030/isoflavones_and_cognitive_function_in_older_women_.4.aspx

Kroenke, K., Strine, T. W., Spitzer, R. L., Williams, J. B., Berry, J. T., & Mokdad, A. H. (2009). The PHQ-8 as a measure of current depression in the general population. *Journal of Affective Disorders*, *114*(1-3), 163-173.

Kuo, P. X., Carp, J., Light, K. C., & Grewen, K. M. (2012). Neural responses to infants linked with behavioral interactions and testosterone in fathers. *Biological psychology*, *91*(2), 302-306.

Lai, J. S., Hiles, S., Bisquera, A., Hure, A. J., McEvoy, M., & Attia, J. (2014). A systematic review and meta-analysis of dietary patterns and depression in community-dwelling adults. *The American journal of clinical nutrition*, *99*(1), 181-197.

Lakenbrink, C., Lapczynski, S., Maiwald, B., & Engelhardt, U. H. (2000). Flavonoids and Other Polyphenols in Consumer Brews of Tea and Other Caffeinated Beverages. *Journal of Agricultural and Food Chemistry*, *48*(7), 2848-2852. https://doi.org/10.1021/jf9908042

Lamport, Pal, D., Macready, A. L., Barbosa-Boucas, S., Fletcher, J. M., Williams, C. M., Spencer, J. P. E., & Butler, L. T. (2016). The effects of flavanone-rich citrus juice on cognitive function and cerebral blood flow: an acute, randomised, placebo-controlled cross-over trial in healthy, young adults. *British Journal of Nutrition*, *116*(12), 2160-2168. https://doi.org/10.1017/S000711451600430X

Lamport, D. J., Christodoulou, E., & Achilleos, C. (2020). Beneficial effects of dark chocolate for episodic memory in healthy young adults: A parallel-groups acute intervention with a white chocolate control. *Nutrients*, *12*(2), 483.

Lamport, D. J., Dye, L., Wightman, J. D., & Lawton, C. L. (2012). The effects of flavonoid and other polyphenol consumption on cognitive performance: a systematic research review of human experimental and epidemiological studies. *Nutrition and Aging*, *1*(1), 5-25.

Lamport, D. J., Lawton, C. L., Mansfield, M. W., Moulin, C. A., & Dye, L. (2014). Type 2 diabetes and impaired glucose tolerance are associated with word memory source monitoring recollection deficits but not simple recognition familiarity deficits following water, low glycaemic load, and high glycaemic load breakfasts. *Physiology & Behavior*, *124*, 54-60.

Lamport, D. J., Pal, D., Moutsiana, C., Field, D. T., Williams, C. M., Spencer, J. P., & Butler, L. T. (2015). The effect of flavanol-rich cocoa on cerebral perfusion in healthy older

adults during conscious resting state: a placebo controlled, crossover, acute trial. *Psychopharmacology (Berl)*, *232*(17), 3227-3234. https://doi.org/10.1007/s00213-015-3972-4

Lamport, D. J., & Williams, C. M. (2020). Polyphenols and cognition in humans: an overview of current evidence from recent systematic reviews and meta-analyses. *Brain Plasticity*, *6*(2), 139-153.

Lamport., Lawton, C. L., Merat, N., Jamson, H., Myrissa, K., Hofman, D., Chadwick, H. K., Quadt, F., Wightman, J. D., & Dye, L. (2016). Concord grape juice, cognitive function, and driving performance: a 12-wk, placebo-controlled, randomized crossover trial in mothers of preteen children. *The American journal of clinical nutrition*, *103*(3), 775-783.

Landman, A., Ngameni, E. G., Dubreucq, M., Dubreucq, J., Tebeka, S., & Dubertret, C. (2024). Postpartum blues: a predictor of postpartum depression, from the IGEDEPP Cohort. *European Psychiatry*, *67*(1), e30, Article e30. https://doi.org/10.1192/j.eurpsy.2024.1741

Laurent, H. K., & Ablow, J. C. (2012). A cry in the dark: depressed mothers show reduced neural activation to their own infant's cry. *Social cognitive and affective neuroscience*, *7*(2), 125-134.

Lebrun, A., Plante, A.-S., Savard, C., Dugas, C., Fontaine-Bisson, B., Lemieux, S., Robitaille, J., & Morisset, A.-S. (2019). Tracking of Dietary Intake and Diet Quality from Late Pregnancy to the Postpartum Period. *Nutrients*, *11*(9), 2080. https://www.mdpi.com/2072-6643/11/9/2080

Lee, B.-H., & Kim, Y.-K. (2010). The roles of BDNF in the pathophysiology of major depression and in antidepressant treatment. *Psychiatry investigation*, *7*(4), 231.

Lee, Y.-B., Lee, H. J., Won, M. H., Hwang, I. K., Kang, T.-C., Lee, J.-Y., Nam, S.-Y., Kim, K.-S., Kim, E., & Cheon, S.-H. (2004). Soy isoflavones improve spatial delayed matching-to-place performance and reduce cholinergic neuron loss in elderly male rats. *The Journal of Nutrition*, *134*(7), 1827-1831.

Leeming, E. R., Johnson, A. J., Spector, T. D., & Le Roy, C. I. (2019). Effect of Diet on the Gut Microbiota: Rethinking Intervention Duration. *Nutrients*, *11*(12), 2862. https://www.mdpi.com/2072-6643/11/12/2862

Lépine, J.-P., & Briley, M. (2011). The increasing burden of depression. *Neuropsychiatric disease and treatment*, *7*(sup1), 3-7.

Letenneur, L., Proust-Lima, C., Le Gouge, A., Dartigues, J., & Barberger-Gateau, P. (2007). Flavonoid Intake and Cognitive Decline over a 10-Year Period. *American journal of epidemiology*, *165*(12), 1364-1371. https://doi.org/10.1093/aje/kwm036

Letourneau, N. L., Dennis, C.-L., Benzies, K., Duffett-Leger, L., Stewart, M., Tryphonopoulos, P. D., Este, D., & Watson, W. (2012). Postpartum depression is a family affair: addressing the impact on mothers, fathers, and children. *Issues in mental health nursing*, *33*(7), 445-457.

Lezak, M. D. (2004). *Neuropsychological assessment*. Oxford University Press, USA.

Li, H., Bowen, A., Bowen, R., Balbuena, L., Feng, C., Bally, J., & Muhajarine, N. (2020). Mood instability during pregnancy and postpartum: a systematic review. *Archives of women's mental health*, *23*(1), 29-41. https://doi.org/10.1007/s00737-019-00956-6

Li, Y., Xu, Y., Le Sayec, M., Kamarunzaman, N. N. Z., Wu, H., Hu, J., Li, S., Gibson, R., & Rodriguez-Mateos, A. (2024). Development of a food frequency questionnaire for the estimation of dietary (poly) phenol intake. *Food & function*, *15*(20), 10414-10433.

Lilja, G., Edhborg, M., & Nissen, E. (2012). Depressive mood in women at childbirth predicts their mood and relationship with infant and partner during the first year

postpartum. *Scandinavian Journal of Caring Sciences*, *26*(2), 245-253. https://doi.org/https://doi.org/10.1111/j.1471-6712.2011.00925.x
Lin, C., Chen, B., Yang, Y., Li, Q., Wang, Q., Wang, M., Guo, S., & Tao, S. (2023). Association between depressive symptoms in the postpartum period and COVID-19: A meta-analysis. *Journal of Affective Disorders*, *320*, 247-253. https://doi.org/https://doi.org/10.1016/j.jad.2022.09.129
Lipsky, L. M., Nansel, T. R., Haynie, D. L., Liu, D., Li, K., Pratt, C. A., Iannotti, R. J., Dempster, K. W., & Simons-Morton, B. (2017). Diet quality of US adolescents during the transition to adulthood: changes and predictors. *The American journal of clinical nutrition*, *105*(6), 1424-1432.
Logan, D. M., Hill, K. R., Jones, R., Holt-Lunstad, J., & Larson, M. J. (2014). How do memory and attention change with pregnancy and childbirth? A controlled longitudinal examination of neuropsychological functioning in pregnant and postpartum women. *Journal of clinical and experimental neuropsychology*, *36*(5), 528-539.
Logothetis, N. K., & Wandell, B. A. (2004). Interpreting the BOLD Signal. *Annual Review of Physiology*, *66*(Volume 66, 2004), 735-769. https://doi.org/https://doi.org/10.1146/annurev.physiol.66.082602.092845
Lorzadeh, E., Kent, K., Do Rosario, V., Roodenrys, S., Weston-Green, K., & Charlton, K. (2024). Habitual consumption of anthocyanin is associated with improvements in mood and cognitive performance in older people with memory complaints. *Proceedings of the Nutrition Society*, *83*(OCE1), E146, Article E146. https://doi.org/10.1017/S0029665124001642
Ma, X., Xu, Y., Li, Y., Gibson, R., Williams, C., Lawrence, A. J., Nosarti, C., Dazzan, P., & Rodriguez-Mateos, A. (2024). Association between Higher Intake of Flavonols and Lignans and Better Mood: Evidence from Dietary and Biomarker Evaluation in Healthy Individuals. *Molecular Nutrition & Food Research*, *68*(20), 2400112. https://doi.org/https://doi.org/10.1002/mnfr.202400112
Macbeth, A. H., & Luine, V. N. (2010). Changes in anxiety and cognition due to reproductive experience: a review of data from rodent and human mothers. *Neuroscience & Biobehavioral Reviews*, *34*(3), 452-467.
Macht, M., & Dettmer, D. (2006). Everyday mood and emotions after eating a chocolate bar or an apple. *Appetite*, *46*(3), 332-336.
Macht, M., & Mueller, J. (2007). Immediate effects of chocolate on experimentally induced mood states. *Appetite*, *49*(3), 667-674. https://doi.org/https://doi.org/10.1016/j.appet.2007.05.004
Macready, A. L., George, T. W., Chong, M. F., Alimbetov, D. S., Jin, Y., Vidal, A., Spencer, J. P., Kennedy, O. B., Tuohy, K. M., & Minihane, A.-M. (2014). Flavonoid-rich fruit and vegetables improve microvascular reactivity and inflammatory status in men at risk of cardiovascular disease—FLAVURS: a randomized controlled trial. *The American journal of clinical nutrition*, *99*(3), 479-489.
Maki, P. M., & Jaff, N. G. (2022). Brain fog in menopause: a health-care professional's guide for decision-making and counseling on cognition. *Climacteric*, *25*(6), 570-578. https://doi.org/10.1080/13697137.2022.2122792
Maleki, A., Faghihzadeh, S., & Niroomand, S. (2018). The relationship between paternal prenatal depressive symptoms with postnatal depression: The PATH model. *Psychiatry research*, *269*, 102-107.
Manach, C., Williamson, G., Morand, C., Scalbert, A., & Rémésy, C. (2005). Bioavailability and bioefficacy of polyphenols in humans. I. Review of 97 bioavailability studies. *Am J Clin Nutr*, *81*(1 Suppl), 230s-242s. https://doi.org/10.1093/ajcn/81.1.230S

Mancia, G., Sega, R., Bravi, C., Vito, G. D., Valagussa, F., Cesana, G., & Zanchetti, A. (1995). Ambulatory blood pressure normality: results from the PAMELA study. *Journal of Hypertension*, *13*(12), 1377-1390. https://journals.lww.com/jhypertension/fulltext/1995/12000/ambulatory_blood_pressure_normality__results_from.3.aspx

Manjunath, N. G., & Venkatesh, G. (2011). Postpartum blue is common in socially and economically insecure mothers. *Indian journal of community medicine: official publication of Indian Association of Preventive & Social Medicine*, *36*(3), 231.

Marino, S. E., Meador, K. J., Loring, D. W., Okun, M. S., Fernandez, H. H., Fessler, A. J., Kustra, R. P., Miller, J. M., Ray, P. G., Roy, A., Schoenberg, M. R., Vahle, V. J., & Werz, M. A. (2009). Subjective perception of cognition is related to mood and not performance. *Epilepsy & Behavior*, *14*(3), 459-464. https://doi.org/https://doi.org/10.1016/j.yebeh.2008.12.007

Markon, K. E., Brunette, C. A., Whitney, B. M., & O'Hara, M. W. (2021). Mood during pregnancy: Trends, structure, and invariance by gestational day. *Journal of psychiatric research*, *140*, 260-266. https://doi.org/https://doi.org/10.1016/j.jpsychires.2021.06.006

Marsh, C. E., Green, D. J., Naylor, L. H., & Guelfi, K. J. (2017). Consumption of dark chocolate attenuates subsequent food intake compared with milk and white chocolate in postmenopausal women. *Appetite*, *116*, 544-551. https://doi.org/https://doi.org/10.1016/j.appet.2017.05.050

Marshall, N. E., Abrams, B., Barbour, L. A., Catalano, P., Christian, P., Friedman, J. E., Hay, W. W., Hernandez, T. L., Krebs, N. F., Oken, E., Purnell, J. Q., Roberts, J. M., Soltani, H., Wallace, J., & Thornburg, K. L. (2022). The importance of nutrition in pregnancy and lactation: lifelong consequences. *American Journal of Obstetrics and Gynecology*, *226*(5), 607-632. https://doi.org/https://doi.org/10.1016/j.ajog.2021.12.035

Märthesheimer, S., Hagenbeck, C., Helbig, M., Balan, P., Fehm, T., & Schaal, N. K. (2025). A longitudinal study of the subjective birth experience and the relationship to mental health. *BMC Pregnancy and Childbirth*, *25*(1), 216. https://doi.org/10.1186/s12884-025-07348-y

Martin, F.-P. J., Antille, N., Rezzi, S., & Kochhar, S. (2012). Everyday eating experiences of chocolate and non-chocolate snacks impact postprandial anxiety, energy and emotional states. *Nutrients*, *4*(6), 554-567.

Martin, J. C., Joham, A. E., Mishra, G. D., Hodge, A. M., Moran, L. J., & Harrison, C. L. (2020). Postpartum Diet Quality: A Cross-Sectional Analysis from the Australian Longitudinal Study on Women's Health. *Journal of Clinical Medicine*, *9*(2), 446. https://www.mdpi.com/2077-0383/9/2/446

Masand, P. S., & Gupta, S. (2002). Long-term side effects of newer-generation antidepressants: SSRIS, venlafaxine, nefazodone, bupropion, and mirtazapine. *Annals of Clinical Psychiatry*, *14*, 175-182.

Massee, L. A., Ried, K., Pase, M., Travica, N., Yoganathan, J., Scholey, A., Macpherson, H., Kennedy, G., Sali, A., & Pipingas, A. (2015). The acute and sub-chronic effects of cocoa flavanols on mood, cognitive and cardiovascular health in young healthy adults: a randomized, controlled trial. *Frontiers in pharmacology*, *6*, 93.

Mastroiacovo, D., Kwik-Uribe, C., Grassi, D., Necozione, S., Raffaele, A., Pistacchio, L., Righetti, R., Bocale, R., Lechiara, M. C., Marini, C., Ferri, C., & Desideri, G. (2015). Cocoa flavanol consumption improves cognitive function, blood pressure control, and metabolic profile in elderly subjects: the Cocoa, Cognition, and Aging (CoCoA)

Study—a randomized controlled trial14. *The American journal of clinical nutrition*, *101*(3), 538-548. https://doi.org/https://doi.org/10.3945/ajcn.114.092189

Matthey, S., Barnett, B., Howie, P., & Kavanagh, D. J. (2003). Diagnosing postpartum depression in mothers and fathers: whatever happened to anxiety? *Journal of Affective Disorders*, *74*(2), 139-147. https://doi.org/https://doi.org/10.1016/S0165-0327(02)00012-5

Matthey, S., Barnett, B., Ungerer, J., & Waters, B. (2000). Paternal and maternal depressed mood during the transition to parenthood. *Journal of Affective Disorders*, *60*(2), 75-85.

Maxwell, D., Robinson, S. R., & Rogers, K. (2019). "I keep it to myself": A qualitative meta-interpretive synthesis of experiences of postpartum depression among marginalised women. *Health & Social Care in the Community*, *27*(3), e23-e36. https://doi.org/https://doi.org/10.1111/hsc.12645

Mazor, E., Sheiner, E., Wainstock, T., Attias, M., & Walfisch, A. (2019). The Association between Depressive State and Maternal Cognitive Function in Postpartum Women. *Am J Perinatol*, *36*(03), 285-290. https://doi.org/10.1055/s-0038-1667376

McEvoy, K. M., Rayapati, D., Washington Cole, K. O., Erdly, C., Payne, J. L., & Osborne, L. M. (2019). Poor postpartum sleep quality predicts subsequent postpartum depressive symptoms in a high-risk sample. *Journal of Clinical Sleep Medicine*, *15*(9), 1303-1310.

McEwen, B. S., & Alves, S. E. (1999). Estrogen Actions in the Central Nervous System*. *Endocrine Reviews*, *20*(3), 279-307. https://doi.org/10.1210/edrv.20.3.0365

McKeown, N. M., Day, N. E., Welch, A. A., Runswick, S. A., Luben, R. N., Mulligan, A. A., McTaggart, A., & Bingham, S. A. (2001). Use of biological markers to validate self-reported dietary intake in a random sample of the European Prospective Investigation into Cancer United Kingdom Norfolk cohort. *The American journal of clinical nutrition*, *74*(2), 188–196. https://doi.org/10.1093/ajcn/74.2.188

McNamara, R. K., Kalt, W., Shidler, M. D., McDonald, J., Summer, S. S., Stein, A. L., Stover, A. N., & Krikorian, R. (2018). Cognitive response to fish oil, blueberry, and combined supplementation in older adults with subjective cognitive impairment. *Neurobiology of aging*, *64*, 147-156.

Mestrom, A., Charlton, K. E., Thomas, S. J., Larkin, T. A., Walton, K. L., Elgellaie, A., & Kent, K. (2024). Higher anthocyanin intake is associated with lower depressive symptoms in adults with and without major depressive disorder. *Food Science & Nutrition*, *12*(3), 2202-2209.

Meyer, Ginovart, N., Boovariwala, A., Sagrati, S., Hussey, D., Garcia, A., Young, T., Praschak-Rieder, N., Wilson, A. A., & Houle, S. (2006). Elevated monoamine oxidase a levels in the brain: an explanation for the monoamine imbalance of major depression. *Archives of general psychiatry*, *63*(11), 1209-1216.

Meyer, Wang, Z., Santhirakumar, A., Dowlati, Y., Docteur, N., Shoaib, A., Purnava, J., Wang, Y., Wang, W., & Chen, S. (2024). Dietary supplement for mood symptoms in early postpartum: a double-blind randomized placebo controlled trial. *EClinicalMedicine*, *71*.

Micek, A., Godos, J., Del Rio, D., Galvano, F., & Grosso, G. (2021). Dietary Flavonoids and Cardiovascular Disease: A Comprehensive Dose–Response Meta-Analysis. *Molecular Nutrition & Food Research*, *65*(6), 2001019. https://doi.org/https://doi.org/10.1002/mnfr.202001019

Miller, M. G., Hamilton, D. A., Joseph, J. A., & Shukitt-Hale, B. (2018). Dietary blueberry improves cognition among older adults in a randomized, double-blind, placebo-controlled trial. *European journal of nutrition*, *57*, 1169-1180.

Miller, M. G., Thangthaeng, N., Rutledge, G. A., Scott, T. M., & Shukitt-Hale, B. (2021). Dietary strawberry improves cognition in a randomised, double-blind, placebo-controlled trial in older adults. *British Journal of Nutrition*, *126*(2), 253-263.

Miller, M. L., Kroska, E. B., & Grekin, R. (2017). Immediate postpartum mood assessment and postpartum depressive symptoms. *Journal of Affective Disorders*, *207*, 69-75. https://doi.org/https://doi.org/10.1016/j.jad.2016.09.023

Miller, R. L., Pallant, J. F., & Negri, L. M. (2006). Anxiety and stress in the postpartum: is there more to postnatal distress than depression? *BMC psychiatry*, *6*, 1-11.

Miranda, A. R., Cortez, M. V., Scotta, A. V., Rivadero, L., Serra, S. V., & Soria, E. A. (2021). Memory enhancement in Argentinian women during postpartum by the dietary intake of lignans and anthocyanins. *Nutrition Research*, *85*, 1-13. https://doi.org/https://doi.org/10.1016/j.nutres.2020.10.006

Miranda, A. R., Cortez, M. V., Scotta, A. V., & Soria, E. A. (2022). Dietary Intake of Polyphenols Enhances Executive/Attentional Functioning and Memory with an Improvement of the Milk Lipid Profile of Postpartum Women from Argentina. *J Intell*, *10*(2). https://doi.org/10.3390/jintelligence10020033

Mithul Aravind, S., Wichienchot, S., Tsao, R., Ramakrishnan, S., & Chakkaravarthi, S. (2021). Role of dietary polyphenols on gut microbiota, their metabolites and health benefits. *Food Research International*, *142*, 110189. https://doi.org/https://doi.org/10.1016/j.foodres.2021.110189

Monti, F., Agostini, F., Marano, G., & Lupi, F. (2008). The course of maternal depressive symptomatology during the first 18 months postpartum in an Italian sample. *Archives of women's mental health*, *11*, 231-238.

Moran, T., & O'hara, M. (2006). A partner-rating scale of postpartum depression: The Edinburgh Postnatal Depression Scale–Partner (EPDS-P). *Archives of women's mental health*, *9*, 173-180.

Mulinari, S. (2012). Monoamine Theories of Depression: Historical Impact on Biomedical Research. *Journal of the History of the Neurosciences*, *21*(4), 366-392. https://doi.org/10.1080/0964704X.2011.623917

Munk-Olsen, T., Laursen, T. M., Pedersen, C. B., Mors, O., & Mortensen, P. B. (2006). New Parents and Mental DisordersA Population-Based Register Study. *JAMA*, *296*(21), 2582-2589. https://doi.org/10.1001/jama.296.21.2582

Muntaner, C., Eaton, W. W., Miech, R., & O'Campo, P. (2004). Socioeconomic Position and Major Mental Disorders. *Epidemiologic Reviews*, *26*(1), 53-62. https://doi.org/10.1093/epirev/mxh001

Muraca, G. M., & Joseph, K. (2014). The association between maternal age and depression. *Journal of obstetrics and gynaecology Canada*, *36*(9), 803-810.

Murphy, P. K., Mueller, M., Hulsey, T. C., Ebeling, M. D., & Wagner, C. L. (2010). An exploratory study of postpartum depression and vitamin D. *Journal of the American Psychiatric Nurses Association*, *16*(3), 170-177.

Narita, Z., Nozaki, S., Shikimoto, R., Hori, H., Kim, Y., Mimura, M., Tsugane, S., & Sawada, N. (2022). Association between vegetable, fruit, and flavonoid-rich fruit consumption in midlife and major depressive disorder in later life: the JPHC Saku Mental Health Study. *Translational Psychiatry*, *12*(1), 412. https://doi.org/10.1038/s41398-022-02166-8

Nathan, P. J., Tanner, S., Lloyd, J., Harrison, B., Curran, L., Oliver, C., & Stough, C. (2004). Effects of a combined extract of Ginkgo biloba and Bacopa monniera on cognitive function in healthy humans. *Hum Psychopharmacol*, *19*(2), 91-96. https://doi.org/10.1002/hup.544

National Institute for Health and Care Excellence, N. (2014). *Maternal and child nutrition, Public health guideline (PH11)*. Retrieved 7.1.2025 from https://www.nice.org.uk/guidance/ph11

Nemoto, K., Kokubun, K., Ogata, Y., Koike, Y., Arai, T., & Yamakawa, Y. (2022). Dark chocolate intake may reduce fatigue and mediate cognitive function and gray matter volume in healthy middle-aged adults. *Behavioural neurology*, *2022*(1), 6021811.

Neshatdoust, S., Saunders, C., Castle, S. M., Vauzour, D., Williams, C., Butler, L., Lovegrove, J. A., & Spencer, J. P. (2016). High-flavonoid intake induces cognitive improvements linked to changes in serum brain-derived neurotrophic factor: Two randomised, controlled trials. *Nutrition and healthy aging*, *4*(1), 81-93.

Neuhouser, M. L. (2004). Review: Dietary Flavonoids and Cancer Risk: Evidence From Human Population Studies. *Nutrition and Cancer*, *50*(1), 1-7. https://doi.org/10.1207/s15327914nc5001_1

NHS. (2020). *Breastfeeding and drinking alcohol*. Retrieved 14/03/2025 from https://www.nhs.uk/conditions/baby/breastfeeding-and-bottle-feeding/breastfeeding-and-lifestyle/alcohol/

NHS. (2022). *How and when to take folic acid*. Retrieved 7.1.2025 from https://www.nhs.uk/medicines/folic-acid/how-and-when-to-take-folic-acid/

Nieman, D. C., Gillitt, N. D., Chen, G. Y., Zhang, Q., Sha, W., Kay, C. D., Chandra, P., Kay, K. L., & Lila, M. A. (2020). Blueberry and/or Banana Consumption Mitigate Arachidonic, Cytochrome P450 Oxylipin Generation During Recovery From 75-Km Cycling: A Randomized Trial. *Front Nutr*, *7*, 121. https://doi.org/10.3389/fnut.2020.00121

Nilsson, J. P., Söderström, M., Karlsson, A. U., Lekander, M., Åkerstedt, T., Lindroth, N. E., & Axelsson, J. (2005). Less effective executive functioning after one night's sleep deprivation. *Journal of sleep research*, *14*(1), 1-6.

Nott, P., Franklin, M., Armitage, C., & Gelder, M. (1976). Hormonal changes and mood in the puerperium. *The British Journal of Psychiatry*, *128*(4), 379-383.

Ntaouti, E., Gonidakis, F., Nikaina, E., Varelas, D., Creatsas, G., Chrousos, G., & Siahanidou, T. (2020). Maternity blues: risk factors in Greek population and validity of the Greek version of Kennerley and Gath's blues questionnaire. *The Journal of Maternal-Fetal & Neonatal Medicine*, *33*(13), 2253-2262. https://doi.org/10.1080/14767058.2018.1548594

O'Hara, M. W., Schlechte, J. A., Lewis, D. A., & Wright, E. J. (1991). Prospective study of postpartum blues. Biologic and psychosocial factors. *Arch Gen Psychiatry*, *48*(9), 801-806. https://doi.org/10.1001/archpsyc.1991.01810330025004

O'hara, M. W., & Swain, A. M. (1996). Rates and risk of postpartum depression—a meta-analysis. *International review of psychiatry*, *8*(1), 37-54.

O'Neil, A., Perez, J., Young, L. M., John, T., Turner, M., Saunders, D., Mahoney, S., Bryan, M., Ashtree, D. N., & Jacka, F. N. (2024). Clinical and cost-effectiveness of remote-delivered, online lifestyle therapy versus psychotherapy for reducing depression: results from the CALM non-inferiority, randomised trial. *The Lancet Regional Health–Western Pacific*.

Okun, M. L., Mancuso, R. A., Hobel, C. J., Schetter, C. D., & Coussons-Read, M. (2018). Poor sleep quality increases symptoms of depression and anxiety in postpartum women. *Journal of behavioral medicine*, *41*, 703-710.

Opie, R. S., Uldrich, A. C., & Ball, K. (2020). Maternal Postpartum Diet and Postpartum Depression: A Systematic Review. *Maternal and Child Health Journal*, *24*(8), 966-978. https://doi.org/10.1007/s10995-020-02949-9

Orchard, Rutherford, H. J. V., Holmes, A. J., & Jamadar, S. D. (2023). Matrescence: lifetime impact of motherhood on cognition and the brain. *Trends in Cognitive Sciences*, *27*(3), 302-316. https://doi.org/10.1016/j.tics.2022.12.002

Orchard, Ward, P. G. D., Chopra, S., Storey, E., Egan, G. F., & Jamadar, S. D. (2020). Neuroprotective Effects of Motherhood on Brain Function in Late Life: A Resting-State fMRI Study. *Cerebral Cortex*, *31*(2), 1270-1283. https://doi.org/10.1093/cercor/bhaa293

Orchard, Ward, P. G. D., Egan, G. F., & Jamadar, S. D. (2022). Evidence of Subjective, But Not Objective, Cognitive Deficit in New Mothers at 1-Year Postpartum. *Journal of Women's Health*, *31*(8), 1087-1096. https://doi.org/10.1089/jwh.2021.0441

Orchard, Ward, P. G. D., Sforazzini, F., Storey, E., Egan, G. F., & Jamadar, S. D. (2020). Relationship between parenthood and cortical thickness in late adulthood. *PLoS One*, *15*(7), e0236031. https://doi.org/10.1371/journal.pone.0236031

Ortega, M. A., Fraile-Martínez, Ó., García-Montero, C., Alvarez-Mon, M. A., Lahera, G., Monserrat, J., Llavero-Valero, M., Gutiérrez-Rojas, L., Molina, R., Rodríguez-Jimenez, R., Quintero, J., & De Mon, M. A. (2022). Biological Role of Nutrients, Food and Dietary Patterns in the Prevention and Clinical Management of Major Depressive Disorder. *Nutrients*, *14*(15), 3099. https://www.mdpi.com/2072-6643/14/15/3099

Otto, M. W., Smits, J. A., & Reese, H. E. (2006). Combined psychotherapy and pharmacotherapy for mood and anxiety disorders in adults: Review and analysis. *Focus*, *12*(2), 72-214.

Öztora, S., Arslan, A., Çaylan, A., & Dağdeviren, H. N. (2019). Postpartum depression and affecting factors in primary care. *Nigerian journal of clinical practice*, *22*(1).

Pandey, K. B., & Rizvi, S. I. (2009). Plant Polyphenols as Dietary Antioxidants in Human Health and Disease. *Oxidative medicine and cellular longevity*, *2*, 270-278. https://doi.org/10.4161/oxim.2.5.9498

Pandey, K. R., Naik, S. R., & Vakil, B. V. (2015). Probiotics, prebiotics and synbiotics- a review. *Journal of Food Science and Technology*, *52*(12), 7577-7587. https://doi.org/10.1007/s13197-015-1921-1

Pannu, A., Sharma, P. C., Thakur, V. K., & Goyal, R. K. (2021). Emerging role of flavonoids as the treatment of depression. *Biomolecules*, *11*(12), 1825.

Park, M., Choi, J., & Lee, H.-J. (2020). Flavonoid-rich orange juice intake and altered gut microbiome in young adults with depressive symptom: a randomized controlled study. *Nutrients*, *12*(6), 1815.

Park, S.-J., Jaiswal, V., & Lee, H.-J. (2022). Dietary Intake of Flavonoids and Carotenoids Is Associated with Anti-Depressive Symptoms: Epidemiological Study and In Silico—Mechanism Analysis. *Antioxidants*, *11*(1), 53. https://www.mdpi.com/2076-3921/11/1/53

Parmenter, B. H., Croft, K. D., Cribb, L., Cooke, M. B., Bondonno, C. P., Lea, A., McPhee, G. M., Komanduri, M., Nolidin, K., Savage, K., Pase, M. P., Hodgson, J. M., Stough, C., & Bondonno, N. P. (2022). Higher habitual dietary flavonoid intake associates with lower central blood pressure and arterial stiffness in healthy older adults. *British Journal of Nutrition*, *128*(2), 279-289. https://doi.org/10.1017/S000711452100324X

Parmenter, B. H., Thompson, A. S., Bondonno, N. P., Jennings, A., Murray, K., Perez-Cornago, A., Hodgson, J. M., Tresserra-Rimbau, A., Kühn, T., & Cassidy, A. (2025). High diversity of dietary flavonoid intake is associated with a lower risk of all-cause mortality and major chronic diseases. *Nature Food*, *6*(7), 668-680. https://doi.org/10.1038/s43016-025-01176-1

Pase, M. P., Scholey, A. B., Pipingas, A., Kras, M., Nolidin, K., Gibbs, A., Wesnes, K., & Stough, C. (2013). Cocoa polyphenols enhance positive mood states but not cognitive performance: a randomized, placebo-controlled trial. *Journal of Psychopharmacology*, *27*(5), 451-458.

Paulson, J. F., Dauber, S., & Leiferman, J. A. (2006). Individual and combined effects of postpartum depression in mothers and fathers on parenting behavior. *Pediatrics*, *118*(2), 659-668.

Pellowski, J. A., Bengtson, A. M., Barnett, W., DiClemente, K., Koen, N., Zar, H. J., & Stein, D. J. (2019). Perinatal depression among mothers in a South African birth cohort study: Trajectories from pregnancy to 18 months postpartum. *Journal of Affective Disorders*, *259*, 279-287. https://doi.org/https://doi.org/10.1016/j.jad.2019.08.052

Philip, P., Sagaspe, P., Taillard, J., Mandon, C., Constans, J., Pourtau, L., Pouchieu, C., Angelino, D., Mena, P., Martini, D., Del Rio, D., & Vauzour, D. (2019). Acute Intake of a Grape and Blueberry Polyphenol-Rich Extract Ameliorates Cognitive Performance in Healthy Young Adults During a Sustained Cognitive Effort. *Antioxidants*, *8*(12), 650. https://www.mdpi.com/2076-3921/8/12/650

Pieters, S., Brett, B. E., Beijers, R., Kessels, R. P. C., & de Weerth, C. (2021). Working memory from pregnancy to postpartum: Do women really change? *Psychoneuroendocrinology*, *126*, 105169. https://doi.org/https://doi.org/10.1016/j.psyneuen.2021.105169

Pio de Almeida, L. S., Jansen, K., Köhler, C. A., Pinheiro, R. T., da Silva, R. A., & Bonini, J. S. (2012). Working and short-term memories are impaired in postpartum depression. *Journal of Affective Disorders*, *136*(3), 1238-1242. https://doi.org/https://doi.org/10.1016/j.jad.2011.09.031

Pizarro Melendez, G. P., Valero-Jara, V., Acevedo-Hernández, P., & Thomas-Valdés, S. (2024). Impact of polyphenols on stress and anxiety: a systematic review of molecular mechanisms and clinical evidence. *Critical Reviews in Food Science and Nutrition*, *64*(8), 2340-2357.

Pollack, M. H. (2005). Comorbid anxiety and depression. *Journal of Clinical Psychiatry*, *66*, 22.

Pop, V. J., Truijens, S. E., Spek, V., Wijnen, H. A., Van Son, M. J., & Bergink, V. (2015). A new concept of maternity blues: Is there a subgroup of women with rapid cycling mood symptoms? *Journal of Affective Disorders*, *177*, 74-79.

Pope, C. J., & Mazmanian, D. (2016). Breastfeeding and postpartum depression: an overview and methodological recommendations for future research. *Depression research and treatment*, *2016*(1), 4765310.

Pribis, P., Bailey, R. N., Russell, A. A., Kilsby, M. A., Hernandez, M., Craig, W. J., Grajales, T., Shavlik, D. J., & Sabatè, J. (2012). Effects of walnut consumption on cognitive performance in young adults. *British Journal of Nutrition*, *107*(9), 1393-1401. https://doi.org/10.1017/S0007114511004302

Price, J. L., & Drevets, W. C. (2012). Neural circuits underlying the pathophysiology of mood disorders. *Trends in Cognitive Sciences*, *16*(1), 61-71.

Qiu, C., Gelaye, B., Zhong, Q.-Y., Enquobahrie, D. A., Frederick, I. O., & Williams, M. A. (2016). Construct validity and factor structure of the Pittsburgh Sleep Quality Index among pregnant women in a Pacific-Northwest cohort. *Sleep and Breathing*, *20*, 293-301.

Radavelli-Bagatini, S., Anokye, R., Bondonno, N. P., Sim, M., Bondonno, C. P., Stanley, M. J., Harms, C., Woodman, R., Magliano, D. J., Shaw, J. E., Daly, R. M., Hodgson, J. M., Lewis, J. R., & Blekkenhorst, L. C. (2021). Association of habitual intake of fruits

and vegetables with depressive symptoms: the AusDiab study. *European journal of nutrition*, *60*(7), 3743-3755. https://doi.org/10.1007/s00394-021-02532-0

Reck, C., Struben, K., Backenstrass, M., Stefenelli, U., Reinig, K., Fuchs, T., Sohn, C., & Mundt, C. (2008). Prevalence, onset and comorbidity of postpartum anxiety and depressive disorders. *Acta Psychiatrica Scandinavica*, *118*(6), 459-468. https://doi.org/https://doi.org/10.1111/j.1600-0447.2008.01264.x

Rees, A., Dodd, G. F., & Spencer, J. P. E. (2018). The Effects of Flavonoids on Cardiovascular Health: A Review of Human Intervention Trials and Implications for Cerebrovascular Function. *Nutrients*, *10*(12).

Rezaie-Keikhaie, K., Arbabshastan, M. E., Rafiemanesh, H., Amirshahi, M., Ostadkelayeh, S. M., & Arbabisarjou, A. (2020). Systematic review and meta-analysis of the prevalence of the maternity blues in the postpartum period. *Journal of Obstetric, Gynecologic & Neonatal Nursing*, *49*(2), 127-136.

Rist, P. M., Sesso, H. D., Johnson, L. G., Aragaki, A. K., Wang, L., Rautiainen, S., Hazra, A., Tobias, D. K., LeBoff, M. S., Schroeter, H., Friedenberg, G., Copeland, T., Clar, A., Tinker, L. F., Hunt, R. P., Bassuk, S. S., Sarkissian, A., Smith, D. C., Pereira, E., . . . Manson, J. E. (2022). Design and baseline characteristics of participants in the COcoa Supplement and Multivitamin Outcomes Study (COSMOS). *Contemporary Clinical Trials*, *116*, 106728. https://doi.org/https://doi.org/10.1016/j.cct.2022.106728

Rodriguez-Mateos, A., Rendeiro, C., Bergillos-Meca, T., Tabatabaee, S., George, T. W., Heiss, C., & Spencer, J. P. (2013). Intake and time dependence of blueberry flavonoid–induced improvements in vascular function: a randomized, controlled, double-blind, crossover intervention study with mechanistic insights into biological activity. *The American journal of clinical nutrition*, *98*(5), 1179-1191.

Romaszko, E., Wiczkowski, W., Romaszko, J., Honke, J., & Piskula, M. K. (2014). Exposure of breastfed infants to quercetin after consumption of a single meal rich in quercetin by their mothers. *Mol Nutr Food Res*, *58*(2), 221-228. https://doi.org/10.1002/mnfr.201200773

Rose, N., Koperski, S., & Golomb, B. A. (2010). Mood food: chocolate and depressive symptoms in a cross-sectional analysis. *Archives of internal medicine*, *170*(8), 699-703.

Rowland, M. K., Adamson, A. J., Poliakov, I., Bradley, J., Simpson, E., Olivier, P., & Foster, E. (2018). Field Testing of the Use of Intake24-An Online 24-Hour Dietary Recall System. *Nutrients*, *10*(11). https://doi.org/10.3390/nu10111690

Rupanagunta, G. P., Nandave, M., Rawat, D., Upadhyay, J., Rashid, S., & Ansari, M. N. (2023). Postpartum depression: aetiology, pathogenesis and the role of nutrients and dietary supplements in prevention and management. *Saudi Pharmaceutical Journal*, *31*(7), 1274-1293. https://doi.org/https://doi.org/10.1016/j.jsps.2023.05.008

Rutledge, G. A., Fisher, D. R., Miller, M. G., Kelly, M. E., Bielinski, D. F., & Shukitt-Hale, B. (2019). The effects of blueberry and strawberry serum metabolites on age-related oxidative and inflammatory signaling in vitro [10.1039/C9FO01913H]. *Food & function*, *10*(12), 7707-7713. https://doi.org/10.1039/C9FO01913H

Sacher, J., Wilson, A. A., Houle, S., Rusjan, P., Hassan, S., Bloomfield, P. M., Stewart, D. E., & Meyer, J. H. (2010). Elevated brain monoamine oxidase A binding in the early postpartum period. *Arch Gen Psychiatry*, *67*(5), 468-474. https://doi.org/10.1001/archgenpsychiatry.2010.32

Safi-Keykaleh, M., Aliakbari, F., Safarpour, H., Safari, M., Tahernejad, A., Sheikhbardsiri, H., & Sahebi, A. (2022). Prevalence of postpartum depression in women amid the COVID-19 pandemic: A systematic review and meta-analysis. *International Journal*

*of Gynecology & Obstetrics*, *157*(2), 240-247. https://doi.org/https://doi.org/10.1002/ijgo.14129

Salehi, L., Rahimzadeh, M., Molaei, E., Zaheri, H., & Esmaelzadeh-Saeieh, S. (2020). The relationship among fear and anxiety of COVID-19, pregnancy experience, and mental health disorder in pregnant women: A structural equation model. *Brain and Behavior*, *10*(11), e01835. https://doi.org/https://doi.org/10.1002/brb3.1835

Salthouse, T. A., Atkinson, T. M., & Berish, D. E. (2003). Executive functioning as a potential mediator of age-related cognitive decline in normal adults. *Journal of experimental psychology: General*, *132*(4), 566.

Samieri, C., Sun, Q., Townsend, M. K., Rimm, E. B., & Grodstein, F. (2014). Dietary flavonoid intake at midlife and healthy aging in women123. *The American journal of clinical nutrition*, *100*(6), 1489-1497. https://doi.org/https://doi.org/10.3945/ajcn.114.085605

Santomauro, D. F., Herrera, A. M. M., Shadid, J., Zheng, P., Ashbaugh, C., Pigott, D. M., Abbafati, C., Adolph, C., Amlag, J. O., & Aravkin, A. Y. (2021). Global prevalence and burden of depressive and anxiety disorders in 204 countries and territories in 2020 due to the COVID-19 pandemic. *The Lancet*, *398*(10312), 1700-1712.

Schalla, M. A., & Stengel, A. (2024). The role of stress in perinatal depression and anxiety – A systematic review. *Frontiers in neuroendocrinology*, *72*, 101117. https://doi.org/https://doi.org/10.1016/j.yfrne.2023.101117

Schielzeth, H., Dingemanse, N. J., Nakagawa, S., Westneat, D. F., Allegue, H., Teplitsky, C., Réale, D., Dochtermann, N. A., Garamszegi, L. Z., & Araya-Ajoy, Y. G. (2020). Robustness of linear mixed-effects models to violations of distributional assumptions. *Methods in Ecology and Evolution*, *11*(9), 1141-1152. https://doi.org/https://doi.org/10.1111/2041-210X.13434

Schiller, C. E., Meltzer-Brody, S., & Rubinow, D. R. (2015). The role of reproductive hormones in postpartum depression. *CNS Spectrums*, *20*(1), 48-59. https://doi.org/10.1017/S1092852914000480

Scholey, A., Downey, L. A., Ciorciari, J., Pipingas, A., Nolidin, K., Finn, M., Wines, M., Catchlove, S., Terrens, A., Barlow, E., Gordon, L., & Stough, C. (2012). Acute neurocognitive effects of epigallocatechin gallate (EGCG). *Appetite*, *58*(2), 767-770. https://doi.org/https://doi.org/10.1016/j.appet.2011.11.016

Scholey, A. B., French, S. J., Morris, P. J., Kennedy, D. O., Milne, A. L., & Haskell, C. F. (2010). Consumption of cocoa flavanols results in acute improvements in mood and cognitive performance during sustained mental effort. *Journal of Psychopharmacology*, *24*(10), 1505-1514.

Sedov, I. D., & Tomfohr-Madsen, L. M. (2021). Trajectories of insomnia symptoms and associations with mood and anxiety from early pregnancy to the postpartum. *Behavioral Sleep Medicine*, *19*(3), 395-406.

Sesso, H. D., Manson, J. E., Aragaki, A. K., Rist, P. M., Johnson, L. G., Friedenberg, G., Copeland, T., Clar, A., Mora, S., & Moorthy, M. V. (2022). Effect of cocoa flavanol supplementation for the prevention of cardiovascular disease events: the COcoa Supplement and Multivitamin Outcomes Study (COSMOS) randomized clinical trial. *The American journal of clinical nutrition*, *115*(6), 1490-1500.

Shah, B. S., Freeland-Graves, J. H., Cahill, J. M., Lu, H., & Graves, G. R. (2010). Diet Quality as Measured by the Healthy Eating Index and the Association with Lipid Profile in Low-Income Women in Early Postpartum. *Journal of the American Dietetic Association*, *110*(2), 274-279. https://doi.org/https://doi.org/10.1016/j.jada.2009.10.038

Sherwin, B. B. (2000). Oestrogen and Cognitive Function Throughout the Female Lifespan. In *Neuronal and Cognitive Effects of Oestrogens* (pp. 188-201). https://doi.org/https://doi.org/10.1002/0470870818.ch14

Shields, G. S., Sazma, M. A., & Yonelinas, A. P. (2016). The effects of acute stress on core executive functions: A meta-analysis and comparison with cortisol. *Neuroscience & Biobehavioral Reviews*, *68*, 651-668.

Shin, J.-H., Kim, C.-S., Cha, J., Kim, S., Lee, S., Chae, S., Chun, W. Y., & Shin, D.-M. (2022a). Consumption of 85% cocoa dark chocolate improves mood in association with gut microbial changes in healthy adults: a randomized controlled trial. *The Journal of nutritional biochemistry*, *99*, 108854.

Shin, J.-H., Kim, C.-S., Cha, L., Kim, S., Lee, S., Chae, S., Chun, W. Y., & Shin, D.-M. (2022b). Consumption of 85% cocoa dark chocolate improves mood in association with gut microbial changes in healthy adults: a randomized controlled trial. *The Journal of nutritional biochemistry*, *99*, 108854.

Shorey, S., Chee, C. Y. I., Ng, E. D., Chan, Y. H., San Tam, W. W., & Chong, Y. S. (2018). Prevalence and incidence of postpartum depression among healthy mothers: A systematic review and meta-analysis. *Journal of psychiatric research*, *104*, 235-248.

Sichel, D. A., Cohen, L. S., Robertson, L. M., Ruttenberg, A., & Rosenbaum, J. F. (1995). Prophylactic estrogen in recurrent postpartum affective disorder. *Biological psychiatry*, *38*(12), 814-818.

Silber, M., Almkvist, O., Larsson, B., & Uvnäs-Moberg, K. (1990). Temporary peripartal impairment in memory and attention and its possible relation to oxytocin concentration. *Life Sciences*, *47*(1), 57-65. https://doi.org/https://doi.org/10.1016/0024-3205(90)90566-A

Silva, Y. P., Bernardi, A., & Frozza, R. L. (2020). The Role of Short-Chain Fatty Acids From Gut Microbiota in Gut-Brain Communication [Review]. *Frontiers in Endocrinology*, *11*. https://doi.org/10.3389/fendo.2020.00025

Silverio, S. A., Davies, S. M., Christiansen, P., Aparicio-García, M. E., Bramante, A., Chen, P., Costas-Ramón, N., de Weerth, C., Della Vedova, A. M., & Infante Gil, L. (2021). A validation of the Postpartum Specific Anxiety Scale 12-item research short-form for use during global crises with five translations. *BMC Pregnancy and Childbirth*, *21*, 1-12.

Silverman, M. E., Reichenberg, A., Savitz, D. A., Cnattingius, S., Lichtenstein, P., Hultman, C. M., Larsson, H., & Sandin, S. (2017). The risk factors for postpartum depression: A population-based study. *Depression and anxiety*, *34*(2), 178-187.

Simpson, E. E., Furlong, O. N., Parr, H. J., Hodge, S. J., Slevin, M. M., McSorley, E. M., McCormack, J. M., McConville, C., & Magee, P. J. (2019). The effect of a randomized 12-week soy drink intervention on everyday mood in postmenopausal women. *Menopause*, *26*(8), 867-873.

Sinclair, J., Bottoms, L., Dillon, S., Allan, R., Shadwell, G., & Butters, B. (2022). Effects of montmorency tart cherry and blueberry juice on cardiometabolic and other health-related outcomes: A three-arm placebo randomized controlled trial. *International Journal of Environmental Research and Public Health*, *19*(9), 5317.

Singh-Curry, V., & Husain, M. (2009). The functional role of the inferior parietal lobe in the dorsal and ventral stream dichotomy. *Neuropsychologia*, *47*(6), 1434-1448. https://doi.org/https://doi.org/10.1016/j.neuropsychologia.2008.11.033

Singmann, H., & Kellen, D. (2019). An Introduction to Mixed Models for Experimental Psychology. In (pp. 4-31). https://doi.org/10.4324/9780429318405-2

Skevington, S. M., Lotfy, M., & O'Connell, K. A. (2004). The World Health Organization's WHOQOL-BREF quality of life assessment: psychometric properties and results of

the international field trial. A report from the WHOQOL group. *Quality of life Research*, *13*, 299-310.
Sloan, R. P., Wall, M., Yeung, L.-K., Feng, T., Feng, X., Provenzano, F., Schroeter, H., Lauriola, V., Brickman, A. M., & Small, S. A. (2021). Insights into the role of diet and dietary flavanols in cognitive aging: results of a randomized controlled trial. *Scientific reports*, *11*(1), 3837. https://doi.org/10.1038/s41598-021-83370-2
Smit, H. J., Gaffan, E. A., & Rogers, P. J. (2004). Methylxanthines are the psycho-pharmacologically active constituents of chocolate. *Psychopharmacology*, *176*, 412-419.
Smythe, K. L., Petersen, I., & Schartau, P. (2022). Prevalence of Perinatal Depression and Anxiety in Both Parents: A Systematic Review and Meta-analysis. *JAMA Network Open*, *5*(6), e2218969-e2218969. https://doi.org/10.1001/jamanetworkopen.2022.18969
Snyder, H. R. (2013). Major depressive disorder is associated with broad impairments on neuropsychological measures of executive function: a meta-analysis and review. *Psychological bulletin*, *139*(1), 81.
Soma-Pillay, P., Nelson-Piercy, C., Tolppanen, H., & Mebazaa, A. (2016). Physiological changes in pregnancy. *Cardiovascular journal of Africa*, *27*(2), 89-94. https://doi.org/10.5830/cvja-2016-021
Sorond, F. A., Lipsitz, L. A., Hollenberg, N. K., & Fisher, N. D. (2008). Cerebral blood flow response to flavanol-rich cocoa in healthy elderly humans. *Neuropsychiatric disease and treatment*, *4*(2), 433-440.
Sparling, T. M., Henschke, N., Nesbitt, R. C., & Gabrysch, S. (2017). The role of diet and nutritional supplementation in perinatal depression: a systematic review. *Maternal & Child Nutrition*, *13*(1). https://doi.org/https://doi.org/10.1111/mcn.12235
Spencer, J. P. E. (2008). Flavonoids: modulators of brain function? *British Journal of Nutrition*, *99*(E-S1), ES60-ES77. https://doi.org/10.1017/S0007114508965776
Spielberger, C. D. (1983). State-trait anxiety inventory for adults.
Srisurapanont, M., Suttajit, S., Eurviriyanukul, K., & Varnado, P. (2017). Discrepancy between objective and subjective cognition in adults with major depressive disorder. *Scientific reports*, *7*(1), 3901. https://doi.org/10.1038/s41598-017-04353-w
Stein, G. S. (1980). The pattern of mental change and body weight change in the first post-partum week. *Journal of Psychosomatic Research*, *24*(3-4), 165-171.
Strapasson, M. R., Ferreira, C. F., & Ramos, J. G. (2018). Associations between postpartum depression and hypertensive disorders of pregnancy. *International Journal of Gynecology & Obstetrics*, *143*(3), 367-373.
Sultan, P., Ando, K., Sultan, E., Hawkins, J., Blake, L., Barwick, F., Kawai, M., & Carvalho, B. (2021). A systematic review of patient-reported outcome measures used to assess sleep in postpartum women using Consensus Based Standards for the Selection of Health Measurement Instruments (COSMIN) guidelines. *Sleep*, *44*(10). https://doi.org/10.1093/sleep/zsab128
Sumiyoshi, E., Matsuzaki, K., Sugimoto, N., Tanabe, Y., Hara, T., Katakura, M., Miyamoto, M., Mishima, S., & Shido, O. (2019). Sub-Chronic Consumption of Dark Chocolate Enhances Cognitive Function and Releases Nerve Growth Factors: A Parallel-Group Randomized Trial. *Nutrients*, *11*(11), 2800. https://www.mdpi.com/2072-6643/11/11/2800
Sun, J., Li, Z., Li, Y., & Zhang, D. (2021). Intakes of specific categories of vegetables and fruits are inversely associated with depressive symptoms among adults. *Journal of Epidemiology*, *31*(3), 210-219.

Sun, Y., Ferguson, M., Reeves, M. M., & Kelly, J. T. (2023). Maternal Dietary Patterns and Risk of Postpartum Depression: A Systematic Review. *Matern Child Health J*, *27*(12), 2077-2090. https://doi.org/10.1007/s10995-023-03781-7

Swain, A. M., O'Hara, M. W., Starr, K. R., & Gorman, L. L. (1997). A Prospective Study of Sleep, Mood, and Cognitive Function in Postpartum and Nonpostpartum Women. *Obstetrics & Gynecology*, *90*(3), 381-386. https://doi.org/https://doi.org/10.1016/S0029-7844(97)89252-6

Swain, J. E. (2011). The human parental brain: in vivo neuroimaging. *Progress in Neuro-Psychopharmacology and Biological Psychiatry*, *35*(5), 1242-1254.

Tariq, N., Naeem, H., Tariq, A., & Naseem, S. (2021). Maternal depression and its correlates: A longitudinal study. *J Pak Med Assoc*, *71*(6), 1618-1622.

Thorp, A. A., Sinn, N., Buckley, J. D., Coates, A. M., & Howe, P. R. (2009). Soya isoflavone supplementation enhances spatial working memory in men. *Br J Nutr*, *102*(9), 1348-1354. https://doi.org/10.1017/s0007114509990201

Tikotzky, L. (2016). Postpartum maternal sleep, maternal depressive symptoms and self-perceived mother–infant emotional relationship. *Behavioral Sleep Medicine*, *14*(1), 5-22.

Tomaszewski Farias, S., Cahn-Weiner, D. A., Harvey, D. J., Reed, B. R., Mungas, D., Kramer, J. H., & Chui, H. (2009). Longitudinal Changes in Memory and Executive Functioning are Associated with longitudinal change in instrumental activities of daily living in older Adults. *The Clinical Neuropsychologist*, *23*(3), 446-461. https://doi.org/10.1080/13854040802360558

Tosto, V., Ceccobelli, M., Lucarini, E., Tortorella, A., Gerli, S., Parazzini, F., & Favilli, A. (2023). Maternity blues: a narrative review. *Journal of personalized medicine*, *13*(1), 154.

Treves, A., & Rolls, E. T. (1994). Computational analysis of the role of the hippocampus in memory. *Hippocampus*, *4*(3), 374-391. https://doi.org/https://doi.org/10.1002/hipo.450040319

Tsang, C., Hodgson, L., Bussu, A., Farhat, G., & Al-Dujaili, E. (2019). Effect of polyphenol-rich dark chocolate on salivary cortisol and mood in adults. *Antioxidants*, *8*(6), 149.

Tucker, A. M., Whitney, P., Belenky, G., Hinson, J. M., & Van Dongen, H. P. (2010). Effects of sleep deprivation on dissociated components of executive functioning. *Sleep*, *33*(1), 47-57.

Tulving, E., & Markowitsch, H. J. (1998). Episodic and declarative memory: role of the hippocampus. *Hippocampus*, *8*(3), 198-204.

Unno, K., Yamada, H., Iguchi, K., Ishida, H., Iwao, Y., Morita, A., & Nakamura, Y. (2017). Anti-stress effect of green tea with lowered caffeine on humans: A pilot study. *Biological and Pharmaceutical Bulletin*, *40*(6), 902-909.

van Bussel, J. C. H., Spitz, B., & Demyttenaere, K. (2009). Anxiety in pregnant and postpartum women. An exploratory study of the role of maternal orientations. *Journal of Affective Disorders*, *114*(1), 232-242. https://doi.org/https://doi.org/10.1016/j.jad.2008.07.018

Vauzour, D. (2012). Dietary polyphenols as modulators of brain functions: biological actions and molecular mechanisms underpinning their beneficial effects. *Oxidative medicine and cellular longevity*, *2012*(1), 914273.

Velichkov, M., Bezur, Z., Van Reekum, C. M., & Williams, C. M. (2024). A biphasic response to blueberry supplementation on depressive symptoms in emerging adults: a double-blind randomized controlled trial. *European journal of nutrition*, 1-18.

Vogiatzoglou, A., Mulligan, A. A., Lentjes, M. A., Luben, R. N., Spencer, J. P., Schroeter, H., Khaw, K.-T., & Kuhnle, G. G. (2015). Flavonoid intake in European adults (18 to 64 years). *PLoS One*, *10*(5), e0128132.

Vyas, C. M., Manson, J. E., Sesso, H. D., Cook, N. R., Rist, P. M., Weinberg, A., Moorthy, M. V., Baker, L. D., Espeland, M. A., Yeung, L. K., Brickman, A. M., & Okereke, O. I. (2024). Effect of multivitamin-mineral supplementation versus placebo on cognitive function: results from the clinic subcohort of the COcoa Supplement and Multivitamin Outcomes Study (COSMOS) randomized clinical trial and meta-analysis of 3 cognitive studies within COSMOS. *The American journal of clinical nutrition*, *119*(3), 692–701. https://doi.org/10.1016/j.ajcnut.2023.12.011

Walters, M., & Hines-Martin, V. (2018). Overview of executive functions in mood and depressive disorders: A review of the literature. *Archives of Psychiatric Nursing*, *32*(4), 617-637. https://doi.org/https://doi.org/10.1016/j.apnu.2018.02.011

Wang, D., Ho, L., Faith, J., Ono, K., Janle, E. M., Lachcik, P. J., Cooper, B. R., Jannasch, A. H., D'Arcy, B. R., & Williams, B. A. (2015). Role of intestinal microbiota in the generation of polyphenol-derived phenolic acid mediated attenuation of Alzheimer's disease β-amyloid oligomerization. *Molecular Nutrition & Food Research*, *59*(6), 1025-1040.

Wang, Z., Liu, J., Shuai, H., Cai, Z., Fu, X., Liu, Y., Xiao, X., Zhang, W., Krabbendam, E., Liu, S., Liu, Z., Li, Z., & Yang, B. X. (2021). Mapping global prevalence of depression among postpartum women. *Translational Psychiatry*, *11*(1), 543. https://doi.org/10.1038/s41398-021-01663-6

Warner, R., Appleby, L., Whitton, A., & Faragher, B. (1996). Demographic and obstetric risk factors for postnatal psychiatric morbidity. *The British Journal of Psychiatry*, *168*(5), 607-611.

Watanabe, M., Wada, K., Sakata, Y., Aratake, Y., Kato, N., Ohta, H., & Tanaka, K. (2008). Maternity blues as predictor of postpartum depression: A prospective cohort study among Japanese women. *Journal of Psychosomatic Obstetrics & Gynecology*, *29*(3), 211-217. https://doi.org/10.1080/01674820801990577

Watson, A., Okello, E., Brooker, H., Lester, S., McDougall, G., & Wesnes, K. (2019). The impact of blackcurrant juice on attention, mood and brain wave spectral activity in young healthy volunteers. *Nutritional neuroscience*, *22*(8), 596-606.

Watson, A. W., Haskell-Ramsay, C. F., Kennedy, D. O., Cooney, J. M., Trower, T., & Scheepens, A. (2015). Acute supplementation with blackcurrant extracts modulates cognitive functioning and inhibits monoamine oxidase-B in healthy young adults. *Journal of functional foods*, *17*, 524-539.

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: the PANAS scales. *Journal of personality and social psychology*, *54*(6), 1063.

Weber, M. T., Maki, P. M., & McDermott, M. P. (2014). Cognition and mood in perimenopause: a systematic review and meta-analysis. *The Journal of steroid biochemistry and molecular biology*, *142*, 90-98.

Weisenberg, M., Gerby, Y., & Mikulincer, M. (1993). Aerobic exercise and chocolate as means for reducing learned helplessness. *Cognitive therapy and research*, *17*, 579-592.

Wenzel, A., Haugen, E. N., Jackson, L. C., & Brendle, J. R. (2005). Anxiety symptoms and disorders at eight weeks postpartum. *Journal of Anxiety Disorders*, *19*(3), 295-311. https://doi.org/https://doi.org/10.1016/j.janxdis.2004.04.001

WHO. (2020). Nutritional interventions update: multiple micronutrient supplements during pregnancy. Published July 29, 2020. In.

Whyte, Schafer, G., & Williams, C. M. (2016). Cognitive effects following acute wild blueberry supplementation in 7- to 10-year-old children. *European journal of nutrition*, *55*(6), 2151-2162. https://doi.org/10.1007/s00394-015-1029-4
Whyte, & Williams. (2012). The cognitive effects of acute blueberry anthocyanin interventions on 7–9 year old children. *Appetite*, *59*(2), 637. https://doi.org/https://doi.org/10.1016/j.appet.2012.05.108
Whyte, & Williams. (2015). Effects of a single dose of a flavonoid-rich blueberry drink on memory in 8 to 10 y old children. *Nutrition*, *31*(3), 531-534. https://doi.org/https://doi.org/10.1016/j.nut.2014.09.013
Whyte, A. R., Cheng, N., Butler, L. T., Lamport, D. J., & Williams, C. M. (2019). Flavonoid-rich mixed berries maintain and improve cognitive function over a 6 h period in young healthy adults. *Nutrients*, *11*(11), 2685.
Whyte, A. R., Cheng, N., Fromentin, E., & Williams, C. M. (2018). A randomized, double-blinded, placebo-controlled study to compare the safety and efficacy of low dose enhanced wild blueberry powder and wild blueberry extract (ThinkBlue™) in maintenance of episodic and working memory in older adults. *Nutrients*, *10*(6), 660.
Whyte, A. R., Lamport, D. J., Schafer, G., & Williams, C. M. (2020). The cognitive effects of an acute wild blueberry intervention on 7- to 10-year-olds using extended memory and executive function task batteries [10.1039/C9FO02284H]. *Food & function*, *11*(5), 4793-4801. https://doi.org/10.1039/C9FO02284H
Whyte, A. R., Rahman, S., Bell, L., Edirisinghe, I., Krikorian, R., Williams, C. M., & Burton-Freeman, B. (2021). Improved metabolic function and cognitive performance in middle-aged adults following a single dose of wild blueberry. *European journal of nutrition*, *60*(3), 1521-1536. https://doi.org/10.1007/s00394-020-02336-8
Whyte, A. R., Schafer, G., & Williams, C. M. (2017). The effect of cognitive demand on performance of an executive function task following wild blueberry supplementation in 7 to 10 years old children. *Food & function*, *8*(11), 4129-4138.
Wiggins, J. L., Mitchell, C., Stringaris, A., & Leibenluft, E. (2014). Developmental Trajectories of Irritability and Bidirectional Associations With Maternal Depression. *Journal of the American Academy of Child & Adolescent Psychiatry*, *53*(11), 1191-1205.e1194. https://doi.org/https://doi.org/10.1016/j.jaac.2014.08.005
Wilcox, R. R. (1987). New designs in analysis of variance. *Annual review of psychology*.
Williams, Abd El Mohsen, M., Vauzour, D., Rendeiro, C., Butler, L. T., Ellis, J. A., Whiteman, M., & Spencer, J. P. (2008). Blueberry-induced changes in spatial working memory correlate with changes in hippocampal CREB phosphorylation and brain-derived neurotrophic factor (BDNF) levels. *Free Radical Biology and Medicine*, *45*(3), 295-305.
Wolke, D., & James-Roberts, I. S. (1987). Multi-Method Measurement of the Early Parent-Infant System with Easy and Difficult Newborns. In H. Rauh & H.-C. Steinhausen (Eds.), *Advances in Psychology* (Vol. 46, pp. 49-70). North-Holland. https://doi.org/https://doi.org/10.1016/S0166-4115(08)60345-3
Wood, E., Hein, S., Mesnage, R., Fernandes, F., Abhayaratne, N., Xu, Y., Zhang, Z., Bell, L., Williams, C., & Rodriguez-Mateos, A. (2023). Wild blueberry (poly)phenols can improve vascular function and cognitive performance in healthy older individuals: a double-blind randomized controlled trial. *The American journal of clinical nutrition*, *117*(6), 1306-1319. https://doi.org/https://doi.org/10.1016/j.ajcnut.2023.03.017
Woolhouse, H., Brown, S., Krastev, A., Perlen, S., & Gunn, J. (2009). Seeking help for anxiety and depression after childbirth: results of the Maternal Health Study. *Archives of women's mental health*, *12*, 75-83.

Wu, B., Kulkarni, K., Basu, S., Zhang, S., & Hu, M. (2011). First-pass metabolism via UDP-glucuronosyltransferase: a barrier to oral bioavailability of phenolics. *Journal of pharmaceutical sciences*, *100*(9), 3655-3681.

Xiao, J. (2022). Recent advances in dietary flavonoids for management of type 2 diabetes. *Current Opinion in Food Science*, *44*, 100806. https://doi.org/https://doi.org/10.1016/j.cofs.2022.01.002

Xu, X., Zhao, X., Berde, Y., Low, Y. L., & Kuchan, M. J. (2019). Milk and Plasma Lutein and Zeaxanthin Concentrations in Chinese Breast-Feeding Mother-Infant Dyads With Healthy Maternal Fruit and Vegetable Intake. *J Am Coll Nutr*, *38*(2), 179-184. https://doi.org/10.1080/07315724.2018.1490934

Yalom, I. D., Lunde, D. T., Moos, R. H., & Hamburg, D. A. (1968). Postpartum blues syndrome: A description and related variables. *Archives of general psychiatry*, *18*(1), 16-27.

Yan, H., Ding, Y., & Guo, W. (2020). Mental Health of Pregnant and Postpartum Women During the Coronavirus Disease 2019 Pandemic: A Systematic Review and Meta-Analysis [Systematic Review]. *Frontiers in Psychology*, *11*. https://doi.org/10.3389/fpsyg.2020.617001

Ye, X., Bhupathiraju, S. N., & Tucker, K. L. (2013). Variety in fruit and vegetable intake and cognitive function in middle-aged and older Puerto Rican adults. *British Journal of Nutrition*, *109*(3), 503-510. https://doi.org/10.1017/S0007114512001183

Yeh, T.-S., Yuan, C., Ascherio, A., Rosner, B. A., Willett, W. C., & Blacker, D. (2021). Long-term Dietary Flavonoid Intake and Subjective Cognitive Decline in US Men and Women. *Neurology*, *97*(10), e1041-e1056. https://doi.org/10.1212/WNL.0000000000012454

Yildirim-Elikoglu, S., & Erdem, Y. K. (2018). Interactions between milk proteins and polyphenols: Binding mechanisms, related changes, and the future trends in the dairy industry. *Food reviews international*, *34*(7), 665-697.

Youdim, K. A., Shukitt-Hale, B., & Joseph, J. A. (2004). Flavonoids and the brain: interactions at the blood–brain barrier and their physiological effects on the central nervous system. *Free Radical Biology and Medicine*, *37*(11), 1683-1693.

Youdim, M. B. H., Edmondson, D., & Tipton, K. F. (2006). The therapeutic potential of monoamine oxidase inhibitors. *Nature Reviews Neuroscience*, *7*(4), 295-309. https://doi.org/10.1038/nrn1883

Yuen, M., Hall, O. J., Masters, G. A., Nephew, B. C., Carr, C., Leung, K., Griffen, A., McIntyre, L., Byatt, N., & Moore Simas, T. A. (2022). The Effects of Breastfeeding on Maternal Mental Health: A Systematic Review. *Journal of Women's Health*, *31*(6), 787-807. https://doi.org/10.1089/jwh.2021.0504

Yunes, R., Poluektova, E., Dyachkova, M., Klimina, K., Kovtun, A., Averina, O., Orlova, V., & Danilenko, V. (2016). GABA production and structure of gadB/gadC genes in Lactobacillus and Bifidobacterium strains from human microbiota. *Anaerobe*, *42*, 197-204.

Zamora-Ros, R., Agudo, A., Luján-Barroso, L., Romieu, I., Ferrari, P., Knaze, V., Bueno-de-Mesquita, H. B., Leenders, M., Travis, R. C., & Navarro, C. (2012). Dietary flavonoid and lignan intake and gastric adenocarcinoma risk in the European Prospective Investigation into Cancer and Nutrition (EPIC) study. *The American journal of clinical nutrition*, *96*(6), 1398-1408.

Zamora-Ros, R., Andres-Lacueva, C., Lamuela-Raventós, R. M., Berenguer, T., Jakszyn, P., Barricarte, A., Ardanaz, E., Amiano, P., Dorronsoro, M., & Larrañaga, N. (2010). Estimation of dietary sources and flavonoid intake in a Spanish adult population (EPIC-Spain). *Journal of the American Dietetic Association*, *110*(3), 390-398.

Zhang, J., Wang, H., Ai, C., Lu, R., Chen, L., Xiao, J., & Teng, H. (2024). Food matrix-flavonoid interactions and their effect on bioavailability. *Critical Reviews in Food Science and Nutrition*, *64*(30), 11124-11145. https://doi.org/10.1080/10408398.2023.2232880

Zhang, K., Wang, M., Zhang, J., Du, X., & Chen, Z. (2020). Brain Structural Plasticity Associated with Maternal Caregiving in Mothers: A Voxel- and Surface-Based Morphometry Study. *Neurodegenerative Diseases*, *19*(5-6), 192-203. https://doi.org/10.1159/000506258

Zhang, Q., Yang, H., Wang, J., Li, A., Zhang, W., Cui, X., & Wang, K. (2013). Effect of green tea on reward learning in healthy individuals: a randomized, double-blind, placebo-controlled pilot study. *Nutrition journal*, *12*, 1-7.

Zhang, S., Lu, B., & Wang, G. (2023). The role of gut microbiota in the pathogenesis and treatment of postpartum depression. *Annals of General Psychiatry*, *22*(1), 36. https://doi.org/10.1186/s12991-023-00469-8

Zhong, Q.-Y., Gelaye, B., Sánchez, S. E., & Williams, M. A. (2015). Psychometric properties of the Pittsburgh Sleep Quality Index (PSQI) in a cohort of Peruvian pregnant women. *Journal of Clinical Sleep Medicine*, *11*(8), 869-877.

Zhou, R., Liu, H.-M., Zou, L.-W., Wei, H.-X., Huang, Y.-N., Zhong, Q., Gu, S.-Y., Chen, M.-F., Wang, S.-L., & Sun, H.-X. (2022). Associations of parity with change in global cognition and incident cognitive impairment in older women. *Frontiers in Aging Neuroscience*, *14*, 864128.

Ziomkiewicz, A., Wichary, S., & Jasienska, G. (2019). Cognitive costs of reproduction: life-history trade-offs explain cognitive decline during pregnancy in women. *Biological Reviews*, *94*(3), 1105-1115.

Zlokovic, B. V. (2008). The blood-brain barrier in health and chronic neurodegenerative disorders. *Neuron*, *57*(2), 178-201.

Appendices

Appendix A. Main effects, covariates and interaction effects from the data presented in Chapter 4.

| Outcome | Main effect of Visit | Main effect of Condition | Significant covariates | Interaction effects |
|---|---|---|---|---|
| EPDS | $F_{[1, 37]}$= 3.28, *p*=.078 | $F_{[1, 36]}$= .081, *p*=.778 | | $F_{[1, 37]}$= 10.38, *p*=.003; pairwise comparisons showing significant differences between the flavonoid conditions at baseline (M= 10.29, SE= 1.34) and post intervention (M= 7.69, SE= 1.29) (*p*=.002) which was not evident in the control group (*p*=.276). |
| PA | $F_{[1, 37]}$= 4.92, *p*=.033 | $F_{[1, 36]}$= .128, *p*=.722 | Age: $F_{[1, 37]}$= 4.62, *p*=.038; Age and positive affect scores were not significantly associated at baseline (r=-.098, *p*= .557), or change from baseline (r=.285, *p*=.083), though were marginally significant post-intervention (r=-.308, *p*=.060). | $F_{[1, 37]}$= 5.13, *p*=.029; pairwise comparisons showing significant differences between the flavonoid conditions at baseline (M= 27.56, SE= 1.76) and post intervention (M= 31.96, SE= 2.00) (*p*=.006) which was not evident in the control group (*p*=.971). |
| STAI | $F_{[1, 37]}$= 4.10, *p*=.050: pairwise comparisons showed significantly lower STAI scores from baseline (M= 38.45, SE=1.57) to post | $F_{[1, 37]}$= 1.35, *p*=.252 | | $F_{[1, 37]}$= 2.26, *p*=.141 |

| | | | |
|---|---|---|---|
| | intervention (M= 35.62, SE= 1.63) ($p$=.050). | | |
| NA | $F_{[1, 37]}$= 4.78, $p$=.035; pairwise comparisons showed significantly lower NA scores from baseline (M= 16.26, SE=0.85) to post intervention (M= 14.63, SE= 0.73) ($p$=.035). | $F_{[1, 37]}$= .030, $p$=.864 | $F_{[1, 37]}$= .724, $p$=.400 |
| PSAS-RSF-C | $F_{[1, 37]}$= 12.46, $p$<.001; pairwise comparisons showed significantly lower scores from baseline (M= 21.98, SE=0.78) to post intervention (M= 19.48, SE= 0.76) ($p$<.001). | $F_{[1, 37]}$= .546, $p$=.464 | $F_{[1, 37]}$= 1.83, $p$=.184 |
| WHOQOL Physical | $F_{[1, 37]}$= 5.07, $p$=.029; pairwise comparisons showed significantly higher scores from baseline (M= 63.80, SE=2.65) to post intervention (M= 70.97, SE= 2.04) ($p$=*.029*). | $F_{[1, 37]}$= 1.45, $p$=.233 | $F_{[1, 37]}$= 1.32, $p$=.256 |
| WHOQOL Psychological | $F_{[1, 37]}$= 3.24, $p$=.080 | $F_{[1, 37]}$= 2.56, $p$=.118 | $F_{[1, 37]}$= .204, $p$=.654 |
| WHOQOL Social | $F_{[1, 37]}$= 1.91, $p$=.175 | $F_{[1, 37]}$= .104, $p$=.754 | $F_{[1, 37]}$= .632, $p$=.432 |
| WHOQOL Environmental | $F_{[1, 37]}$= .2.36, $p$=.133 | $F_{[1, 37]}$= .041, $p$=.840 | $F_{[1, 37]}$= 1.73, $p$=.196 |

Appendix B. T-tests, main effects, covariates and interaction effects from the data presented in Chapter 5.

| Outcome | Changes from pregnancy to 0-4 days postpartum | Main effect of Visit | Main effect of Condition | Significant covariates | Interaction effect |
|---|---|---|---|---|---|
| EPDS | t(55)=0.66, *p*=.507 | $F_{[4,157]}$= 2.03, *p*=.111 | $F_{[2,48]}$=0.95, *p*=.390 | Sleep: $F_{[1,193]}$=5.12, *p*=.024; Baseline flavonoid intake: $F_{[1,48]}$=4.73, *p*=.034 | $F_{[6,156]}$=0.41, *p*=.865 |
| STAI | t(55)=-0.96, *p*=.336 | $F_{[3,159]}$= 2.28, *p*=.080 | $F_{[2,49]}$=0.07, *p*=.923 | Sleep: $F_{[1,202]}$=17.02, *p*<.001 | $F_{[6,157]}$= 0.32, *p*=.924 |
| PA | t(55)=-0.38, *p*=.703 | $F_{[3,158]}$=.94 , *p*=.419 | $F_{[2,50]}$=0.18, *p*=.834 | Sleep: $F_{[1,190]}$=26.12, *p*<.001). | $F_{[6,157]}$= 0.32, *p*=.924 |
| NA | t(55)=-2.12, *p*=.038; Higher NA at Visit 2 (M=17.34, SD= 6.17) compared to Visit 1 (M=15.75, SD= 5.33) | $F_{[3,159]}$=0.84 , *p*=.472 | $F_{[2,50]}$=0.20, *p*=.817 | Sleep :$F_{[1,196]}$=10.90, *p*=.001 | $F_{[6,157]}$= 1.12 *p*=.349 |
| PSAS | N/A | $F_{[3,150]}$= 1.92, *p*=.127 | $F_{[2,48]}$=1.28, *p*=.286 | Sleep: $F_{[1,161]}$=6.75, *p*=.010; Baseline flavonoid intake: $F_{[1,48]}$=4.83, *p*=.032 | $F_{[6,149]}$=2.14, *p*=.051 |
| EPDSP | t(55)=-0.08, *p*=.932 | $F_{[4,159]}$= 0.33, *p*=.801 | $F_{[2,50]}$=0.58, *p*=.558 | N/A | $F_{[6,157]}$=0.64, *p*=.694 |
| PRMQ | t(55)=1.76, *p*=.082 | $F_{[3,157]}$= 0.27, *p*=.844 | $F_{[2,49]}$=0.48, *p*=.619 | Baseline flavonoid intake: $F_{[1,50]}$=4.39, *p*=.041 | $F_{[6,157]}$=1.58, *p*=.154 |
| Systolic BP | t(47)=-5.32, *p*<.001 Higher SBP at Visit 2 (M=117.69, SD= 9.71) | $F_{[3,128]}$= 12.94, *p<.001* | $F_{[2,47]}$=1.05, *p*=.356 | N/A | $F_{[6,127]}$=1.15, *p*=.334 |

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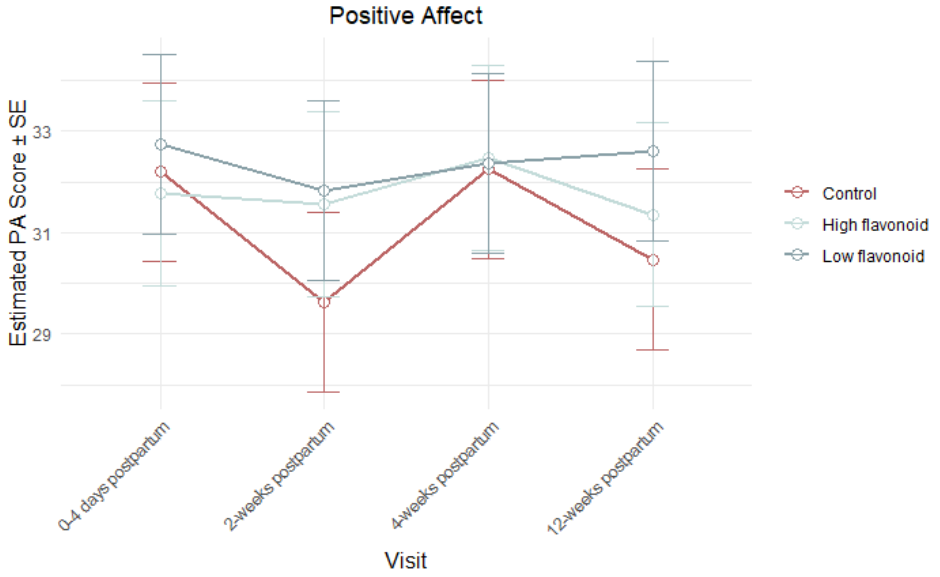
|---|---|---|---|---|---|
| | compared to Visit 1 (M=111.29, SD= 9.75) | | | | |
| Diastolic BP | t(47)=-4.14, $p$<.001 Higher DBP at Visit 2 (M= 76.44, SD= 7.99) compared to Visit 1 (M=72.25, SD= 7.99) | $F_{[3,133]}$= 0.91, $p$=.435 | $F_{[2,48]}$=1.01, $p$=.370 | N/A | $F_{[6,130]}$=1.00, $p$=.423 |
| N-BACK overall accuracy | t(34)=0.27, $p$=.781 | $F_{[3,96]}$=0.51, $p$=.670 | $F_{[2,33]}$=0.98, $p$=.385 | N/A | $F_{[6,95]}$=0.44, $p$=.844 |
| N-BACK overall RT | t(34)=-0.41, $p$=.677 | $F_{[4, 154]}$= 1.42, $p$=.228 | $F_{[2,48]}$=0.25, $p$=.778 | N/A | $F_{[8,153]}$=0.46, $p$=.879 |
| N-BACK N-1 accuracy | | $F_{[3,141]}$= 0.91, $p$=.433 | $F_{[2,42]}$=1.81, $p$=.175 | N/A | $F_{[6,138]}$=1.47, $p$=.192 |
| N-BACK N-1 RT | | $F_{[3,130]}$= 0.20, $p$=.893 | $F_{[2,43]}$=0.13, $p$=.878 | N/A | $F_{[6,128]}$=0.82, $p$=.551 |
| N-BACK N-2 accuracy | | $F_{[3,116]}$= 2.50, $p$=.062 | $F_{[2,42]}$=1.34, $p$=.270 | N/A | $F_{[6,111]}$=1.96, $p$=.076 |
| N-BACK N-2 RT | | $F_{[3,139]}$= 0.89, $p$=.447 | $F_{[2,47]}$=0.22, $p$=.796 | Sleep: $F_{[1, 178]}$= 4.50, $p$=.035 | $F_{[6,137]}$=1.01, $p$=.418), |
| N-BACK N-3 accuracy | | $F_{[3,135]}$= 4.11, $p$=.007, significant increase in scores between Visit 3 ($M$=1.54, $SE$=.07) to Visit 4 ($M$=1.78, $SE$=.07) ($p$=.046). | $F_{[2,45]}$=1.07, $p$=.348 | Age: $F_{[1,45]}$= 4.88, $p$=.032 | $F_{[6,133]}$=0.78, $p$=.584 |
| N-BACK N-3 RT | | $F_{[3,130]}$=2.36, $p$=.073 | $F_{[2,44]}$=0.96, $p$=.390 | N/A | $F_{[6,127]}$=0.54, $p$=.775 |
| N-BACK N-4 accuracy | | $F_{[3, 118]}$= 4.63, $p$=.004, significant increase from Visit 2 ($M$=2.26, $SE$=.09) to Visit 3 ($M$=2.63, $SE$=.09) ($p$=.022) in addition to significant differences between Visit 2 ($M$=2.26, $SE$=.09) to Visit 4 ($M$=2.69, $SE$=.10) ($p$=.005). | $F_{[2,37]}$=0.89, $p$=.416 | N/A | $F_{[6, 116]}$=1.80, $p$=.104), |

| | | | | | |
|---|---|---|---|---|---|
| N-BACK N-4 RT | | ($F_{[3,136]}$= 3.25, $p$=.023, pairwise comparisons $p$>.05. | $F_{[2,44]}$=1.26, $p$=.291 | N/A | $F_{[6,134]}$=0.86, $p$=.525 |
| N-BACK N-5 accuracy | | $F_{[3,163]}$= 1.83, $p$=.142 | $F_{[2,163]}$=1.51, $p$=.222 | N/A | $F_{[6,163]}$=1.77, $p$=.107, |
| N-BACK N-5 RT | | $F_{[3,126]}$= 1.54, $p$=.205 | $F_{[2,45]}$=0.04, $p$=.954 | N/A | $F_{[6,125]}$=0.67, $p$=.669 |
| MANT overall accuracy | t(55)=1.03, $p$=.305 | $F_{[3, 1082]}$=14.58, $p$<.001 Pairwise comparisons showing significant differences between Visit 2 (M= 12.03, SE= 0.46) and Visit 3 (M= 12.65, SE= 0.46)($p$=.004); Visit 2 and Visit 4 (M= 12.90, SE= 0.46) ($p$<.001), Visit 2 and Visit 5 (M=13.11, SE= 0.47) ($p$<.001), Visit 3 and 5 ($p$=.025) | $F_{[2, 35]}$=2.42, $p$=.103 | Sleep: $F_{[1, 1109]}$=8.41, $p$<.003 | $F_{[6, 1080]}$=2.97, $p$=.006, |
| MANT overall RT | t(55)=2.00, $p$=.051 | $F_{[3, 1632]}$ = 2.08, $p$ = .100 | $F_{[2, 36]}$ = 3.06, $p$ = .059 | Age: $F_{[1, 36]}$ = 10.07, $p$ = .003 | $F_{[6, 1050]}$ = 1.10, $p$ = .360 |
| MANT 500ms accuracy | t(45)=-0.634, $p$=.529 | $F_{[3,626]}$=8.44, $p$<.001; pairwise comparisons showing significant differences between Visit 2 ($M$=11.17, $SE$= 0.57) and Visit 5 ($M$= 12.39, $SE$= 0.57) ($p$= <.0001) and Visit 3 ($M$= 11.65, $SE$= 0.57) and Visit 5 postpartum ($p$=.008). | $F_{[2, 46]}$=1.26, $p$=.291 | Flavonoid intake: $F_{[1,662]}$=4.98, $p$=.025 | ($F_{[6,626]}$=2.52, $p$=.020 |
| MANT 500ms RT | t(45)=3.45, $p$=.001, | $F_{[3,625]}$=1.66, $p$=1.66 | $F_{[2, 46]}$=1.46, $p$=.242 | Age: $F_{[1,47]}$=7.32, $p$=.009 | $F_{[6,624]}$=.75, $p$=.603 |

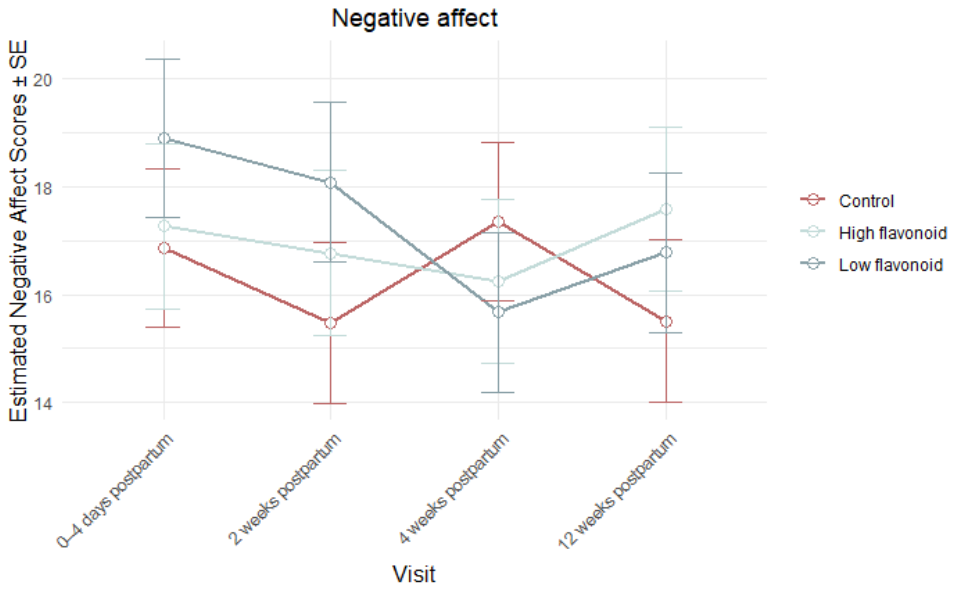
| | | | | | |
|---|---|---|---|---|---|
| | Where quicker RT occurred at Visit 2 (M= 484.8, SD= 50.86) compared to Visit 1 (M=507.17, Sd= 67.46) | | | | |
| MANT 120ms accuracy | t(31)=0.75, $p$=.456 | $F_{[3, 504]}$=12.06, *p<.001;* pairwise comparisons showed significant differences between Visits 2 ($M$=11.87, $SE$=0.42) and Visit 4 ($M$=13.45, $SE$=0.44) ($p$<.001), Visit 2 and Visit 5 ($M$=13.23, $SE$=0.42) (*p<.001*), and Visit 3 ($M$=12.77, $SE$=0.41) and Visit 4 ($p$=.037) | $F_{[2, 36]}$=0.33, $p$=.719 | Sleep: ($F_{[1, 532]}$=24.88, *p<.001* | $F_{[6, 502]}$=1.15, $p$=.326 |
| MANT 120ms RT | t(31)=2.03, $p$=.050, faster reaction times seen at Visit 2 (M=466.31, SD= 59.48), compared to Visit 1 (M=486.05, SD= 63.47) | $F_{[3,496]}$ = 4.57, $p$=.003; pairwise comparisons showing significant decreases in reaction time from Visit 3 ($M$=484.83, $SE$=8.69) and Visit 5 (M = 467.11, SE = 8.80) ($p$ = .006) and between Visit 4 (M = 481.14, SE = 8.87) and Visit 5 ($p$ = .047) | $F_{[2,35]}$ = 0.18, $p$ = .829 | N/A | $F_{[6,494]}$ = 2.22, $p$ = .039 |
| Word span | t(50)=0.18, $p$=.850 | $F_{[3,128]}$= 0.27, $p$=.846 | $F_{[2,44]}$=0.13, $p$=.874 | N/A | $F_{[6,126]}$=1.96, $p$=.075 |
| Final Acquisition | t(50)=-1.22, $p$=.225 | $F_{[1, 140]}$ = 0.85, $p$ = .466 | $F_{[2, 49]}$ = 0.86, $p$ = .429 | $F_{[1, 49]}$ = 6.20, $p$ =.016 | $F_{[2, 138]}$ = 0.48, $p$ =.816 |
| Total Acquisition | t(50)=-0.79, $p$=.430 | $F_{[3, 139]}$ = 0.52, $p$ = .670 | $F_{[2, 49]}$ = 0.55, $p$ = .579 | Age: $F_{[1, 48]}$ = 8.99, $p$ = .004 | $F_{[6, 137]}$ = 1.13, $p$ = .346 |
| Amount Learned | t(50)=-1.20, $p$=.253 | $F_{(3,143)}$ = 0.87, $p$ = .458 | $F_{(2,46)}$ = 1.92, $p$ = .158 | N/A | $F_{(6,140)}$ = 0.78, $p$ = .584 |

| | | | | | |
|---|---|---|---|---|---|
| Proactive Interference | t(50)=-1.41, *p*=.164) | $F_{(3,184)} = 0.42$, $p = .740$ | $F_{(2,184)} = 0.09$, $p = .915$ | Age: $F_{(1,47)} = 5.35$, $p = .025$), | $F_{(6,184)} = 0.60$, $p = .729$ |
| Retroactive Interference | t(50)=-2.49, *p*=.015), with higher scores at Visit 2 (M=1.96, SD= 2.05) compared to Visit 1 (M= 1.07, SD= 2.05) | $F_{(3,142)} = 2.15$, $p = 0.097$ | $F_{(2,47)} = 0.32$, $p = .725$ | N/A | $F_{(6,140)} = 0.18$, $p = .982$ |
| Delayed Recall | t(50)=0.79, *p*=.431 | $F_{(3,137)} = 1.27$, $p = .288$ | $F_{(2,49)} = 1.41$, $p = .253$ | Age: $F_{(1,49)} = 6.08$, $p = .017$). | $F_{(6,135)} = 0.83$, $p = .545$ |
| Word recognition | t(44)=2.53, *p*=.015, with higher scores at Visit 1 (M=20.76, SD=5.28) compared to Visit 2 (M=19.63, SD= 4.96) | $F_{(4,127)} = 0.27$, $p = .896$ | $F_{(2,49)} = 3.59$, $p = .035$), pairwise comparisons showed a significant difference in scores between Control (*M*=21.6, *SE*=1.06) and Low flavonoid (17.8, *SE*=1.05) (*p*=.040). | | $F_{(8,127)} = 0.80$, $p = .602$ |
| Source monitoring accuracy | t(44)=1.87, *p*=.067 | $F_{(3,113)} = 1.11$, $p = .349$ | $F_{[2,47]=} 3.64$, $p = .033$ No significant pairwise comparisons were found (*p>.05)* | N/A | $F_{(6,112)} = 0.65$, $p = .690$ |
| Source monitoring reaction time | t(44)=-0.139, *p*=.889 | $F_{(3,122)} = 0.51$, $p = .674$ | $F_{(2,48)} = 0.35$, $p = .700$ | N/A | $F_{(6,120)} = 1.15$, $p = .337$ |

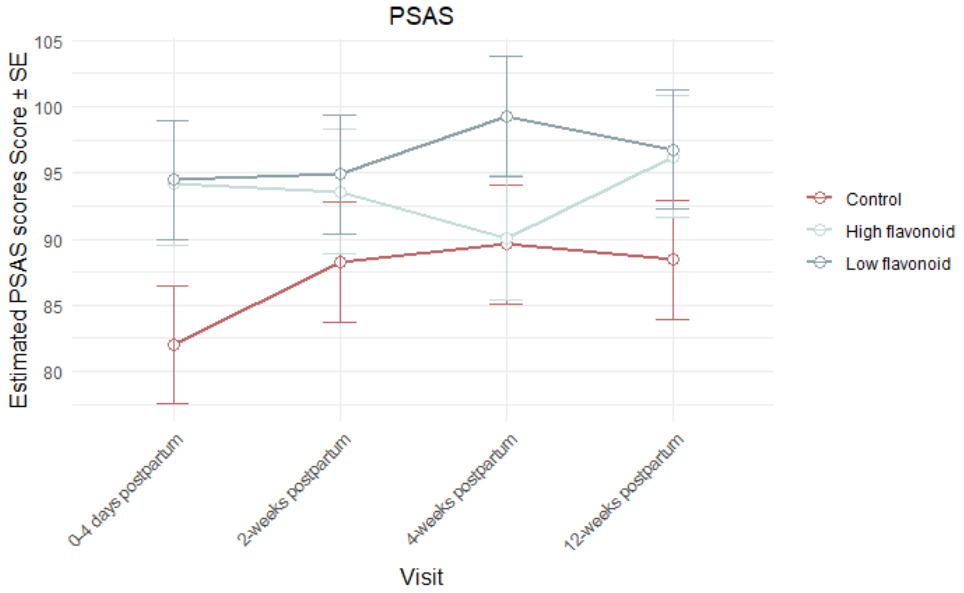
Appendix B.1. Graph showing PANAS PA scores



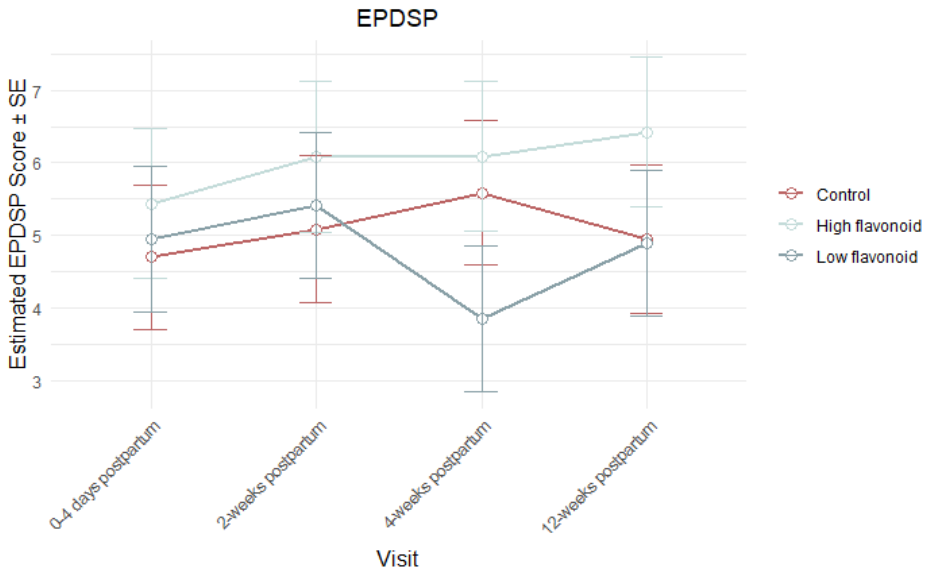

Appendix B.2. Graph showing PANAS NA scores



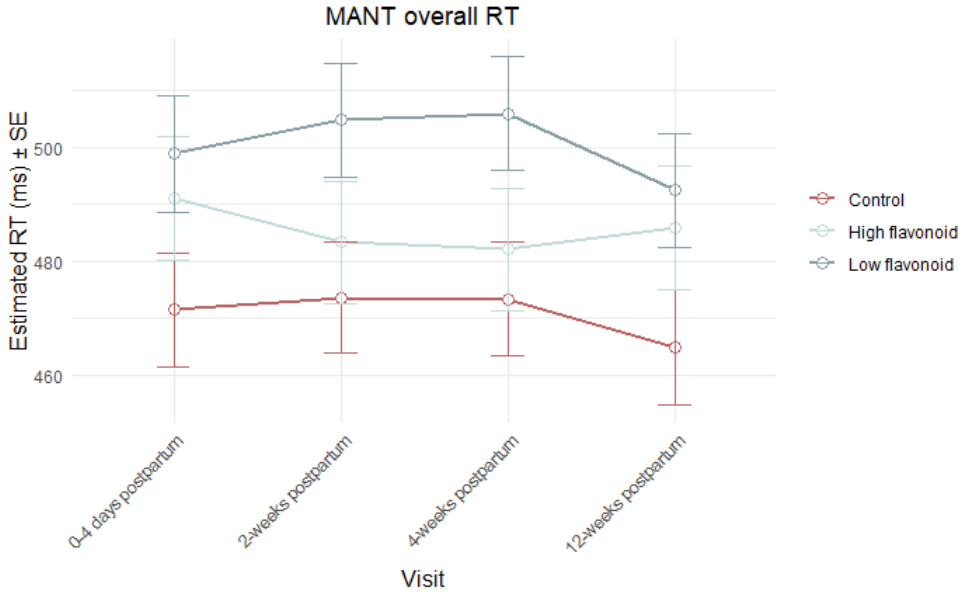
Appendix B.3. Graph showing PSAS scores



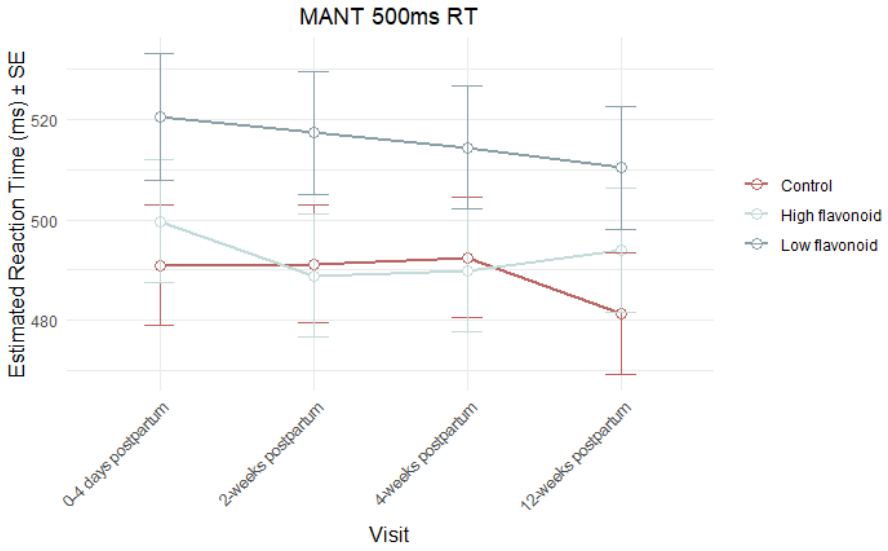

Appendix B.4. Graph showing EPDSP scores



Appendix B.5. Graph showing MANT overall RT scores

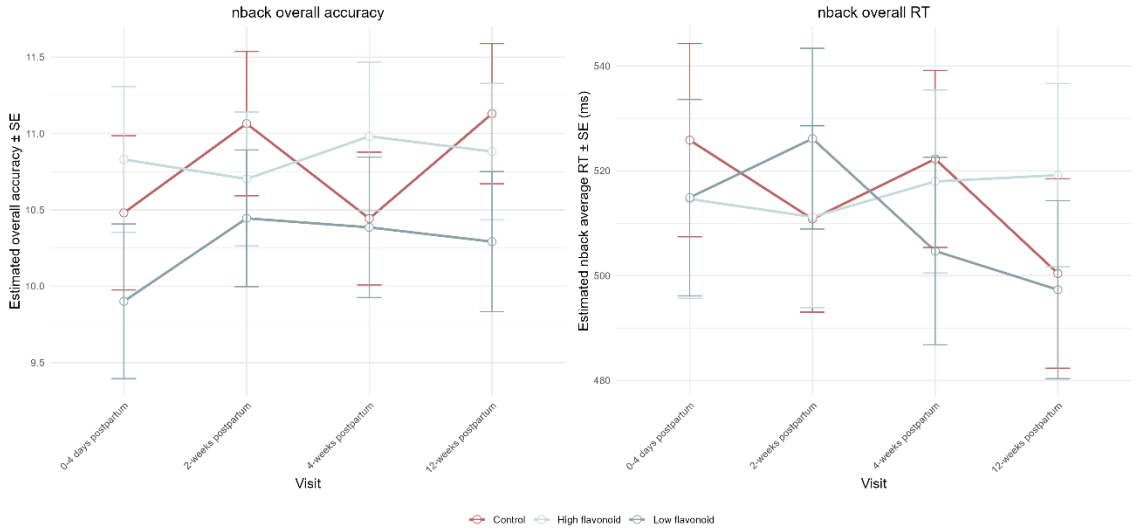



Appendix B.6. Graph showing MANT 500ms RT scores

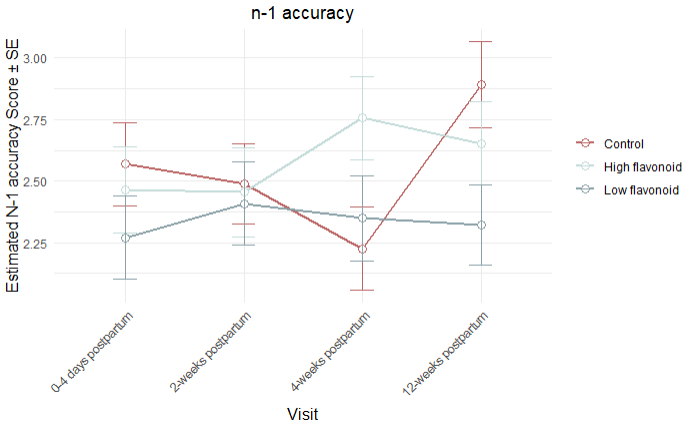



Appendix B.7. Graph showing MANT 120ms RT scores

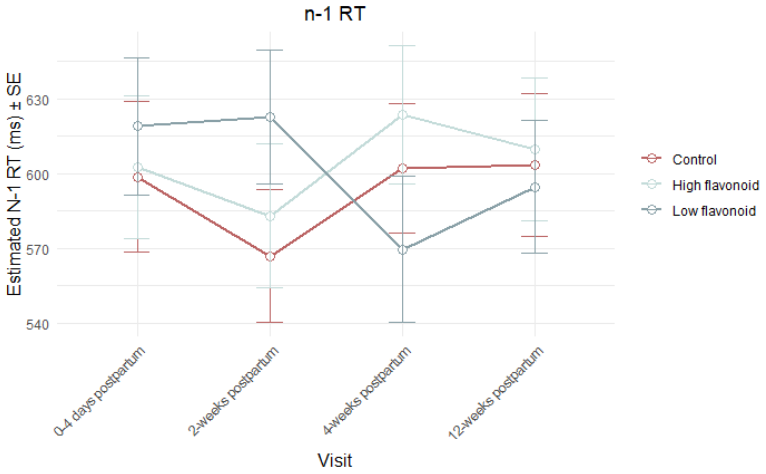
Appendix B.8. Graph showing NBACK overall RT scores



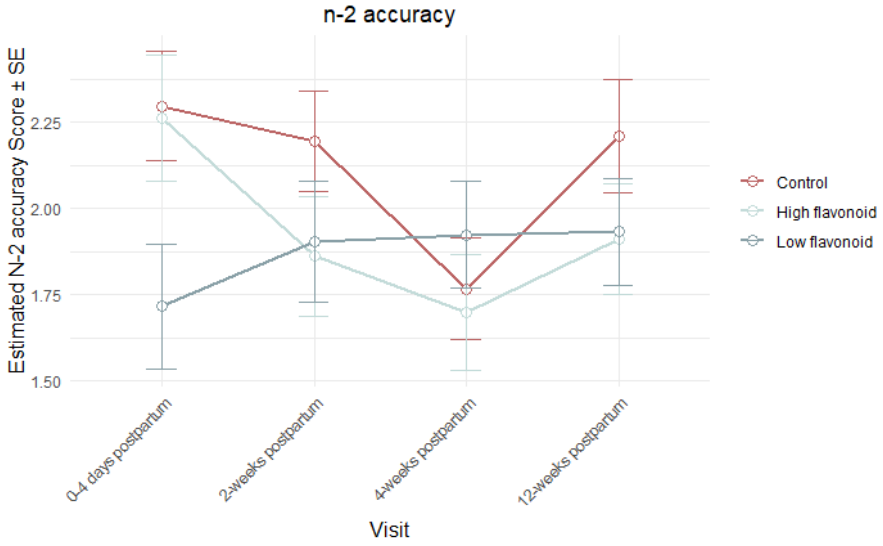

Appendix B.9. Graph showing *n-1* accuracy scores



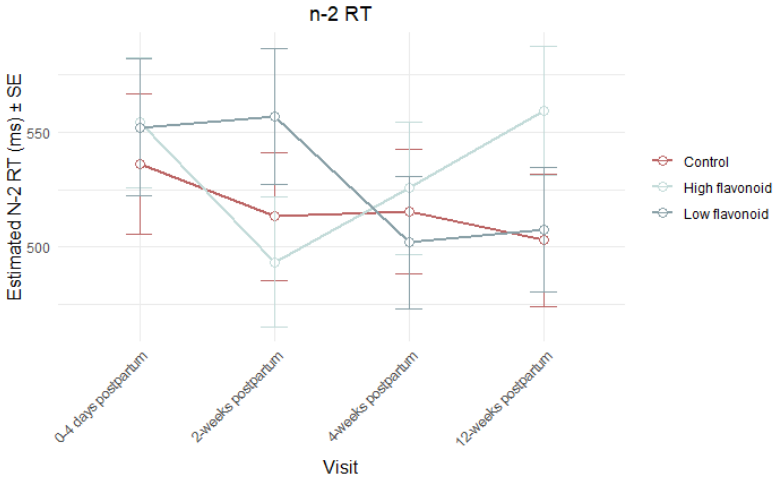

Appendix B.10. Graph showing *n-1* RT



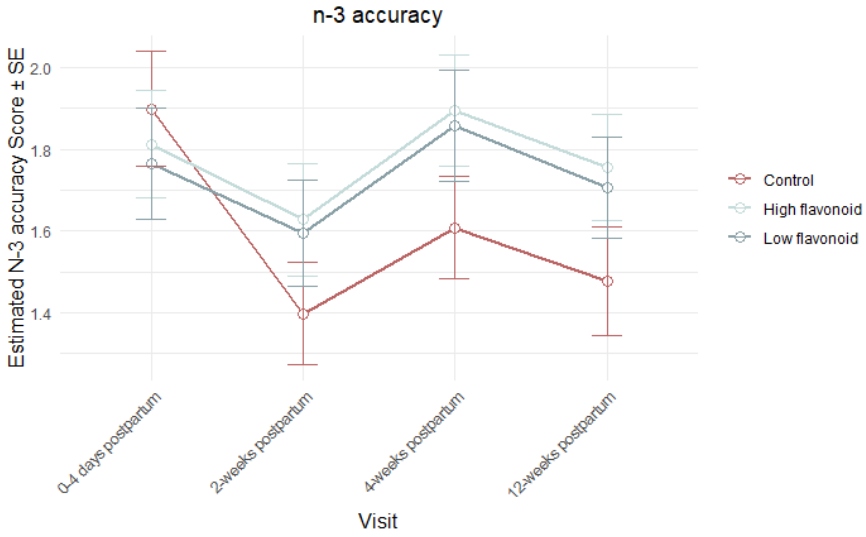
Appendix B.11. Graph showing *n-2* accuracy scores



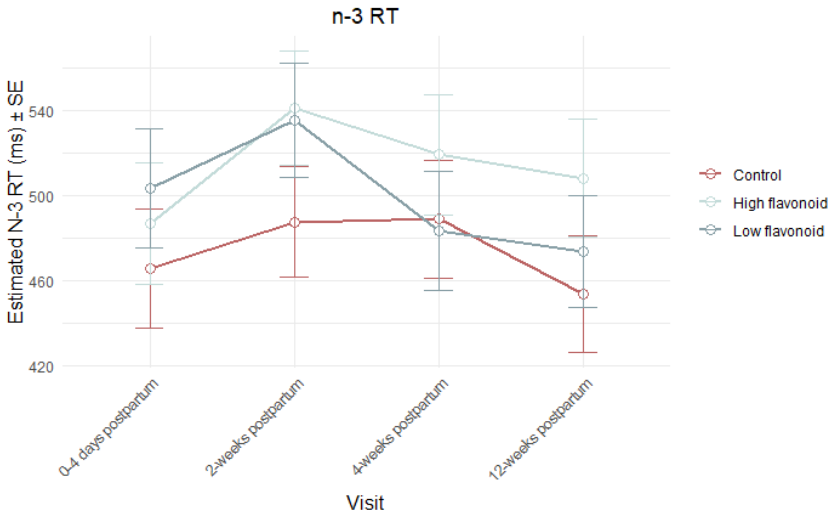

Appendix B.12. Graph showing *n-2* RT



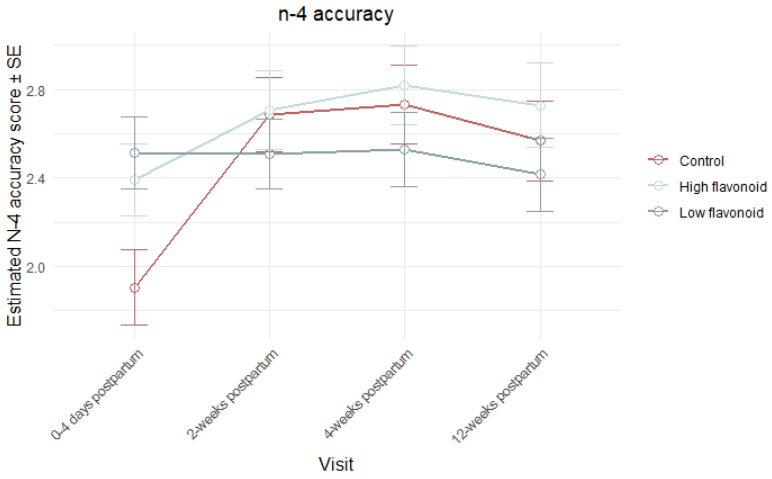

Appendix B.13. Graph showing *n-3* accuracy scores



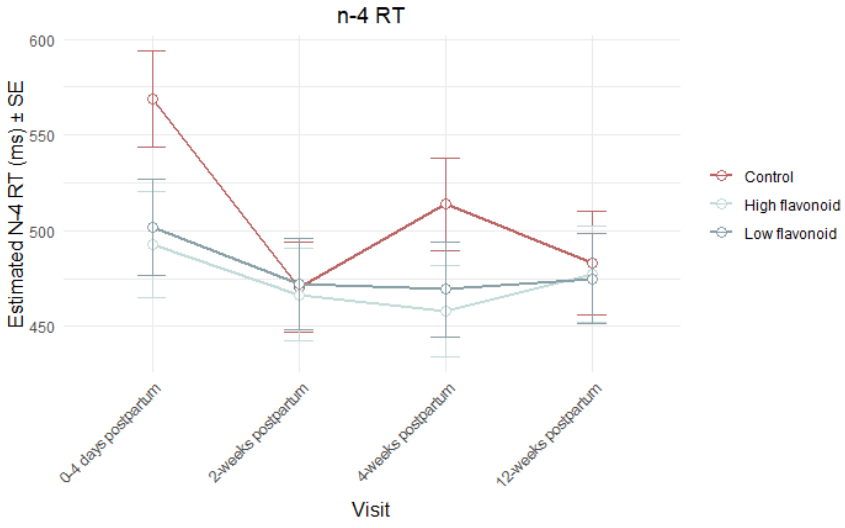
Appendix B.14. Graph showing *n-3* RT



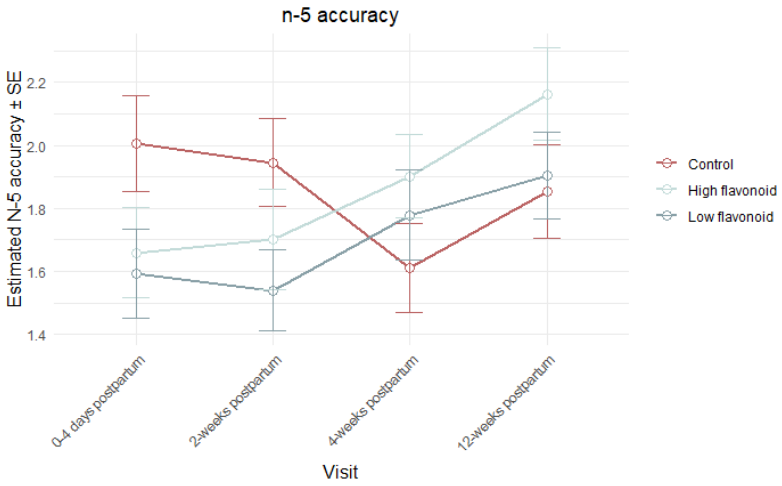

Appendix B.15. Graph showing *n-4* accuracy scores



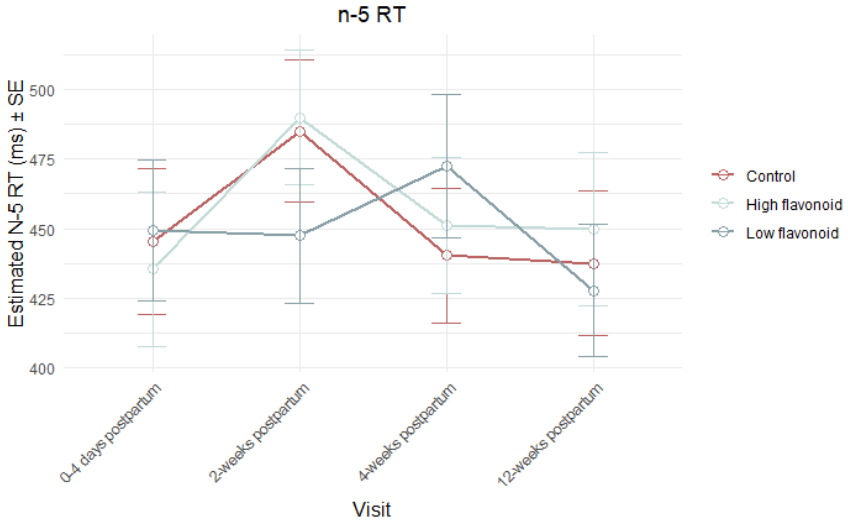

Appendix B.16. Graph showing *n-4* RT



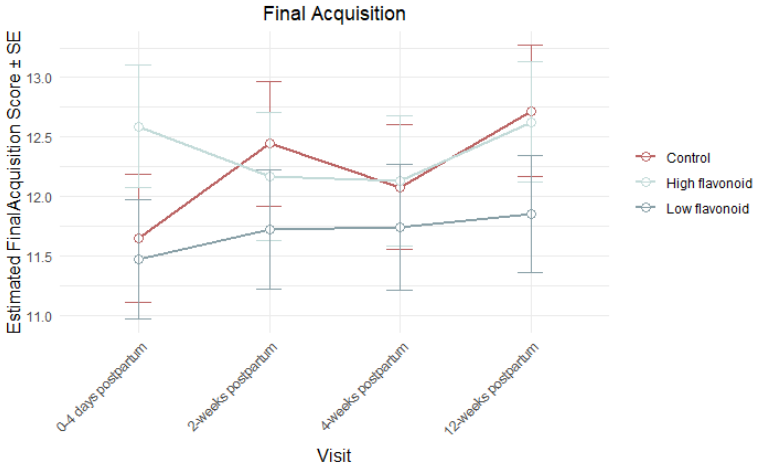
Appendix B.17. Graph showing *n-5* accuracy scores



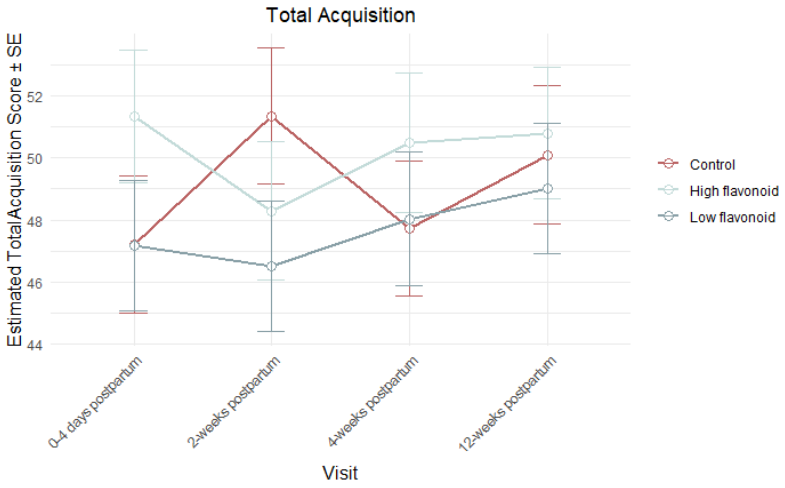

Appendix B.18. Graph showing *n-5* RT



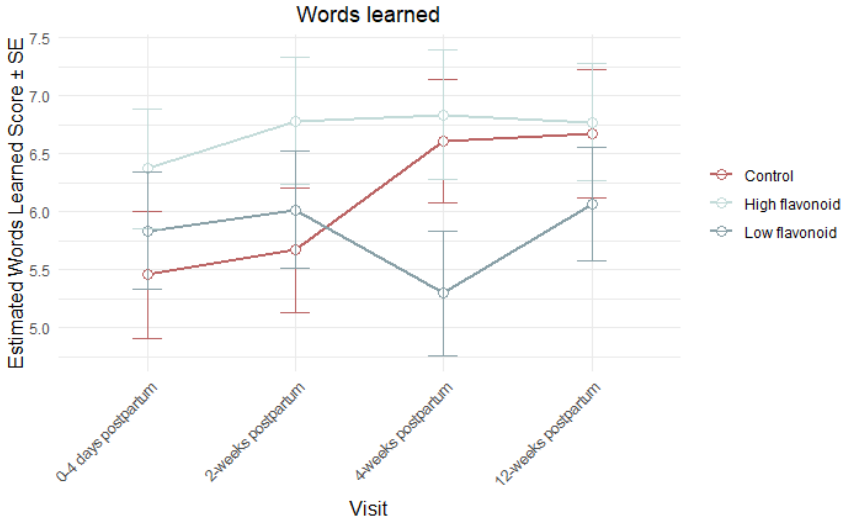

Appendix B.19. Graph showing Final Acquisition scores



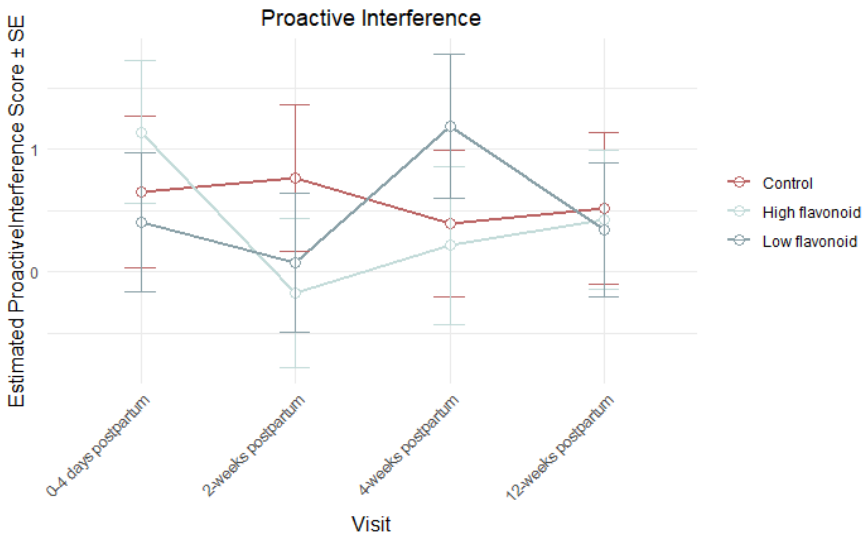
Appendix B.20. Graph showing Total Acquisition scores



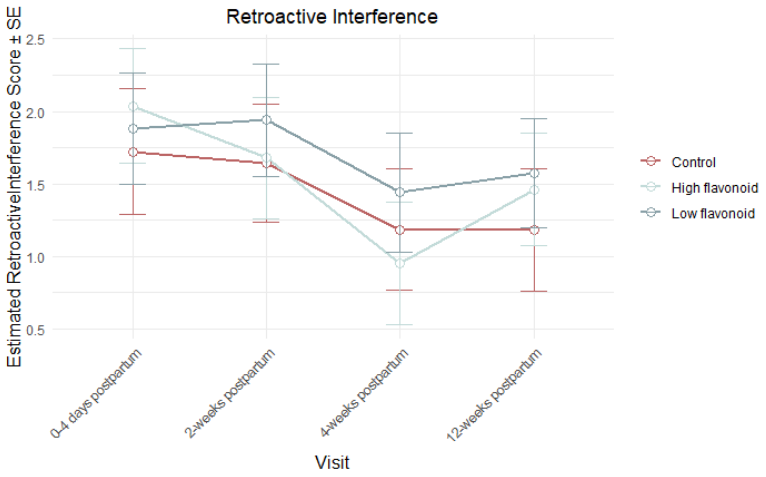

Appendix B.21. Graph showing Words Learned scores



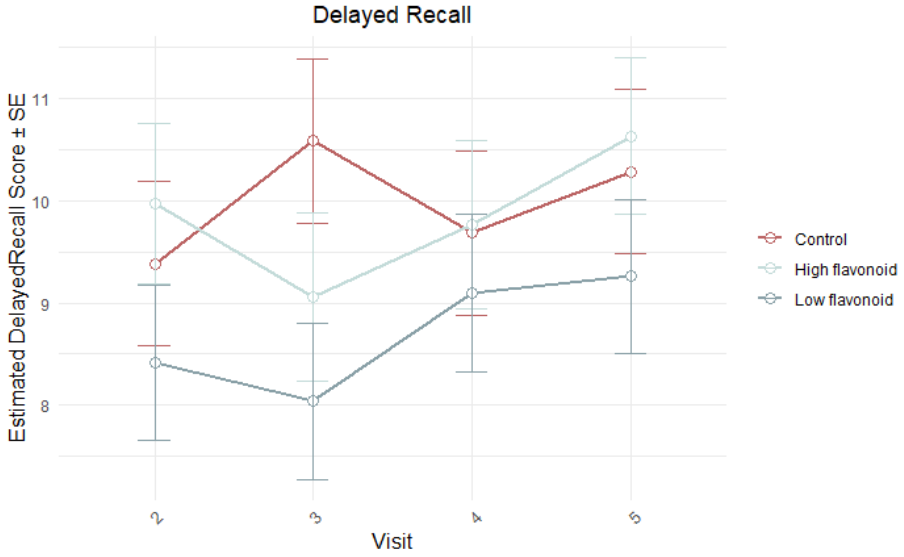

Appendix B.22. Graph showing Proactive Interference scores



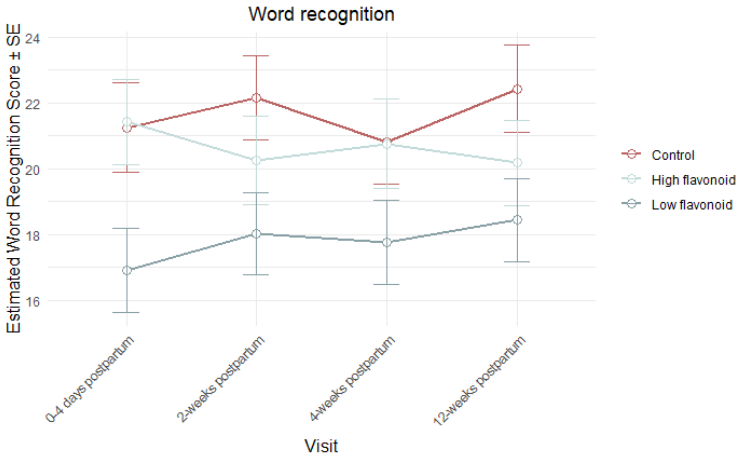
Appendix B.23. Graph showing Retroactive Interference scores



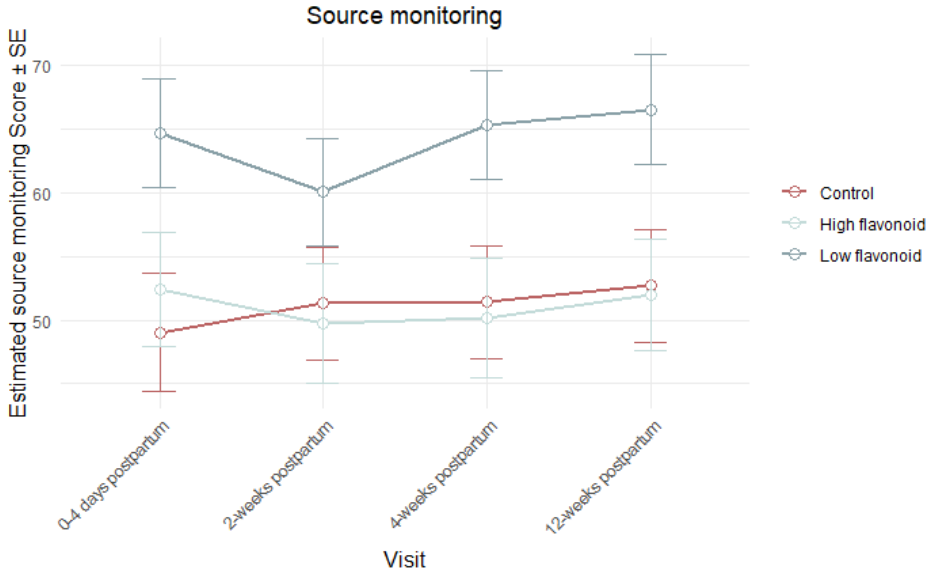

Appendix B.24. Graph showing Delayed Recall scores



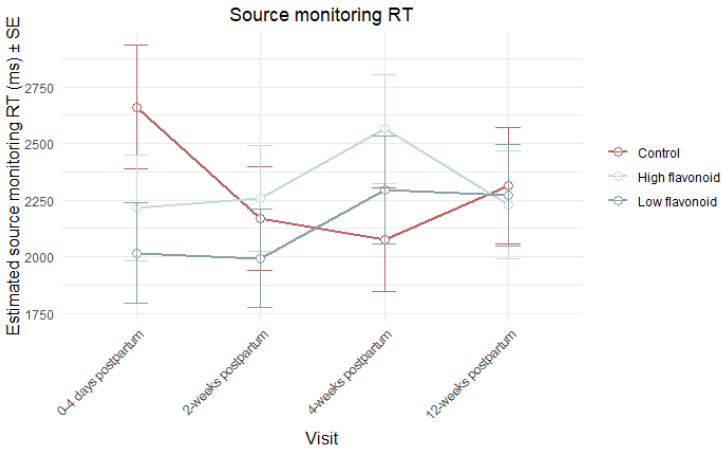

Appendix B.25. Graph showing Word Recognition scores



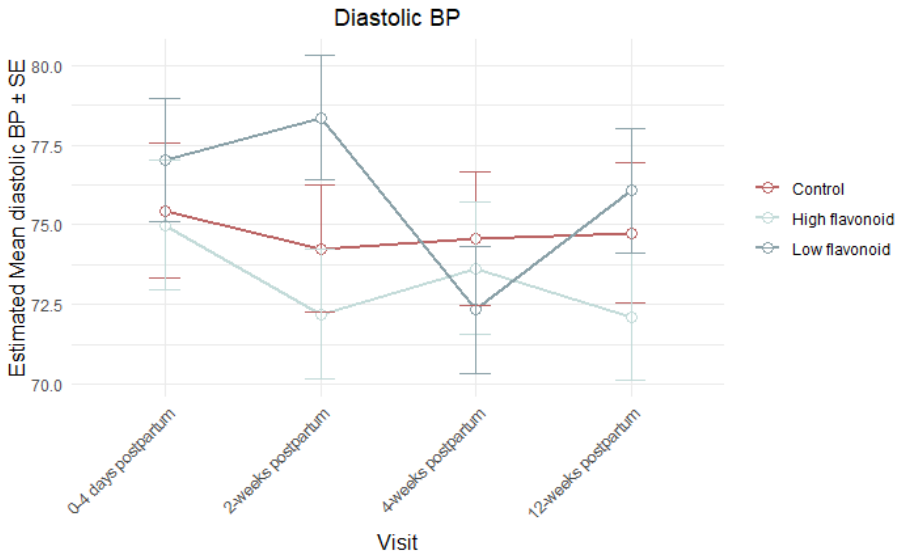
Appendix B.26. Graph showing Source Monitoring accuracy scores




Appendix B.27. Graph showing Source Monitoring RT




Appendix B.28. Graph showing Diastolic BP



Appendix C. Main effects, covariates and interaction effects from the combined data presented in Chapter 6

| Outcome | Main effect of Visit | Main effect of Condition | Significant covariates | Interaction effect |
|---|---|---|---|---|
| PA | $F(1, 107) = 1.19$, $p = .277$ | $F(1, 107) = 0.05$, $p = .815$ | $F(1, 31) = 6.65$, $p = .015$ | $F(1, 104) = 0.66$, $p = .420$ |
| NA | $F(1,106) = 4.41$, $p = .037$: lower negative affect at Post Visit (M = 15.47, SE = 0.69) compared to Baseline (M = 16.74, SE = 0.69). | $F(1,106) = 0.0003$, $p = .987$ | Stress: $F(1,114) = 18.51$, $p < .001$ | $F(1,104) = 0.001$, $p = .993$ |
| IMS | $F_{[1,105]}= 31.07$, $p<.001$: pairwise comparisons showed IMS scores were significantly lower at 2hours (M=-64.65, SE= 2.63) compared to baseline (M= -74.30, SE= 2.62) ($p<.001$) | $F_{[1, 104]}=0.073$, $p=.787$ | Stress: $F_{[1, 137]}= 14.73$, $p<.001$<br>Temperament: $F_{[1, 134]}= 8.72$, $p=.003$<br>Baseline flavonoid intake: $F_{[1, 30]}= 11.81$, $p=.001$ | $F_{[1,101]}=0.007$, $p=.933$ |
| SAI | $F_{[1,106]}= 14.94$, $p<.001$) pairwise comparisons showed SAI scores were significantly lower at 2 hours (M=36.03, SE= 1.38) compared to baseline (M= 39.18, SE= 1.38) ($p<.001$) | $F_{[1, 104]}=0.96$, $p=.327$ | Baseline flavonoid: $F_{[1,58]}= 4.43$, $p=.039$ | $F_{[1,102]}=0.38$, $p=.538$ |
| BL Alert | $F_{[1,103]}= 9.54$, $p=.002$: pairwise comparisons showed alertness was significantly lower at baseline (M=42.25, SE= 2.08) compared to 2-hours (M= 30.06, SE= 2.08) ($p=.002$) | $F_{[1, 104]}=0.03$, $p=.853$ | Baseline flavonoid: $F_{[1, 30]}= 5.48$, $p=.025$; Stress: $F_{[1,136]}= 6.85$, $p=.009$ | $F_{[1,102]}=0.53$, $p=.466$ |
| BL Calm | $F_{[1,106]}= 2.34$, $p=.129$ | $F_{[1, 107]}= 0.64$, $p=.422$ | Baseline flavonoid intake: $F_{[1,30]}= 8.59$, $p=.006$ | $F_{[1,104]}= 0.06$, $p=.798$ |
| BL Content | $F_{[1,104]}= 6.32$, $p=.013$ where pairwise comparisons showed | $F_{[1, 103]}= 0.06$, $p=.804$ | Baseline flavonoid: $F_{[1, 28]}= 7.29$, $p=.011$ | $F_{[1,100]}= 0.01$, $p=.899$ |

| | | | | |
|---|---|---|---|---|
| | lower calmness scores at baseline (M=35.84, SE= 2.11), compared to 2-hrs (M=32.26, SE= 2.11) | | Stress: $F_{[1, 135]}$= 7.15, $p$=.008 | |
| Systolic BP | F(1, 108) = 0.02, $p$ = .879 | F(1, 106) = 0.32, $p$ = .570 | Age: F(1, 33) = 5.09, $p$ = .030 | F(1, 104) = 1.69, $p$ = .195 |
| Diastolic BP | F(1, 101) = 0.03, p = .861 | F(1, 100) = 1.32, p = .253 | | F(1, 98) = 0.74, p = .389 |
| RAVLT Wordspan | $F$(1, 106.29) = 3.03, $p$ = .085 | $F$(1, 107.08) = 0.39, $p$ = .532 | | $F$(1, 104.37) = 0.12, $p$ = .728 |
| RAVLT Final Acquisition | $F$(1, 108) = 0.04, $p$ = .747 | $F$(1, 108) = 0.0003, $p$ = .986 | $F$(1, 32) = 580, $p$ = .021 | $F$(1, 105) = 1.39, $p$ = .239 |
| RAVLT total acquisition | F(1, 108) = 4.06, p = .046: baseline (M = 48.83, SE = 1.47) to post-intervention (M = 47.13, SE = 1.47) | F(1, 106) = 0.08, p = .776 | Age: F(1, 32) = 4.68, p = .037 | F(1, 104) = 0.89, p = .345 |
| RAVLT Amount Learned | F(1, 104) = 1.73, p = .190 | (F(1, 106) = 0.59, p = .440 | | (F(1, 103) = 4.82, p = .030 |
| RAVLT Proactive Interference | F(1, 109) = 0.68, p = .409 | F(1, 109) = 0.33, p = .563 | Birth experience: (F(1, 109) = 4.87, p = .029)<br>Perceived stress: (F(1, 109) = 5.68, p = .018) | F(1, 109) = 3.29, p = .072 |
| RAVLT Retroactive Interference | F(1, 85) = 0.01, p = .897 | F(1, 89) = 0.0008, p = .978 | | (F(1, 82) = 0.22, p = .637 |
| RAVLT Delayed Recall | F(1, 105) = 2.84, $p$ = .094 | F(1, 104) = 0.007, $p$ = .932 | Age: (F(1, 31) = 4.59, $p$ = .039<br>Temperament: (F(1, 133) = 4.93, $p$ = .028 | F(1, 102) = 0.85, $p$ = .358 |
| RAVLT Word Recognition | F(1, 98) = 1.20, $p$ = .274 | F(1, 99) = 0.05, $p$ = .819 | Temperament: F(1, 122) = 5.17, $p$ = .024 | F(1, 97)= 0.29, $p$ = .586 |
| RAVLT Source monitoring accuracy | F(1, 96) = 12.69, $p$ < .001: better performance at Baseline (M = 90.64, SE = 1.55) compared to Post (M = 84.65, SE = 1.51) ($p$=.0006) | F(1, 96) = 0.002, $p$ = .964 | Age: F(1, 30) = 8.12, $p$ = .007 | F(1, 94) = 0.01, $p$ = .908 |
| RAVLT source monitoring RT | F(1, 88) = 0.07, $p$ = .782 | F(1, 88) = 0.07, $p$ = .782 | Location: F(1, 29) = 5.77, $p$ = .022<br>Sleep: F(1, 104) = 7.02, $p$ = .009 | F(1, 86) = 2.21, $p$ = .140), |
| N-BACK overall accuracy | F(1, 106) = 0.92, p = .339 | F(1, 107) = 0.01, p = .918 | | F(1, 104) = 1.45, p = .229 |

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| N-BACK overall RT | F(1, 97) = 0.17, p = .677 | F(1, 96) = 9.91, p = .002: participants in the WBB group responding faster on average (M = 509.03 ms, SE = 7.80) than those in the placebo group (M = 530.58 ms, SE = 7.79 | Age: F(1, 31) = 6.15, p = .018 | F(1, 96) = 3.73, p = .056 |
| N-BACK N-1 accuracy | F(1, 105) = 0.35, p = .550 | F(1, 107) = 1.34, p = .248 | Baseline flavonoid: F(1, 31) = 6.35, p = .016 | F(1, 105) = 4.15, p = .043; participants in the Placebo condition, participants had higher accuracy at Baseline (M = 2.78, SE = 0.10) compared to Post (M = 2.65, SE = 0.09). In contrast, for the WBB condition, accuracy was higher at Post (M = 2.73, SE = 0.09) compared to Baseline (M = 2.49, SE = 0.10), though this difference between the conditions at baseline was not significant (*p=.174)*. |
| N-BACK N-1 RT | F(1, 101) = 1.41, p = .236 | F(1, 103) = 0.38, p = .535 | | F(1, 100) = 0.75, p = .388 |
| N-BACK N-2 accuracy | F(1, 104) = 0.79, p = .373 | F(1, 105) = 0.09, p = .760 | Sleep: F(1, 113) = 3.93, p = .049 | F(1, 103) = 0.79, p = .374 |
| N-BACK N-2 RT | F(1, 104) = 4.21, *p* = .042), with faster responses observed post-intervention (M = 520.07 ms, SE = 14.55) relative to baseline (M = 552.97 ms, SE = 14.56) | F(1, 105) = 4.86, *p* = .029: with participants in the WBB group responding faster on average (M = 519.07 ms, SE = 14.55) compared to the placebo group (M = 553.97 ms, SE = 14.56). | birth experience (F(1, 36) = 4.17, *p* = .048) | F(1, 103) = 1.87, *p* = .173 |
| N-BACK N-3 accuracy | F(1, 103) = 0.35, p = .555 | F(1, 105) = 0.07, p = .780 | | : F(1, 102) = 0.55, p = .456 |
| N-BACK N-3 RT | F(1, 21) = 1.00, p = .327 | F(1, 23) = 0.03, p = .849 | Sleep: F(1, 24) = 6.45, p = .017 Temperament: F(1, 24) = 4.30, p = .048 | F(1, 21) = 0.00, p = .999 |
| N-BACK N-4 accuracy | F(1, 104) = 0.18, p = .669 | F(1, 104) = 0.59, p = .441 | | F(1, 102) = 0.05, p = .822 |

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| N-BACK N-4 RT | F(1, 92) = 0.23, p = .628 | F(1, 92) = 0.01, p = .892 | Age: F(1, 25) = 19.69, p>.001 | : F(1, 92) = 1.19, p = .276 |
| N-BACK N-5 accuracy | F(1, 100) = 0.70, p = .402 | F(1, 101) = 0.14, p = .706 | | F(1, 99) = 0.60, p = .439 |
| N-BACK N-5 RT | F(1, 99) = 0.14, p = .707 | F(1, 99) = 6.00, p = .016, where reaction times were faster for WBB condition (M=446.0, SE= 12.70) compared to placebo (M=480.0, SE= 12.70). | | F(1, 99) = 0.09, p = .760 |
| MANT accuracy | *F*(1, 1029) = 8.27, *p* = .004 | *F*(1, 1026) = 1.02, *p* = .311 | Age: *F*(1, 15) = 2.70, *p* =.029 | *F*(1, 1019) = 0.001, *p* =.966 |
| MANT accuracy, low load trials | *F*(1, 228) = 7.87, *p* = .005 | *F*(1, 228) = 0.68, *p* = .794 | | *F*(1, 225) = 0.15, *p* =.690 |
| MANT RT | *F*(1, 1027) = 0.02, *p* = .886 | *F*(1, 1028) = 0.49, *p* = .482 | | *F*(1, 1020) = 0.004, *p* =.945 |
| MANT RT, low load trials | *F*(1, 230) = 0.24, *p* = .622 | *F*(1, 230) = 0.07, *p* = .790 | Age: *F*(1, 31) = 9.00, *p* =.005<br>Sleep: *F*(1, 258) = 9.69, *p* =.002 | *F*(1, 227) = 0.92, *p* =.338 |

Appendix D. Main effects, covariates and interaction effects from the mothers data presented in Chapter 6

| Outcome | Main effect of Visit | Main effect of Condition | Significant covariates | Interaction effect |
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| PA | *F*(1, 77) = 1.03, *p* = .312 | *F*(1, 80) = 0.37, *p* = .542 | *Baseline flavonoid: F*(1, 21) = 8.96, *p* = .007 | *F*(1, 74) = 0.00, *p* = .997 |
| NA | F(1,78) = 5.43, *p* = .022: higher negative affect at baseline (M = 17.43, SE = 0.87) compared to post-intervention (M = 15.76, SE = 0.87; *p* = .022 | F(1,81) = 0.75, *p* = .388 | Stress: F(1,87) = 12.79, *p* < .001 | F(1,76) = 0.12, *p* = .730 |

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| IMS | F(1, 78) = 24.26, $p$ < .001: pairwise comparisons indicating that IMS scores were significantly lower at 2 hours (M = -65.53, SE = 3.20) compared to baseline (M = -76.29, SE = 3.19) | F(1, 79) = 0.66, $p$ = .415 | Baseline flavonoid: F(1, 24) = 11.34, $p$ = .003<br>Stress: F(1, 97) = 10.44, $p$ = .002<br>Temperament: F(1, 96) = 6.14, $p$ = .014 | F(1, 75) = 0.002, $p$ = .964 |
| SAI | $F_{[1,77]}$= 11.44, $p$=.001; pairwise comparisons showed SAI scores were significantly lower at 2hours (M=37.07, SE= 1.58) compared to baseline (M= 40.67, SE= 1.60) ($p$<.001) | $F_{[1, 78]}$= 0.29, $p$=.587 | Baseline flavonoid: $F_{[1,22]}$= 5.68, $p$=.026 | $F_{[1,73]}$= 0.08, $p$=.774 |
| BL Alert | $F_{[1,78]}$= 7.50, $p$=.007: pairwise comparisons showed alertness scores were significantly higher at 2hours (M=37.79, SE= 2.47) compared to baseline (M=42.40, SE= 2.47) ($p$=.007) | $F_{[1, 79]}$= 0.68, $p$=.409 | Baseline flavonoid intake: $F_{[1,23]}$= 5.04, $p$=.034 | $F_{[1,74]}$= 0.51, $p$=.474 |
| BL Calm | $F_{[1,78]}$= 5.50, $p$=.021: pairwise comparisons showed calmness scores were significantly lower at 2hours (M=36.86, SE= 2.61) compared to baseline (M=42.07, SE= 2.60) ($p$=.021) | $F_{[1, 81]}$= 0.33, $p$=.563 | Baseline flavonoid intake: $F_{[1,24]}$= 5.11, $p$=.032<br>Stress: $F_{[1,87]}$= 6.47, $p$=.012<br>Temperament: $F_{[1,95]}$= 5.80, $p$=.017 | $F_{[1,76]}$= 0.12, $p$=.721 |
| BL Content | $F_{[1,77]}$= 7.81, $p$=.006 Pairwise comparisons showed baseline had higher contentedness (M=37.01, SE= 2.32) compared to 2-hrs (M=32.19, SE= 2.32). | $F_{[1, 80]}$= 3.00, $p$=.087 | Temperament: $F_{[1,95]}$= 4.72, $p$=.032<br>Baseline flavonoid intake: $F_{[1,24]}$= 7.59, $p$=.011<br>Stress: $F_{[1,93]}$= 7.95, $p$=.005 | $F_{[1,74]}$= 0.04, $p$=.833 |
| Systolic BP | F(1, 76) = 0.001, p = .968 | F(1, 77) = 0.001, p = .970 | | F(1, 72) = 1.36, p = .247) |
| Diastolic BP | F(1, 77) = 0.14, p = .704 | F(1, 77) = 0.001, p = .995 | | F(1, 73) = 0.16, p = .689 |
| RAVLT Wordspan | $F$(1, 76) = 1.27, $p$ = .262 | $F$(1, 80) = 0.13, $p$ = .711 | | $F$(1, 73) = 0.11, $p$ = .730 |

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| RAVLT Final Acquisition | *F*(1, 77) = 0.09, *p* = .754 | *F*(1, 80) = 0.16, *p* = .685 | | *F*(1, 75) = 0.02, *p* = .881 |
| RAVLT Total Acquisition | F(1, 78) = 2.29, p = .134 | F(1, 78) = 0.27, p = .601). | Age: F(1, 24) = 4.59, p = .042 | F(1, 74) = 0.66, p = .417 |
| RAVLT Amount Learned | *F*(1, 75) = 0.70, *p* = .402 | *F*(1, 80) = 0.34, *p* = .559 | | *F*(1, 74) = 1.32, *p* = .253 |
| RAVLT Proactive Interference | F(1, 76) = 1.18, p = .279 | F(1, 76) = 0.85, p = .356 | Stress: F(1, 76) = 4.93, p = .029<br><br>Baseline flavonoid: F(1, 76) = 4.02, p = .048 | F(1, 76) = 0.51, p = .476 |
| RAVLT Retroactive Interference | F(1, 57) = 0.68, p = .410 | F(1, 59) = 0.54, p = .464 | | (F(1, 56) = 0.61, p = .437 |
| RAVLT Delayed Recall | F(1, 77) = 0.15, *p* = .691 | F(1, 79) = 0.53, *p* = .466 | Age: F(1, 24) = 9.28, *p* = .005<br>Temperament: F(1, 96) = 5.02, *p* = .027 | F(1, 74) = 0.12, *p* = .723 |
| RAVLT Word Recognition | F(1, 69) = 0.43, *p* = .509 | F(1, 72) = 0.34, *p* = .560 | Age F(1, 25)= 8.51, *p* = .007 | F(1, 68)= 0.36, *p* = .546 |
| RAVLT Source monitoring accuracy | F(1, 69) = 9.53, *p* = .002: source monitoring accuracy was higher at Baseline (M = 90.83, SE = 1.70) compared to Post (M = 85.50, SE = 1.66) (*p* = .003). | F(1, 72) = 0.03, *p* = .854 | Age: F(1, 25) = 11.73, *p* = .001 | F(1, 67) = 0.01, *p* = .920 |
| RAVLT source monitoring RT | F(1, 63) = 0.16, *p* = .682 | F(1, 65) = 0.03, *p* = .847 | | F(1, 61) = 1.13, *p* = .290 |
| N-BACK overall accuracy | F(1, 76) = 1.80, p = .455 | F(1, 80) = 0.56, p = .455 | | F(1, 74) = 2.08, p = .153 |
| N-BACK overall RT | F(1, 72) = 0.07, p = .779 | F(1, 74) = 0.91, p = .343 | | F(1, 70) = 1.28, p = .260 |
| N-BACK N-1 accuracy | F(1, 76) = 0.06, p = .804 | F(1, 81) = 1.17, p = .281 | Baseline flavonoid F(1,22)= 9.62, *p*=.005 | F(1, 75) = 3.53, p = .063 |
| N-BACK N-1 RT | F(1, 73) = 0.75, p = .387 | F(1, 78) = 0.53, p = .467 | | F(1, 72) = 1.91, p = .170 |
| N-BACK N-2 accuracy | F(1, 75) = 0.11, p = .736 | F(1, 79) = 0.04, p = .837 | | F(1, 73) = 0.01, p = .898 |
| N-BACK N-2 RT | (F(1, 66) = 7.35, p = .008: reaction times were faster at post (M=505.00, SE= 18.40), than baseline (M=548, SE= 18.80). | F(1, 67) = 2.81, p = .097 | Location (F(1, 19) = 4.43, p = .048 | F(1, 65) = 4.96, p = .029: pairwise comparisons showed significant differences between the placebo group at baseline (M=579.0, SE=21.9) compared |

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| | | | | to post (M=501.0, SE= 21.60) (*p*=.004), in addition to significantly faster reaction times between placebo group at baseline and WBB group at pot intervention (M=509.01, SE=21.10) (*p*=.015). |
| N-BACK N-3 accuracy | F(1, 74) = 1.22, p = .272 | F(1, 75) = 0.20, p = .653 | Sleep: F(1, 24) = 6.45, p = .017<br>Temperament: F(1, 24) = 4.30, p = .048 | F(1, 73) = 0.89, p = .097 |
| N-BACK N-3 RT | F(1, 99) = 3.24,, p = .074 | Condition F(1, 98) = 4.38, p = .038, pairwise comparisons showed significant differences, where faster reaction times were seen in the WBB group (M=486.00, SE=13.6), compared to placebo (M=520.00, SE=13.70). | | F(1, 98) = 1.83, p = .179 |
| N-BACK N-4 accuracy | : F(1, 74) = 1.76, p = .187 | F(1, 77) = 2.97, p = .088 | | F(1, 72) = 1.24, p = .268 |
| N-BACK N-4 RT | F(1, 60) = 0.07, p = .785 | F(1, 63) = 0.02, p = .880 | | F(1, 61) 3.21, p = .077 |
| N-BACK N-5 accuracy | F(1, 72) = 0.40, p = .527 | F(1, 74) = 0.05, p = .819 | Age: F(1, 26)= 6.20, p = .019 | F(1, 71)= 0.06, p = .802 |
| N-BACK N-5 RT | F(1, 70) = 0.81, p = .369 | F(1, 72) = 4.78, p = .031, where WBB group had faster RT (M=449.0, SE= 16.1) compared to placebo (M=489.0, SE= 16.3). | | F(1, 70)= 0.42, p = .515 |

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| MANT accuracy | $F(1, 722) = 7.67$, $p = .005$: where accuracy increased from baseline (M=11.76, SE= 0.47) to post (M=12.17, SE= 0.48) | $F(1, 727) = 1.35$, $p = .244$ | | $F(1, 710) = 0.88$, $p = .347$ |
| MANT accuracy, low load trials | $F(1, 158) = 8.11$, $p = .004$ | $F(1, 162) = 0.44$, $p = .507$ | Baseline flavonoid: F(1, 20)= 4.37, p = .049 | $F(1, 115) = 0.0006$, $p = .980$ |
| MANT RT | $F(1, 721) = 2.50$, $p = .114$ | $F(1, 725) = 0.97$, $p = .323$ | Age: $F(1, 22) = 5.81$, $p = .024$ | $F(1, 710) = 0.19$, $p = .658$ |
| MANT RT, low load trials | $F(1, 159) = 0.06$, $p = .802$ | $F(1, 159) = 1.30$, $p = .255$ | Sleep: $F(1, 164) = 6.25$, $p = .013$ | $F(1, 157) = 0.08$, $p = .770$ |

Appendix E. Main effects, covariates and interaction effects from the fathers data presented in Chapter 6

| Outcome | Main effect of Visit | Main effect of Condition | Significant covariates | Interaction effect |
|---|---|---|---|---|
| PA | $F(1, 19) = 0.03$, $p = .870$ | $F(1, 21) = 0.79$, $p = .384$ | | $F(1, 18) = 5.38$, $p = .032$ |
| NA | F(1, 20) = 0.003, $p = .956$ | F(1, 23) = 0.25, $p = .620$ | | F(1, 20) = 0.36, $p = .554$ |
| IMS | F(1, 20) = 11.31, $p = .002$: pairwise comparisons showed that IMS scores were significantly lower at 2 hours (M =- 63.79, SE = 6.38) compared to baseline (M = -69.80, SE = 6.30) ($p = .002$) | F(1, 22) = 2.72, $p = .112$ | Sleep: F(1, 23) = 8.62, $p = .007$ | F(1, 20) = 0.20, $p = .656$ |
| SAI | $F_{[1,20]} = 4.16$, $p=.054$ | $F_{[1, 22]}=0.23$, $p=.632$ | Temperament: $F_{[1,23]} = 10.29$, $p=.003$ | $F_{[1,22]}=2.34$, $p=.141$ |
| BL Alert | $F_{[1,16]} = 1.32$, $p=.266$ | $F_{[1, 18]}=0.06$, $p=.799$ | | $F_{[1,14]} = 0.06$, $p=.804$ |
| BL Calm | $F_{[1,19]} = 0.04$, $p=.832$ | $F_{[1, 22]}=0.31$, $p=.577$ | | $F_{[1,19]} = 0.001$, $p=.969$ |
| BL Contentedness | ($F_{[1,20]} = 0.09$, $p=.757$ | $F_{[1, 22]}=1.78$, $p=.195$ | | $F_{[1,20]} = 0.04$, $p=.841$ |
| Systolic BP | F(1, 20) = 0.003, p = .956 | F(1, 23) = 0.21, p = .645 | Birth experience: F(1, 2) = 20.49, p =.039 | F(1, 20) = 0.31, p = .583 |

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| Diastolic BP | F(1, 25) = 1.30, p = .264 | F(1, 25) =7.32, p = .012), with the WBB group showing significantly lower diastolic blood pressure (M = 73.21, SE = 1.26) compared to the Placebo group (M = 78.24, SE = 1.26) (p = .013). | Location: F(1, 25) = 4.41, p = .045 | F(1, 25) = 2.97, p = .097 |
| RAVLT WordSpan | *F*(1, 20) = 1.65, *p* = .212 | *F*(1, 23) = 0.75, *p* = .395 | | *F*(1, 20) = 1.24, *p* = .276 |
| RAVLT Final acquisition | *F*(1, 20) = 0.03, *p* = .855 | *F*(1, 22) = 2.33, *p* = .140 | | *F*(1, 20) = 5.89, *p* = .024* |
| RAVLT Total acquisition | F(1, 20) = 1.79, p = .195 | F(1, 22) = 0.32, p = .859 | | F(1, 20) = 0.14, p = .710 |
| RAVLT Amount Learned | *F*(1, 18) = 1.70, *p* = .207 | *F*(1, 20) = 2.27, *p* = .147 | | *F*(1, 18) = 8.62, *p* = .008* |
| RAVLT Proactive Interference | F(1, 18) = 0.12, p = .726 | F(1, 18) = 0.0002, p = .988 | | (F(1, 18) = 6.18, p = .022* where higher interference was seen for the placebo group from baseline (M= -0.67, SE= .909) to post (M= 1.64, SE= 0.84) not evident to the WBB group from baseline (M= 1.33, SE= 0.85) to post (M= -0.39, SE=0.77). |
| RAVLT Retroactive Interference | F(1, 13) = 2.12, p = .168 | F(1, 13) = 2.75, p = .120 | | F(1, 13) = 0.27, p = .610 |
| RAVLT Delayed Recall | F(1, 16) = 4.92, *p* = .041: decline in performance from Baseline (M = 8.75, SE = 0.60) to Post (M = 7.18, SE = 0.61) (*p* = .039) | F(1, 20) = 0.68, *p* = .417 | | F(1, 16) = 1.60, *p* = .222 |
| RAVLT Word Recognition | F(1, 20) = 0.51, *p* = .482 | F(1, 22) = 0.53, *p* = .470 | | F(1, 20) = 0.0011, *p* = .969 |
| RAVLT Source monitoring accuracy | F(1, 19) = 1.63, *p* = .216 | F(1, 21) = 0.002, *p* = .961 | | F(1, 19) = 0.04, *p* = .831 |
| RAVLT source monitoring RT | F(1, 18) = 0.25, *p* = .621 | F(1, 18) = 0.19, *p* = .668 | Location: F(1, 18) = 11.25, *p* = .003 | F(1, 18) = 1.24, *p* = .279 |

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| | | | Age: F(1, 18) = 4.86, *p* = .040 | |
| N-BACK overall accuracy | *F(1, 22) = 0.0001, p = .991* | *(F(1, 24) = 1.02, p = .322* | | *F(1, 22) = 0.00, p = 1.000* |
| N-BACK overall RT | F(1, 25) = 0.29, p = .593 | F(1, 25) = 3.76, p = .063 | Age: F(1, 25) = 23.07, p>.001<br>Stress: F(1, 25) = 5.22, p = .030<br>Location: F(1, 25) = 7.31, p = .012 | F(1, 25) = 0.07, p = .788 |
| N-BACK N-1 accuracy | F(1, 22) = 0.53, p = .471 | F(1, 24) = 0.56, p = .457 | | F(1, 22) = 0.48, p = .495 |
| N-BACK N-1 RT | F(1,25) = 0.45, p = .504 | F(1, 25) = 0.65, p = .799 | | F(1, 25) = 0.25, p = .619 |
| N-BACK N-2 accuracy | F(1, 20) = 7.95, p = .010: Pairwise comparisons showed better performance at baseline (M=2.14, SE= 0.17), compared to post (M=1.81, SE= 0.16) (*p*=.010) | F(1, 22) = 0.23, p = .632 | Sleep: F(1, 23) = 4.83, p = .037 | F(1, 20) = 0.51, p = .822 |
| N-BACK N-2 RT | F(1, 24) = 0.998, p = .327 | F(1, 24) = 3.27, p = .083 | | F(1, 24) = 0.25, p = .615 |
| N-BACK N-3 accuracy | F(1, 69) = 6.15, p = .015, where pairwise comparisons revealed significantly faster reaction times at baseline (M=476.0, SE= 17.1) compared to post intervention (M=525.1, SE= 15.9) | F(1, 71) = 1.11, p = .295 | | F(1, 69) = 2.30, p = .133 |
| N-BACK N-3 RT | F(1, 21) = 21.07, p = .346 | F(1, 23) = 4.77, p = .039, where significantly faster RT | | F(1, 21) = 0.0001, p = .999 |

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| | | was seen for WBB (M=488.0, SE= 21.3), compared to placebo (M=545.o, SE= 22.0). | | |
| N-BACK N-4 accuracy | F(1, 24) = 0.59, p = .447 | F(1, 24) = 0.28, p = .600 | | F(1, 24) = 0.03, p = .858 |
| N-BACK N-4 RT | F(1, 24) = 0.45, p = .506 | F(1, 24) = 0.37, p = .543 | Age: F(1, 24) = 30.37, *p*>.001 | F(1, 24) = 0.82, p = .373 |
| N-BACK N-5 accuracy | F(1, 25) = 0.006, p = .935 | F(1, 25) = 0.61, p = .438 | | F(1, 25) = 0.51, p = .478 |
| N-BACK N-5 RT | F(1, 20) = 2.48, p = .130 | F(1, 23) = 0.57, p = .454 | Stress: F(1, 12) = 15.39, p = .001 | F(1, 20) = 0.51, p = .479 |
| MANT accuracy | (F(1, 242) = 1.05, p = .304 | *F*(1, 247) = 0.41, *p* = .518 | Sleep: *F*(1, 189) = 7.32, *p* =.007<br><br>Stress: *F*(1, 211) = 14.48, *p* <.001<br><br>Temperament: *F*(1, 214) = 7.66, *p* =.006 | *F*(1, 240) = 1.70, *p* =.192 |
| MANT accuracy, low load trials | *F*(1, 51) = 0.32, *p* = .572 | *F*(1, 53) = 0.36, *p* = .550 | | *F*(1, 51) = 0.78, *p* =.378 |
| MANT RT | *F*(1, 159) = 0.0002, *p* = .989 | *F*(1, 247) = 0.10, *p* = .747 | | *F*(1, 243) = 0.13, *p* =.715 |
| MANT RT, low load trials | *F*(1, 52) = 1.85, *p* = .178 | *F*(1, 54) = 0.06, *p* = .795 | Age: *F*(1, 3) = 32.23, *p* =.009 | *F*(1, 52) = 2.42, *p* =.125 |

Appendix F. Participant information sheets

*F.1. Participant information sheet for Experiment 1*

Title of Study: The effect of diet on parents' mental health in the postnatal period

Information Sheet


| Supervisor: | Email: | Phone: |
|---|---|---|
| Dr Katie Barfoot | katie.barfoot@reading.ac.uk | 0118 378 3347 |

Researchers:
Sean Holden sean.holden@student.reading.ac.uk
Rebecca Colombage r.colombage@pgr.reading.ac.uk


We would be grateful to you if you could assist us by participating in our online study exploring whether diet is associated with mothers' or fathers' mental health. We are asking mothers or fathers who have an infant under the age of 6 months to take part.

The study will be completed online via a weblink. Your participation will be done in two sittings from any location where you have access to the internet. The first session will be completed at your own convenience and will take approximately 30-40 minutes. In this session you will be asked general information about you, your diet and your mood. At the end of session 1, some participants may be asked to include additional common food items to their diet over a 2 week period.
Over this 2 week period, all participants will be asked to keep daily food diaries of what they have consumed each day in simple note form (food weighing is not required).
The second session will be completed 2 weeks later, will take approximately 30-40 minutes and will again include questions about you and your mood.

Your data will be kept confidential and securely stored, with only an anonymous number identifying it. All information will be destroyed after a period of 5 years from the completion of the project. Taking part in this study is completely voluntary; you may withdraw at any time without having to give any reason. Please feel free to ask the researchers any questions that you may have about the study at any point.

*If you score above threshold for risk of depression or anxiety you will be notified via email. Upon completion of the study all participants will be provided with mood & depression support links.*

*This application has been reviewed by the University Research Ethics Committee and has been given a favourable ethical opinion for conduct.*

If you have any questions or concerns then please get in contact with the study researchers, Sean Holden (sean.holden@student.reading.ac.uk), Rebecca Colombage (r.colombage@pgr.reading.ac.uk) or the study supervisor, Dr Katie Barfoot (katie.barfoot@reading.ac.uk)

Thank you for your help.

Data Protection Information

The organisation responsible for protection of your personal information is the University of Reading (the Data Controller). Queries regarding data protection and your rights should be directed to the University Data Protection Officer at imps@reading.ac.uk, or in writing to: University of Reading, Information Management & Policy Services, Whiteknights House, Pepper Lane, Whiteknights, Reading , RG6 6UR, UK.

The University of Reading collects, analyses, uses, shares and retains personal data for the purposes of research in the public interest. Under data protection law we are required to inform you that this use of the personal data we may hold about you is on the lawful basis of being a public task in the public interest and where it is necessary for scientific or historical research purposes. If you withdraw from a research study, which processes your personal data, dependant on the stage of withdrawal, we may still rely on this lawful basis to continue using your data if your withdrawal would be of significant detriment to the research study aims. We will always have in place appropriate safeguards to protect your personal data.

If we have included any additional requests for use of your data, for example adding you to a registration list for the purposes of inviting you to take part in future studies, this will be done only with your consent where you have provided it to us and should you wish to be removed from the register at a later date, you should contact Dr Katie Barfoot (katie.barfoot@reading.ac.uk).

You have certain rights under data protection law which are:

- Withdraw your consent, for example if you opted in to be added to a participant register
- Access your personal data or ask for a copy
- Rectify inaccuracies in personal data that we hold about you
- Be forgotten, that is your details to be removed from systems that we use to process your personal data
- Restrict uses of your data
- Object to uses of your data, for example retention after you have withdrawn from a study

Some restrictions apply to the above rights where data is collected and used for research purposes. You can find out more about your rights on the website of the Information Commissioners Office (ICO) at https://ico.org.uk

You also have a right to complain to the ICO if you are unhappy with how your data has been handled. Please contact the University Data Protection Officer in the first instance.

*F. 2. Participant information sheet for Experiment 2*

School of Psychology and Clinical Language Sciences

Whiteknights

Reading RG6 6AL

| Investigator: | Email: |
|---|---|
| Rebecca Colombage | r.colombage@pgr.reading.ac.uk |

| Supervisors | Email: |
|---|---|
| Daniel Lamport | daniel.lamport@reading.ac.uk |
| Katie Barfoot | katie.barfoot@reading.ac.uk |

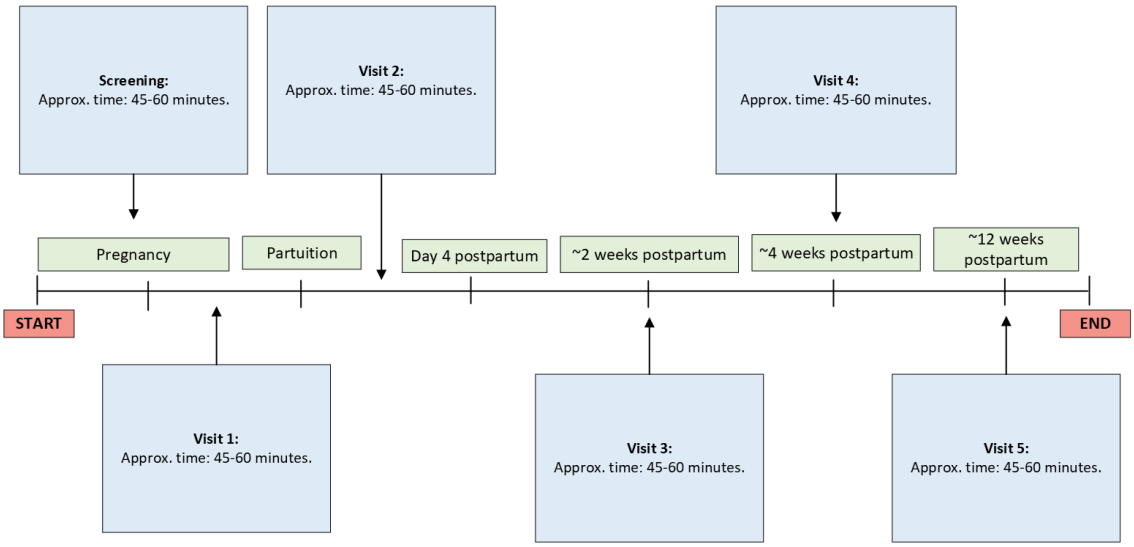
Exploring the effects of diet on perinatal mood and cognition

PARTICIPANT INFORMATION SHEET

We would be grateful if you could assist us by participating in our study investigating whether diet effects mood and cognition in new mothers. We are asking women who are pregnant (under 36 weeks) to take part.

What will I be asked to do?

The study will be completed in person, over six visits where each session should take no longer than 1 hour. The first two visits will take place in your third trimester (prior to week 38 of your pregnancy) and will involve general questions about you, your diet, and your mood, you will then be asked to complete some cognitive tasks and mood questionnaires on a laptop and have your blood pressure recorded. The third visit will be between days 0-4 after you have delivered your baby and you will be asked to complete the same mood questions, cognitive tasks, and blood pressure measurements. At the end of session 3, some participants may be asked to include some additional common food items in their diet over a 30-day period. Both halfway through the 30-days, and at the end of the 30-days, a researcher will visit you and you will again be asked to complete mood questionnaires, cognitive tasks, and blood pressure recordings. Three months after you have delivered your baby, you will have a final visit from the researcher where you will be asked to complete questions about your mood and diet, complete cognitive tasks and have your blood pressure taken. Lastly, over the course of the study you will be occasionally contacted to record your diet from the previous day.




Taking part in this study is completely voluntary; you may withdraw at any time without having to give any reason. Please feel free to ask any questions that you may have about this study at any point.

If the information you share with us during the research [e.g. questionnaires/tests] raises a significant concern about your mental health, we will attempt to contact you at the end of the trial using the contact details you have provided in the Consent Form to discuss with you whether you would consider seeking help and advice from a clinically qualified professional including your General Practitioner.

- Your General Practitioner (GP): Your GP will be able to offer support and advice on possible treatment options for any mental health concerns.
- Your health visitor
- https://www.samaritans.org: Samaritans is a charity that is there to provide help and support for anyone who's struggling to cope, who needs someone to listen without judgement or pressure. Call 116 123 for free or email: jo@samaritans.org
- Mind Charity: Mind provide advice and support to empower anyone experiencing a mental health problem. Call 0300 1233393 or email: info@mind.org.uk to find out
- PANDAS: The PANDAS Foundation offers support and advise to any parent who needs support with perinatal mental illness. Website: http://www.pandasfoundation.org.uk
- The Association for Post-Natal Illness is a charity dedicated to providing support to anyone suffering from or affected by postnatal illness. Call 020 7386 0868, website: https://apni.org/ :
- La Leche League: La Leche League provides breastfeeding support. Website: https://www.laleche.org.uk/

Why have I been invited to participate in this study?

You are being invited to take part in this study if you are over the age of 18 and are pregnant.

Are there any benefits to taking part?

By taking part, you will be compensated £50 Amazon voucher and will receive a personalised dietary analysis. Additionally, by participating in this study, you will be helping to advance the research in this understudied period.

Are there any risks or disadvantages to taking part?

During the study you may find the questions to be emotionally evocative. Please remember that you are free to terminate your participation at any time and for any reason. If at any point, you begin to feel distressed by the questions, please cease completion and let the experimenter know via email. Signposting for mental health support will be provided at the end of the study.

What will happen to my data/how will it be protected?

Your data will be kept confidential and securely stored, with only an anonymous number identifying it. Data collected from this study will be preserved and made available in anonymised form, so that data can be re-used by others.

Who can I contact about data privacy and storage?

The organisation responsible for protection of your personal information is the University of Reading (the Data Controller). Queries regarding data protection and your rights should be directed to the University Data Protection Officer at imps@reading.ac.uk, or in writing to: University of Reading, Information Management & Policy Services, Whiteknights House, Pepper Lane, Whiteknights, Reading , RG6 6UR, UK.

The University of Reading collects, analyses, uses, shares and retains personal data for the purposes of research in the public interest. Under data protection law we are required to inform you that this use of the personal data we may hold about you is on the lawful basis of being a public task in the public interest and where it is necessary for scientific or historical research purposes. If you withdraw from a research study, which processes your personal data, dependant on the stage of withdrawal, we may still rely on this lawful basis to continue using your data if your withdrawal would be of significant detriment to the research study aims. We will always have in place appropriate safeguards to protect your personal data.

You have certain rights under data protection law which are:

- Withdraw your consent, for example if you opted in to be added to a participant register
- Access your personal data or ask for a copy
- Rectify inaccuracies in personal data that we hold about you
- Be forgotten, that is your details to be removed from systems that we use to process your personal data
- Restrict uses of your data
- Object to uses of your data, for example retention after you have withdrawn from a study

Some restrictions apply to the above rights where data is collected and used for research purposes.

You can find out more about your rights on the website of the Information Commissioners Office (ICO) at https://ico.org.uk

You also have a right to complain the ICO if you are unhappy with how your data has been handled. Please contact the University Data Protection Officer in the first instance.

Who has reviewed this study?

This application has been reviewed by the School of Psychology and Clinical Language Sciences Research Ethics Committee and has been given a favourable ethical opinion for conduct (2023-029-DL).

Where can I get more information/who I can contact about this study?

If you have any questions or concerns about the research, please feel free to contact the researcher, Rebecca Colombage

Email: r.colombage@pgr.reading.ac.uk

Thank you for your help.

Lifestyle And Mood in Parents (LAMPs) Research Team,

University of Reading

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*F.3. Participant information sheet for Experiment 3.*

School of Psychology and Clinical Language Sciences

Whiteknights

Reading RG6 6AL

| Investigator: | Email: |
|---|---|
| Rebecca Colombage | r.colombage@pgr.reading.ac.uk |

| Supervisors | Email: |
|---|---|
| Daniel Lamport | daniel.lamport@reading.ac.uk |
| Katie Barfoot | katie.barfoot@reading.ac.uk |

Exploring the effects of a fruit drink on parental mood and cognition

PARTICIPANT INFORMATION SHEET

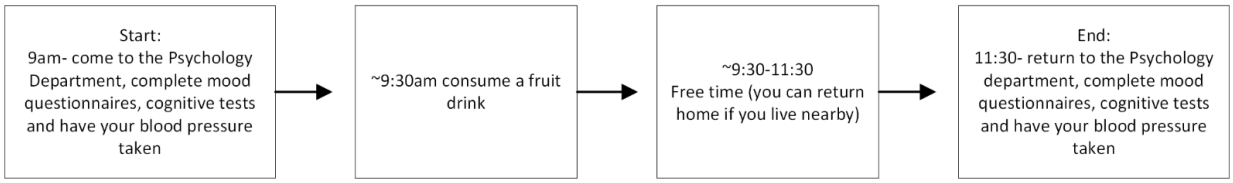
We would be grateful if you could assist us by participating in our study investigating whether diet effects mood and cognition in new parents. We are asking mothers and fathers of biological infants (aged 0-6 months old) with a good understanding of English language to take part.

What will I be asked to do?

The study will be completed in person at the Psychology Department at the University of Reading or at your home if you prefer, over three visits. The first session will last an hour and will involve general questions about you, your diet, and your mood, you will then be asked to complete some cognitive tasks on a computer and have your height and weight taken. The remainder visits will be spaced a week apart, you will come into the department (or have a researcher visit your home) in the morning (around 9 or 10am) and will complete mood questionnaires, cognitive tests and measures of your blood pressure. You will then be asked to consume a fruit drink, 2 hours after consuming the drink, you will be asked to complete the same mood questionnaires, cognitive tests and measures of your blood pressure again. You will then return to the department (or have a researcher visit your home) a week later and repeat the same procedure. These visits will take around 3-3.5 hours each, however you will have time on the day (1.5-2hrs) in between the tests where you'll be free to leave the department (see diagram below). Additionally, 24 hours before the second and third visit, you will be asked to avoid certain foods, alcohol, caffeine and taking recreational drugs, 2 hours before the visit you will be asked to refrain from exercise and to record what you ate for breakfast, you will be asked to have the same breakfast for both visits.

If you conduct the visits at the department, we understand that you may need to bring your infant with you, whilst this is absolutely fine, we ask that you also bring a partner/friend/relative to care for the infant while you are completing the mood and cognitive tasks (taking approximately 30 minutes each time) as these will require your complete attention. They are welcome to stay in the department foyer or explore the University grounds while you visit the lab with the researcher.

Am I eligible to participate?




To participate you must meet the following criteria:

- You are not allergic to blueberries, cranberries or lingonberries (or any other Vaccinium species)
- You have not participated in other interventional studies within the last month
- You do not have cancer, or conditions affecting the liver, heart or kidneys
- You have a good understanding of English language
- You are a biological mother or father to an infant aged 0-6 months

Taking part in this study is completely voluntary; you may withdraw at any time without having to give any reason. Please feel free to ask any questions that you may have about this study at any point.

If the information you share with us during the research [e.g. questionnaires/tests] raises a significant concern about your mental health, we will attempt to contact you at the end of the trial using the

contact details you have provided in the Consent Form to discuss with you whether you would consider seeking help and advice from a clinically qualified professional including your General Practitioner.

- Your General Practitioner (GP): Your GP will be able to offer support and advice on possible treatment options for any mental health concerns.
- Your health visitor
- https://www.samaritans.org: Samaritans is a charity that is there to provide help and support for anyone who's struggling to cope, who needs someone to listen without judgement or pressure. Call 116 123 for free or email: jo@samaritans.org
- Mind Charity: Mind provide advice and support to empower anyone experiencing a mental health problem. Call 0300 1233393 or email: info@mind.org.uk to find out
- PANDAS: The PANDAS Foundation offers support and advise to any parent who needs support with perinatal mental illness. Website: http://www.pandasfoundation.org.uk
- The Association for Post-Natal Illness is a charity dedicated to providing support to anyone suffering from or affected by postnatal illness. Call 020 7386 0868, website: https://apni.org/ :
- La Leche League: La Leche League provides breastfeeding support. Website: https://www.laleche.org.uk/

Why have I been invited to participate in this study?

You are being invited to take part in this study if you are over the age of 18 and are a biological mother or father to an infant aged 0-6 months.

Are there any benefits to taking part?

By taking part, you will be compensated £30 Amazon voucher. Additionally, by participating in this study, you will be helping to advance the research in this understudied period.

Are there any risks or disadvantages to taking part?

During the study you may find the questions to be emotionally evocative. Please remember that you are free to terminate your participation at any time and for any reason. If at any point, you begin to feel distressed by the questions, please cease completion and let the experimenter know via email. Signposting for mental health support will be provided at the end of the study.

What will happen to my data/how will it be protected?

Your data will be kept confidential and securely stored, with only an anonymous number identifying it. Data collected from this study will be preserved and made available in anonymised form, so that data can be re-used by others.

Who can I contact about data privacy and storage?

The organisation responsible for protection of your personal information is the University of Reading (the Data Controller). Queries regarding data protection and your rights should be directed to the University Data Protection Officer at imps@reading.ac.uk, or in writing to: University of Reading, Information Management & Policy Services, Whiteknights House, Pepper Lane, Whiteknights, Reading , RG6 6UR, UK.

The University of Reading collects, analyses, uses, shares and retains personal data for the purposes of research in the public interest. Under data protection law we are required to inform you that this use of the personal data we may hold about you is on the lawful basis of being a public task in the public interest and where it is necessary for scientific or historical research purposes. If you withdraw from a research study, which processes your personal data, dependant on the stage of withdrawal, we may still rely on this lawful basis to continue using your data if your withdrawal would be of significant detriment to the research study aims. We will always have in place appropriate safeguards to protect your personal data.

You have certain rights under data protection law which are:

- Withdraw your consent, for example if you opted in to be added to a participant register
- Access your personal data or ask for a copy
- Rectify inaccuracies in personal data that we hold about you
- Be forgotten, that is your details to be removed from systems that we use to process your personal data
- Restrict uses of your data
- Object to uses of your data, for example retention after you have withdrawn from a study

Some restrictions apply to the above rights where data is collected and used for research purposes.

You can find out more about your rights on the website of the Information Commissioners Office (ICO) at https://ico.org.uk

You also have a right to complain the ICO if you are unhappy with how your data has been handled. Please contact the University Data Protection Officer in the first instance.

Who has reviewed this study?

This application has been reviewed by the School of Psychology and Clinical Language Sciences Research Ethics Committee and has been given a favourable ethical opinion for conduct 2023-234-DL.

Where can I get more information/who I can contact about this study?

If you have any questions or concerns about the research, please feel free to contact the researcher, Rebecca Colombage

Email: r.colombage@pgr.reading.ac.uk

Thank you for your help.

Lifestyle And Mood in Parents (LAMPs) Research Team,

University of Reading

Appendix G. Participant consent form used throughout experiments

Exploring the effects of a fruit drink on parental mood and cognition

Study Consent Form

After you read each statement below, please put your initials in the box next to it to show you understand and agree with the statement.

| | |
|---|---|
| I have read and agree with the arrangements described in the Participant Information Sheet as far as they relate to my participation in this study. I have been given the opportunity to ask questions about the study and these have been answered to my satisfaction. | |
| I am aware that this project has been reviewed by the School of Psychology and Clinical Language Sciences Research Ethics Committee and has been given a favourable ethical opinion for conduct. | |
| I have had explained to me what information will be collected about me, what it will be used for, how it will be kept safe, who it may be shared with, and what my rights are in relation to it. | |
| I understand that the data collected in this study will be preserved in pseudonymised form and could be made available on data repositories, so that it can be consulted and re-used by other researchers. | |
| I authorise the investigators to contact me via email if necessary. | |
| I understand that participation is entirely voluntary and that I have the right to withdraw from the study at any time without having to give an explanation. | |
| I have received a copy of this Consent Form and of the accompanying Participant Information Sheet. | |

Name of participant:

……..……..……...…

Date of birth: ……..……

Signature: ……..……

Name of researcher taking consent:

……..……...……...…

Signature: ……

Date: ……..……

Appendix H. Participant debrief forms

H.1. Debrief form used in Experiment 1

Title of Study: *Does regular consumption of high flavonoid food/drink items improve mothers' mental health in the immediate 6-month postnatal period?*

Researchers: Rebecca Colombage and Sean Holden

Researcher e-mail: r.colombage@pgr.reading.ac.uk

sean.holden@student.reading.ac.uk

Chief Investigator: Dr Katie Barfoot
Email: katie.barfoot@reading.ac.uk

Debrief Form

Thank you for participating in this study. We hope you enjoyed the experience. This form provides background about our research to help you learn more about why we are doing this study. Please feel free to ask any questions or to comment on any aspect of the study.

The purpose of this study was to explore whether an implementation of a flavonoid-rich diet across a 2-week period positively affects parents' mental health, specifically mood, anxiety, depressive symptoms and perceived quality of life.
Flavonoids are naturally occurring compounds found in high levels in foods such as berry and citrus fruits, leafy green vegetables, tea, dark chocolate and red wine. Evidence suggests that consumption of high flavonoid foods in the diet can improve health and cognitive outcomes. Preliminary research further indicates that flavonoid interventions in the postpartum period may help to manage mood in a key period for mothers and their babies.

In the current study, some participants were randomly assigned to a 'flavonoid' group and were asked to add 2 high flavonoid food items to their normal diet each day across a 2-week period. Other participants were randomly assigned to a 'control' group and were asked to continue their diet as normal. Both groups were asked to keep daily food logs over this period and to email these to the researcher upon completion. Questionnaires on food intake, mood, anxiety, depression and quality of life were asked before and after the 2-week period.

Your data is linked to your anonymous participant number and is stored securely for research purposes only. As stated at the beginning of the study, if your Edinburgh Postnatal Depression Scale or anxiety score is above threshold risk then you will be contacted in confidence by the Supervisor of the study to encourage you to seek advice from your GP. There is no way that the Supervisor or Researchers can contact your GP directly. It is important to note that we are not clinicians and so a score above threshold does not mean that you have a diagnosis. Your score is, however, a good indicator of whether you may need to seek some extra support from your GP at this time.

As you know, your participation in this study is voluntary. If you so wish, you may withdraw from the study after reading this debriefing form, at which point all records of your participation will be

destroyed. You will not be penalized if you withdraw. If you wish to withdraw, please e-mail the researcher, including your initials and date of birth so that your data can be identified and removed. If you wish, you can also request a copy of your responses from the researcher by emailing the researcher.

This project is currently ongoing. Because of this, it is important that you do not talk (or write or e-mail, etc.) about this project to other parents who may be taking part or thinking of taking part. The main reason for this is that your comments could influence their expectations, and therefore, answers of future participants, which could bias our data. We hope you will support our research by keeping your knowledge of this study confidential.

Additionally, if you feel you need support with your mental health for any reason we recommend these following support networks:

1. The Samaritans: 116 123
2. PANDAS (PND awareness and support): 0808 1961 776
3. NHS weblink for PND: https://www.nhs.uk/mental-health/conditions/post-natal-depression/overview/
4. MIND weblink for PND: https://www.mind.org.uk/information-support/types-of-mental-health-problems/postnatal-depression-and-perinatal-mental-health/about-maternal-mental-health-problems/
5. Association for Postnatal Illness: https://apni.org/

If you feel your situation requires urgent attention, please contact 999 or your local emergency line as soon as possible.

Please keep a copy of this debriefing for your records.

If you have questions please e-mail either the researcher or the chief investigator (for details, see above).

Again, thank you for your participation.

The Nutritional Psychology UROP research team
Rebecca, Sean and Katie

H.2. Debrief form used in Experiment 2

**School of Psychology and Clinical Language Sciences**

University of Reading
Earley Gate
Reading RG6 6AL

Exploring the effects of diet on perinatal mood and cognition

Researchers:

Rebecca Colombage – r.colombage@pgr.reading.ac.uk

Daniel Lamport – Daniel.lamport@reading.ac.uk (Chief investigator)

Katie Barfoot - katie.barfoot@reading.ac.uk

## Debrief Form

Thank you for participating in this study. We hope you enjoyed the experience. This form provides background about our research to help you learn more about why we are doing this study. Please feel free to ask any questions or for feedback on any aspect of the study.

The purpose of this study was to explore whether implementation of a flavonoid-rich diet across a 4-week period positively affects mother's mental health and cognition. Flavonoids are naturally occurring compounds found in high levels in foods such as berry and citrus fruits, leafy green vegetables, tea, dark chocolate and red wine. Evidence suggests that consumption of high flavonoid foods in the diet can improve health and cognitive outcomes. Previous research further indicates that flavonoid interventions in the postpartum can show promise for the management of mood in a key period for mothers and their babies, where risk for PND is high.

This study consisted of six visits between your third trimester and week 12 postpartum where measures of mood, cognition and blood pressure were taken. You were also contacted several times throughout the study to record the foods you had consumed the previous day. There were three different groups in this study; a control condition (no change to diet); low flavonoid condition (one portion of flavonoid-rich food items per day) and a high flavonoid condition (two portions of flavonoid-rich food items per day). You were randomly assigned to the __ condition.

Your data is linked to your anonymous participant number and is stored securely for research purposes only. As you know, your participation in this study is voluntary. If you so wish, you may withdraw from the study after reading this debriefing form, at which point all records of your participation will be destroyed. You will not be penalised if you withdraw. If you wish to withdraw, please e-mail the researcher, including your initials and date of birth so that your data can be identified and removed.

This project is currently ongoing. Because of this, it is important that you do not talk (or write or e-mail, etc.) about this project to other people who may be taking part or thinking of taking part. The main reason for this is that your comments could influence their expectations, and therefore, answers of future

participants, which could bias our data. We hope you will support our research by keeping your knowledge of this study confidential.

Additionally, if you feel you need support with your mental health for any reason, we recommend these following support networks:

1. The Samaritans: 116 123

3. Contact your local GP

4. The NHS information pages relating to depression: https://www.nhs.uk/mental-health/conditions/clinical-depression/overview/

5. MIND information about depression: https://www.mind.org.uk/information-support/types-of-mental-health-problems/depression/about-depression/

6. The NHS information pages relating to anxiety: https://www.nhs.uk/mental-health/conditions/generalised-anxiety-disorder/

7. MIND information about anxiety: https://www.mind.org.uk/information-support/types-of-mental-health-problems/anxiety-and-panic-attacks/about-anxiety/

If you feel your situation requires urgent attention, please contact 999 emergency line as soon as possible.

Please keep a copy of this debriefing for your records.

If you have any questions or concerns about the research, please feel free to contact the researcher, Rebecca Colombage

Email: r.colombage@pgr.reading.ac.uk

Thank you for your help.

Lifestyle And Mood in Parents (LAMPs) Research Team,

University of Reading

H.3. Debrief form used in Experiment 3

University of Reading

Exploring the effects of a fruit drink on parental mood and cognition

Researchers:

Rebecca Colombage – r.colombage@pgr.reading.ac.uk

Daniel Lamport – Daniel.lamport@reading.ac.uk (Chief investigator)

Katie Barfoot - katie.barfoot@reading.ac.uk

## Debrief Form

Thank you for participating in this study. We hope you enjoyed the experience. This form provides background about our research to help you learn more about why we are doing this study. Please feel free to ask any questions or for feedback on any aspect of the study.

The purpose of this study was to explore whether blueberries, which are particularly rich in beneficial substances called flavonoids, can improve mood and cognition in parents in the 0-6 month postpartum. Flavonoids are naturally occurring compounds found in high levels in foods such as berry and citrus fruits, leafy green vegetables, tea, dark chocolate and red wine. Evidence suggests that consumption of high flavonoid foods in the diet can improve health and cognitive outcomes. Previous research further indicates that flavonoid interventions in the postpartum can show promise for the management of mood in a key period for parents, where risk for mood disorders such as postnatal depression is high.

This study consisted of three visits to the Psychology Department where measures of mood, cognition and blood pressure were taken before and after consuming either a blueberry drink or a placebo drink. In the information sheet that we gave you before you agreed to take part in the study, we did not specifically describe our interest in blueberries and mood/cognition. This is commonly done in psychological research so that your expectations would not influence the results of the study. This project is currently ongoing, because of this, it is important that you do not talk (or write or e-mail, etc.) about this project to other people who may be taking part or thinking of taking part. The main reason for this is that your comments could influence their expectations, and therefore, answers of future participants, which could bias our data. We hope you will support our research by keeping your knowledge of this study confidential.

Your data is linked to your anonymous participant number and is stored securely for research purposes only. As you know, your participation in this study is voluntary. If you so wish, you may withdraw from the study after reading this debriefing form, at which point all records of your participation will be destroyed. You will not be penalised if you withdraw. If you wish to withdraw, please e-mail the researcher, including your initials and date of birth so that your data can be identified and removed.

Additionally, if you feel you need support with your mental health for any reason, we recommend these following support networks:

1. The Samaritans: 116 123

3. Contact your local GP

4. The NHS information pages relating to depression: https://www.nhs.uk/mental-health/conditions/clinical-depression/overview/

5. MIND information about depression: https://www.mind.org.uk/information-support/types-of-mental-health-problems/depression/about-depression/

6. The NHS information pages relating to anxiety: https://www.nhs.uk/mental-health/conditions/generalised-anxiety-disorder/

7. MIND information about anxiety: https://www.mind.org.uk/information-support/types-of-mental-health-problems/anxiety-and-panic-attacks/about-anxiety/

If you feel your situation requires urgent attention, please contact 999 emergency line as soon as possible.

Please keep a copy of this debriefing for your records.

If you have any questions or concerns about the research, please feel free to contact the researcher, Rebecca Colombage

Email: r.colombage@pgr.reading.ac.uk

Thank you for your help.

Lifestyle And Mood in Parents (LAMPs) Research Team,

University of Reading

Appendix I. Participant instructions

*I.1. Instructions and food log for Experiment 1.*

Thank you for completing your session 1 questionnaires.

As part of the study, you have been randomly chosen to include some additional common food items in your diet over the next 2 weeks.

Please note that we are not requiring that you change your current diet. We would like you to carry on eating as normal and include these items in addition to your current diet.

We would like to add, if you already consume one of the items on the list below in your diet typically, then this does not count as one of your additional food items. We would like you to add 2 items in addition to what you would typically eat.

*Example 1*

If you consume a glass of orange juice with your breakfast typically, then please do not count this as an additional food item. In the study, you would drink your normal orange juice at breakfast and then include 2 additional food items from the list below on top of that.

*Example 2*

If you already consume 4-5 cups of tea or coffee in your daily diet, then this would not be counted as one of your additional foods. You would drink your normal 4-5 cups and then include 2 additional food items from the list below.

NOTE: If you do already consume some of the items on the list below then we do not want you to change this. Please carry on consuming these as you normally would and choose 2 other items to add to your diet that day. The additional items do not have to be the same each day, so on day 1 you may choose to add a portion of strawberries & 2 squares of dark chocolate, on day 2 you may choose a glass of orange juice & a portion of leafy green vegetables and so on. If though, it is easier to stick with the same two items each day, then that is also fine.

We DO NOT expect you to overconsume one or two items, especially if overconsuming may affect your mind or body adversely. It is best to go with different additional items rather than doubling or tripling the same item. *For example*, if you have 4-5 cups of tea/coffee a day in your typical diet, we do not encourage you to double or triple your consumption to 10 or 15 cups to meet your 2 additional item requirements, as this would be a high level of caffeine which your body may not be used to. Similarly, if you already have a glass of red wine on one day, we do not encourage you to double or triple your consumption of wine for the purposes of the study due to the alcoholic content. We would advise you to use general common sense when choosing your foods each day so that you are eating across a range of foods in moderation.

List of food additions

Please try to include 2 of the following food items each day over the next 2 weeks:

- Berry fruits (~120g) e.g. blueberries, raspberries, strawberries, blackberries, blackcurrants, mixed berries
- 2 large squares of dark chocolate (at least 70% cocoa)
- 4-5 cups of tea (black or green) or coffee (normal or decaf varieties)

- 1 large glass of red wine* (250ml)
- 1 portion of leafy green vegetables such as spinach or cabbage (~70g)
- 1 glass (250ml) of fresh orange or grapefruit juice (not from concentrate)

*Please drink responsibly and use appropriate common sense on items containing alcohol.

If you do not like or wish to eat/drink a certain food item listed above then not to worry, please select foods that you do like/eat.

*The information above will be emailed to you for your records.*

Please keep a food log of all the foods you consume each day over the 2 week period using the template below. We do not need food weightings, just simple descriptions of your food intake e.g. cheese sandwich (wholemeal bread), spaghetti bolognese, 1 apple, 1 digestive biscuit etc. Please highlight your 2 additional food items each day e.g. underline, asterisk, highlight.

If you miss a day, don't worry! Just make a note that you missed that day in the log below and carry on with your diet and additional items the next day…

*Top tip:* Add a calendar event to your phone for the end of each day over the next 2 weeks to remind you to fill in the food log. You can also paste the log over to the 'Notes' app on your phone so it's easier to fill in wherever you are.

*It is your choice whether you would like Day 1 to be today or tomorrow.*

Example format:

Date of Day 1:

Day 1 Breakfast:

Lunch:

Dinner:

Snacks:

Drinks:

Please save your food logs and email across to a researcher once you have completed the 14 days. You will then be asked to fill in your last set of questionnaires for the study.

Researchers:

Sean Holden – sean.holden@student.reading.ac.uk

Rebecca Colombage – r.colombage@pgr.reading.ac.uk

Thanks for being amazing and contributing to important research!

I.2. Participant instructions and food log for Experiment 2

Participant number _____

Instructions

As part of the study, you have been randomly selected to include some additional common items of food in your diet across the next 30-days.

Please note that we are not requiring that you change your current diet. We would like you to carry on eating as normal and include these items in addition to your current diet.

Please try to include 1 of the following food items each day over the next 30-days.

If you do not wish to eat/drink a certain food item listed above then not to worry, please select foods that you do like/eat. Food items can be purchased as fresh or frozen.

| Food item | Amount (in grams/mls) | Quantity of item |
|---|---|---|
| Orange juice | 190.53 | 1/3rd pint |
| Grapefruit juice | 169.50 | Just under 1/3rd Pint |
| Dark chocolate | 64.41 | 6 squares |
| Spinach | 109.5 | Large handful (raw spinach) |
| Blueberry | 64.71 | ½ cup |
| Strawberry | 157.10 | 1 cup sliced strawberries |
| Blackberry | 81.35 | 10 blackberries |
| Blackcurrant | 61.24 | 21 blackberries |
| Cherries | 182.74 | 15 cherries |
| Plums | 90.21 | 2 plums |
| Black grapes | 142.02 | One medium bunch |
| Oranges | 247.17 | 2 medium-large oranges |
| Black olives | 89.24 | 9 olives |
| Red grapes | 339.64 | One large bunch |

Food log

Please take a note of what additional food item you included in your diet each day. Please take a note of what additional food items you included in your diet each day. If you do forget to fill in your food log on one day, do not worry. Try and remember what you ate that day and then fill it in. If you cannot remember the food you consumed on the day you missed, leave this day blank and continue the food diary as normal.

| Day | Food item |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |

| | |
|---|---|
| 8 | |
| 9 | |
| 10 | |
| 11 | |
| 12 | |
| 13 | |
| 14 | |
| 15 | |
| 16 | |
| 17 | |
| 18 | |
| 19 | |
| 20 | |
| 21 | |
| 22 | |
| 23 | |
| 24 | |
| 25 | |
| 26 | |
| 27 | |
| 28 | |
| 29 | |
| 30 | |

If you have any questions about the study please don't hesitate to contact the study researcher:
Rebecca Colombage (r.colombage@reading.ac.uk)

I.3. Low polyphenol diet for Experiment 3

Low Polyphenol Diet

Please avoid eating foods shown below for 24h before the test day at the Nutritional Psychology Unit and for the duration of each test visit. Please also avoid exercising during this time.

- All berries
- Fruit and vegetables (except potatoes and other exceptions stated below)
- Fruit juices
- Nuts and seeds
- Plant oils
- Jams and preserves
- Red wine
- Fruit teas
- Soy products
- Chocolate/cocoa
- Tea (black, green. earl grey etc)
- Coffee
- All high energy and/or caffeinated drinks, eg: Coca-Cola, Red Bull, Lucozade.
- All dietary supplements

Foods you may eat include those shown below:

- White bread
- Potatoes
- Rice
- Sweetcorn
- Mushrooms
- Carrots
- Bananas
- Pasta
- Meat
- Dairy products (not fruit or chocolate flavoured)

Appendix J. RAVLT word lists

## *J.1. RAVLT word lists in Experiment 2*

### *J.1.1. Version A*

| List A | List B |
|---|---|
| MOOSE | FLEA |
| LEVER | BISCUIT |
| HEDGE | PIG |
| STATUE | HARDWOOD |
| TOAD | WAX |
| SANDAL | PIGEON |
| BRIDGE | JAIL |
| VILLAGE | DOORWAY |
| CHEEK | SLEEVE |
| STADIUM | CURLER |
| FARM | NECK |
| JET | COKE |
| WOMAN | PICTURE |
| DECK | SPOOL |
| RICE | RAT |

### *J.1.2. Version B*

| List A | List B |
|---|---|
| FLASK | QUILL |
| MIXER | POSTER |
| BENCH | OWL |
| SADDLE | TORTOISE |
| LENS | SAUCE |
| FOREST | BASEMENT |
| STOOL | WOLF |
| MACHINE | POCKET |
| MAP | GOLD |
| TEACHER | BUTTON |
| BALL | WHEEL |
| POT | GROUND |
| LOBSTER | BARREL |
| STREET | ROOM |
| EGG | ARM |

### *J.1.3. Version C*

| List A | List B |
|---|---|
| VEST | MOSS |
| TROMBONE | BASKET |
| QUILT | WORM |
| HATCHET | SARDINE |
| MUG | NET |
| LEMON | COTTON |
| KNOB | BONE |
| PIMPLE | CIGAR |
| GUY | SHORE |
| PUPIL | MUSCLE |
| BANK | STAR |

| | |
|---|---|
| DESK | DIME |
| BEDROOM | MONEY |
| PRUNE | BARN |
| CHIN | WEED |

*J.1.4. Version D*

| List A | List B |
|---|---|
| TWEED | SWAMP |
| RIBBON | CANNON |
| TROUT | WHALE |
| APPLE | BROTHER |
| SAIL | SPRUCE |
| EARTHWORM | FOREARM |
| LAWN | NURSE |
| UNCLE | SHOVEL |
| SWEAT | LUNG |
| WHISKEY | STATION |
| PARK | CLOTH |
| WIFE | FLOOR |
| CABBAGE | TULIP |
| CORD | CLAM |
| JEEP | WINE |

*J.1.5. Version E*

| List A | List B |
|---|---|
| WHIP | SPIKE |
| CHISEL | HAMSTER |
| KILT | DART |
| WOODLAND | HAIRPIN |
| CURB | COUCH |
| PUDDLE | HAMMER |
| DRUM | SPONGE |
| METAL | IRON |
| TOOL | CAMP |
| MIRROR | PICKLE |
| EARTH | COIN |
| LAKE | WALL |
| CHILDREN | PENNY |
| BOOTH | CORPSE |
| COCK | CRANE |

*J.1.6. Version F*

| List A | List B |
|---|---|
| MORGUE | DOVE |
| SATIN | ARROW |
| FUDGE | YACHT |
| BURLAP | FERRY |
| THROAT | HEEL |
| PEDAL | HARBOUR |
| RIB | FUR |
| WALLET | WIRE |
| GATE | PURSE |

| | |
|---|---|
| DENTIST | ELBOW |
| SOCK | TOAST |
| MEAT | HILL |
| TRUMPET | TOWER |
| HAND | TREE |
| BEAST | MAST |

J.2. RAVLT word lists in Experiment 3

J.2.1. Version A

| List A | List B |
|---|---|
| dew | crane |
| forest | pig |
| prune | shrub |
| dairy | cellar |
| knight | cone |
| cotton | daisy |
| drain | pole |
| iron | salad |
| crown | stool |
| teacher | brother |
| nurse | beard |
| broom | corn |
| paper | bedroom |
| Leaf | Plate |
| Rice | Rat |

J.2.2. Version B

| List A | List B |
|---|---|
| latch | fawn |
| metal | bowl |
| fox | doll |
| armour | beehive |
| branch | duck |
| measles | barrel |
| brick | shore |
| linen | hammer |
| tool | bush |
| chicken | motor |
| star | land |
| ball | glove |
| garden | button |
| meat | ring |
| spoon | tree |

J.2.3. Version C

| List A | List B |
|---|---|
| scout | beast |
| palace | shield |
| pit | crow |
| lily | farmyard |

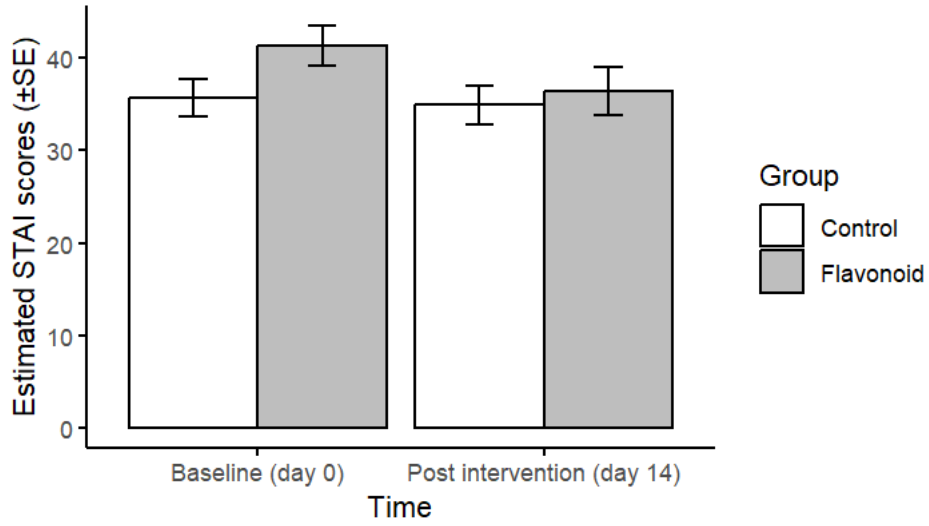
| | |
|---|---|
| shell | heel |
| gravel | laundry |
| blade | shark |
| gravy | movie |
| flag | chin |
| wire | uncle |
| oil | throat |
| tray | sleeve |
| building | pillow |
| brush | lamp |
| book | girl |

J.2.4. Version D

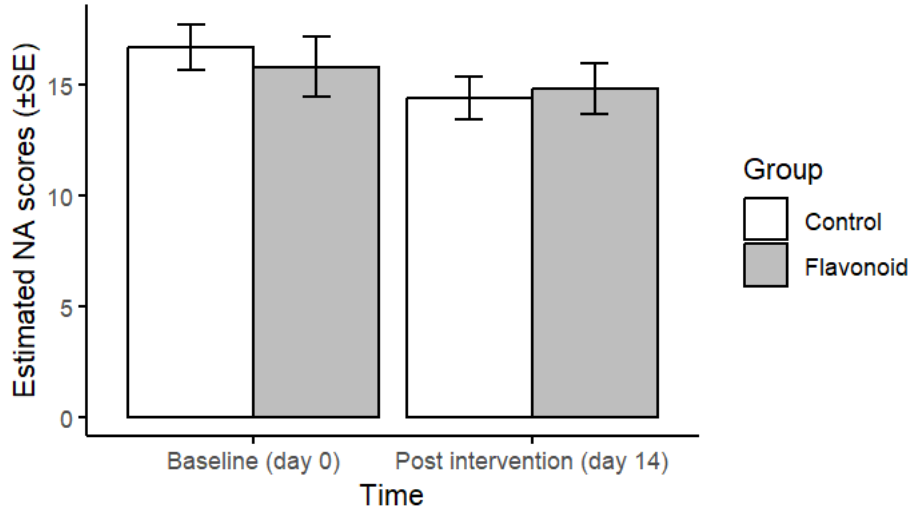
| List A | List B |
|---|---|
| cane | sword |
| needle | pipe |
| spike | vest |
| ferry | kennel |
| owl | cliff |
| package | napkin |
| pearl | deck |
| bullet | lemon |
| lung | frost |
| shoulder | pepper |
| church | cloth |
| jar | stone |
| picture | mirror |
| dog | seat |
| bag | door |

Appendix K. Chapter 4 supplementary figures

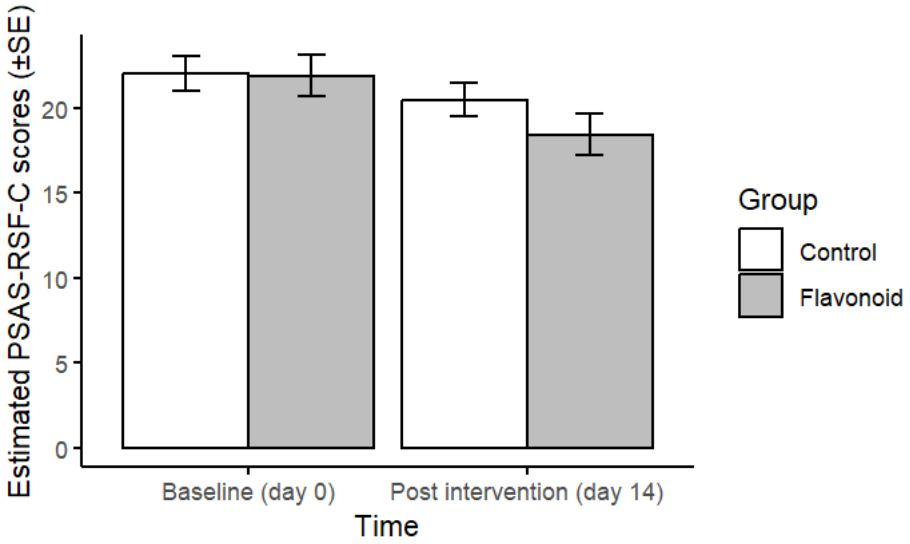
K.1. Graph showing STAI scores




K.2. Graph showing PANAS NA scores

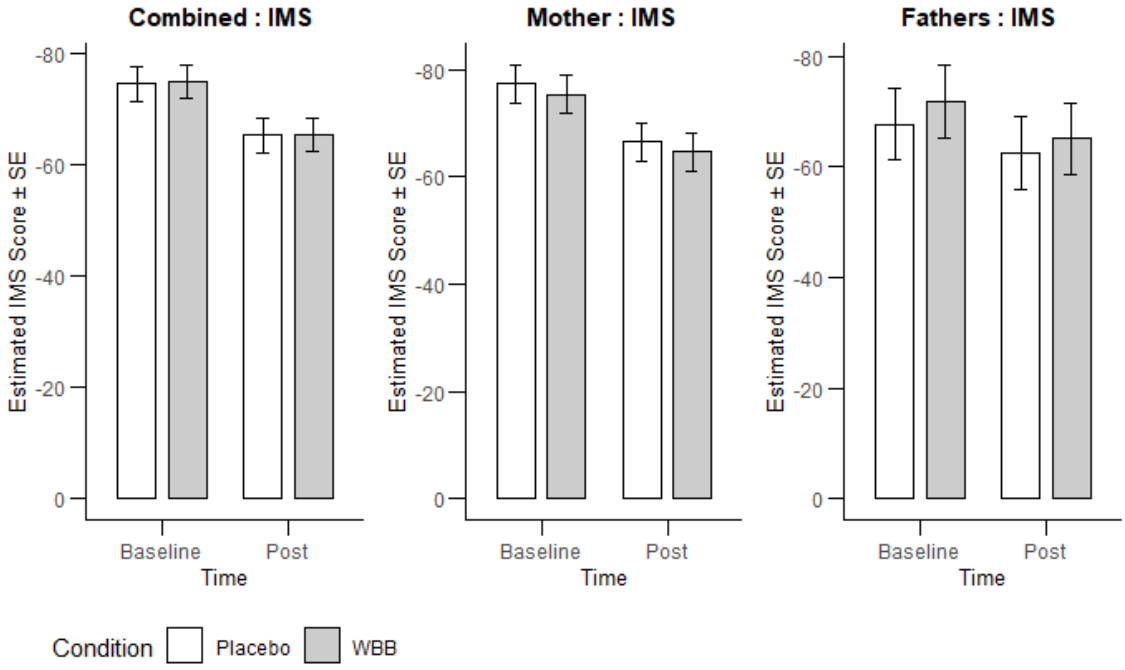


K.3 Graph showing PSAS-RSF-C scores

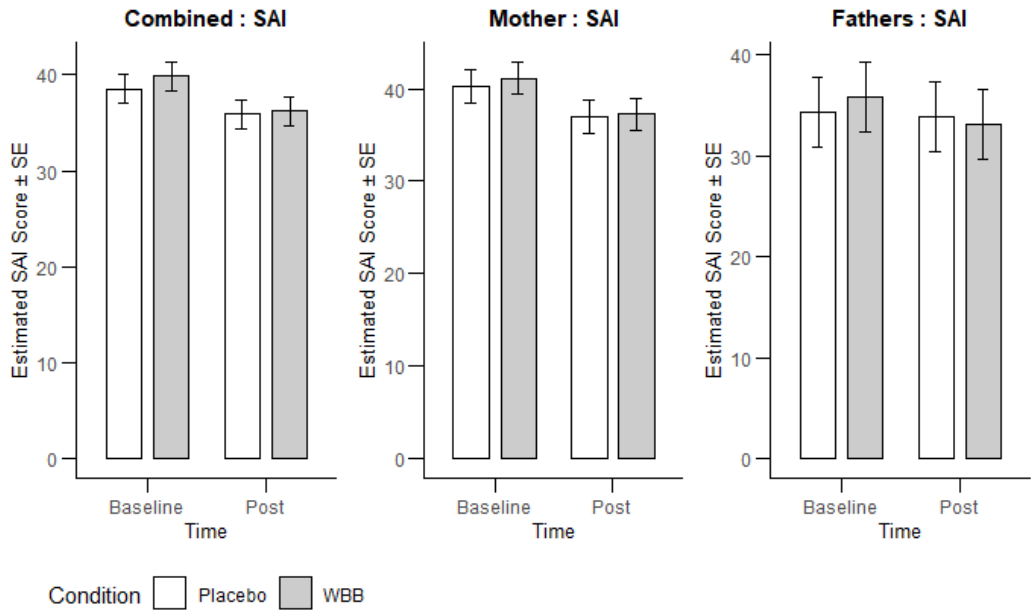



Appendix L. Chapter 6 supplementary figures

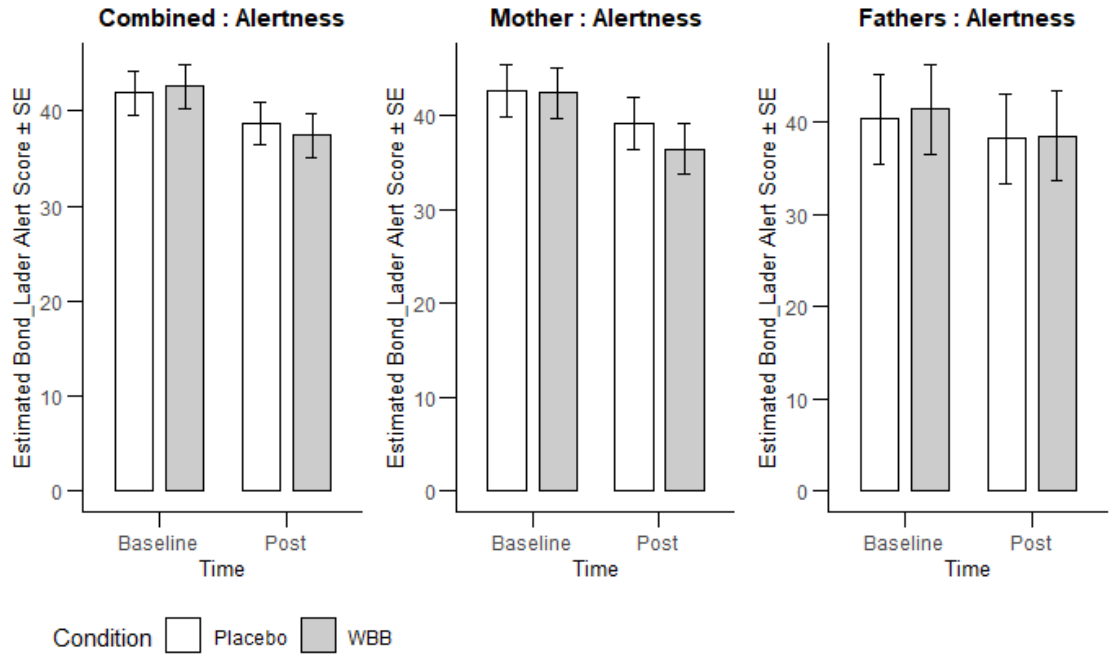
L.1. Graph showing IMS scores



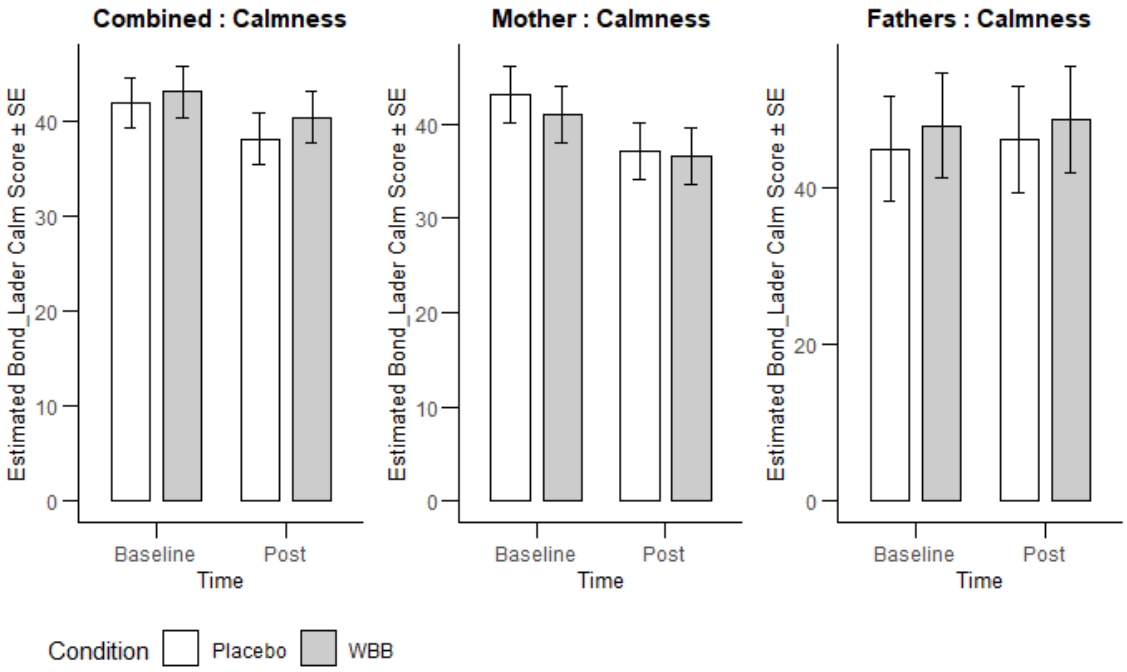

L.2. Graph showing SAI scores



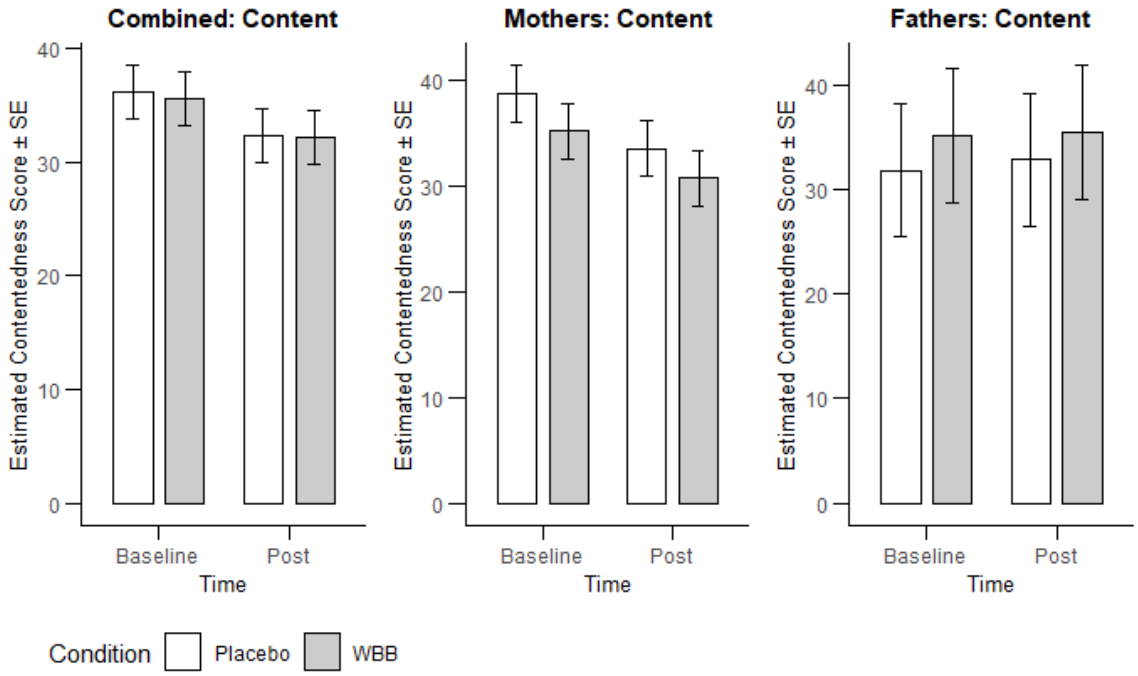

L.3. Graph showing BL-VAS alertness scores



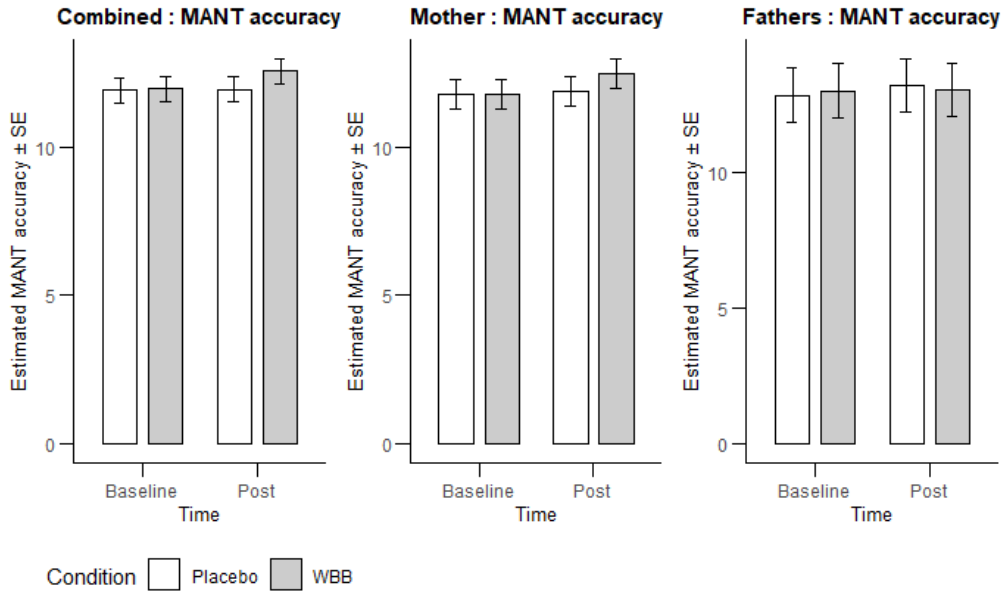
L.4. Graph showing BL-VAS Calmness scores




L.5. Graph showing BL-VAS Contentedness scores



L.6. Graph showing MANT accuracy scores




L.7. Graph showing MANT RT scores