University of Reading

Exploring Intolerance of Uncertainty: behavioural, cognitive and emotional responses to uncertainty, and developmental associations with mental health.

Doctorate of Philosophy

School of Psychology and Clinical Language Sciences

Zoe Ryan

February 2024

Declaration

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

Zoe Ryan

January 2024

Contribution to Papers

Statement of Contribution by Zoe Ryan and by co-authors on papers in preparation, and included in this thesis.

Zoe Ryan was the lead researcher for all the research that is reported in the papers within this thesis.

Study 1: Does Intolerance of Uncertainty predict child anxiety? A longitudinal study

Zoe Ryan's contribution to this paper included the design of the study at timepoints 2 and 3, gaining ethical approval, generation of questionnaires on the survey platform, collecting the data, writing and running analysis scripts and writing the manuscript for publication. Dr Holly Rayson assisted in the analysis planning. Dr Rayson, Professor Helen Dodd and Dr Jayne Morriss all provided feedback on the written manuscript. Professor Helen Dodd led the collection of data at baseline, Zoe Ryan was a Research Assistant on the project at that stage and Dr Holly Rayson was a Postdoctoral Research Fellow.

Study 2: Uncertain World: How Children's Curiosity and Intolerance of Uncertainty Relate to their Behaviour and Emotion under Uncertainty.

Zoe Ryan contributed to the design, development and creation of the game, along with gaining ethical approval, generation of questionnaires on the survey platform, recruiting participants, collecting the data, writing and running analysis scripts and led the writing of the manuscript for publication. Dr Lily FitzGibbon contributed to this paper by supporting the design, development and creation of the game, and the management of the web server storage. Chris Morea assisted in coding videos and co-writing the coding manual alongside Dr Lily FitzGibbon and Zoe Ryan. Dr Lily FitzGibbon and Professor Helen Dodd provided feedback on the manuscript.

Study 3: Uncertain World: How Adult's Curiosity and Intolerance of Uncertainty Relate to their Behaviour and Emotion under Uncertainty, and how it compares with children.

Zoe Ryan contributed to the design, development and creation of the game, along with gaining ethical approval, recruiting participants, collecting the data, writing and running analysis scripts and led the writing of the manuscript for publication. Again, Dr Lily FitzGibbon contributed to this paper in the design, development and creation of the game, and the management of the web server storage. Dr Lily FitzGibbon, Dr Jayne Morriss and Professor Helen Dodd provided feedback on the manuscript.

Candidate's name and signature

Zoe Ryan, 9 February 2024

Primary Supervisor's name and signature

Professor Helen Dodd, 9 February 2024

University of Reading Supervisor's name and signature

Dr Rachel McCloy, 9 February 2024

Thesis acknowledgements

"We live in uncertain times. Do you want to win? Embrace the uncertainty. Live in the worry."

Doctor Who, Revolution of the Daleks, BBC, 1 January 2021

Firstly I would like to thank the University of Reading for awarding me a Regional PhD Bursary. I also would not have been able to do any of this research without all my wonderful participants, particularly the Watch Them Grow families who continue to take part in my research despite a global pandemic and the forward movement of time.

I have been so lucky to have input from the wider academic community, and I want to express my thanks to thank Dr Dan Brady and Dr Anthony Haffey for their expert guidance in all things PsychoPy; their patience with me was vast. I would like to thank UoR students Chris Morea and Victor Bhagwandin for their support in video coding and piloting respectively. I would also like to thank Dr Eugene McSorley for being a superb monitor and Professor Kate Harvey for providing so much input in all things qualitative. A massive thanks goes to Dr Holly Rayson, who supported me when I was a Research Assistant, and has always been willing to share her knowledge to elevate others. I also want to thank Dr Jayne Morriss and Dr Rachel McCloy for being a wonderful source of support and guidance.

There is a team of people around me who have seen me through thick and thin, and I want to thank them from the bottom of my heart. I want to thank Dr Rachel Nesbit for never ceasing to make me laugh and Dr Monika Parkinson for cups of tea and long walks and chats. Dr Shannon Wake, Brooke Oliver and Gill Hearnshaw, thank you for being such lovely friends. To the old guard Dr Samantha Pearcey and Dr Jeni Fisk, for keeping me sane and showing me there is an end.

I wish that my brother, Phillip Pettengell and Dr Suzannah Stuijfzand could be here to celebrate this accomplishment with me, but sadly they have left us too early. I raise a glass to you.

My family deserve a medal for putting up with my never-ending quest for knowledge. Thank you so much to Andy Ryan for listening to my rants about broken R code, EndNote foibles, and generally all things PhD. Massive thanks and love to my boys, Harry and Eddie Ryan, who have never once complained about me being tied to my desk. Thanks to them for being flexible, understanding, proud and always ready with a cuddle when I need one. You boys are the best. Thank you to my darling friend Maggie Wray. You fill up my cup daily and I am so lucky to have you. Also thanks and love to Rachel Sutton. Our friendship means so much to me; your support has been unwavering.

Dr Lily FitzGibbon. Quite possibly one of the smartest, kindest, most collegiate people I know. I feel absolutely blessed to have spent so much time with her over my PhD journey. She has taught me so much and I am forever indebted.

Last, but certainly not least. Professor Helen Dodd. Where would I be without her? Helen is quite possibly the best supervisor, teacher, role model, cheerleader and friend I could have hoped for. From the day she offered me a job as her Research Assistant back in 2016, she has seen me through an unbelievable amount; broken hearted applications for studentships, nerve-wracking conference presentations, a pandemic, bereavement but also a lot of joy and laughter and happiness. She has taught me so much, she has picked me up when I have fallen, dusted me off, and got me started again. I thank you from the bottom of my heart.

COVID-19 Impact Statement

'Uncertainty is the only certainty there is. And knowing how to live with insecurity is the only security.' (John Allen Paulos)

I started my PhD in October 2018, and planned out a full programme of work aiming to examine the associations between anxiety and children's physiological and behavioural reactions to uncertainty and if parent-report IU is related, and whether IU predicts anxiety over time in children. This programme of work included two computer-based tasks using Galvanic Skin Response and pupil dilation techniques to measure physiological responses to uncertainty, an information seeking task and a battery of observation tasks. Parents completed questionnaire measures. For an overview of the research questions and methods, see Appendix 14. Target families for recruitment had taken part a few years prior in a research study called Watch Them Grow. I completed piloting and had begun testing sessions with participants when the COVID-19 pandemic began and the country went into lockdown. The research I had planned was all in person and lab-based. I did not know if we would return to in-person sessions so had to consider alternate plans.

Just after lockdown, I decided to conduct a questionnaire study as families could do this from home. Watch Them Grow study parents had already completed anxiety and Intolerance of Uncertainty measures at baseline, and a follow up on these measures seemed a natural step considering the pandemic. This study was successful, however we were still awaiting news on whether we would get back into the lab in time to return to the originally planned work. It became clear that this was not going to happen quickly, and therefore a new programme of work needed to be developed, taking into account the original overarching research questions of the thesis. Prior to the pandemic, I had been working with a collaborator, Dr Lily FitzGibbon, applying for grants to add physiological measures to the information seeking task (48 Buttons) from my original lab-based studies, examining children's behaviour under uncertainty. After lockdown, we decided to re-programme the task so that participants could take part from home, and in place of the physiological measures, we planned a novel webcam recording aspect of the game where children's facial affect could be coded. This game was then also used for the final study of the PhD, but with adults.

My PhD is part-time, so I have always worked alongside it, and at the time of the pandemic, for work I was going to schools and collecting questionnaire measures with children, and also conducting in person anxiety assessments. My work had to adjust to the "new normal" and there was a steep learning curve to changing processes and procedures to doing my job effectively and safely from home. Lastly, being a mother to two teenage boys, throughout the lockdowns, I was not only having to re-imagine my PhD, adjust how I worked, and deal with the uncertainties of the world, I also had to become teacher to my children. Although I am very happy with how my work has developed over such a stressful time, it has taken me much longer than originally anticipated.

Table of Contents

Abstract

Anxiety disorders are the most common mental health issues experienced in society, and can occur earlier in the lifespan than other mental health disorders. Untreated anxiety in young people can lead to challenges at school and home, and can increase the probability of long-term mental health problems. Intolerance of Uncertainty (IU) has been linked to higher levels of anxiety and worry in both adults and children but a number of limitations exist. There is limited research examining IU and worry in young children, a lack of longitudinal research examining associations between IU and worry across childhood, and almost no understanding of how high IU relates to behavioural, cognitive and emotional responses under uncertainty, particularly in children.

In Study 1, IU and generalised anxiety were assessed across childhood. The results revealed associations between generalised anxiety and IU at each time point; those with higher IU had higher symptoms than those with lower IU. Contrary to expectations, longitudinal analysis showed that higher IU predicted downward trends in generalised anxiety over time. This suggests that IU is associated with generalised anxiety across childhood but is unlikely to play a causal role in the onset of generalised anxiety. Following this, Study 2 explored the relationship between IU and children's behaviour and affect under uncertainty. This study also examined the role of curiosity to tease apart effects of IU from curiosity. IU was not found to predict children's emotional responses, however children did seek more information under higher uncertainty than lower uncertainty, but this was not related to either IU or curiosity. Lastly, Study 3 replicated Study 2 but with adult participants. Those higher in IU were more worried and had more negative affect than those with lower IU, particularly in high uncertainty trials, but they did not seek more information.

Overall, these studies provide new knowledge about developmental associations between IU and generalised anxiety and advance current understanding of the construct of IU and how it is associated with behavioural, cognitive and emotional responses to uncertainty. Future priorities lie in psychophysiological, observational and qualitative work with children.

Chapter 1. General Introduction

1.1 Anxiety

Anxiety is a maladaptive response to threat, where the response is out of proportion to the threat and disrupts normal functioning (Arroll & Kendrick, 2018). Worry refers to generalised anxiety related to a broad range of actual or potential threats. Anxiety disorders are the most common mental health issues experienced in society, with 33.7% of people experiencing an anxiety disorder at some point over the lifespan (Bandelow & Michaelis, 2015). Anxiety can occur in childhood or early adolescence, which is an earlier onset than in other mental health disorders (De Lijster et al., 2017; Kessler et al., 2005) and is fairly common in young people, with 2.4% to 6.5% of young people experiencing an anxiety disorder (Costello et al., 2003; Polanczyk et al., 2015). Anxiety impacts children's lives in numerous ways, where they may experience problems with social activities and peer relationships, family processes and school performance (Essau et al., 2000; Strauss et al., 1987) as well as poor school attendance/truancy (Finning et al., 2019) and early school withdrawal (Van Ameringen et al., 2003). Considering these factors, it is not surprising that childhood anxiety has been found to increase the probability of long-term mental health issues (Gregory et al., 2007; Wehry et al., 2015) at a high social and economic cost to society (Department of Health, 2011; Trautmann et al., 2016). Early intervention improves children's quality of life and decreases their long-term risk for mental health problems (Department of Health and Social Care and Department for Education, 2017).

1.2 Risk factors for anxiety

Many factors have been found to influence the development of anxiety in children. There are factors internal to the child that have been linked to anxiety in previous research, such as genetic influences and temperament, as well as external factors, such as parenting and negative life events. Below, these risk factors will be discussed.

1.2.1 Internal factors

1.2.1.1 Genetics. It is well documented that anxiety runs in families; children of anxious parents are more likely to be anxious themselves and anxious children are more likely to have anxious parents (Ahmadzadeh et al., 2019; Biederman et al., 1991; Cooper et al., 2006). Whilst some of this familial aggregation has a genetic basis, genes only account for around 30% of the variance in children's anxiety, leaving a substantial role for environmental factors (Ahmadzadeh et al., 2019; Eley & Gregory, 2004). More recently, research has moved beyond this binary distinction between environment and genes, with improved understanding that environment affects the expression of genes, therefore research focused on establishing risk for anxiety disorders will further examine epigenetic modification of DNA by specific environments (Lin & Tsai, 2020; Shimada-Sugimoto et al., 2015).

1.2.1.2 Child Temperament. Another risk factor found to be linked with the development of child anxiety is Behavioural Inhibition (BI). BI is a style of temperament where children are found to be quiet and shy, and may retreat or withdraw in novel situations (Kagan et al., 1984). BI has been seen to be a robust predictor of children's anxiety as seen in Sandstrom et al. (2020)'s meta-analysis, over multiple timepoints (Dodd et al., 2020; Hudson et al., 2011b), and is particularly implicated in risk for social withdrawal (Pérez-Edgar et al., 2010) and social anxiety disorder (Clauss & Blackford, 2012).

1.2.2 External factors

1.2.2.1 Parenting. As emphasised in several aetiological models of child anxiety, parenting is an important source of environmental influence for children (Bayer et al., 2006; Ginsburg & Schlossberg, 2002; Hudson & Rapee, 2004; Vallance & Fernandez, 2016; Vasey &

Dadds, 2001). Overly controlling/overinvolved parenting has been linked to child anxiety for some time (Hudson & Dodd, 2012; Hudson et al., 2019; McLeod et al., 2007). Parker (1983) defines the overcontrolling parent as hypervigilant and intrusive, excessively regulating children's activities and discouraging autonomy. This parenting style can unintentionally communicate to a child that the world is dangerous and decrease opportunities for the child to develop coping skills. As a result, the likelihood of child avoidance and anxiety is increased (Chorpita & Barlow, 2018; Laurin et al., 2015; Rapee, 1997). Initially it was theorised that parental negativity would be associated with child anxiety alongside overcontrol (Rapee, 1997), but evidence has not been convincing regarding any causal association (McLeod et al., 2007).

A further influence on children's anxiety is parental anxiety. As described, children with an anxious parent are at increased risk of developing an anxiety disorder themselves (Beidel & Turner, 1997; Ginsburg & Schlossberg, 2002; Hirshfeld-Becker et al., 2008; Lawrence et al., 2019). Mothers' anxiety in particular is a strong predictor of their child's anxiety. Mother's current anxiety when children were preschoolers has been shown to be strongly associated with their child's anxiety over time, moreso than mother's lifetime history of anxiety (Hudson et al., 2011a; Hudson et al., 2011b). This suggests that mothers' behaviour and communication when anxious may be influencing their child's anxiety risk. Kerns et al. (2017) also suggested that mother's emotion regulation could influence their child's anxiety. Interestingly, Hudson et al. (2011a) found no relationship between *paternal* anxiety and child anxiety.

1.2.2.2 Attachment. Bowlby (1982) theorised that in the first year of life, children develop attachments to their primary caregivers who protect and care for them. However the quality of the attachment can vary vastly depending on the caregiver's availability, sensitivity and responsiveness, leading to ambivalent, avoidant, disorganised or secure attachment between the child and parent (Ainsworth, 1979). It is theorised that where children are unsure about the availability, sensitivity and responsiveness of their caregiver, this leads to insecure attachment, and that this lack of protection and comfort can lead to anxiety. There is some evidence linking insecure attachment to child anxiety (e.g. a meta-analysis by Colonnesi et al., 2011) but this is not consistently found (Hudson & Dodd, 2012). Inconsistencies in the measures used and ages examined drives some of this disparity (Kerns & Brumariu, 2014). It has been highlighted that insecurity can manifest in ways other than anxiety, for example maintaining a distance and being extremely self-reliant (Main, Kaplan, & Cassidy, 1985).

1.2.2.3 Life events. A further robust risk factor for anxiety is negative life events, such as bereavement, divorce, academic failure, illness or financial stressors, however it has been suggested that events with higher ratings of loss or danger rather than other contexts of life events (e.g. humiliation and/or entrapment) predicted the onset of generalised anxiety in adults (Kendler et al., 2003). Negative life events have been found to precede anxiety disorders in young people aged 11 – 26 years old, and greater exposure to such events has been found to predict more severe anxiety (Ginsburg et al., 2014). Again, as in adults, the impact of negative life events can be dependent on context in children, for example with Casline et al. (2021) finding that academic negative life events (whether it be increased academic pressure or poor performance) were significant predictors of future anxiety in young people, however that negative family events (such as divorce and bereavement) and physical health were unrelated.

1.2.3 The interplay between risk factors

Risk factors for child anxiety do not necessarily exist or affect risk independently. It is likely that a range of risk factors will show additive effects and interact with one another to affect the likelihood of a child experiencing problematic anxiety. For example, Hudson et al. (2019) found an interplay of factors influenced a child's risk of developing anxiety, with BI in preschoolers interacting with maternal over-involvement to predict anxiety symptoms through to early adolescence. Broeren et al. (2014) suggest that BI and life events operate as additive risk factors in the development of anxiety with Mumper et al. (2020) concluding that stress and life events moderate early BI and its relationship with adolescent anxiety symptoms. A robust understanding of risk factors for anxiety is important for two reasons. First, to help identify which children are at risk for anxiety and may benefit from prevention programmes. Second, to better understand why anxiety develops, which helps to inform the development of prevention programmes as well as treatment approaches.

As discussed, there are external factors that influence the development of anxiety in children, but there are also aspects of the child themselves that may influence this risk. One such trait-like aspect is the construct of intolerance of uncertainty (IU) which captures individual differences in reactions to uncertainty and which is the focus of this thesis. Further research to better understand the construct of IU and its associations with anxiety over time is needed. The next section focuses on outlining this construct and existing research in this area.

1.3 Intolerance of Uncertainty

Uncertainty happens when we feel unsure and we do not have all the information about a situation; it is ubiquitous in everyday life. Carleton (2016, p. 32) defined IU as "dispositional incapacity to endure an aversive response triggered by the perceived absence of salient, key, or sufficient information, and sustained by the associated perception of uncertainty".

1.3.1 Links with anxiety and worry

Uncertainty can be uncomfortable for many, and where coping responses are maladaptive, it can lead to psychological distress (Stewart et al., 2010). There are various models of uncertainty which explore the nature of the relationship between uncertainty and anxiety, one being the Uncertainty and Anticipation Model of Anxiety (UAMA) (Grupe & Nitschke, 2013) where the authors suggest that dysfunctional processing of uncertainty is a feature of pathological anxiety. In both children and adults, there is clear evidence in clinical and non-clinical populations that IU is linked with higher levels of anxiety and worry (Buhr & Dugas, 2002; Counsell et al., 2017; Holaway et al., 2006; Osmanağaoğlu et al., 2018; Sexton & Dugas, 2009). There is however limited research regarding IU and anxiety in young children, potentially due to a lack of a suitable measure for IU in children under 9 years of age (Comer et al., 2009).

Despite the well documented relationship between IU and anxiety in adults, it is still unclear whether IU should be considered a stable dispositional characteristic and whether it is a precursor, a vulnerability factor or a maintenance mechanism for anxiety, or quite simply a feature of anxiety. What is observed however is that IU is a transdiagnostic factor for social anxiety disorder (SAD), panic disorder, agoraphobia, generalised anxiety disorder (GAD), obsessive-compulsive disorder (OCD), eating disorder (ED) and depression (e.g. a meta-analysis by McEvoy et al., 2019). Whilst IU is associated with all of the above disorders, the particular nature of the uncertainty experienced may prompt specific symptoms, depending on the focus of the disorder. For example, in SAD, where the individual fears negative evaluation in social situations, symptoms are more likely to present when uncertainty has negative behavioural and self-referent implications, whereas in GAD, where the individual struggles with day-to-day worries, symptoms are more likely to appear when uncertainty is perceived as unfair (Counsell et al., 2017). With OCD, IU is most closely linked to the symptoms of doubting, repeating and checking, where the individual might struggle with the uncertainty about their ability to avoid risks or danger (Holaway et al., 2006; Tolin et al., 2003). Carleton et al. (2014) suggest that in PD, the struggle with uncertainty lies in the meaning, outcome and recurrence in panic attacks.

IU may also mediate associations between other risk factors for anxiety. For example, IU has been found to mediate the relationship between adult attachment and worry (Wright et al., 2017; Çarıkçı-Özgül & Işık, 2024). These authors suggest that attachment anxiety may act indirectly on worry via its impact on IU. Recent research however has not supported these findings; Çarıkçı-Özgül & Işık (2024) found that IU did not play a mediating role between avoidant attachment and anxiety.

Within the domain of broader psychopathology, the construct of internalising problems brings together symptoms of anxiety and depression, whereas the construct of externalising problems captures impulsive and conduct-related problems (Achenbach, 1966). It has been suggested that IU may be a transdiagnostic construct associated with both internalising and externalising problems in children (Gramszlo et al., 2018).

1.3.2 Links with the interpretation of threat

Elevated perception of threat in uncertain situations appears to play both a causal and maintaining role in anxiety, and also contributes to maintenance factors such as avoidance in adults (Beck, 1979; Carleton, Mulvogue, et al., 2012; Holaway et al., 2006). This has been explored through meta-analyses regarding Cognitive Bias Modification for interpretation bias (CBM-I), where individuals are trained to interpret ambiguous stimuli neutrally or positively rather than negatively (Jones & Sharpe, 2017; Krebs et al., 2018). This retraining has been seen to improve anxiety in both youth and adults, supporting the causal/maintenance role of uncertainty in anxiety. This links to IU because those high in IU are more likely to interpret an uncertain situation (whether positive or negative) as threatening than those lower in IU (Dugas et al., 2005). This elevated perception of threat can lead to certain behavioural and cognitive responses (Carleton, Weeks, et al., 2012; Krohne, 1993), elevated anxiety and more negative reactions (Buhr & Dugas, 2006; Oglesby & Schmidt, 2017). It has also been suggested that when those high in IU learn a threat association (whether it is a true threat or not), they take longer to “unlearn” these associations than those low in IU (Morriss & van Reekum, 2019). This relationship between IU, anxiety and the interpretation and extinction of threat has been explored through manipulating threat experimentally, using varying levels of threat and varying levels of uncertainty. There are inconsistencies found across the studies, where in some circumstances, individuals with high IU may experience more anxiety with an uncertain threat rather than a certain threat (Carleton et al., 2007), and in others, there is no difference in response to uncertain and certain threat (Oglesby & Schmidt, 2017). Even when there is no threat, IU has been found to regulate attention to uncertainty (Morriss & McSorley, 2019) and those high in IU continue to be affected by uncertainty (Pepperdine et al., 2018).

The extent to which a clear plausible threat is necessary for those high in IU to react differently to those low in IU is not yet clear but there is some indication in the literature reviewed above that uncertainty itself is perceived and responded to as threatening by those high in IU.

1.3.3 Behavioural, emotional and cognitive responses to uncertainty

Various models/conceptualisations outline hypothesised dysfunctional processing of uncertainty in IU (Hebert & Dugas, 2019; Hillen et al., 2017). Each of these models begins with an event or stimulus, which then may trigger the perception of uncertainty, and when there is a dysfunctional belief or interpretation of the uncertainty, resulting responses to the uncertainty may be behavioural, emotional and/or cognitive. In fact, Freeston et al. (1994, p. 792) states that "Intolerance to uncertainty is thus defined as a relatively broad construct representing cognitive, emotional, and behavioural reactions to uncertainty in everyday life situations". The extent to which IU drives differences in behaviour, emotions and cognitions, and under what conditions has been the subject of substantial research, although mostly with adult samples.

1.3.3.1 Emotional responses to uncertainty. Research has demonstrated that those who are high in IU see uncertainty as disconcerting and stressful. As a result they are more likely than those low in IU to have a negative emotional response to it (Buhr & Dugas, 2002; Morriss et al., 2023). They may also have maladaptive strategies for regulating emotions, leading to greater emotional distress (Sahib et al., 2023). Uncertainty also appears to impact the experience of positive emotion for those high in IU. For example, Morriss et al. (2023) found that in those high in IU, a positive emotional state was less likely to be evoked by uncertainty than a negative emotional state and was dampened by uncertainty, whereas uncertainty heightened negative emotional states. There is however limited research examining IU and emotional responses to uncertainty, and in particular, IU and emotion regulation in children (Sahib et al., 2023).

1.3.3.2 Cognitive responses to uncertainty. The primary cognitive response to uncertainty seen in individuals high in IU is to engage in worry. Indeed, the original work on the construct of IU came from research on worry (Dugas et al., 1998; Freeston et al., 1994; Ladouceur et al., 1999). For example, Koerner and Dugas (2006) theorise that under uncertainty, IU stimulates worry and those with high IU are more likely to participate in that worrying than their counterparts with lower IU (Koerner & Dugas, 2008). High IU is thought to lead to worry via processes such as cognitive avoidance. Cognitive avoidance occurs when individuals try to reduce the arousal linked to threatening mental images and thoughts that might be distressing; typically this is only successful in providing short-term relief (Koerner & Dugas, 2006). Birrell et al. (2011) further suggest that uncertainty paralysis (or “freeze” response to threat) may be another aspect of cognitive avoidance in those with high IU when faced with uncertainty.

In contrast to more conscious cognitive responses to uncertainty, IU has also been associated with attention alerting, whereby an individual’s cognitive systems maintain an alert, or activated state. For example, Fergus and Carleton (2016) found that IU was positively associated with alerting on the attention network test, suggesting that the alerting attentional network of those high in IU may be overactive in noticing possible signs of uncertainty, and that this may be expressed in hypervigilance.

1.3.3.3 Behavioural responses to uncertainty. Adults high in IU may use a range of safety behaviours such as reassurance seeking, information seeking, avoidance, procrastination, overpreparation, (and others) to reduce the discomfort associated with uncertainty (Hebert & Dugas, 2019). A number of studies have examined behavioural responses to uncertainty in IU to better capture the repertoire of safety behaviours used and the circumstances under which they are engaged.

In one of the first studies to explore the use of a behavioural task to examine responses to uncertainty associated with high IU, Jacoby et al. (2014) used the Beads Task, a probabilistic inference task, with adults. The version used was computerised with conditions with varying levels of uncertainty: low uncertainty involved two jars with a high proportion (85:15) of blue to red beads in one jar and vice versa in the other, intermediate uncertainty involved two jars with a more even proportion (60:40) of purple and green beads in one jar and vice versa in the other, and high uncertainty involved three jars with the proportion of 44:28:28 orange, yellow and pink, 44:28:28 yellow, pink and orange and finally 44:28:28 pink, orange and yellow. There were also two groups: anxious and non-anxious. Participants were asked to request beads from a jar (up to a maximum of 30) and to make a decision as to which jar they thought they had come from. The sequence of beads that could be drawn from each jar was pre-determined up to 20 beads, and then was random. The more uncertain the task, the more information participants sought before making a decision (via drawing beads) and the more time they took to make the decision, but there were no group differences between anxious and non-anxious participants. The more uncertain the condition, the more distressed participants were, particularly in the anxious group. Surprisingly, IU was not associated with time to decision (regarding the jar) but was linked with level of distress after making a decision on the intermediate and high uncertainty jars. IU was also associated with information seeking (asking for a higher number of beads) but only on the intermediate trials. This study therefore supports the idea that those with anxiety, and those high in IU feel more distress than those without anxiety or with lower IU when uncertainty is greater, however in general, they do not exhibit different behavioural responses to higher uncertainty by way of asking for more beads prior to making a decision and taking longer to make a decision.

Further experimental work examining behaviours related to IU includes Bartoszek et al.'s (2022) investigation of information seeking behaviour and IU. Adult participants were informed that they would take a test of intellectual and emotional functioning and, depending on condition, were told it was either very good or very poor at predicting future outcomes. Participants were grouped by high and low IU, and the number of questions they asked about the test and post-test feedback requests were measured as information seeking behaviours. In the condition where they were told that the test was very good at predicting future outcomes, those with both high and low IU asked a relatively high number of questions. However, in the condition where they were told the test was poor at predicting outcomes (and there was therefore no threat associated with the task), those with high IU asked more questions than those with low IU. With post-test feedback requests, although those with high IU requested more feedback than those with low IU, this was not dependent on whether the test was good at predicting future outcomes or not. However, participants who were motivated by anxiety rather than interest sought more feedback. Where participants were motivated by interest rather than anxiety, both those with high and with low IU sought similar feedback, emphasising the importance of motivation when examining behaviours and IU.

A potential deficit in safety learning in high IU has also been suggested by recent research, building on the understanding of how individuals with high IU may respond differently to those with low IU to uncertainty in their environments. For example, in Morriss et al. (2020), they used an associative threat learning task, where an unconditioned aversive sound was paired with a specific coloured visual shape at a 50% reinforcement rate. Another coloured shape was not paired with a sound. In the extinction phase, both coloured shapes were not paired with a sound. There were two conditions; regular exposure or extended exposure (with 33% more trials). Those with higher IU in the extended exposure condition had better safety-retention than those with high IU in regular exposure, suggesting that longer exposure may be required for those high in IU to update associations with threat to associations with safety, relative to those low in IU.

Taken together these studies show that high IU is associated with a range of behavioural, cognitive and emotional responses to uncertainty, although some of this research remains preliminary and there are some inconsistencies. The participants for all of the studies outlined have been adults and there is a paucity of research examining behavioural, cognitive and emotional responses under uncertainty associated with high IU in children. This is despite the fact that some of the tasks used may be able to be adapted to measure responses to uncertainty in children (Osmanağaoğlu et al., 2018).

1.3.4 Intolerance of Uncertainty Research in Children

The relationship between IU and anxiety in children and adolescents under the age of 21 was examined in Osmanağaoğlu et al. (2018)'s meta-analysis. They identified that there is indeed limited research with limited methodologies into IU and anxiety in young people, and that this is an important field to further explore as the findings in the extensive adult literature may not translate to children due to developmental differences across childhood. Children's cognitive and general abilities to monitor and reason with uncertainty improve through childhood (Beran et al., 2012; Lyons & Ghetti, 2011; Roebers et al., 2007), however it is not clear if IU and its association with worry also develops through childhood, or whether it fluctuates throughout development. Osmanağaoğlu et al. (2018) also found additional gaps in the literature; the age ranges in existing literature were quite broad meaning that any age-related differences may be masked. They also identified that many of the studies regarding IU in children were based around questionnaire measures, some of which were not suitable for measuring IU. Osmanağaoğlu, Creswell, Snuggs, et al. (2021) found a popular measure of uncertainty in children, the Intolerance of Uncertainty Scale for Children (IUS-C) had numerous issues including a reading age that was too high, unclear items, with poor agreement between parent and child measures. It is therefore possible that some questionnaire measures may not be capturing all aspects of IU.

A further concern about the IUS-C is that it is not suitable for younger children. Despite the measure being validated for children aged 7 and up, it was found to be an unsuitable measure for children under 9 years old (Comer et al., 2009), In order to address these shortcomings, the Responses to Uncertainty and Low Environmental Structure (RULES) questionnaire (Sanchez et al., 2017) was developed as a parent-report measure of early childhood IU, for children aged 3 - 10. The measure has favourable psychometric properties and was found to be appropriate for pre-school and primary school aged children. In addition, previous measures of IU tend to capture children's attitudes to uncertainty, however this measure focuses importantly on children's emotional and behavioural responses to uncertainty.

The HiLo game was the first task used to examine behavioural responses to uncertainty in 13 – 17 year old adolescents (Krain et al., 2008; Krain et al., 2006). Participants were shown a numbered card (1-9) on a computer screen, alongside a mystery card, and they needed to decide if the mystery card was higher or lower than the numbered card. The value of the mystery card was most uncertain when the 5 card was shown, and most certain when the 1 and 9 cards were shown. In general, participants took longer to respond regarding less certain cards. Those who had higher IU had higher anxiety and were less certain about being correct, however there was no significant association between self-reported IU and response time. These results indicate that, in general, response times are slower when uncertainty is higher but that this is not related to IU in adolescents, however there was increased emotional and cognitive response to task uncertainty in those higher in IU.

Osmanağaoğlu, Creswell and Dodd (2021) identified a lack of research examining behavioural manifestations of IU in pre-adolescent children and adapted the Beads Task (Jacoby et al., 2014) for use in this population. The design was similar to Jacoby's, with low, moderate and high uncertainty conditions, however there were some changes made to account for the age of the participants (7 – 11 years old). Rather than being computerised, the task was in person with pom poms, the ratio of beads in the high uncertainty condition was changed to 50:25:25, and the maximum number of requests for beads was changed to 20. The results revealed that in general, with increased uncertainty, there was no effect on time to make a decision, however participants did seek more information and were more worried. Child's self-reported IU was related to worry but parent and child reported IU were not related to information seeking on the task. Again, there appears to be a relationship between IU and emotion, but any relationship with behaviour is less clear.

There are a number of gaps in the literature with regards to IU in children, responses to uncertainty and links to anxiety. It is unclear whether threat is needed for those high in IU to be bothered by uncertainty. Crucially we need to know what role IU plays with regards to anxiety and whether it is a risk factor or a consequence/correlate of anxiety. To our knowledge, there is no research examining how IU is related to anxiety developmentally and whether this relationship fluctuates throughout development, or examining how development influences IU itself. We also need a better understanding of how IU links to cognitive, emotional and behavioural responses to uncertainty in children; experimental tasks examining IU in children are sparse and are modelled after adult tasks. Lastly, we need to consider how we measure IU in children, as questionnaires that have been created by adapting adult measures may not be ideal. It is important that we address these gaps so that we have a better understanding of the construct of IU in order to do a better job of treating anxiety and worry.

1.3.5 Treatment of IU

As IU has clear links with anxiety, it is unsurprising that treatments targeting the improvement of tolerance of uncertainty in adults have been successful in reducing symptoms of Social Phobia (Mahoney & McEvoy, 2012) and GAD (Dugas & Ladouceur, 2000; van der Heiden et al., 2012). A recent meta-analysis by Miller and McGuire (2023) examined whether evidence-based treatment for anxiety affects IU. They found that evidence-based treatments targeting anxiety-related disorders led to significant decreases in IU. These treatment effects on IU were greater for unified protocol and/or spiritual-based Interventions than behavioural, relaxation-based and cognitive bias modification interventions. Other factors that produced stronger treatment effects on IU were longer intervention duration and/or more intervention hours. Despite these promising findings in adults, research evaluating how IU is affected by child anxiety treatment is scarce. A commonly used treatment for anxiety is Cognitive Behaviour Therapy (CBT) but only 58.9% of young people under the age of 19 who had this treatment no longer had an anxiety diagnosis after therapy (James et al., 2020), therefore there are a large number who may need a different approach and targeting IU may offer a logical next step. However, because the basic research into IU in children has lagged behind that in adults, the field is perhaps not yet advanced enough for evidence-based IU-focused treatments to be developed for children. For example, it remains unclear exactly how IU presents in children and young people, whether this differs across development, and what behaviours, emotions and cognitions are associated with uncertainty in children high in IU.

1.4 Curiosity

It is important to recognise that uncertainty does not only elicit negative emotions, but can be linked to positive emotional responses, particularly in epistemic curiosity. The construct of curiosity can be challenging to define due to the varied theoretical and operational differences in the literature. Within this thesis, I use Jirout and Klahr (2012, p. 150)'s definition of curiosity as "the threshold of desired uncertainty in the environment which leads to exploratory behaviour". This exploratory behaviour can be seen as seeking information in order to plug an information gap (Loewenstein, 1994). Thus, both IU and curiosity may drive information seeking under uncertainty. In curiosity, uncertainty can be enjoyable and motivating; filling the information gap can lead to increased knowledge. Possibly because of this, curiosity has been linked to academic achievement (Gottfried et al., 2016; Shah et al., 2018), positive affect and greater life satisfaction, in both adults and adolescents (Jovanovic & Brdaric, 2012; Kashdan et al., 2004). Resolving uncertainty through plugging an information gap and increasing knowledge is rewarding (Kang et al., 2009; Murayama et al., 2019). The nature of this reward may vary depending on the context within which information is sought. Litman (2008) suggested that curiosity can be considered as having two dimensions; interest and deprivation. In interest-type, individuals who are information seeking find discovering something new rewarding, and in deprivation-type, individuals seek information when they feel information is lacking, and closing the gap on the unpleasant feelings associated with the uncertainty is rewarding (Grossnickle, 2016).

Similar behaviours in response to uncertainty may be driven by IU or curiosity but with different motivations. In general, individuals high in IU would be expected to seek information to decrease discomfort, whereas individuals high in curiosity may seek information to resolve uncertainty for their own interest. Despite these obvious links between information seeking, IU and curiosity, only one set of studies examines them together. Jach and Smillie (2021) found that IU was associated with information seeking in adults, as was curiosity, but not consistently across their studies. They also found a significant positive association between IU and deprivation-type curiosity. This highlights that further work would be beneficial in examining the links between curiosity and IU as both appear to influence reactions to uncertainty. Furthermore, there are no studies examining information seeking and the constructs of curiosity and IU in children.

1.5 Thesis overview

Research related to anxiety, intolerance of uncertainty and emotional, cognitive and behavioural responses to uncertainty has been reviewed. Although it is clear that anxiety (especially generalised anxiety/worry) and IU have links in both adults and children, it is unclear how IU and worry are related longitudinally, and how the association between IU and worry might change across childhood. In addition, the intricacies of the links between IU and behavioural, emotional and cognitive responses to uncertainty are unclear, particularly in children, and it is unclear how well the effect of IU and curiosity can be disentangled.

This thesis aims to examine the association between IU and worry in young children and examine the relationship between IU and worry over time. It also aims to clarify the relationship between IU and behaviour and affect under uncertainty in both children and in adults, and whether these patterns can be distinguished from curiosity. These aims are addressed through three papers, the outlines of which can be found below.

1.5.1 Outline of studies

1.5.1.1 Study 1: Does Intolerance of Uncertainty predict child anxiety? A longitudinal study. Generalised anxiety has been shown to be linked with higher IU in both adults and children, however the relationship between generalised anxiety and IU in young children has not been previously explored. It is also unclear whether IU predicts and is a risk factor for generalised anxiety across childhood. Given the recognised links between anxiety and IU, and the impact anxiety can have on children and their futures, understanding how IU and its relationship with generalised anxiety transforms, fluctuates and develops over childhood is important to ensure interventions are correctly targeted.

Study 1 examines 1) how IU is associated with generalised anxiety in preschool-aged children, 2) the relationship between IU and generalised anxiety at three timepoints across childhood cross-sectionally and whether the relationship is consistent or changes with age, and 3) whether IU in preschool-aged children is associated with the trajectory of generalised anxiety symptoms over time into middle childhood. An additional aim was to examine whether IU was associated with the trajectory of internalising symptoms and externalising symptoms over time.

1.5.1.2 Study 2: Uncertain World: How Children's Curiosity and Intolerance of Uncertainty Relate to their Behaviour and Emotion under Uncertainty. There is limited research examining how IU and curiosity are each associated with children's behaviour and affect, and no research examining IU and curiosity together in relation to uncertainty in children. It is important to understand how children feel and act in the face of uncertainty and what drives these responses in order to further theoretical understanding of IU and, in turn, to design better measures of IU and interventions that target IU.

Study 2 evaluates whether 1) children's information seeking is related to curiosity and IU by examining associations between the number of buttons pressed in a decision-making task and parent-reported IU and curiosity, 2) curiosity is associated with positive emotional responses to uncertainty by examining associations between parent-reported curiosity and both facial affect and self-reported emotional valence, and 3) IU is associated with negative emotional responses to uncertainty through facial affect and self-reported emotional valence, but also through self-reported worry.

1.5.1.3 Study 3: Uncertain World: How Adult's Curiosity and Intolerance of Uncertainty Relate to their Behaviour and Emotion under Uncertainty, and how it compares with children. In Study 2, the findings were not as expected. Given that the task used in Study 2 had initially been conducted with adults, it was decided to focus Study 3 on adults, using an identical task as was used in Study 2. Study 3 therefore evaluates whether 1) adult's information seeking is related to curiosity and IU by examining associations between the number of buttons pressed in a decision-making task and self-reported IU and curiosity, 2) curiosity is associated with positive emotional responses to uncertainty by examining associations between self-reported curiosity and self-reported emotional valence, and 3) IU is associated with negative emotional responses to uncertainty through self-reported emotional valence, but also through self-reported worry.

1.5.2 Overarching hypotheses.

There are two overarching hypotheses examined in this thesis.

1. That IU is related to increased worry (generalised anxiety) within a longitudinal study and within a behavioural task
2. After controlling for the effect of curiosity, that IU is related to information seeking behaviour and negative affect under uncertainty in children and adults.

1.6 References

Achenbach, T. M. (1966). The classification of children's psychiatric symptoms: A factor-analytic study. *Psychological Monographs: General and Applied*, *80*(7), 1-37. https://doi.org/10.1037/h0093906

Ahmadzadeh, Y. I., Eley, T. C., Leve, L. D., Shaw, D. S., Natsuaki, M. N., Reiss, D., Neiderhiser, J. M., & McAdams, T. A. (2019). Anxiety in the family: A genetically informed analysis of transactional associations between mother, father and child anxiety symptoms. *Journal of Child Psychology and Psychiatry*, *60*(12), 1269-1277.

Ainsworth, M. S. (1979). Infant–mother attachment. American psychologist, 34(10), 932.

Arroll, B., & Kendrick, T. (2018). Definition of anxiety. *Primary care mental health*, *20*, 125-137.

Bandelow, B., & Michaelis, S. (2015). Epidemiology of anxiety disorders in the 21st century. *Dialogues in clinical neuroscience*, *17*(3), 327-335.

Bartoszek, G., Ranney, R. M., Curanovic, I., Costello, S. J., & Behar, E. (2022). Intolerance of uncertainty and information-seeking behavior: Experimental manipulation of threat relevance. *Behaviour Research and Therapy*, *154*, 104125. https://doi.org/https://doi.org/10.1016/j.brat.2022.104125

Bayer, J. K., Sanson, A. V., & Hemphill, S. A. (2006). Parent influences on early childhood internalizing difficulties. *Journal of Applied Developmental Psychology*, *27*(6), 542-559.

Beck, A. T. (1979). *Cognitive therapy and the emotional disorders*. Penguin.

Beidel, D. C., & Turner, S. M. (1997). At Risk for Anxiety: I. Psychopathology in the Offspring of Anxious Parents. *Journal of the American Academy of Child & Adolescent Psychiatry*, *36*(7), 918-924. https://doi.org/https://doi.org/10.1097/00004583-199707000-00013

Beran, M. J., Decker, S., Schwartz, A., & Smith, J. D. (2012). Uncertainty Monitoring by Young Children in a Computerized Task. *Scientifica*, *2012*, 692890. https://doi.org/10.6064/2012/692890

Biederman, J., Rosenbaum, J. F., Bolduc, E. A., Faraone, S. V., & Hirshfeld, D. R. (1991). A high risk study of young children of parents with panic disorder and agoraphobia with and without comorbid major depression. *Psychiatry research*, *37*(3), 333-348.

Birrell, J., Meares, K., Wilkinson, A., & Freeston, M. (2011). Toward a definition of intolerance of uncertainty: A review of factor analytical studies of the Intolerance of Uncertainty

Scale. *Clinical Psychology Review*, *31*(7), 1198-1208. https://doi.org/10.1016/J.CPR.2011.07.009

Bowlby, J. (1982). Attachment and loss: Vol. 1. Attachment (2nd ed.). New York, NY: Basic Books.

Broeren, S., Newall, C., Dodd, H. F., Locker, R., & Hudson, J. L. (2014). Longitudinal investigation of the role of temperament and stressful life events in childhood anxiety. *Development and Psychopathology*, *26*(2), 437-449.

Buhr, K., & Dugas, M. J. (2002). The intolerance of uncertainty scale: Psychometric properties of the English version. *Behaviour Research and Therapy*, *40*(8), 931-945.

Buhr, K., & Dugas, M. J. (2006). Investigating the construct validity of intolerance of uncertainty and its unique relationship with worry. *Journal of Anxiety Disorders*, *20*(2), 222-236.

Çarıkçı-Özgül, D. N., & Işık, Ü. (2024). Exploring adult attachment and anxiety: the role of intolerance of uncertainty and social support. Current Psychology, 1-9.

Carleton, R. N. (2016). Into the unknown: A review and synthesis of contemporary models involving uncertainty. *Journal of Anxiety Disorders*, *39*, 30-43. https://doi.org/https://doi.org/10.1016/j.janxdis.2016.02.007

Carleton, R. N., Duranceau, S., Freeston, M. H., Boelen, P. A., McCabe, R. E., & Antony, M. M. (2014). "But it might be a heart attack": Intolerance of uncertainty and panic disorder symptoms. *Journal of Anxiety Disorders*, *28*(5), 463-470.

Carleton, R. N., Mulvogue, M. K., Thibodeau, M. A., McCabe, R. E., Antony, M. M., & Asmundson, G. J. G. (2012). Increasingly certain about uncertainty: Intolerance of uncertainty across anxiety and depression. *Journal of Anxiety Disorders*, *26*(3), 468-479. https://doi.org/10.1016/J.JANXDIS.2012.01.011

Carleton, R. N., Sharpe, D., & Asmundson, G. J. G. (2007). Anxiety sensitivity and intolerance of uncertainty: Requisites of the fundamental fears? *Behaviour Research and Therapy*, *45*(10), 2307-2316. https://doi.org/https://doi.org/10.1016/j.brat.2007.04.006

Carleton, R. N., Weeks, J. W., Howell, A. N., Asmundson, G. J. G., Antony, M. M., & McCabe, R. E. (2012). Assessing the latent structure of the intolerance of uncertainty construct: An initial taxometric analysis. *Journal of Anxiety Disorders*, *26*(1), 150-157. https://doi.org/https://doi.org/10.1016/j.janxdis.2011.10.006

Casline, E. P., Ginsburg, G. S., Piacentini, J., Compton, S., & Kendall, P. (2021). Negative life events as predictors of anxiety outcomes: an examination of event type. *Research on Child and Adolescent Psychopathology*, *49*, 91-102.

Chorpita, B. F., & Barlow, D. H. (2018). The development of anxiety: The role of control in the early environment. *The Neurotic Paradox, Vol 2*, 227-264.

Clauss, J. A., & Blackford, J. U. (2012). Behavioral Inhibition and Risk for Developing Social Anxiety Disorder: A Meta-Analytic Study. *Journal of the American Academy of Child & Adolescent Psychiatry*, *51*(10), 1066-1075.e1061. https://doi.org/10.1016/j.jaac.2012.08.002

Comer, J. S., Roy, A. K., Furr, J. M., Gotimer, K., Beidas, R. S., Dugas, M. J., & Kendall, P. C. (2009). The intolerance of uncertainty scale for children: a psychometric evaluation. *Psychological assessment*, *21*(3), 402-411. https://doi.org/10.1037/a0016719

Colonnesi, C., Draijer, E. M., Jan JM Stams, G., Van der Bruggen, C. O., Bögels, S. M., & Noom, M. J. (2011). The relation between insecure attachment and child anxiety: A meta-analytic review. Journal of Clinical Child & Adolescent Psychology, 40(4), 630-645.

Cooper, P. J., Fearn, V., Willetts, L., Seabrook, H., & Parkinson, M. (2006). Affective disorder in the parents of a clinic sample of children with anxiety disorders. *Journal of Affective Disorders*, *93*(1-3), 205-212.

Costello, E. J., Mustillo, S., Erkanli, A., Keeler, G., & Angold, A. (2003). Prevalence and Development of Psychiatric Disorders in Childhood and Adolescence. *Archives of General Psychiatry*, *60*(8), 837-837. https://doi.org/10.1001/archpsyc.60.8.837

Counsell, A., Furtado, M., Iorio, C., Anand, L., Canzonieri, A., Fine, A., Fotinos, K., Epstein, I., & Katzman, M. A. (2017). Intolerance of uncertainty, social anxiety, and generalized anxiety: Differences by diagnosis and symptoms. *Psychiatry research*, *252*, 63-69.

De Lijster, J. M., Dierckx, B., Utens, E. M., Verhulst, F. C., Zieldorff, C., Dieleman, G. C., & Legerstee, J. S. (2017). The age of onset of anxiety disorders: a meta-analysis. *Canadian journal of psychiatry. Revue canadienne de psychiatrie*, *62*(4), 237.

Department of Health. (2011). *No Health Without Mental Health: A Cross-Government Mental Health Outcomes Strategy for People of all Ages. Supporting Document – The Economic Case for Improving Efficiency and Quality in Mental Health* [pdf] https://assets.publishing.service.gov.uk/media/5a7cab32e5274a2f304ef5a3/dh_123993.pdf

Department of Health and Social Care and Department for Education. (2017). *Transforming children and young people's mental health provision: a green paper.* https://www.gov.uk/government/consultations/transforming-children-and-young-peoples-mental-health-provision-a-green-paper

Dodd, H. F., Rayson, H., Ryan, Z., Bishop, C., Parsons, S., & Stuijfzand, B. (2020). Trajectories of anxiety when children start school: The role of behavioral inhibition and attention bias to angry and happy faces. *Journal of Abnormal Psychology*, *129*(7), 701.

Dugas, M. J., Gagnon, F., Ladouceur, R., & Freeston, M. H. (1998). Generalized anxiety disorder: A preliminary test of a conceptual model. *Behaviour Research and Therapy*, *36*(2), 215-226.

Dugas, M. J., Hedayati, M., Karavidas, A., Buhr, K., Francis, K., & Phillips, N. A. (2005). Intolerance of Uncertainty and Information Processing: Evidence of Biased Recall and Interpretations. *Cognitive Therapy and Research*, *29*(1), 57-70. https://doi.org/10.1007/s10608-005-1648-9

Dugas, M. J., & Ladouceur, R. (2000). Treatment of GAD: Targeting intolerance of uncertainty in two types of worry. *Behavior Modification*, *24*(5), 635-657. https://doi.org/10.1177/0145445500245002

Einstein, D. A. (2014). Extension of the transdiagnostic model to focus on intolerance of uncertainty: a review of the literature and implications for treatment. *Clinical Psychology: Science and Practice*, *21*(3), 280.

Eley, T. C., & Gregory, A. M. (2004). Behavioral genetics. In *Anxiety disorders in children and adolescents, 2nd ed.* (pp. 71-97). The Guilford Press.

Essau, C. A., rer, s., Conradt, J., Petermann, F., & Phil. (2000). Frequency, Comorbidity, and Psychosocial Impairment of Anxiety Disorders in German Adolescents. *Journal of Anxiety Disorders*, *14*(3), 263-279. https://doi.org/10.1016/S0887-6185(99)00039-0

Fergus, T. A., & Carleton, R. N. (2016). Intolerance of uncertainty and attentional networks: Unique associations with alerting. *Journal of Anxiety Disorders*, *41*, 59-64.

Finning, K., Ukoumunne, O. C., Ford, T., Danielson-Waters, E., Shaw, L., Romero De Jager, I., Stentiford, L., & Moore, D. A. (2019). Review: The association between anxiety and poor attendance at school – a systematic review. *Child and Adolescent Mental Health*, *24*(3), 205-216. https://doi.org/https://doi.org/10.1111/camh.12322

Freeston, M. H., Rhéaume, J., Letarte, H., Dugas, M. J., & Ladouceur, R. (1994). Why do people worry? *Personality and Individual Differences*, *17*(6), 791-802. https://doi.org/https://doi.org/10.1016/0191-8869(94)90048-5

Ginsburg, G. S., Becker, E. M., Keeton, C. P., Sakolsky, D., Piacentini, J., Albano, A. M., Compton, S. N., Iyengar, S., Sullivan, K., Caporino, N., Peris, T., Birmaher, B., Rynn, M., March, J., & Kendall, P. C. (2014). Naturalistic Follow-up of Youths Treated for Pediatric Anxiety Disorders. *JAMA Psychiatry*, *71*(3), 310-318. https://doi.org/10.1001/jamapsychiatry.2013.4186

Ginsburg, G. S., & Schlossberg, M. C. (2002). Family-based treatment of childhood anxiety disorders. *International Review of Psychiatry*, *14*(2), 143-154.

Gottfried, A. E., Preston, K. S. J., Gottfried, A. W., Oliver, P. H., Delany, D. E., & Ibrahim, S. M. (2016). Pathways from parental stimulation of children's curiosity to high school science course accomplishments and science career interest and skill. *International Journal of Science Education*, *38*(12), 1972-1995.

Gramszlo, C., Fogleman, N. D., Rosen, P. J., & Woodruff-Borden, J. (2018). Intolerance of uncertainty in children with attention-deficit/hyperactivity disorder. *ADHD Attention Deficit and Hyperactivity Disorders*, *10*(3), 189-197. https://doi.org/10.1007/s12402-017-0244-7

Gregory, A. M., Caspi, A., Moffitt, T. E., Koenen, K., Eley, T. C., & Poulton, R. (2007). Juvenile mental health histories of adults with anxiety disorders. *American Journal of Psychiatry*, *164*(2), 301-308. https://doi.org/10.1176/AJP.2007.164.2.301/ASSET/IMAGES/LARGE/R422F0.JPEG

Grossnickle, E. M. (2016). Disentangling curiosity: Dimensionality, definitions, and distinctions from interest in educational contexts. *Educational Psychology Review*, *28*(1), 23-60.

Grupe, D. W., & Nitschke, J. B. (2013). Uncertainty and anticipation in anxiety: an integrated neurobiological and psychological perspective. *Nature Reviews Neuroscience*, *14*(7), 488-501. https://doi.org/10.1038/nrn3524

Hebert, E. A., & Dugas, M. J. (2019). Behavioral Experiments for Intolerance of Uncertainty: Challenging the Unknown in the Treatment of Generalized Anxiety Disorder. *Cognitive and Behavioral Practice*, *26*(2), 421-436. https://doi.org/10.1016/J.CBPRA.2018.07.007

Hillen, M. A., Gutheil, C. M., Strout, T. D., Smets, E. M. A., & Han, P. K. J. (2017). Tolerance of uncertainty: Conceptual analysis, integrative model, and implications for healthcare. *Social Science and Medicine*, *180*, 62-75. https://doi.org/10.1016/j.socscimed.2017.03.024

Hirshfeld-Becker, D. R., Micco, J. A., Simoes, N. A., & Henin, A. (2008). High risk studies and developmental antecedents of anxiety disorders. In *American Journal of Medical Genetics Part C: Seminars in Medical Genetics* (Vol 148, No.2, pp. 99-117). Hoboken: Wiley Subscription Services Inc., A Wiley Company.

Holaway, R. M., Heimberg, R. G., & Coles, M. E. (2006). A comparison of intolerance of uncertainty in analogue obsessive-compulsive disorder and generalized anxiety disorder. *Journal of Anxiety Disorders*, *20*(2), 158-174.

Hudson, J. L., & Dodd, H. F. (2012). Informing Early Intervention: Preschool Predictors of Anxiety Disorders in Middle Childhood. *PLOS ONE*, *7*(8), e42359. https://doi.org/10.1371/journal.pone.0042359

Hudson, J. L., Dodd, H. F., & Bovopoulos, N. (2011a). Temperament, Family Environment and Anxiety in Preschool Children. *Journal of Abnormal Child Psychology*, *39*(7), 939-951. https://doi.org/10.1007/s10802-011-9502-x

Hudson, J. L., Dodd, H. F., Lyneham, H. J., & Bovopoulous, N. (2011b). Temperament and family environment in the development of anxiety disorder: Two-year follow-up. *Journal of the American Academy of Child & Adolescent Psychiatry*, *50*(12), 1255-1264. e1251.

Hudson, J. L., Murayama, K., Meteyard, L., Morris, T., & Dodd, H. F. (2019). Early Childhood Predictors of Anxiety in Early Adolescence. *Journal of Abnormal Child Psychology*, *47*(7), 1121-1133. https://doi.org/10.1007/s10802-018-0495-6

Hudson, J. L., & Rapee, R. M. (2004). From Anxious Temperament to Disorder: An Etiological Model In R. G. Heimberg, C. L. Turk, & D. S. Mennin (Eds.). *Generalized anxiety disorder: Advances in research and practice* 51–74.

Jach, H. K., & Smillie, L. D. (2021). Testing the Information-Seeking Theory of Openness/Intellect. *European Journal of Personality*, *35*(1), 103-119. https://doi.org/10.1002/per.2271

Jacoby, R. J., Abramowitz, J. S., Buck, B. E., & Fabricant, L. E. (2014). How is the Beads Task related to intolerance of uncertainty in anxiety disorders? *Journal of Anxiety Disorders*, *28*(6), 495-503. https://doi.org/10.1016/J.JANXDIS.2014.05.005

James, A. C., Reardon, T., Soler, A., James, G., & Creswell, C. (2020). Cognitive behavioural therapy for anxiety disorders in children and adolescents. *Cochrane database of systematic reviews*(11).

Jirout, J., & Klahr, D. (2012). Children's scientific curiosity: In search of an operational definition of an elusive concept. *Developmental Review 32*(2), 125-160. https://doi.org/10.1016/j.dr.2012.04.002

Jones, E. B., & Sharpe, L. (2017). Cognitive bias modification: A review of meta-analyses. *Journal of Affective Disorders*, *223*, 175-183.

Jovanovic, V., & Brdaric, D. (2012). Did curiosity kill the cat? Evidence from subjective well-being in adolescents. *Personality and Individual Differences*, *52*(3), 380-384. https://doi.org/https://doi.org/10.1016/j.paid.2011.10.043

Kagan, J., Reznick, J. S., Clarke, C., Snidman, N., & Garcia-Coll, C. (1984). Behavioral Inhibition to the Unfamiliar. *Child Development*, *55*(6), 2212-2225. https://doi.org/10.2307/1129793

Kang, M. J., Hsu, M., Krajbich, I. M., Loewenstein, G., McClure, S. M., Wang, J. T.-y., & Camerer, C. F. (2009). The wick in the candle of learning: Epistemic curiosity activates reward circuitry and enhances memory. *Psychological Science*, *20*(8), 963-973.

Kashdan, T. B., Rose, P., & Fincham, F. D. (2004). Curiosity and Exploration: Facilitating Positive Subjective Experiences and Personal Growth Opportunities. *Journal of Personality Assessment*, *82*(3), 291-305. https://doi.org/10.1207/s15327752jpa8203_05

Kendler, K. S., Hettema, J. M., Butera, F., Gardner, C. O., & Prescott, C. A. (2003). Life Event Dimensions of Loss, Humiliation, Entrapment, and Danger in the Prediction of Onsets of Major Depression and Generalized Anxiety. *Archives of General Psychiatry*, *60*(8), 789-796. https://doi.org/10.1001/archpsyc.60.8.789

Kerns, K. A., & Brumariu, L. E. (2014). Is insecure parent–child attachment a risk factor for the development of anxiety in childhood or adolescence?. Child development perspectives, 8(1), 12-17.

Kerns, C. E., Pincus, D. B., McLaughlin, K. A., & Comer, J. S. (2017). Maternal emotion regulation during child distress, child anxiety accommodation, and links between maternal and child anxiety. *Journal of Anxiety Disorders*, *50*, 52-59. https://doi.org/https://doi.org/10.1016/j.janxdis.2017.05.002

Kessler, R. C., Berglund, P., Demler, O., Jin, R., Merikangas, K. R., & Walters, E. E. (2005). Lifetime prevalence and age-of-onset distributions of DSM-IV disorders in the National Comorbidity Survey Replication. *Archives of General Psychiatry*, *62*(6), 593-602.

Koerner, N., & Dugas, M. J. (2006). A cognitive model of generalized anxiety disorder: The role of intolerance of uncertainty. *Worry and its psychological disorders: Theory, assessment and treatment*, 201-216.

Koerner, N., & Dugas, M. J. (2008). An investigation of appraisals in individuals vulnerable to excessive worry: the role of intolerance of uncertainty. *Cognitive Therapy and Research*, *32*(5), 619-638. https://doi.org/10.1007/s10608-007-9125-2

Krain, A. L., Gotimer, K., Hefton, S., Ernst, M., Castellanos, F. X., Pine, D. S., & Milham, M. P. (2008). A Functional Magnetic Resonance Imaging Investigation of Uncertainty in Adolescents with Anxiety Disorders. *Biological Psychiatry*, *63*(6), 563-568. https://doi.org/10.1016/j.biopsych.2007.06.011

Krain, A. L., Hefton, S., Pine, D. S., Ernst, M., Xavier Castellanos, F., Klein, R. G., & Milham, M. P. (2006). An fMRI examination of developmental differences in the neural correlates of uncertainty and decision-making. *Journal of Child Psychology and Psychiatry*, *47*(10), 1023-1030.

Krebs, G., Pile, V., Grant, S., Degli Esposti, M., Montgomery, P., & Lau, J. Y. (2018). Research review: Cognitive bias modification of interpretations in youth and its effect on anxiety: A meta-analysis. *Journal of Child Psychology and Psychiatry*, *59*(8), 831-844.

Krohne, H. W. (1993). Vigilance and cognitive avoidance as concepts in coping research.

Ladouceur, R., Dugas, M. J., Freeston, M. H., Rhéaume, J., Blais, F., Boisvert, J.-M., Gagnon, F., & Thibodeau, N. (1999). Specificity of generalized anxiety disorder symptoms and processes. *Behavior Therapy*, *30*(2), 191-207.

Laurin, J. C., Joussemet, M., Tremblay, R. E., & Boivin, M. (2015). Early Forms of Controlling Parenting and the Development of Childhood Anxiety. *Journal of Child and Family Studies*, *24*(11), 3279-3292. https://doi.org/10.1007/s10826-015-0131-9

Lawrence, P. J., Murayama, K., & Creswell, C. (2019). Systematic Review and Meta-Analysis: Anxiety and Depressive Disorders in Offspring of Parents With Anxiety Disorders. *Journal of the American Academy of Child & Adolescent Psychiatry*, *58*(1), 46-60. https://doi.org/https://doi.org/10.1016/j.jaac.2018.07.898

Lin, E., & Tsai, S.-J. (2020). Gene-Environment Interactions and Role of Epigenetics in Anxiety Disorders. *Anxiety disorders: rethinking and understanding recent discoveries*, 93-102. https://doi.org/10.1007/978-981-32-9705-0_6

Litman, J. A. (2008). Interest and deprivation factors of epistemic curiosity. *Personality and Individual Differences*, *44*, 1585-1595. https://doi.org/10.1016/j.paid.2008.01.014

Loewenstein, G. (1994). The Psychology of Curiosity: A Review and Reinterpretation. *Psychological Bulletin*, *116*(1), 75-98.

Lyons, K. E., & Ghetti, S. (2011). The development of uncertainty monitoring in early childhood. *Child Development*, *82*(6), 1778-1787.

Main, M., Kaplan, N., & Cassidy, J. (1985). Security in infancy, childhood, and adulthood: A move to the level of representation. Monographs of the society for research in child development, 66-104.

Mahoney, A. E., & McEvoy, P. M. (2012). A transdiagnostic examination of intolerance of uncertainty across anxiety and depressive disorders. *Cognitive Behaviour Therapy*, *41*(3), 212-222.

McEvoy, P. M., Hyett, M. P., Shihata, S., Price, J. E., & Strachan, L. (2019). The impact of methodological and measurement factors on transdiagnostic associations with intolerance of uncertainty: A meta-analysis. *Clinical Psychology Review*, *73*, 101778. https://doi.org/https://doi.org/10.1016/j.cpr.2019.101778

McLeod, B. D., Wood, J. J., & Weisz, J. R. (2007). Examining the association between parenting and childhood anxiety: A meta-analysis. *Clinical Psychology Review*, *27*(2), 155-172.

Miller, M. L., & McGuire, J. F. (2023). Targeting intolerance of uncertainty in treatment: A meta-analysis of therapeutic effects, treatment moderators, and underlying mechanisms. *Journal of Affective Disorders*, *341*, 283-295. https://doi.org/https://doi.org/10.1016/j.jad.2023.08.132

Morriss, J., Goh, K., Hirsch, C. R., & Dodd, H. F. (2023). Intolerance of uncertainty heightens negative emotional states and dampens positive emotional states. *Frontiers in Psychiatry*, *14*, 1147970.

Morriss, J., & McSorley, E. (2019). Intolerance of uncertainty is associated with reduced attentional inhibition in the absence of direct threat. *Behaviour Research and Therapy*, *118*, 1-6. https://doi.org/https://doi.org/10.1016/j.brat.2019.03.011

Morriss, J., & van Reekum, C. M. (2019). I feel safe when i know: Contingency instruction promotes threat extinction in high intolerance of uncertainty individuals. *Behaviour Research and Therapy*, *116*, 111-118.

Morriss, J., Wake, S., Lindner, M., McSorley, E., & Dodd, H. (2020). How many times do I need to see to believe? The impact of intolerance of uncertainty and exposure experience on safety-learning and retention in young adults. *International Journal of Psychophysiology*, *153*, 8-17. https://doi.org/https://doi.org/10.1016/j.ijpsycho.2020.04.012

Mumper, E. E., Dyson, M. W., Finsaas, M. C., Olino, T. M., & Klein, D. N. (2020). Life stress moderates the effects of preschool behavioral inhibition on anxiety in early adolescence. *Journal of Child Psychology and Psychiatry*, *61*(2), 167-174.

Murayama, K., Fitzgibbon, L., & Sakaki, M. (2019). Process Account of Curiosity and Interest: A Reward-Learning Perspective. *Educational Psychology Review*, *31*(4), 875-895. https://doi.org/10.1007/s10648-019-09499-9

Oglesby, M. E., & Schmidt, N. B. (2017). The Role of Threat Level and Intolerance of Uncertainty (IU) in Anxiety: An Experimental Test of IU Theory. *Behavior Therapy*, *48*(4), 427-434. https://doi.org/https://doi.org/10.1016/j.beth.2017.01.005

Osmanağaoğlu, N., Creswell, C., & Dodd, H. F. (2018). Intolerance of Uncertainty, anxiety, and worry in children and adolescents: A meta-analysis. *Journal of Affective Disorders*, *225*, 80-90. https://doi.org/10.1016/J.JAD.2017.07.035

Osmanağaoğlu, N., Creswell, C., & Dodd, H. F. (2021). Development of a behavioural measure of Intolerance of Uncertainty in preadolescent children: Adaptation of the beads task. *Journal of Behavior Therapy and Experimental Psychiatry*, *72*, 101654-101654. https://doi.org/10.1016/J.JBTEP.2021.101654

Osmanağaoğlu, N., Creswell, C., Snuggs, S., Stuijfzand, S., & Dodd, H. F. (2021). Evaluating the psychometric properties of the intolerance of uncertainty scale for children in a preadolescent sample. *Journal of Anxiety Disorders*, *77*, 102343. https://doi.org/https://doi.org/10.1016/j.janxdis.2020.102343

Parker, G. (1983). Parental 'Affectionless Control' as an Antecedent to Adult Depression: A Risk Factor Delineated. *Archives of General Psychiatry*, *40*(9), 956-960. https://doi.org/10.1001/archpsyc.1983.01790080038005

Pepperdine, E., Lomax, C., & Freeston, M. H. (2018). Disentangling intolerance of uncertainty and threat appraisal in everyday situations. *Journal of Anxiety Disorders*, *57*, 31-38. https://doi.org/10.1016/j.janxdis.2018.04.002

Pérez-Edgar, K., Bar-Haim, Y., McDermott, J. M., Chronis-Tuscano, A., Pine, D. S., & Fox, N. A. (2010). Attention Biases to Threat and Behavioral Inhibition in Early Childhood Shape Adolescent Social Withdrawal. *Emotion (Washington, D.C.)*, *10*(3), 349-357. https://doi.org/10.1037/a0018486

Polanczyk, G. V., Salum, G. A., Sugaya, L. S., Caye, A., & Rohde, L. A. (2015). Annual research review: A meta-analysis of the worldwide prevalence of mental disorders in children and adolescents. *Journal of Child Psychology and Psychiatry*, *56*(3), 345-365.

Rapee, R. M. (1997). Potential role of childrearing practices in the development of anxiety and depression. *Clinical Psychology Review*, *17*(1), 47-67.

Roebers, C. M., von der Linden, N., & Howie, P. (2007). Favourable and unfavourable conditions for children's confidence judgments. *British Journal of Developmental Psychology*, *25*(1), 109-134.

Sahib, A., Chen, J., Cárdenas, D., & Calear, A. L. (2023). Intolerance of uncertainty and emotion regulation: A meta-analytic and systematic review. *Clinical Psychology Review*, *101*, 102270. https://doi.org/https://doi.org/10.1016/j.cpr.2023.102270

Sanchez, A. L., Cornacchio, D., Chou, T., Leyfer, O., Coxe, S., Pincus, D., & Comer, J. S. (2017). Development of a scale to evaluate young children’s responses to uncertainty and low environmental structure. *Journal of Anxiety Disorders*, *45*, 17-23. https://doi.org/10.1016/J.JANXDIS.2016.11.006

Sandstrom, A., Uher, R., & Pavlova, B. (2020). Prospective Association between Childhood Behavioral Inhibition and Anxiety: a Meta-Analysis. *Research on Child and Adolescent Psychopathology*, *48*(1), 57-66. https://doi.org/10.1007/s10802-019-00588-5

Sexton, K. A., & Dugas, M. J. (2009). Defining distinct negative beliefs about uncertainty: validating the factor structure of the Intolerance of Uncertainty Scale. *Psychological assessment*, *21*(2), 176.

Shah, P. E., Weeks, H. M., Richards, B., & Kaciroti, N. (2018). Early childhood curiosity and kindergarten reading and math academic achievement. *Pediatric Research*, *84*(3), 380-386. https://doi.org/10.1038/s41390-018-0039-3

Shimada-Sugimoto, M., Otowa, T., & Hettema, J. M. (2015). Genetics of anxiety disorders: Genetic epidemiological and molecular studies in humans. *Psychiatry and clinical neurosciences*, *69*(7), 388-401.

Stewart, J. L., Mishel, M. H., Lynn, M. R., & Terhorst, L. (2010). Test of a conceptual model of uncertainty in children and adolescents with cancer. *Research in Nursing & Health*, *33*(3), 179-191.

Strauss, C. C., Frame, C. L., & Forehand, R. (1987). Psychosocial impairment associated with anxiety in children. *Journal of clinical child psychology*, *16*(3), 235-239.

Tolin, D. F., Abramowitz, J. S., Brigidi, B. D., & Foa, E. B. (2003). Intolerance of uncertainty in obsessive-compulsive disorder. *Journal of Anxiety Disorders*, *17*(2), 233-242. https://doi.org/https://doi.org/10.1016/S0887-6185(02)00182-2

Trautmann, S., Rehm, J., & Wittchen, H. U. (2016). The economic costs of mental disorders: Do our societies react appropriately to the burden of mental disorders? *EMBO reports*, *17*(9), 1245-1249.

Vallance, A. K., & Fernandez, V. (2016). Anxiety disorders in children and adolescents: Aetiology, diagnosis and treatment. *BJPsych advances*, *22*(5), 335-344.

Van Ameringen, M., Mancini, C., & Farvolden, P. (2003). The impact of anxiety disorders on educational achievement. *Journal of Anxiety Disorders*, *17*(5), 561-571. https://doi.org/10.1016/S0887-6185(02)00228-1

van der Heiden, C., Muris, P., & van der Molen, H. T. (2012). Randomized controlled trial on the effectiveness of metacognitive therapy and intolerance-of-uncertainty therapy for generalized anxiety disorder. *Behaviour Research and Therapy*, *50*(2), 100-109. https://doi.org/10.1016/J.BRAT.2011.12.005

Vasey, M., & Dadds, M. (2001). *The developmental psychopathology of anxiety.* Oxford University Press.

Wehry, A. M., Beesdo-Baum, K., Hennelly, M. M., Connolly, S. D., & Strawn, J. R. (2015). Assessment and Treatment of Anxiety Disorders in Children and Adolescents. *Current Psychiatry Reports*, *17*(7), 52. https://doi.org/10.1007/s11920-015-0591-z

Wright, C. J., Clark, G. I., Rock, A. J., & Coventry, W. L. (2017). Intolerance of uncertainty mediates the relationship between adult attachment and worry. Personality and Individual Differences, 112, 97-102.

Chapter 2. Study 1: Does Intolerance of Uncertainty predict child generalised anxiety? A longitudinal study

Manuscript in preparation for submission to the Journal of Anxiety Disorders

Ryan, Z.J., Rayson, H. & Dodd, H.F. Does Intolerance of Uncertainty predict child generalised anxiety? A longitudinal study. Manuscript in preparation

Appendices Associated with this Chapter:

Abstract

Intolerance of uncertainty (IU) refers to individual differences in responses to uncertainty. IU is related to worry and anxiety in adults and children but it is unclear whether IU plays a maintenance or causal role, particularly in childhood. Our research examined whether IU is associated with generalised anxiety in preschool-aged children, and whether IU in preschool-aged children is associated with the trajectory of generalised anxiety symptoms into middle childhood. Additionally, we explored specificity by examining whether IU was associated with the trajectory of internalising symptoms and externalising symptoms over time. Parents were asked to complete questionnaires about their children at three timepoints when their child was: 3-4 years old; 5-7 years old; 8-10 years old. Parents completed measures of child anxiety, IU, and internalising and externalising symptoms. Those with higher IU had higher concurrent generalised anxiety, internalising and externalising symptoms at each measurement point, including when the children were preschoolers. This supports the notion that IU is associated with a range of mental health conditions. Preschoolers with higher IU had, on average, higher generalised anxiety across childhood, relative to those who had lower IU as preschoolers. Unexpectedly though, children who were higher in IU as preschoolers were more likely to show a decrease in generalised anxiety over time. These findings indicate that IU is a consistent correlate of generalised anxiety, but that it may not play a causal role in the onset of generalised anxiety in children.

Keywords: Intolerance of Uncertainty, Internalising, Externalising, Generalised Anxiety, Longitudinal

2 Introduction

Some level of uncertainty is common throughout our daily lives. For many people, this uncertainty goes mostly unnoticed. However, for some, uncertainty can be unpleasant and anxiety-provoking, stimulating worry and fear. Intolerance of uncertainty (IU) is a construct capturing trait-like individual difference in reactions to uncertainty (Carleton, 2016a). IU is defined as a "dispositional incapacity to endure an aversive response triggered by the perceived absence of salient, key, or sufficient information, and sustained by the associated perception of uncertainty" (Carleton, 2016b, p. 32), and is linked with elevated worry and anxiety in clinical and non-clinical populations in adults and children (Buhr & Dugas, 2002; Counsell et al., 2017; Holaway et al., 2006; Mathes et al., 2017; Osmanağaoğlu et al., 2018; Sexton & Dugas, 2009). Despite robust associations with anxiety and worry, it remains unclear whether IU plays a causal and/or maintenance role in anxiety and worry. In adults, treatments focusing on IU lead to a decrease in worry and diagnosis of Generalised Anxiety Disorder (GAD) (Dugas et al., 2003; Miller & McGuire, 2023), which is consistent with IU playing at least a maintenance role. Nonetheless, it remains possible that having negative reactions to uncertainty may be characteristic of anxiety and worry rather than causal (Carleton, 2012; Carleton et al., 2012). Although the onset of anxiety disorders often happens during childhood (De Lijster et al., 2017), there is a dearth of developmental research examining whether early IU predicts the emergence of anxiety symptoms.

Elevated anxiety can be problematic across the lifespan, but anxiety in childhood can be particularly problematic as it can have a significant effect on development (Rapee et al., 2009); anxiety during childhood can affect academic performance, family processes, relationships with peers and longer term mental health (Essau et al., 2000; Ezpeleta et al., 2001; Giora et al., 2005; Gregory et al., 2007; Strauss et al., 1987; Van Ameringen et al., 2003). Given this, a substantial body of research has examined risk factors and correlates of anxiety in children. Some risk factors are now well-established, including behavioural inhibition (Pérez-Edgar et al., 2010) and overcontrolling parenting (Hudson & Dodd, 2012; Rapee, 1997), and having a parent with an anxiety disorder (Beidel & Turner, 1997; Ginsburg & Schlossberg, 2002; Hudson, Dodd, & Bovopoulos, 2011; Hudson, Dodd, Lyneham, et al., 2011). Understanding and identifying potential risk factors for child anxiety is critical because early intervention can improve the child's quality of life and decrease risk of future mental health problems (Morgan et al., 2016).

IU may be predictive of anxiety over time in adults (Furtado et al., 2019), and there is some evidence that during adolescence, IU and worry have a bidirectional and reciprocal association over time (Dugas et al., 2012). To our knowledge, there is no longitudinal research evaluating whether IU increases risk for anxiety in children over time. Osmanağaoğlu et al. (2018) conducted a meta-analysis of IU research focused on children and young people. This established a strong association between IU and anxiety/worry in young people, but highlighted a number of significant limitations within the literature. One limitation was that all research was cross-sectional, and thus could not capture whether IU is associated with trajectories of anxiety over time. Furthermore, the age range in most studies is quite broad despite the fact that children's cognitions and ability to deal with uncertainty emerge and improve as they develop (Lyons & Ghetti, 2011; Roebers et al., 2007). This means that any relationship between IU and anxiety may change across childhood and may not match the profile of IU and anxiety in adults (Osmanağaoğlu et al., 2018).

Relatedly, no research had considered associations between IU and anxiety in preschool-aged children. This is a particularly important age to examine as early signs of anxiety are present at this age or even earlier (Luby, 2013), and identifying potential risk factors for anxiety could support preventative programmes. Two examples of anxiety prevention programmes are Cool Little Kids and the Turtle program, which target children with

Behavioural Inhibition and have been found to be effective anxiety prevention programmes for preschool children (Chronis-Tuscano et al., 2022; Ooi et al., 2022). If IU is a precursor to anxiety in children then it may be useful as a screening mechanism for identifying at-risk children and a target for preventative work.

Although IU is clearly associated with anxiety and worry, it is unclear how specific this association is and whether IU may be associated with broader psychopathology, e.g. externalising and internalising problems (Lemery-Chalfant et al., 2007). Externalising problems include impulsive, disruptive conduct problems, and internalising problems include symptoms of depression as well as anxiety (Lemery-Chalfant et al., 2007). Some recent work with children suggests that IU may be a transdiagnostic construct that is positively associated with both internalising and externalising psychopathology (Gramszlo et al., 2018; Sadeh & Bredemeier, 2021), but further work is required to establish the nature of these associations.

Given the paucity of longitudinal research in this area and the lack of research examining IU and anxiety in young children, the primary aims here were to: 1) examine how IU is associated with anxiety in preschool children; and 2) explore whether IU in preschool children is associated with the trajectory of generalised anxiety symptoms into middle childhood. An additional aim was to explore specificity by examining whether IU was associated with the trajectory of internalising symptoms and externalising symptoms over time. We hypothesised that IU would be associated with generalised anxiety when children were preschoolers (and when they were older), and that IU would interact with time to predict trends in generalised anxiety, internalising and externalising scores across early to middle childhood. Specifically, due to the associations found between IU and worry, we tentatively expected to see that early IU is associated with a worsening symptom trajectory over time.

2.1 Methods

2.1.1 Participants

Participants were originally recruited as part of a longitudinal study (the 'Watch them Grow' study) via local preschools, advertisements in family magazines, social media and word of mouth. Parents completed time point 1 (TP1) questionnaire measures as two separate cohorts, one in 2017 and one in 2018, when their children were aged 3.46 – 4.67 years (*M* = 4.00, *SD* = 0.24). We invited 179 of the original 180 families (one withdrew) to take part at time point 2 (TP2) in Spring 2020 (1.96 - 3.34 years after TP1 (*M* = 2.62, *SD* = 0.45)) and at time point 3 (TP3) in Autumn 2022 (2.52 – 2.72 years after the TP2 (*M* = 2.59, *SD* = 0.50)). At TP2, 162 (91%) participated, with children aged 5.72 – 7.71 years (*M* = 6.62, *SD* = 0.54). At TP3, 148 (83%) participated, with children aged 8.27 - 10.36 years (*M* = 9.23, *SD* = 0.54). The time between TP1 and TP3 was 4.51 – 5.98 years (*M* = 5.23, *SD* = 0.45). Further demographic information for participants at each time point is available in Table S1 of Supplementary Materials. Full details of the original sample are provided here: http://reshare.ukdataservice.ac.uk/853813/.

2.1.2 Procedure

At TP1, Watch Them Grow participants were invited to attend a session at the University of Reading which included a variety of lab-based and observational tasks. The parent attending completed a battery of questionnaire measures via Survey Monkey on an iPad whilst the child was taking part in the tasks. This study was approved by the University of Reading Research Ethics committee (UREC 16/56) at TP1, and by the School of Psychology and Clinical Language Sciences Research Ethics committee at TP2 (2019-080-HD) and TP3 (2022-172-RM).

At TP1, parents consented to being contacted for future research. For the purpose of the present study, families were contacted for follow-ups in 2020 and 2022, when we invited them to complete measures online via Survey Monkey. They were offered a £5 voucher at each follow-up. Invitations to the first follow up were sent in May 2020, shortly after the first COVID-19 lockdown began in the UK.

2.1.3 Parent Report Measures

2.2.3.1 The Preschool Anxiety Scale (PAS; Spence et al., 2001). Child anxiety and worry were measured at TP1 using the PAS generalised anxiety (GA) subscale. The PAS is a parent report questionnaire designed to measure anxiety in young children (aged 3-6 years). It consists of 28 items answered using a 5-point Likert scale. The GA subscale comprises five items such as Has difficulty stopping him/herself from worrying or Is tense, restless or irritable due to worrying; parents are asked to indicate how true each statement is for their child. The PAS GA subscale has demonstrated good construct validity and adequate psychometric properties. It is correlated (r = 0.6) with the Child Behaviour Checklist Internalising scale (Achenbach, 1992; Spence et al., 2001). Internal consistency for the GA scale in our TP1 data is good with Cronbach's alpha being .83.

2.2.3.2 The Spence Children's Anxiety Scale – Parent report (SCAS-P; Nauta et al., 2004). Child anxiety and worry were measured at time points 2 and 3 using the SCAS-P Generalised Anxiety (GA) subscale. The SCAS-P is a parent-report questionnaire designed to measure anxiety in children aged 6 - 18 years. It is an adaptation of the SCAS (Spence, 1998). The measure consists of 38 items, answered using a 4-point Likert scale. We examined associations between all time points of GA, Social Anxiety (SA) and Separation Anxiety (Sep) subscales and RULES scores (see Table S2 in Supplementary Materials). All of these variables were correlated with each other at all time points, apart from TP1 SA and TP3 GA. For the analyses, we chose to use the GA subscale to capture children's worry and general anxiety rather than the total score because all of the subscales are significantly correlated with each other, it is conceptually closest to our research questions, and the total score includes separation anxiety and social anxiety subscales, which were less relevant to the research questions about IU. The GA subscale comprises six items such as My child worries about things or My child worries that something bad will happen to him/her; parents are asked to indicate the response that best describes their child. The SCAS-P GA subscale score has demonstrated good internal consistency (α =.92) and differentiates well between children with anxiety-disorders and controls (Nauta et al., 2004). In our sample at TP2, the GA subscale had α =.69 and at TP3 Cronbach's alpha was 0.79.

2.2.3.3 The Responses to Uncertainty and Low Environmental Structure (RULES) questionnaire (Sanchez et al., 2017). Child intolerance of uncertainty (IU) was measured at TP1 and both follow-up time points using the RULES. The RULES is a parent-report measure of IU comprising 17 items that are rated on a 5-point Likert scale. Parents are asked to rate how much certain statements describe their child, such as My child has a hard time coping with even minor changes and My child complains of physical symptoms (e.g., headaches, stomachaches) when he/she is about to enter a new situation. The RULES has demonstrated strong predictive, convergent and divergent validity and excellent internal consistency with Cronbach's alpha being 0.93, and item-total correlations ranging from 0.47 to 0.81 (Sanchez et al., 2017). In our TP1 data, Cronbach's alpha was excellent at .93, as well as at TP2 (α =.96) and at TP3 (α =.96).

2.2.3.4 Health Behaviour Questionnaire (HBQ) (Armstrong & Goldstein, 2003). Internalising and externalising symptoms were captured via the HBQ internalising and externalising scales, respectively. The HBQ is a parent-report measure that includes a range of scales. The internalising symptoms scale consists of 29 items rated on a 3-point Likert scale and captures symptoms of depression (e.g. Feels worthless or inferior) and anxiety (e.g.

Worries about things in the future). The externalising symptoms scale consists of 46 items rated on a 3-point Likert scale and captures symptoms of oppositional defiance (e.g. Has temper tantrums or hot temper), conduct problems, hostility, aggression, inattention (e.g. Distractible, has trouble sticking to any activity) and impulsivity. The HBQ has demonstrated good internal consistency (Lemery-Chalfant et al., 2007), good test-retest reliability for both subscales in the community and clinic over 7-10 days and a year apart and also good group discriminant validity (Armstrong & Goldstein, 2003). In our TP1 data the internal consistency for both scales was good (Internalising scale: α = .89; externalising scale: α = .93), and was excellent at both TP2 (Internalising scale: α = .90; externalising scale: α = .95) and TP3 (Internalising scale: α = .92; externalising scale: α = .95).

2.2.3.5 Trait scale of Y2 State-Trait Anxiety Inventory (STAI-Y2; Speilberger et al., 1983). The trait scale of the STAI-Y2 is used to capture parent trait anxiety at both follow-up time points. The STAI-Y2 comprises 20 items such as I feel pleasant and I feel nervous and restless, rated on a 4-point Likert scale. STAI-Y2 demonstrates good construct validity and internal consistency ranging from .86 to .95 (Speilberger et al., 1983). Cronbach's alpha for this measure in our sample was excellent at TP1 (α = .93), TP2 (α = .94) and TP3 (α = .92).

2.1.4 Design

This study was a within-subjects repeated-measures observational design. RULES total score was used to capture early childhood IU at three time points. Child anxiety and worry were captured by the GA subscales of the PAS scale at TP1 and SCAS scales at TP2 and TP3. These were converted to z-scores based on published norms for each scale, as available on www.scaswebsite.com (Nauta et al., 2004; Spence et al., 2001). Internalising problems were measured by HBQ internalising scale score and externalising problems captured by HBQ externalising scale score at each time point. SCAS GA subscale scores (converted to z-score), HBQ internalising score and HBQ externalising score were the outcome variables (DVs).

2.1.5 Data Preparation

Child gender, ethnicity, birth order, parental marital status, education level and employment status were examined as potential confounds in relation to TP1 RULES, and TP2 and TP3 SCAS GA, HBQ internalising symptoms and HBQ externalising symptoms in advance of conducting the analysis. Of these, there was only a significant effect of marital status at TP1 on HBQ externalising at TP2 $F(2,159) = 3.84$, $p = .024$ and TP3 $F(2,145) = 3.41$, $p = .036$ and on HBQ internalising at TP3 $F(2,145) = 4.61$, $p = .012$, where children with two parents at home had lower HBQ internalising and externalising scores than those with one parent at home. Given this, we chose to control for marital status in all analyses for consistency. Parent anxiety as measured by STAI-Y2 total score at each time point was also controlled for in the analysis due to its potential influence on child anxiety.

2.1.6 Missing data

At TP2 and TP3 the only missing data came from those participants who did not take part (TP2 = 18; TP3 = 32). At TP1 one participant did not complete IU and parent anxiety measures. We used mixed models for our longitudinal analyses as this enabled all participants to be retained for analyses even with missing data.

2.1.7 Data Analysis

We ran hierarchical growth curve analyses to investigate how RULES scores may moderate trajectories of GA subscale scores, HBQ internalising and HBQ externalising symptoms over time. Centred RULES scores at TP1 were included as a fixed effect, as were linear and quadratic orthogonal polynomial time terms (poly1 and poly2, respectively), and their interactions with TP1 RULES scores. Subject-specific offsets were included as a random effect. Type III Wald F tests were used to obtain p-values and degrees of freedom were approximated with the Kenward-Rogers method. Significant interactions between continuous variables were probed using the Johnson-Neyman technique (Johnson & Neyman, 1936).

For transparency we also include results with outliers included in Supplementary Materials.

2.2 Results

2.2.1 Descriptive statistics

The descriptive statistics for each of the main variables used in the analyses can be found in Table 1 and Table 2 below, as well as bivariate correlations between the variables. As shown in Table 1, GA subscale scores across the three time points were moderately to highly correlated, RULES total scores across time points were also moderately to highly correlated. Furthermore, RULES and GA subscale scores were moderately to highly correlated with each other at each time point. Table 2 shows that HBQ internalising scores across the three time points were moderately to highly correlated, as were HBQ externalising scores. RULES, HBQ internalising scores and HBQ externalising scores were all moderately to highly correlated with each other at each time point, apart from TP1 RULES and TP3 HBQ externalising scores, which were weakly correlated.

Table 1. Means, standard deviations, and correlations with confidence intervals for the RULES, PAS/SCAS GA subscale score and STAI scores at each time point

Variable	*M*	*SD*	1	2	3	4	5	6	7	8
1. TP1 RULES	35.01	11.48								
2. TP2 RULES	34.38	14.95	.62** [.52, .71]							
3. TP3 RULES	35.76	15.62	.51** [.38, .62]	.78** [.70, .84]						
4. TP1 GA subscale score	0.34	1.11	.74** [.67, .80]	.53** [.41, .63]	.42** [.28, .55]					
5. TP2 GA subscale score	0.19	1.11	.46** [.32, .57]	.68** [.59, .76]	.53** [.40, .64]	.56** [.44, .66]				
6. TP3 GA subscale score	0.41	1.39	.34** [.19, .48]	.45** [.31, .58]	.60** [.48, .69]	.38** [.23, .51]	.57** [.45, .67]			
7. TP1 STAI	40.01	9.84	.26** [.12, .39]	.08 [-.07, .23]	.09 [-.07, .25]	.23** [.08, .36]	.12 [-.04, .27]	.03 [-.13, .19]		
8. TP2 STAI	42.82	10.36	.10 [-.05, .25]	.19* [.03, .33]	.16 [-.00, .32]	.12 [-.03, .27]	.13 [-.02, .28]	.16 [-.01, .31]	.66** [.56, .74]	
9. TP3 STAI	42.48	9.62	.12 [-.04, .28]	.18* [.01, .33]	.23** [.07, .38]	.18* [.01, .33]	.18* [.01, .33]	.28** [.12, .42]	.60** [.48, .69]	.74** [.66, .81]

Note: * indicates $p < .05$. ** indicates $p < .01$. Child generalised anxiety scores have been z-scored based on the published norms

Table 2. Means, standard deviations, and correlations with confidence intervals for RULES, HBQ internalising HBQ externalising and STAI scores at each time point

Variable	*M*	*SD*	1	2	3	4	5	6	7	8	9	10	11
1. TP1 RULES	35.01	11.48											
2. TP2 RULES	34.38	14.95	.62** [.52, .71]										
3. TP3 RULES	35.76	15.62	.51** [.38, .62]	.78** [.70, .84]									
4. TP1 HBQ Internalising	2.68	2.28	.76** [.69, .82]	.52** [.40, .62]	.46** [.32, .58]								
5. TP2 HBQ Internalising	3.62	2.79	.54** [.42, .64]	.77** [.70, .82]	.71** [.62, .79]	.66** [.56, .74]							
6. TP3 HBQ Internalising	4.19	3.15	.37** [.22, .50]	.52** [.39, .63]	.74** [.66, .81]	.43** [.29, .55]	.72** [.63, .79]						
7. TP1 HBQ Externalising	3.10	1.90	.43** [.30, .54]	.36** [.22, .49]	.37** [.23, .51]	.51** [.39, .61]	.46** [.33, .57]	.30** [.14, .44]					
8. TP2 HBQ Externalising	3.35	2.38	.30** [.15, .44]	.55** [.44, .65]	.53** [.40, .64]	.37** [.23, .50]	.60** [.49, .69]	.43** [.28, .55]	.68** [.59, .76]				
9. TP3 HBQ Externalising	3.00	2.37	.19* [.03, .34]	.43** [.29, .56]	.62** [.51, .71]	.27** [.11, .41]	.54** [.41, .64]	.59** [.48, .69]	.52** [.40, .63]	.76** [.69, .83]			
10. TP1 STAI	40.01	9.84	.26**	.08	.09	.31**	.15	.17*	.30**	.19*	.22**		

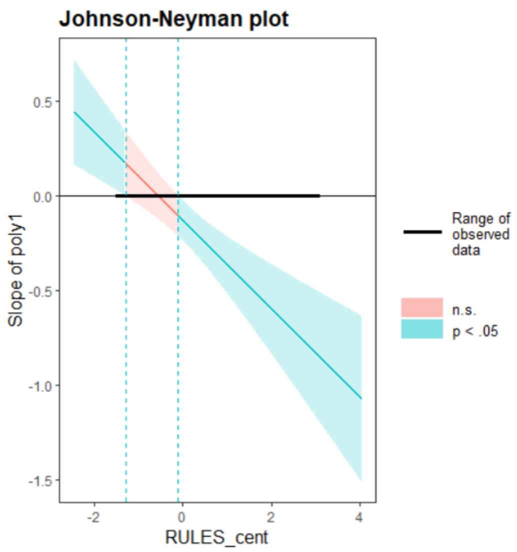
			[.12, .39]	[-.07, .23]	[-.07, .25]	[.17, .44]	[.00, .30]	[.00, .32]	[.16, .43]	[.04, .34]	[.06, .37]		
11. TP2 STAI	42.82	10.36	.10	.19*	.16	.15	.24**	.21*	.14	.24**	.23**	.66**	
			[-.05, .25]	[.03, .33]	[-.00, .32]	[-.00, .30]	[.09, .38]	[.05, .36]	[-.02, .29]	[.09, .38]	[.07, .38]	[.56, .74]	
12. TP3 STAI	42.48	9.62	.12	.18*	.23**	.23**	.23**	.31**	.17*	.24**	.27**	.60**	.74**
			[-.04, .28]	[.01, .33]	[.07, .38]	[.07, .38]	[.07, .38]	[.16, .45]	[.01, .32]	[.07, .39]	[.11, .41]	[.48, .69]	[.66, .81]

2.2.2 *Linear mixed effect models and hierarchical growth curve analyses*

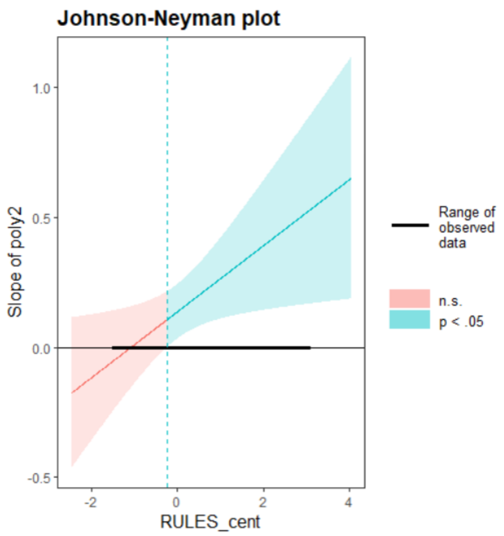
Growth curve analyses were run to examine the effects of RULES on trajectories of GA subscale score, HBQ internalising and HBQ externalising scores using the lme4 package in R (R Core Team, 2022). Models were run examining RULES and: 1) GA subscale score; 2) HBQ internalising score ;3) HBQ externalising score, all including STAI and marital status as controls. Residuals for all linear mixed-effects models were checked, and these were not normally distributed. A number of outliers were detected using Cook's distance (4/n) (Model 1, n = 19; Model 2, n = 24; Model 3, n = 23). Each model was run with outliers removed, which greatly improved normality of residuals. The results for these models are reported below (see Table 3). For transparency, models without outliers removed, and models without STAI and marital status included, can be found in Supplementary Materials; patterns of results were very similar.

2.2.3 *Model 1 RULES and GA subscale score models controlling for STAI and marital status, 19 outliers removed*

RULES was a significant predictor of GA subscale score[$F[1] = 114.85$, $p < .001$], and there was a significant linear effect of time [$F[1] = 5.93$, $p = .015$] and quadratic effect of time [$F[1] = 6.73$, $p = .010$]. Marital status was not a significant predictor [$F[2] = 2.14$, $p = .121$], however STAI was [$F[1] = 4.28$, $p = .039$]. There were significant interactions between RULES and the linear effect of time [$F[1] = 19.03$, $p < .001$] as well as the quadratic effect of time [$F[1] = 5.05$, $p = .025$]. To explore this interaction, the raw data and quadratic curves were plotted (see Fig. 4A). This indicates that for children with high RULES scores, anxiety decreased between TP1 and TP2 and then increased slightly between TP2 and TP3, showing a clear quadratic effect with a linear decrease over time. In contrast, participants with low RULES scores showed a very small increase in anxiety over time. Consistent with this, the Johnson-Neyman technique showed that a higher RULES score was linked to a decrease in GA subscale score over time (Fig 1A) whereas a low RULES score was linked to an increase in GA subscale score over time, however this was predominantly outside the range of observed data. Further probing of the interaction between RULES and the quadratic effect of time using the Johnson Neyman technique showed that with high RULES scores there is a quadratic effect of time which is not present when RULES scores are lower (Fig 1B). GA subscale scores remained lower for those with low RULES scores relative to participants with high RULES scores across all time points.



A



B

Fig 1. RULES and GA subscale score, controlling for STAI and marital status with outliers removed. A & B show Johnson-Neyman plots illustrating the significant interaction effects. Plot A shows the relation between RULES scores and linear slope of GA subscale score over time. Plot B shows the relation between RULES and the quadratic slope of GA subscale score over time. The range of observed data is shown by the bold black horizonal line, the blue shaded areas show where the slopes were significant (*p* < .05), and the red shaded areas show where the slopes were not significant (n.s). RULES moderated a decrease of GA subscale score over time (A); when RULES scores were ≥ -0.11, the linear decrease of GA subscale score over time differed significantly from zero. The higher the RULES, the stronger the linear decrease of GA subscale score over time. The opposite was found with low RULES scores. Where RULES ≤ -1.30, there was a linear increase in GA subscale score over time, however this lay predominantly outside of the range of observed data. Plot B shows that when looking at the quadratic effects of time, RULES moderated an increase of GA subscale score; when RULES was ≥ -0.24, the quadratic effect of time differed significantly from zero.

2.2.4 Model 2: RULES and HBQ Internalising models controlling for STAI and marital status, 24 outliers removed

RULES was a significant predictor of HBQ Internalising [F[1] = 119.12, p < .001], and there was a significant linear effect of time [F[1] = 33.49, p < .001]. The quadratic effect of time approached significance [F[1] = 3.18, p = .075]. There was no significant effect of marital status [F[2] = 2.29, p = .104], but there was a significant effect of STAI [F[1] = 29.31, p < .001]. There was a significant interaction between RULES and linear effect of time [F[1] = 14.06, p < .001], but the interaction between RULES and quadratic effect of time did not reach significance [F[1] = 2.75, p = .098]. To explore the interaction raw data and linear curves are visualised in Fig 4B. This shows that, although there was a linear increase in HBQ Internalising score overall, HBQ Internalising was relatively stable over the three time points for those with high RULES scores, however those with low RULES scores had a linear increase in HBQ Internalising across the time points. Across all time points, participants with low RULES scores had lower symptoms levels than those with high RULES scores. Further probing of the interaction between RULES and the linear effect of time using Johnson-Neyman technique supported this; a lower RULES score was linked to an increase in HBQ Internalising scores over time (Fig 2) whereas a higher RULES score was linked to a decrease in HBQ internalising scores over time, however this was predominantly outside the range of observed data.

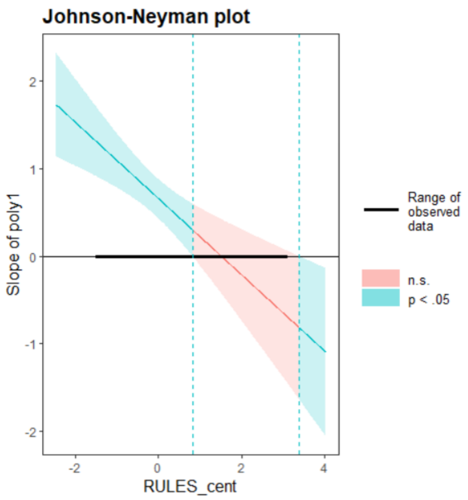


Fig 2. RULES and HBQ Internalising controlling for STAI and marital status with outliers removed. Figure 2 shows a Johnson-Neyman plot illustrating the significant interaction effects. It shows the relation between RULES scores and linear slope of HBQ Internalising over time. The range of observed data is shown by the bold black horizonal line, the blue shaded areas show where the slopes were significant ($p < .05$), and the red shaded areas show where the slopes were not significant (n.s). RULES moderated an increase of HBQ internalising over time; when RULES scores were ≤ 0.82, the linear increase of HBQ internalising over time differed significantly from zero. The lower the RULES, the stronger the linear increase of HBQ internalising over time. The opposite was found with high RULES scores. Where RULES ≥3.38, there was a linear decrease in HBQ internalising over time, however this lay predominantly outside of the range of observed data.

2.2.5 Model 3: RULES and HBQ Externalising models controlling for STAI and marital status, 23 outliers removed

RULES was a significant predictor of HBQ Externalising [F[1] = 22.33, $p < .001$] but there was no significant linear effect of time [F[1] = 2.69, $p = .102$], and the quadratic effect of time only approached significance [F[1] = 3.37, $p = .067$]. There was however a significant effect of STAI [$F[1] = 23.33$, $p < .001$] and a significant effect of marital status [$F[2] = 3.48$, $p = .033$]. There was no significant interaction between RULES and the linear effect of time [$F[1] = 2.15$, $p = .143$, but there was a significant interaction between RULES and the quadratic effect of time [$F[1] = 5.41$, $p = .021$]. To explore this interaction, the raw data and quadratic curves are visualised in Fig 4C. This shows that, for those with high RULES scores there was a slight increase between TP1 and TP2 and a steeper decrease between TP2 and TP3. The HBQ externalising scores were relatively stable over the three time points for those with low RULES scores. HBQ externalising scores remained lower for those with low RULES scores relative to participants with high RULES scores across all time points. Further probing of this interaction using the Johnson-Neyman technique revealed that at higher levels of RULES, there was a stronger quadratic curve over time for HBQ Externalising scores; no significant quadratic curve was found at lower RULES scores (Fig 3).

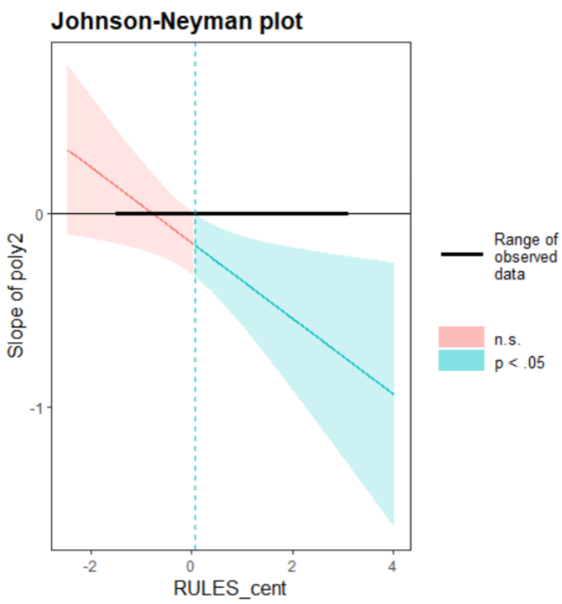


Fig 3. RULES and HBQ Externalising controlling for parental anxiety and marital status with outliers removed. This figure shows a Johnson-Neyman plot illustrating significant interaction effects. It shows the relation between RULES and the quadratic slope of HBQ externalising over time. The range of observed data is shown by the bold black horizonal line, the blue

shaded areas show where the slopes were significant ($p < .05$), and the red shaded areas show where the slopes were not significant (n.s). Figure 3 shows that when looking at the quadratic effect of time, RULES moderated an decrease in HBQ Externalising ; when RULES was ≥ 0.06, the quadratic effect of time differed significantly from zero.

Table 3. LMM Results for models predicting Generalised Anxiety Subscale, HBQ Internalising and HBQ Externalising symptoms.

	GA Subscale Scores			HBQ Internalising			HBQ Externalising		
Predictors	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*
Intercept	0.51	0.19 – 0.84	**0.002**	4.05	3.30 – 4.81	**<0.001**	4.09	3.28 – 4.90	**<0.001**
RULES	0.58	0.47 – 0.69	**<0.001**	1.32	1.08 – 1.56	**<0.001**	0.62	0.36 – 0.87	**<0.001**
Linear Time	-0.13	-0.24 – -0.03	**0.015**	0.66	0.43 – 0.88	**<0.001**	-0.14	-0.31 – 0.03	0.101
Quadratic Time	0.14	0.03 – 0.24	**0.010**	-0.20	-0.42 – 0.02	0.075	-0.15	-0.31 – 0.01	0.067
STAI	0.09	0.01 – 0.18	**0.038**	0.53	0.34 – 0.72	**<0.001**	0.42	0.25 – 0.59	**<0.001**
Marital Status - Two Parents at home	-0.34	-0.68 – 0.01	0.058	-0.87	-1.66 – -0.07	**0.034**	-1.14	-2.00 – -0.28	**0.009**
Marital Status - Other	-0.15	-0.61 – 0.30	0.505	-0.68	-1.71 – 0.35	0.194	-1.18	-2.29 – -0.07	**0.038**
RULES x Linear Time	-0.23	-0.34 – -0.13	**<0.001**	-0.43	-0.66 – -0.21	**<0.001**	-0.13	-0.30 – 0.04	0.143
RULES x Quadratic Time	0.13	0.02 – 0.24	**0.025**	-0.19	-0.42 – 0.04	0.098	-0.20	-0.36 – -0.03	**0.020**
Random Effects									
σ^2	0.42			1.79			0.98		
τ_{00}	0.32 $_{child\_ID}$			1.71 $_{child\_ID}$			2.45 $_{child\_ID}$		
ICC	0.43			0.49			0.71		
N	178 $_{child\_ID}$			178 $_{child\_ID}$			176 $_{child\_ID}$		
Observations	468			463			463		
Marginal R^2 / Conditional R^2	0.370 / 0.642			0.428 / 0.707			0.192 / 0.769		

Note: RULES scores and STAI are centred.

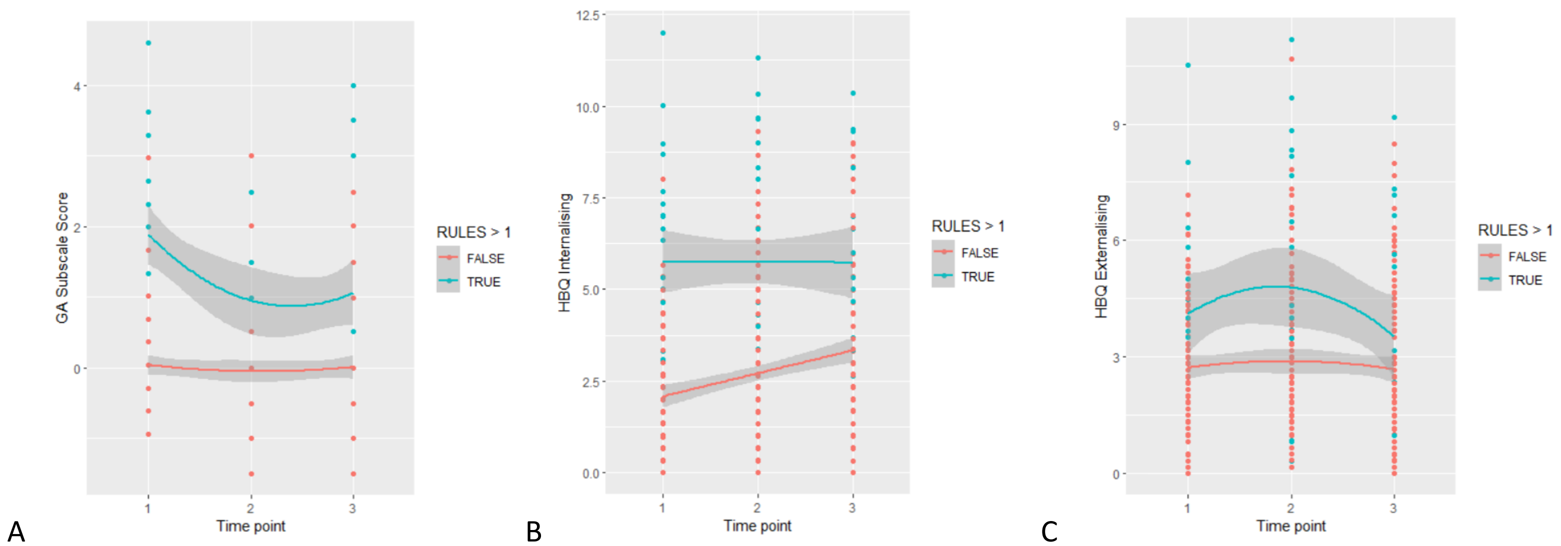


Figure 4 . Data and quadratic fit for models 1 and 3 and linear fit for model 2. 4A shows child GA subscale score data, 4 B shows HBQ Internalising score data and 4 C shows HBQ Externalising score data, all plotted over three time points with RULES split into higher and lower RULES for plotting only. The red line in each figure reflects lower RULES scores (with RULES scores over 1 which is 1 SD over the mean) and the blue line higher scores of RULES (RULES scores under 1).

2.3 Discussion

This research aimed to examine whether IU in preschool-aged children is associated with generalised anxiety, and whether preschool IU is associated with the trajectory of generalised anxiety over time through to middle childhood. An additional aim was to examine whether IU was associated with internalising and externalising symptom trajectories to determine whether IU is linked to generalised anxiety specifically, rather than representing a more general risk factor for psychopathology at this age. We will discuss the findings in relation to each aim below.

We hypothesised that IU would be associated with generalised anxiety in preschoolers, and across childhood, and that IU would interact with time to predict trends in anxiety over childhood. The results largely supported these hypotheses, but the pattern of effects over time was not consistent with our predictions. IU and generalised anxiety were significantly associated at each time-point, consistent with Osmanağaoğlu et al. (2018)'s meta-analysis. Limited research has examined associations between IU and anxiety in younger children, so these findings extend the existing literature and indicate that IU is linked to generalised anxiety symptoms even in preschoolers. IU interacted with time indicating that preschool IU predicted trends in generalised anxiety through to middle childhood. In contrast to what we had expected, higher IU was related to a decrease in generalised anxiety over time rather than an increase. For those with lower IU, generalised anxiety remained relatively stable over time. It is important to note that higher IU at baseline was related to higher overall generalised anxiety across childhood, relative to those with lower IU at baseline, but on average, anxiety decreased for those with higher IU as preschoolers.

These results provide no indication that IU temporally precedes the development of generalised anxiety symptoms in children; preschool children with high IU do not show a trajectory of worsening anxiety symptoms over time. The association between IU and generalised anxiety seems to already be established even in preschoolers, and those with high IU (and high anxiety) as preschoolers remain more anxious in middle childhood than those with low IU (and low anxiety). We currently however have no way to measure IU in younger children. We did find that preschool IU is predictive of later anxiety but trajectories show that, if anything, anxiety decreases over time in these children. Given this, it is not clear whether targeting IU in interventions with younger children would be useful for reducing future generalised anxiety.

In relation to internalising symptoms, the results supported the hypothesis that IU would be associated with internalising symptoms at each time point, in line with Carleton et al. (2012). An interaction between IU and time was also found, with lower IU associated with a linear increase in internalising symptoms over time; no significant effects of time were found for high IU. Despite these distinct trajectories, participants with high IU had higher internalising symptoms across all time points relative to those with lower IU. These findings are therefore relatively consistent with the results for generalised anxiety; IU predicts elevated symptoms across childhood, but does not precede the development of internalising problems in children.

Finally, in relation to externalising symptoms, the results supported the hypothesis that IU would be significantly associated with externalising symptoms at each time point. The cross-sectional findings support previous research by Gramszlo et al. (2018) and Sadeh and Bredemeier (2021). In addition, there was a significant interaction between IU and quadratic time indicating that IU predicted trends in externalising symptoms over time. For those high in IU, there was a significant quadratic curve over time, with externalising symptoms increasing between TP1 and TP2 and decreasing between TP2 and TP3. For those with low IU, externalising scores remained relatively stable over the three time points. Those higher in IU had higher externalising symptoms across all time points relative to those with low IU. These findings suggest that early IU may be associated with some initial increased risk for externalising symptoms, although these then return to baseline levels. IU is not typically examined in relation to externalising symptoms and there are, to our knowledge, no theoretical links between IU and externalising symptoms, making these findings difficult to interpret with any confidence. It is also noteworthy that the second time point happened during the Covid-19 pandemic, which could have affected externalising behaviours. These findings therefore need to be treated with caution, but they suggest that IU may be associated with a broader range of psychopathology than is typically assumed. It would be of interest to further explore links between IU and externalising psychopathology in future research.

The quadratic trend over time in the high IU group for generalised anxiety symptoms was unexpected. Symptoms decreased between TP1 and TP2 and then increased slightly between TP2 and TP3. The timing of the TP2 data collection in relation to the COVID-19 pandemic may provide some explanation for this. The UK-wide lockdown began in March 2020 and we collected TP2 responses in May 2020. It seems plausible that by this stage of lockdown there was less uncertainty in children’s day to day lives than would be typical because most children were not attending school or any of their regular activities. This lowered uncertainty may have led to lower symptoms in children with high IU during this period. TP3 data were collected at a point where children’s lives had returned to relative normality, which may explain this relative increase in generalised anxiety back towards levels seen at TP1. As we did not assess the level of perceived uncertainty in children’s lives at each time point we cannot be confident in this explanation, but the quadratic trend was relatively subtle and does not impact the conclusions of the study in relation to the primary aims.

This study has a number of strengths. It is the first longitudinal study of its kind, examining IU and mental health symptoms from preschool age through to middle childhood. This allowed us to examine associations between IU and generalised anxiety at three time-points. Although children's cognitive and emotional skills develop rapidly across this period, the associations between IU and generalised anxiety at each time-point remain strong and consistent. There was a relatively low attrition rate which was favourable. The COVID-19 lockdown at TP2 could be seen as a strength because it introduced a natural stressor into the study, however it could also be seen as a limitation, as it is difficult to ascertain the extent to which the pandemic was a significant stressor for each individual child. The use of parent-report questionnaires to examine IU also represents a limitation. Following on from Osmanağaoğlu et al. (2021), there have been discrepancies between findings from parent-report and child-report related to IU, so this may impede the examination of IU over time. Nevertheless, parent-report was necessary at least at the first time point because participants were too young to provide reliable self-report. Another point of note is that increased parental anxiety was linked with increases in generalised anxiety, internalising symptoms and externalising symptoms, supporting well-established findings (Beidel & Turner, 1997; Ginsburg & Schlossberg, 2002). For this reason, we chose to control for parent anxiety in our analyses and the above effects were also found when parent anxiety has not been controlled for.

Future work could replicate and extend the current study by comparing the RULES against a newly developed measure of IU; the Youth Intolerance of Uncertainty – Parent Report (YIU – PR) (Wong & Caporino, 2023), which may be more sensitive to developmental changes. Extension of longitudinal research into adolescence would also be informative and contribute significantly to the literature.

2.3.1 Conclusion

Our findings suggest that IU is related to concurrent generalised anxiety across childhood, even in preschool-aged children. High IU during the preschool years was associated with higher generalised anxiety symptoms across childhood. Surprisingly, trajectory analysis showed that higher IU predicted a decrease in children's generalised anxiety over time rather than the expected increase. IU may, therefore, not play a causal role in the onset of generalised anxiety in preschool-aged children and may, instead, be a consistent correlate of generalised anxiety across childhood. Alternatively, because we started our research when children were preschoolers, it is possible that IU may be involved in the onset of generalised anxiety but that this process may occur earlier in development, meaning that IU and generalised anxiety are already associated in preschoolers. In addition, there was a consistently strong association across all time-points between IU and internalising and externalising symptoms, supporting the notion that IU is associated with a range of psychopathologies.

2.4 References

Achenbach, T. M. (1992). *Manual for the Child Behavior Checklist/2-3 and 1992 profile*. Department of Psychiatry, University of Vermont.

Armstrong, J., & Goldstein, L. (2003). Manual for the MacArthur health and behavior questionnaire (HBQ 1.0). *MacArthur Foundation Research Network on Psychopathology and Development, University of Pittsburgh*.

Beidel, D. C., & Turner, S. M. (1997). At Risk for Anxiety: I. Psychopathology in the Offspring of Anxious Parents. *Journal of the American Academy of Child & Adolescent Psychiatry*, *36*(7), 918-924. https://doi.org/https://doi.org/10.1097/00004583-199707000-00013

Buhr, K., & Dugas, M. J. (2002). The intolerance of uncertainty scale: Psychometric properties of the English version. *Behaviour Research and Therapy*, *40*(8), 931-945.

Carleton, R. N. (2012). The intolerance of uncertainty construct in the context of anxiety disorders: Theoretical and practical perspectives. *Expert review of neurotherapeutics*, *12*(8), 937-947.

Carleton, R. N. (2016a). Fear of the unknown: One fear to rule them all? *Journal of Anxiety Disorders*, *41*, 5-21. https://doi.org/https://doi.org/10.1016/j.janxdis.2016.03.011

Carleton, R. N. (2016b). Into the unknown: A review and synthesis of contemporary models involving uncertainty. *Journal of Anxiety Disorders*, *39*, 30-43. https://doi.org/https://doi.org/10.1016/j.janxdis.2016.02.007

Carleton, R. N., Mulvogue, M. K., Thibodeau, M. A., McCabe, R. E., Antony, M. M., & Asmundson, G. J. G. (2012). Increasingly certain about uncertainty: Intolerance of uncertainty across anxiety and depression. *Journal of Anxiety Disorders*, *26*(3), 468-479. https://doi.org/10.1016/J.JANXDIS.2012.01.011

Chronis-Tuscano, A., Novick, D. R., Danko, C. M., Smith, K. A., Wagner, N. J., Wang, C. H., Druskin, L., Dougherty, L. R., & Rubin, K. H. (2022). Early intervention for inhibited young children: a randomized controlled trial comparing the Turtle Program and Cool Little Kids. *Journal of Child Psychology and Psychiatry*, *63*(3), 273-281.

Counsell, A., Furtado, M., Iorio, C., Anand, L., Canzonieri, A., Fine, A., Fotinos, K., Epstein, I., & Katzman, M. A. (2017). Intolerance of uncertainty, social anxiety, and generalized anxiety: Differences by diagnosis and symptoms. *Psychiatry research*, *252*, 63-69.

De Lijster, J. M., Dierckx, B., Utens, E. M., Verhulst, F. C., Zieldorff, C., Dieleman, G. C., & Legerstee, J. S. (2017). The age of onset of anxiety disorders: a meta-analysis. *Canadian journal of psychiatry. Revue canadienne de psychiatrie*, *62*(4), 237.

Dugas, M. J., Ladouceur, R., Léger, E., Freeston, M. H., Langolis, F., Provencher, M. D., & Boisvert, J.-M. (2003). Group cognitive-behavioral therapy for generalized anxiety disorder: treatment outcome and long-term follow-up. *Journal of Consulting and Clinical Psychology*, *71*(4), 821.

Dugas, M. J., Laugesen, N., & Bukowski, W. M. (2012). Intolerance of uncertainty, fear of anxiety, and adolescent worry. *Journal of Abnormal Child Psychology*, *40*(6), 863-870. https://doi.org/10.1007/s10802-012-9611-1

Essau, C. A., rer, s., Conradt, J., Petermann, F., & Phil. (2000). Frequency, Comorbidity, and Psychosocial Impairment of Anxiety Disorders in German Adolescents. *Journal of Anxiety Disorders*, *14*(3), 263-279. https://doi.org/10.1016/S0887-6185(99)00039-0

Ezpeleta, L., Keeler, G., Erkanli, A., Costello, E. J., & Angold, A. (2001). Epidemiology of psychiatric disability in childhood and adolescence. *The Journal of Child Psychology and Psychiatry and Allied Disciplines*, *42*(7), 901-914.

Furtado, M., Van Lieshout, R. J., Van Ameringen, M., Green, S. M., & Frey, B. N. (2019). Biological and psychosocial predictors of anxiety worsening in the postpartum period: A longitudinal study. *Journal of Affective Disorders*, *250*, 218-225.

Ginsburg, G. S., & Schlossberg, M. C. (2002). Family-based treatment of childhood anxiety disorders. *International Review of Psychiatry*, *14*(2), 143-154.

Giora, A., Gega, L., Landau, S., & Marks, I. (2005). Adult recall of having been bullied in attenders of an anxiety disorder unit and attenders of a dental clinic: A pilot controlled study. *Behaviour Change*, *22*(1), 44-49.

Gramszlo, C., Fogleman, N. D., Rosen, P. J., & Woodruff-Borden, J. (2018). Intolerance of uncertainty in children with attention-deficit/hyperactivity disorder. *ADHD Attention*

Deficit and Hyperactivity Disorders, *10*(3), 189-197. https://doi.org/10.1007/s12402-017-0244-7

Gregory, A. M., Caspi, A., Moffitt, T. E., Koenen, K., Eley, T. C., & Poulton, R. (2007). Juvenile mental health histories of adults with anxiety disorders. *American Journal of Psychiatry*, *164*(2), 301-308. https://doi.org/10.1176/AJP.2007.164.2.301/ASSET/IMAGES/LARGE/R422F0.JPEG

Holaway, R. M., Heimberg, R. G., & Coles, M. E. (2006). A comparison of intolerance of uncertainty in analogue obsessive-compulsive disorder and generalized anxiety disorder. *Journal of Anxiety Disorders*, *20*(2), 158-174.

Hudson, J. L., & Dodd, H. F. (2012). Informing Early Intervention: Preschool Predictors of Anxiety Disorders in Middle Childhood. *PLOS ONE*, *7*(8), e42359. https://doi.org/10.1371/journal.pone.0042359

Hudson, J. L., Dodd, H. F., & Bovopoulos, N. (2011). Temperament, Family Environment and Anxiety in Preschool Children. *Journal of Abnormal Child Psychology*, *39*(7), 939-951. https://doi.org/10.1007/s10802-011-9502-x

Hudson, J. L., Dodd, H. F., Lyneham, H. J., & Bovopoulous, N. (2011). Temperament and Family Environment in the Development of Anxiety Disorder: Two-Year Follow-up. *Journal of the American Academy of Child & Adolescent Psychiatry*, *50*(12), 1255-1264.e1251. https://doi.org/https://doi.org/10.1016/j.jaac.2011.09.009

Johnson, P. O., & Neyman, J. (1936). Tests of certain linear hypotheses and their application to some educational problems. *Statistical research memoirs*.

Lemery-Chalfant, K., Schreiber, J. E., Schmidt, N. L., Van Hulle, C. A., Essex, M. J., & Goldsmith, H. H. (2007). Assessing internalizing, externalizing, and attention problems in young children:

Validation of the MacArthur HBQ. *Journal of the American Academy of Child and Adolescent Psychiatry*, *46*(10), 1315-1323. https://doi.org/10.1097/chi.0b013e3180f616c6

Luby, J. L. (2013). Treatment of Anxiety and Depression in the Preschool Period. *Journal of the American Academy of Child & Adolescent Psychiatry*, *52*(4), 346-358. https://doi.org/https://doi.org/10.1016/j.jaac.2013.01.011

Lyons, K. E., & Ghetti, S. (2011). The development of uncertainty monitoring in early childhood. *Child Development*, *82*(6), 1778-1787.

Mathes, B. M., Oglesby, M. E., Short, N. A., Portero, A. K., Raines, A. M., & Schmidt, N. B. (2017). An examination of the role of intolerance of distress and uncertainty in hoarding symptoms. *Comprehensive Psychiatry*, *72*, 121-129.

Miller, M. L., & McGuire, J. F. (2023). Targeting intolerance of uncertainty in treatment: A meta-analysis of therapeutic effects, treatment moderators, and underlying mechanisms. *Journal of Affective Disorders*, *341*, 283-295. https://doi.org/https://doi.org/10.1016/j.jad.2023.08.132

Morgan, A. J., Rapee, R. M., & Bayer, J. K. (2016). Prevention and early intervention of anxiety problems in young children: A pilot evaluation of Cool Little Kids Online. *Internet Interventions*, *4*, 105-112. https://doi.org/10.1016/j.invent.2016.05.001

Nauta, M. H., Scholing, A., Rapee, R. M., Abbott, M., Spence, S. H., & Waters, A. (2004). A parent-report measure of children's anxiety: psychometric properties and comparison with child-report in a clinic and normal sample. *Behaviour Research and Therapy*, *42*, 813-839. https://doi.org/10.1016/S0005-7967(03)00200-6

Ooi, J., Dodd, H. F., Meiser-Stedman, R., Hudson, J. L., Bridges, J., & Pass, L. (2022). The efficacy of interventions for behaviourally inhibited preschool-aged children: A meta-analysis. *Journal* *of Anxiety Disorders*, *88*, 102559. https://doi.org/https://doi.org/10.1016/j.janxdis.2022.102559

Osmanağaoğlu, N., Creswell, C., & Dodd, H. F. (2018). Intolerance of Uncertainty, anxiety, and worry in children and adolescents: A meta-analysis. *Journal of Affective Disorders*, *225*, 80-90. https://doi.org/10.1016/J.JAD.2017.07.035

Osmanağaoğlu, N., Creswell, C., Snuggs, S., Stuijfzand, S., & Dodd, H. F. (2021). Evaluating the psychometric properties of the intolerance of uncertainty scale for children in a preadolescent sample. *Journal of Anxiety Disorders*, *77*, 102343. https://doi.org/https://doi.org/10.1016/j.janxdis.2020.102343

Pérez-Edgar, K., Bar-Haim, Y., McDermott, J. M., Chronis-Tuscano, A., Pine, D. S., & Fox, N. A. (2010). Attention Biases to Threat and Behavioral Inhibition in Early Childhood Shape Adolescent Social Withdrawal. *Emotion (Washington, D.C.)*, *10*(3), 349-357. https://doi.org/10.1037/a0018486

R Core Team. (2022). *R: A language and environment for statistical computing.* . In R Foundation for Statistical Computing. https://www.R-project.org/

Rapee, R. M. (1997). Potential role of childrearing practices in the development of anxiety and depression. *Clinical Psychology Review*, *17*(1), 47-67.

Rapee, R. M., Schniering, C. A., & Hudson, J. L. (2009). Anxiety Disorders During Childhood and Adolescence: Origins and Treatment. *Annual Review of Clinical Psychology*, *5*(1), 311-341. https://doi.org/10.1146/annurev.clinpsy.032408.153628

Roebers, C. M., von der Linden, N., & Howie, P. (2007). Favourable and unfavourable conditions for children's confidence judgments. *British Journal of Developmental Psychology*, *25*(1), 109-134.

Sadeh, N., & Bredemeier, K. (2021). Engaging in risky and impulsive behaviors to alleviate distress mediates associations between intolerance of uncertainty and externalizing psychopathology. *Journal of personality disorders*, *35*(3), 393-408.

Sanchez, A. L., Cornacchio, D., Chou, T., Leyfer, O., Coxe, S., Pincus, D., & Comer, J. S. (2017). Development of a scale to evaluate young children's responses to uncertainty and low environmental structure. *Journal of Anxiety Disorders*, *45*, 17-23. https://doi.org/10.1016/J.JANXDIS.2016.11.006

Sexton, K. A., & Dugas, M. J. (2009). Defining distinct negative beliefs about uncertainty: validating the factor structure of the Intolerance of Uncertainty Scale. *Psychological assessment*, *21*(2), 176.

Speilberger, C. D., Gorsuch, R., Lushene, R., Vagg, P., & Jacobs, G. (1983). Manual for the state-trait anxiety inventory. *Palo Alto, CA: Consulting Psychologists*.

Spence, S. H. (1998). A measure of anxiety symptoms among children. *Behaviour Research and Therapy*, *36*(5), 545-566.

Spence, S. H., Rapee, R., McDonald, C., & Ingram, M. (2001). The structure of anxiety symptoms among preschoolers. *Behaviour Research and Therapy*, *39*(11), 1293-1316. https://doi.org/https://doi.org/10.1016/S0005-7967(00)00098-X

Strauss, C. C., Frame, C. L., & Forehand, R. (1987). Psychosocial impairment associated with anxiety in children. *Journal of clinical child psychology*, *16*(3), 235-239.

Van Ameringen, M., Mancini, C., & Farvolden, P. (2003). The impact of anxiety disorders on educational achievement. *Journal of Anxiety Disorders*, *17*(5), 561-571. https://doi.org/10.1016/S0887-6185(02)00228-1

Wong, J. X., & Caporino, N. E. (2023). Youth Intolerance of Uncertainty – Parent-Report (YIU-PR): A Developmentally Sensitive Measure of Intolerance of Uncertainty in Children and Adolescents. *Journal of Psychopathology and Behavioral Assessment*, *45*(1), 194-206. https://doi.org/10.1007/s10862-022-10016-6

Chapter 3. Study 2: Uncertain World: How Children's Curiosity and Intolerance of Uncertainty Relate to their Behaviour and Emotion under Uncertainty.

Manuscript submitted for publication to Quarterly Journal of Experimental Psychology

Ryan, Z.J., Dodd, H.F. & FitzGibbon, L. Uncertain World: How Children's Curiosity and Intolerance of Uncertainty Relate to their Behaviour and Emotion under Uncertainty. Manuscript submitted for publication.

Appendices Associated with this Chapter:

Abstract

Curiosity and intolerance of uncertainty (IU) are both thought to drive information seeking but have very different affective profiles; curiosity is associated with positive affective responses to uncertainty and improved learning outcomes, whereas IU is associated with negative affective responses and anxiety. Curiosity and IU have not previously been examined together in children but may both play an important role in understanding how children respond to uncertainty. Our research aimed to examine how individual differences in parent-reported curiosity and IU were associated with behavioural and emotional responses to uncertainty. Children aged 8-12 (n=133) completed a game in which they were presented with an array of buttons on the screen that, when clicked, played neutral or aversive sounds. Children pressed buttons (information seeking) and rated their emotions and worry under conditions of high and low uncertainty. Facial expressions were also monitored for affective responses. Analyses revealed that children sought more information under high uncertainty than low uncertainty trials and that more curious children reported feeling happier. Contrary to expectations, IU and curiosity were not related to the number of buttons children pressed, nor to their self-reported emotion or worry. However, exploratory analyses suggest that children who are high in IU may engage in more information seeking that reflects checking or safety-seeking than those who are low in IU. Additionally, our findings suggest that there may be age-related change in the effects of IU on worry, with IU more strongly related to worry in uncertain situations for older children than younger children.

Keywords: Intolerance of Uncertainty, curiosity, uncertainty, emotion, behaviour, children

3 Introduction

Uncertainty, a state of imperfect or unknown information, is pervasive in everyday life and leads to complex patterns of behavioural and affective responses. While humans are generally motivated to resolve uncertainty (Kruglanski et al., 2020), they also tend to find uncertainty uncomfortable or aversive (van Lieshout et al., 2021). Despite these general trends, individuals differ in their responses to uncertainty, resulting in positive and negative behavioural, emotional and cognitive responses (Hillen et al., 2017). Whilst some people find uncertainty exciting and motivating, easily interacting with it, others have difficulty coping with uncertainty and experience psychological distress when faced with it (Stewart et al., 2010). These individual differences in dealing with uncertainty are conceptually associated with curiosity and Intolerance of Uncertainty (IU) respectively. These two constructs come from largely siloed areas of psychological research and there is, therefore, a dearth of research considering them together. Curiosity is typically studied with relation to motivation and education and is associated with enhanced learning in the face of uncertainty (Gruber et al., 2014; von Stumm et al., 2011) along with enhanced wellbeing (Kashdan et al., 2004). In contrast, IU is typically studied from a clinical perspective and is associated with elevated anxiety and worry under uncertainty (Dugas et al., 1998; Dugas et al., 2001). Having a better understanding of how children respond to uncertainty and how responses are associated with IU and curiosity has relevance to both children's learning and their mental health. This study uses a novel behavioural task to examine how children's responses to uncertainty are associated with individual differences in curiosity and IU.

Curiosity is a complex and multifaceted construct (Grossnickle, 2016), and there is still considerable debate over how it is best defined (Kidd & Hayden, 2015). Here, we follow Jirout and Klahr (2012)'s operationalisation of curiosity as a preference for uncertainty that drives exploratory behaviour. Anecdotally, children exhibit curiosity when given a wrapped (and thus uncertain) gift – they ask questions to establish what is inside, shake it, smell it, explore it and open it, to satiate their curiosity. Indeed, studies of children's exploratory behaviour have demonstrated that from an early age, children explore and seek information through their interactions with their environment and questioning of more knowledgeable adults (Callanan & Oakes, 1992; Frazier et al., 2009). From infancy, children's attention is often directed towards uncertain or unpredictable events, maximising their opportunities for experiential learning (Kidd et al., 2012; Schulz & Bonawitz, 2007).

There are individual differences in children's curiosity, with higher levels of curiosity associated with both academic and wellbeing outcomes. Individual differences in curiosity are associated with differences in academic achievement, showing strong predictive validity over time (Gottfried et al., 2016; Shah et al., 2018). Indeed, in one study, primary-aged children who preferred to explore more uncertain environments in a computer game were found to acquire more information and learn more in an inquiry-based learning context than those who preferred the less uncertain environments (van Schijndel et al., 2018). Kashdan et al. (2004) found that, in adults, curiosity is related to positive affect and life satisfaction, and Jovanovic and Brdaric (2012) found the same in adolescents, along with an association between curiosity and a greater sense of purpose in life. Shoshani (2019) found that in 3- to 6-year-olds, parent-reported curiosity was positively related to a host of other positive character traits including creativity and social intelligence, and that a broader factor of 'intellectual strengths' was positively related to emotional wellbeing. Thus, it seems plausible that those with greater curiosity may have more positive affective responses to uncertain situations than those with lower trait curiosity.

A more nuanced approach to the affective character of curiosity can also be considered. As well as positive feelings of interest and excitement at the prospect of new knowledge, sometimes curiosity may be associated with frustration or a sense of deprivation as a result of not having information. Litman and Silvia (2006) suggest that there are two types of curiosity, interest type, which is motivated by the desire for new information and is associated with positive feelings about that information, and deprivation type, which is motivated by a lack of information and is associated with unpleasant feelings of deprivation and frustration until the information is gained. This distinction has been identified in both adults and children (Litman, 2008; Piotrowksi et al., 2014). Recent research with adults suggests that the benefits of curiosity may be more strongly associated with interest- than with deprivation-type curiosity (Whitecross & Smithson, 2023). When measuring children's trait curiosity, the only validated measure is the parent-report questionnaire Epistemic Curiosity in Young Children (I/D-YC) (Piotrowksi et al., 2014). This measure has separate scales for interest- and deprivation-type curiosity, and a two-factor model has been found to provide the best fit although the two factors are strongly correlated. To our knowledge, relationships between children's behavioural and affective responses to uncertain situations and individual differences in trait curiosity (in general or separated into subtypes) have not previously been explored.

Intolerance of Uncertainty (IU) is a trait characterised by finding uncertainty aversive or distressing (Carleton, 2016a). IU is defined as having a "dispositional incapacity to endure the aversive response triggered by the perceived absence of salient, key, or sufficient information, and sustained by the associated perception of uncertainty" (Carleton, 2016b, p. 32). Despite uncertainty itself being aversive, the perception or presence of threat may bring about a negative response to uncertainty (Osmanağaoğlu et al., 2018; Tanovic et al., 2018). The distress felt by individuals high in IU is thought to be underpinned by dysfunctional processing of uncertainty (Grupe & Nitschke, 2011). It is theorised that, in high IU individuals, uncertainty stimulates worry and that those high in IU are, in turn, more likely to engage with that worrying (Koerner & Dugas, 2008) and have IU "running in the background" as they navigate the world (Hebert & Dugas, 2019).

For people high in IU, feeling uncertain may lead to information seeking behaviour such as compulsive checking of light switches or locks or seeking health related tests and screenings (Fourtounas & Thomas, 2016; Rosen & Knäuper, 2009). Research has shown that adults with Generalised Anxiety Disorder (GAD), a condition strongly associated with IU, use these so-called "safety behaviours" to reduce the discomfort associated with uncertainty (Hebert & Dugas, 2019). For anxious adults, the desire to resolve uncertainty can be so strong that information is sought even when it comes at a cost (Bennett et al., 2020). Thus, whilst information seeking behaviour may be expected in both those high in IU and highly curious individuals, the affective responses to uncertain situations would be expected to differ between these groups. It seems somewhat self-evident that those who are high in IU would be expected to experience negative affective responses to uncertain situations.

The majority of research examining IU has focused on adults but there is an emerging literature exploring IU in children. This work was reviewed by Osmanağaoğlu et al. (2018) who found that IU has a consistent strong association with both anxiety and worry. The review also highlighted that research has relied almost entirely on questionnaire measures. In the first study to examine behaviour in response to uncertainty and IU in preadolescent children, Osmanağaoğlu et al. (2021) used an adaptation of the Beads task (Jacoby et al., 2014). In this task, children were asked to select beads one at a time from a hidden jar and asked to decide which jar (from a variety of options) the beads were coming from. The colour of the beads in the jars varied at different ratios to provide different levels of uncertainty. On average, as uncertainty increased in the task, information seeking increased, as well as self-reported worry. In relation to IU, Osmanağaoğlu et al. (2021) found that task-related worry was associated with children's self-reported IU but that neither parent nor child self-reported IU were associated with information seeking. Osmanağaoğlu et al. (2021) interpreted these findings as indicating that when pre-adolescent children self-report using IU questionnaires, they "capture subjective, affective reactions to uncertainty" (Osmanağaoğlu et al., 2021, p. 7), hence why scores were only associated with self-reported worry and not information seeking behaviour (Osmanağaoğlu et al., 2021; see also Krain et al., 2006, 2008). Osmanağaoğlu et al. (2021) also theorized that parents may respond to IU questionnaires based on their child's observable behaviour so we may be more likely to find associations between child behaviour and parent-reported IU, as opposed to child self-report.

Despite the fact that both curiosity and IU describe people's dispositional responses to uncertainty, to date there is very little empirical or theoretical work bringing these constructs together, largely resulting from these constructs being developed and investigated in siloed research fields. An exception to this is a recent series of studies examining individual differences in adults' information seeking (Jach et al., 2022; Jach & Smillie, 2021). In these studies, information seeking was assessed for two types of information – information relating to the veracity of arbitrary choices, and information relating to upcoming reward outcomes (whether they had won a bonus in the last game). Curiosity and IU, as well as several other personality traits, were measured via self-report questionnaires with adults. Across these studies, curiosity was more likely to be related to seeking of arbitrary information whereas IU was related to seeking of information about reward outcomes. Interestingly, across these studies, moderate significant positive associations between IU and deprivation-type curiosity and moderate negative associations between IU and interest-type curiosity were found. These authors also found some moderate relationships with other constructs relating to uncertainty such as ambiguity tolerance and openness to experience.

Experimental research has demonstrated that, in general, humans tend to be motivated to resolve uncertainty. Several studies have shown that uncertainty leads to information seeking, even when there is a possibility of a negative outcome (FitzGibbon et al., 2021; Hsee & Ruan, 2016), although these studies are so far limited to adult populations. For example, Hsee and Ruan (2016) explored information seeking in adults by conducting four studies where uncertainty was manipulated and could be resolved by participants but, resolution required participants to risk negative consequences. In their third study (on which the design of the current experiment was based), Hsee and Ruan (2016) presented participants with an array of labelled buttons each indicating that, when pressed, they would play a neutral or aversive sound. There were also buttons labelled with '?' indicating that they could play either the neutral or aversive sound. In the certain condition, there were 44 certain buttons and 4 uncertain, and vice versa for the uncertain condition. Participants were invited to press as many or as few buttons as they liked during the study which would last a few minutes. These authors found that in the uncertain condition participants clicked more buttons than in the certain condition. They also found that the more buttons a participant clicked the worse they felt, and participants in the uncertain condition felt significantly less happy than those in the certain condition. This pattern, that was observed across the series of studies, suggests that the drive to resolve uncertainty can outweigh the negative consequences of doing so. However, individual differences in responses to more or less uncertain situations were not previously explored in these studies, so it is not yet known whether there are individual differences in the motivational underpinnings of their information seeking under uncertainty and the affective responses that correspond with it.

There is currently limited research exploring IU and curiosity together in the context of uncertainty and it is not well understood how IU and curiosity are associated with affect and information seeking behaviour in children. To address this, we created a behavioural task in which uncertainty was manipulated and both affective responses and information seeking behaviour was measured. Our task was based on Hsee and Ruan (2016)'s Study 3 where greater uncertainty was associated with more information seeking, even when there was a possibility of a negative outcome. The task allows information seeking and affect to be captured under varying levels of uncertainty. In case it is not just the aversiveness of the uncertainty causing the response but the presence of possible threat, we have included a mildly aversive stimulus. In the task, children are presented with an array of buttons on the screen that, when clicked, play neutral or aversive sounds. Uncertainty was manipulated between trials by giving the buttons informative (low uncertainty) or uninformative (high uncertainty) labels. Information seeking behaviour was indexed by the number of buttons children pressed. In addition, affective responses were observed via videos of children's faces and via self-report of emotional valence and worry after initial exposure to each button array.

The first aim of the study was to evaluate whether children's information seeking is related to curiosity and IU by examining associations between the number of buttons pressed and parent-reported IU and curiosity. We hypothesised that both higher IU and higher curiosity would be associated with more button presses, indicative of greater information seeking. The second aim was to evaluate whether curiosity was associated with positive emotional responses to uncertainty by examining associations between parent-reported curiosity and both the child's facial affect and self-reported emotional valence. We expected higher curiosity to be associated with positive emotional responses to uncertainty in high uncertainty trials but not in low uncertainty trials. Our final aim was to evaluate whether IU was associated with negative emotional responses to uncertainty, again through the child's facial affect and self-reported emotional valence, but also through self-reported worry. We hypothesised that higher IU would be associated with more negative emotional responses in higher uncertainty trials.

3.1 Method

3.1.1 Pre-registration

The design, sample size, hypotheses and analysis plan for the study were pre-registered on OSF. Further detail can be found here.

3.1.2 Participants

Participants were 133 children, recruited via two lab databases and social media posts. An a priori power calculation determined that a sample size of 132 participants would be sufficient to reach 80% power for a small interaction effect (standardised beta = 0.02 - 0.05) based on the variance in pilot data (see the preregistration for further details). Of the 133 participants, 68 were boys, 64 girls and one preferred not to say. Their ages ranged from 8 to 12.96 years (M = 9.71 years, SD = 1.30). The majority identified as White (111) and 11 as Asian, 2 as Black, 8 as Mixed Race and 1 as Arab. The majority of parents reported completion of a higher education degree (49 Bachelors degree, 34 Masters degree, 33 Postgraduate degree). Of the other parents, 3 achieved GCSEs, 3 A Levels, 10 College Course Certificates, and 1 preferred not to say. All children in the study met the following inclusion criteria: they had normal or corrected hearing and vision, were typically developing and were living in the UK (so that safeguarding procedures relating to video recordings could be followed). This project was approved by the School of Psychology and Clinical Language Sciences Ethics Committee at the University of Reading (2020-072-HD). Further demographic information is available in Supplementary Materials (Table S1).

3.1.3 Exclusions

24 additional parents completed the questionnaires but did not meet the above inclusion criteria, so their children were not invited to complete the game. A further 12 questionnaire responses were flagged as suspicious based on their responses to address and name open-text questions– subsequent emails for clarification of responses were ignored therefore these families were not invited to complete the game. Further detail can be found in the Supplementary Materials.

An additional 36 participants were eligible for the study but were not included in the final dataset because their parents did not complete the questionnaires (7), they did not start the game (22), they had technical issues with the game (6), or they withdrew after the practice round (1). Videos recorded from the webcam during the task were checked for parental interference and no participants were excluded on this basis. No participants were excluded after completing the task.

3.1.4 Parent-report Measures

Parents completed questionnaires about their child's curiosity and IU and provided demographic information via an online form.

3.2.4.1 Curiosity. Children's trait curiosity was measured using the 10 item parent-report Interest/Deprivation-Young Children (I/D-YC) scale (Litman, 2005; Piotrowksi et al., 2014), which is currently the only validated individual differences measure of children's curiosity. The measure has two scales capturing two dimensions of curiosity (Litman, 2005). The I-type subscale captures intellectual interest in obtaining new knowledge with questions such as “My child has fun learning about new topics or subjects” and the D-type subscale captures the desire to obtain knowledge to reduce information deprivation with questions like “My child is bothered when he/she does not understand something and tries to make sense of it”. The I/D-YC uses a 4-point Likert scale where 1 indicates “almost never”, 2 “sometimes”, 3 “often” and 4 “almost always”. A validation study with children aged 3 to 8 revealed that the I/D-YC scale demonstrates satisfactory construct validity and acceptable internal consistency for both the I-type ($\alpha = 0.85$) and D-type scale ($\alpha = 0.80$), and the two subscales are highly correlated ($r = .84$) (Piotrowksi et al., 2014). We also found the subscales to be correlated $r(131) = 0.47$, $p < .001$ (see Table 1), although to a lesser extent than in previous research. Internal consistency for the whole scale was very good in our sample ($\alpha = 0.82$). In line with previous research (Jansen et al., 2021) looking at curiosity generally, we combined the two subscales to produce a single measure of curiosity in our main analyses. Additionally, we explored the separate effects of the two subscales.

3.2.4.1 Intolerance of Uncertainty. The child’s responses to uncertainty were captured via the 17 item parent-report Responses to Uncertainty and Low Environmental Structure (RULES) questionnaire (Sanchez et al., 2017). The RULES uses a 5-point Likert scale where 1 is “not at all”, 3 is “somewhat” and 5 is “very much”, asking questions such as “My child has a hard time coping with even minor changes” and “My child seeks reassurance prior to entering an unfamiliar situation”. The RULES scale is validated as a measure of children’s IU, has demonstrated convergent validity and strong internal consistency ($\alpha = 0.93$) as a parent-report measure in child samples, including those under the age of 10 years (Sanchez et al., 2017). Internal consistency was excellent in our sample ($\alpha = 0.90$).

3.1.5 Task Procedure

After completing the questionnaires, parents were sent a link to the Uncertain World online game if the inclusion criteria were met. Completion of the game was ‘asynchronous’, with no live interaction with the researcher. The game was built using jsPsych (de Leeuw, 2014) in html and JavaScript and run directly from a web server hosted by the University of Reading. The task materials and programme can be found in the GitHub directory in the pre-registration (here). Parents were asked to allow the browser access to the computer’s webcam and microphone and to enter a word that was played through the speakers as a means of checking the computer audio. Parents were then asked to hand control of the computer to their child.

First, children completed a practice phase. A computerized voice provided the child with instructions for the game. Children were taught about how the symbols represented neutral (“ok” hand gesture) and aversive (“thumbs down” hand gesture) sounds as well as how the question mark symbol represented uncertain buttons. Children were required to press buttons and hear example sounds in the practice phase. There was then a check to confirm that the child heard the sounds in the practice, and that they wished to proceed with the game. If they answered yes to both of these checks, then they proceeded to the test trials.

Children completed four test trials, two with high uncertainty, two with low uncertainty (see Trial Design for more details) in a counterbalanced order. Each of the four test trials consisted of a camera check, an anticipatory period, three self-report questions, and a button pressing phase (see Figure 1). To ensure that the child could be seen by the webcam, they were shown the video feed from the webcam positioned in a spaceship window on the screen. Children were asked to make sure they could see themselves in the window of the spaceship before each trial. When the child was happy they could see themselves, they clicked a button “Next” to proceed with the trial. In the anticipation period, the 48 buttons for the trial ahead were shown on the screen for 10 seconds. During this phase, children were instructed to look at the buttons but not press them and their faces were recorded via the webcam for coding of affective responses (see Facial affect recording, coding and scoring section). The child was asked to self-report emotional valence, worry and uncertainty (see Self-reported emotion valence, worry and uncertainty section). In the button pressing phase, the buttons were activated for one minute, and children could press as many or as few buttons as they liked and hear the sounds. A neutral and an aversive sound was allocated to each of the four trials (see Trial Design for more details). Neutral and aversive sounds selected from the International Affective Digitized Sounds-2 (IADS-2) database (Bradley & Lang, 2007) were used in the task (see Supplementary Materials for details).

As a manipulation check, once all four trials were completed, the child rated how each sound made them feel. They were then asked to hand over to their parent. The parent was asked to confirm consent for the video to be uploaded, and was then provided with a debrief for the project on screen, with an option to download it. Parents were then sent a £5 voucher as a contribution to their reasonable expenses incurred in taking part in the research.

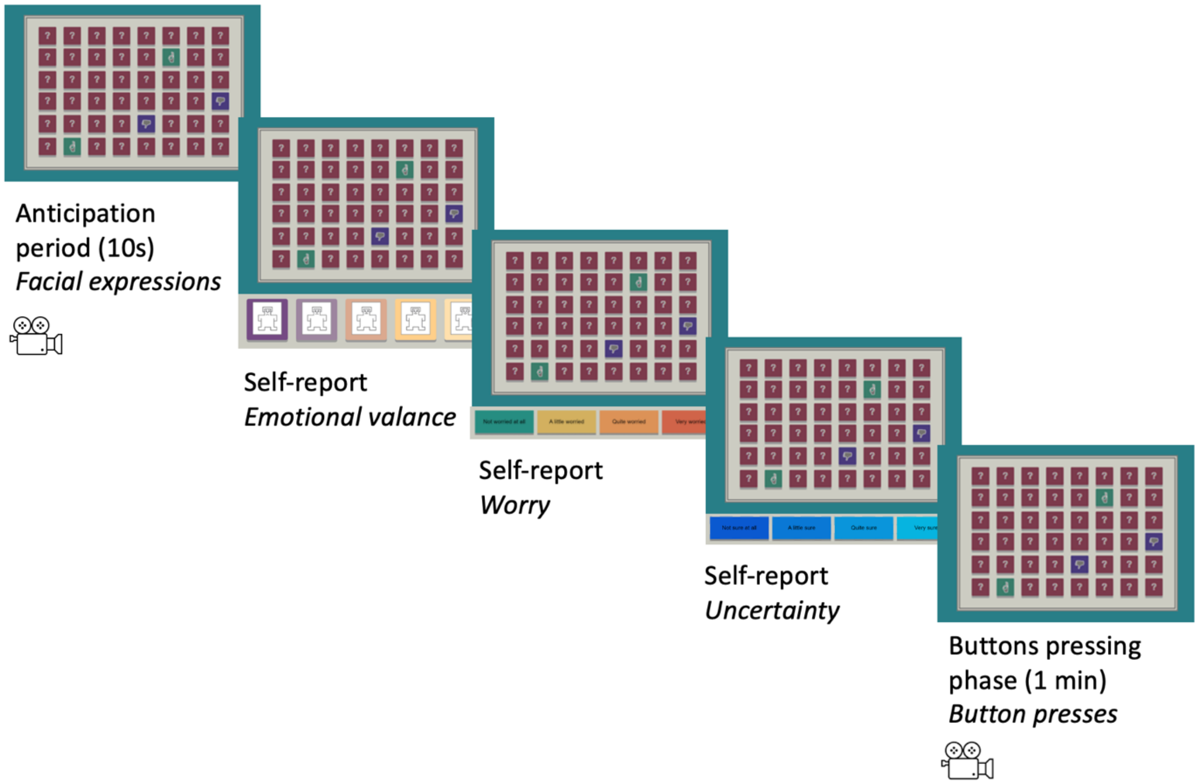


Figure 1. Trial procedure depicting a high uncertainty trial. Self-report measures were displayed until a response was made. Buttons were only responsive in the Button pressing phase. Measures captured during each phase of the trial are shown in italics. Note: Please refer to the online version of the article for the colour version of this figure.

3.2.5.1 Trial design. In each of the four trials, 48 buttons were shown on the screen. Allocation of sounds to buttons followed the procedure from Hsee and Ruan (2016)'s buttons task (Experiment 3). The four neutral and four aversive sounds were randomly allocated across the four trials such that one neutral and one aversive sound were allocated to each trial, and those sounds were repeated across relevant buttons in that trial. In high uncertainty trials, 44 buttons were uncertain, and four buttons were certain, two neutral and two aversive. In low uncertainty trials, 4 buttons were uncertain, and 44 buttons were certain, with 22 neutral and 22 aversive (see

Figure 2). Where buttons were uncertain, sounds were randomly allocated across the buttons such that half were allocated a neutral sound and half an aversive sound. Buttons were individually mapped onto sounds such that the same sound played each time a specific uncertain button was pressed. When a button was pressed, the sound would play for 2 seconds during which time the buttons were disabled, resulting in a maximum possible number of button presses of 30 during the 1 minute button pressing phase.

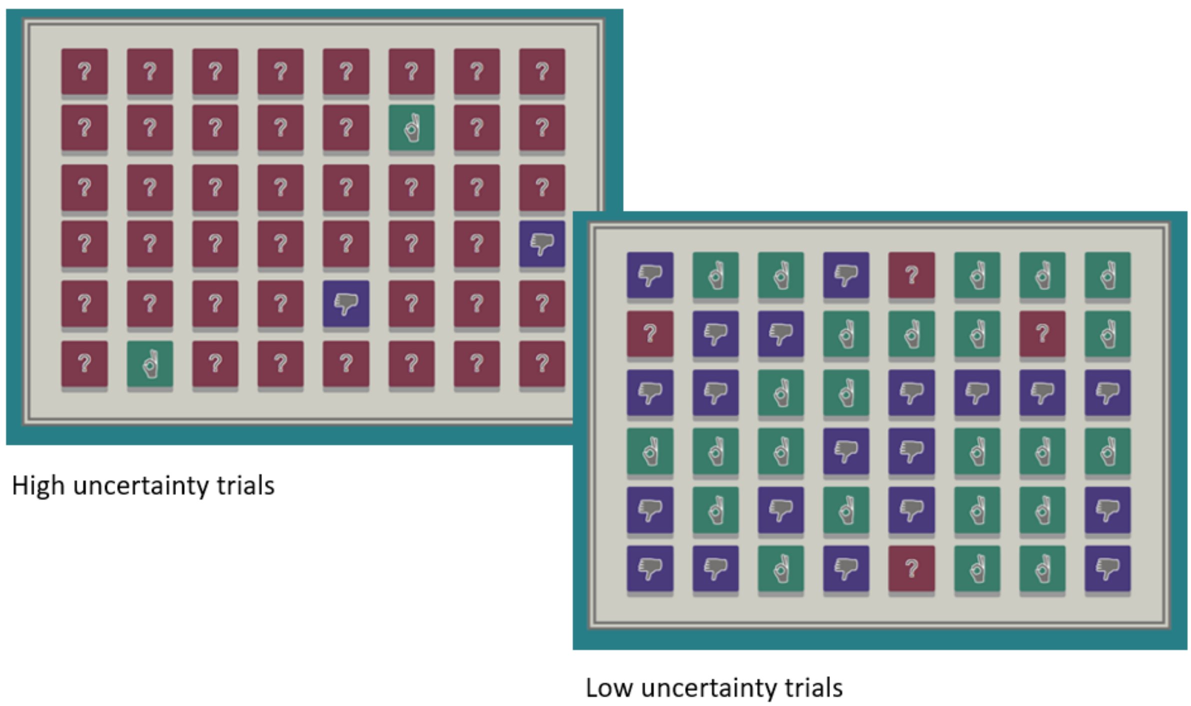


Figure 2. Example button arrays for high and low uncertainty trials. *Note*. Please refer to online version of article for colour version of the figure.

3.1.6 Task measures

3.2.6.1 Button Presses. During the button pressing phase, children were invited to press as many or as few buttons as they liked. The number of button presses children made during the button pressing phase on each certain and uncertain trial was recorded. The total number of buttons pressed per trial was used in the analyses (following Hsee and Ruan (2016). Additionally, for exploratory purposes, we calculated the proportion of unique, certain, and uncertain buttons pressed on each trial.

3.2.6.2 Self-reported emotion valence, worry and uncertainty. To measure children's emotional valance, we asked children to report how they felt about pressing the buttons in the round on a 5-point Self Assessment Mannikin (SAM; from "very unhappy" to "very happy") (Bradley & Lang, 1994). Emotional valence rating scores were skewed towards very happy ("very happy" responses were made on 50% of trials).

To measure children's worry, we asked children to report how worried they felt about the round on a 4-point scale for self-reported worry (from "not at all worried" to "very worried"). Self-report worry rating scores were skewed towards not at all worried ("not at all worried" responses were made on 70% of trials).

As a manipulation check, we measured children's uncertainty on each trial. We asked children to report how sure or not sure they felt about the sounds they would hear in the round on a 4-point scale from "not at all sure" to "very sure". This question was arrived upon following piloting and feedback from children that rating uncertainty was more challenging than rating how sure they felt. Responses were therefore reversed to give a rating of uncertainty. Self-report uncertainty rating scores were skewed towards very sure ("very sure" responses were made on 50% of trials).

3.2.6.3 Facial affect recording, coding and scoring. Children's faces were recorded during each 10 second anticipation period using the webcam. We pre-registered two measures of facial affect, a subjective score and an objective score, as well as a composite of the two. The master coder coded all videos and reliability coder coded 20% of videos as is established practice for determining reliability (see Syed & Nelson, 2015). Coders were blind to the trial uncertainty.

The subjective facial affect score was rated by the coders on a 5-point Likert scale per video from –2 (very unhappy) to +2 (very happy) based on their overall impression of the child's affect during the trial. The Intra Class Correlation (ICC) for subjective facial affect score was .68 with a 95% confidence interval from .56 to .77, indicating moderate reliability.

The objective facial affect score was derived as follows. The time spent in smile and frown expressions were coded according to a simple coding scheme developed for this study, based on the Facial Action Coding System (FACS; Ekman & Friesen, 1978) and facial electromyography (fEMG; Cacioppo et al., 1986) methodology. The resulting measure was a proportion score between -1 (always frowning) and +1 (always smiling). The ICC for objective facial affect score was .54 with a 95% confidence interval from .39 to .67, indicating poor to moderate reliability. Further detail about the coding and scoring of the objective facial affect score can be found in Supplementary Materials.

The subjective and objective facial affect scores were related to each other, as tested with a multi-level correlation analysis accounting for clustering of trials within participants, $r(509) = .54$, $p < .001$. Given this, we created a composite score by first scaling and then summing the subjective and objective scores. The ICC for the composite score was .69 with a 95% confidence interval from .57 to .78. It was decided that the composite score would be used in the analysis as it had the best ICC from the three facial affect scores, hereafter referred to as the 'facial affect score'. Models using subjective and objective facial affect scores are reported in Supplementary Table S7.

3.2.6.4 Self-reported sound ratings. As a manipulation check, we asked children to rate each of the sounds they heard during the task. Each sound was played and children used a 5-point SAM scale (from "very unhappy" to "very happy") to rate how each sound made them feel.

3.1.7 Data Analysis

3.2.7.1 Missing data and data cleaning. Data on the behavioural task were collected from 133 participants, but video data was missing for four participants due to transfer issues. Additionally, video data for three trials was missing for one participant, and video data for one trial was missing from a further two participants. Trials where video data were missing were excluded from facial affect models.

Data for all variables was visualised to detect outliers. Three outliers were identified for RULES and these scores were Winsorised at the participant level (2%), following our preregistered data-analysis plan. Thirteen outliers for the number of button presses (2%) and 11 outliers from the facial affect scores (2%) were Winsorised at the trial level, also following our preregistered data-analysis plan.

Data for all three self-report measures was skewed such that the majority of responses were made at one end of the scale. This skew could not be corrected by transformation. We did not preregister a plan for dealing with skewed data. To assess the robustness of the results with these variables, binary variables were created taking the most frequent response ("Very happy", "Not at all worried", and "Very sure") as one value and any other response as the second value. All planned analyses were repeated using the binarised version of the variable. This did not affect the pattern or significance of the main findings, so the planned analyses are reported and analyses with binary variables are reported in Supplementary Tables S5 and S6. Where differences were noted, these are reported alongside the reported results.

3.2.7.2 Preregistered analysis. The analysis plan was preregistered. The analysis strategy was to assess the predictive value of parent report measures of intolerance of uncertainty (RULES) and curiosity (I/D-YC) on four dependent variables (DVs) capturing children's behavioural and emotional responses to uncertainty: number of buttons pressed, self-reported emotion, self-reported worry, and facial affect score. The effects of intolerance of uncertainty and curiosity, as well as their interactions with trial uncertainty were modelled for each dependent variable. Effects of IU and curiosity were first modelled separately (reported in Supplementary Materials Tables S3-S6) and then together, with negligible difference in the model estimates between the approaches.

Linear mixed effects models were run in R (R Core Team, 2022) using the package lme4 (Bates et al., 2014). In all models, random effects for participant (intercepts and random slopes for trial uncertainty) were initially included in the models, but the random effects structure was simplified to intercept only models in all cases to deal with convergence and singular fit errors across all reported models, as described in the preregistration. The syntax for each of the preregistered models reported in this paper are as follows:

N_buttons_pressed ~ (I/D-YC + RULES) * trial_uncertainty + (1 | participant)

sr_emotion_valence ~ (I/D-YC + RULES) * trial_uncertainty + (1 | participant)

sr_worry ~ (I/D-YC + RULES) * trial_uncertainty + (1 | participant)

facial_affect ~ (I/D-YC + RULES) * trial_uncertainty + (1 | participant)

Trial uncertainty was effect coded, where low uncertainty was coded -1 and high uncertainty was coded +1. To make model parameter estimates across RULES and I/D-YC scales comparable, scores for each were converted to z-scores.

3.2.7.3 Additional exploratory analysis. To investigate asymmetry in selection of certain and uncertain buttons across high and low uncertainty trials and whether this could be explained by curiosity and IU, we ran an additional model. On high uncertainty trials, 44 buttons were uncertain and 4 were certain, so certain buttons were in the minority. On low uncertainty trials, 44 buttons were certain and 4 were uncertain, so uncertain buttons were in the minority. To determine whether there was asymmetry in certain and uncertain button pressing that is not related to the different number of each type of button available within a trial, and whether this was associated with trial uncertainty and individual differences in curiosity and IU, we calculated the proportion of minority buttons pressed and used this as the dependent variable in a new model. The syntax for this model is as follows:

prop_minority_buttons_pressed ~ (I/D-YC + RULES) * trial_uncertainty + (1 | participant)

Given the fairly wide age range included in our study, additional models including age were run to determine whether age moderated the relationships under investigation. Model syntax follows that of the main analysis with an additional interactive term for age, resulting in two- and three-way interactions between age and trial uncertainty and individual differences measures. The results of these additional analyses are summarised alongside the pre-registered analyses and reported in full in Supplementary Table S10.

dv ~ (I/D-YC + RULES) * trial_uncertainty * age + (1 | participant)

To investigate differential effects of Interest- and Deprivation-type curiosity, we repeated the models with each curiosity type. Model syntax follows that of the main analysis but the total scale score was replaced with the subscale scores. The results of these additional models are summarised below and reported in full in the Supplementary Tables S8-S9.

3.2 Results

3.2.1 Descriptive statistics

Descriptive statistics of child-level factors - children's age, IU (RULES score) and curiosity (I/D-YC total score, Interest-type subscale score, and Deprivation-type subscale score), as well as their correlations are presented in Table 1. Age was not correlated with IU, curiosity, or either of the curiosity subtypes. IU was not related to curiosity or either of the curiosity subtypes. Both Interest-type and Deprivation-type scores were strongly related to the total I/D-YC score and moderately related to each other.

Table 1. Means, standard deviations, and correlations with 95% confidence intervals of child age, IU (RULES score) and curiosity (I/D-YC total score; interest-type subscale score; and deprivation-type subscale score).

Variable	M (SD)	1	2	3	4
1. Child Age (years)	9.71 (1.30)				
2. IU (RULES total score)	34.89 (9.44)	.02 [-.15, .19]			
3. Curiosity (I/D-YC total score)	28.56 (4.70)	-.10 [-.27, .07]	-.11 [-.28, .06]		
4. Interest-type Curiosity (I-type subscale score)	16.39 (2.62)	-.15 [-.31, .02]	-.17 [-.33, .00]	.84*** [.79, .89]	
5. Deprivation-type Curiosity (D-type subscale score)	12.17 (2.86)	-.03 [-.20, .14]	-.03 [-.20, .14]	.87*** [.82, .91]	.47*** [.33, .59]

Note. ****p* < .001. RULES scores are Winsorised.

Descriptive statistics for button presses across high and low uncertainty trials are presented in Table 2, showing the number of buttons pressed, and the proportion of these that were unique, certain, and uncertain buttons. In our analyses, we include the total number of button presses, including instances where children press a button they have pressed before. We note the asymmetry between the proportion of certain and uncertain button presses on high and low uncertainty trials. This is investigated further in additional exploratory analysis, as outlined above.

Table 2. Descriptive statistics of button-pressing behaviour. Mean (standard deviation) number of buttons pressed per trial (Winsorised) and proportion of unique, certain, and uncertain buttons pressed.

Trial Uncertainty	Number of buttons	Proportion unique	Proportion certain	Proportion uncertain
High	18.79 (3.30)	0.81 (0.16)	0.31 (0.17)	0.69 (0.17)
Low	18.28 (3.33)	0.84 (0.14)	0.78 (0.12)	0.22 (0.12)

Note. One participant did not press any buttons on one low-uncertainty trial and this trial was excluded from the calculation of proportions. Means and standard deviations are calculated by first summarising across trials within participants and then across participants to account for clustering.

Descriptive statistics and correlations between affect measures are presented in Table 3. Self-reported emotion valence and worry were negatively related to each other; the happier a child reported feeling, the less worried they reported feeling. Self-reported emotion valence was weakly positively related to the facial affect score; the happier a child reported feeling, the happier the coder rated their facial affect. Self-reported worry was not related to the facial affect score.

Table 3. Means, standard deviations, and correlations with 95% confidence intervals of affective responses at the trial level.

Variable	M (SD)	1	2
1. Emotion-valence rating	4.21 (0.74)		
2. Worry rating	1.41 (0.52)	-.48*** [-.55, -.41]	
3. Facial affect score	0.02 (0.63)	.13** [-.04, .22]	-.08 [-.16, .01]

Note. Standard deviations are calculated at the participant level. Correlations are adjusted for participant-level clustering.

3.2.2 Manipulation checks

To check that children recognised that some trials involved more uncertainty than others, the effect of trial uncertainty (high or low) on uncertainty ratings was examined using a linear mixed effect model. There was a small but significant effect of trial uncertainty on uncertainty ratings (b = 0.04, 95% CI [0.01-0.07], p = .010), although we note that this was reduced to a trend when self-reported uncertainty was treated as a binary variable (OR = 1.22, 95% CI [0.99-1.49], p = .057). Children reported that they felt less sure about the sounds they would hear on the high uncertainty trials than on low uncertainty trials. See Supplementary Table S2 for full model results.

To check that children found the aversive sounds unpleasant, we conducted a linear mixed effects model on the sound ratings taken at the end of the trial. There was a significant effect of valence on sound ratings (b = 0.22, 95% CI [0.18-0.27], p < .001); neutral sounds were rated more positively than aversive sounds. Distributions of rating scores for neutral and aversive sounds are reported in Supplementary Figure S1.

3.2.3 The influence of uncertainty, IU and curiosity on the number of button presses

We hypothesised that there would be a positive relationship between information seeking under uncertainty (button presses) and both curiosity and IU, reflected in interactions between trial uncertainty and each individual differences measure. Across two separate models (one with IU as a predictor and one with curiosity as a predictor) the following results were found. In both models there was a significant effect of trial uncertainty on buttons presses (b = 0.01, 95% CI [0.00, 0.03], p = .039). Children pressed significantly more buttons in high uncertainty trials than in low uncertainty trials suggesting that children want to try to resolve uncertainty (see Figure 3), however, this effect was very small, reflected in the mean difference of less than one button in Table 2. IU did not predict button pressing (b = -0.02, 95% CI [-0.05, 0.01], p = .268). Curiosity did not predict button presses (b = 0.01, 95% CI [-0.02, 0.03], p = .716). Crucially for our hypotheses, neither IU (b = 0.00, 95% CI [-0.01, 0.02], p = .509) nor curiosity (b = -0.00, 95% CI [-0.02, 0.01], p = .554) significantly interacted with trial uncertainty to predict button presses. See Table 4 for LMM results. An exploratory analysis including age did not change the pattern or significance of these effects and no two- or three-way interactions with age were significant, see Supplementary Table S10 for the LMM results.

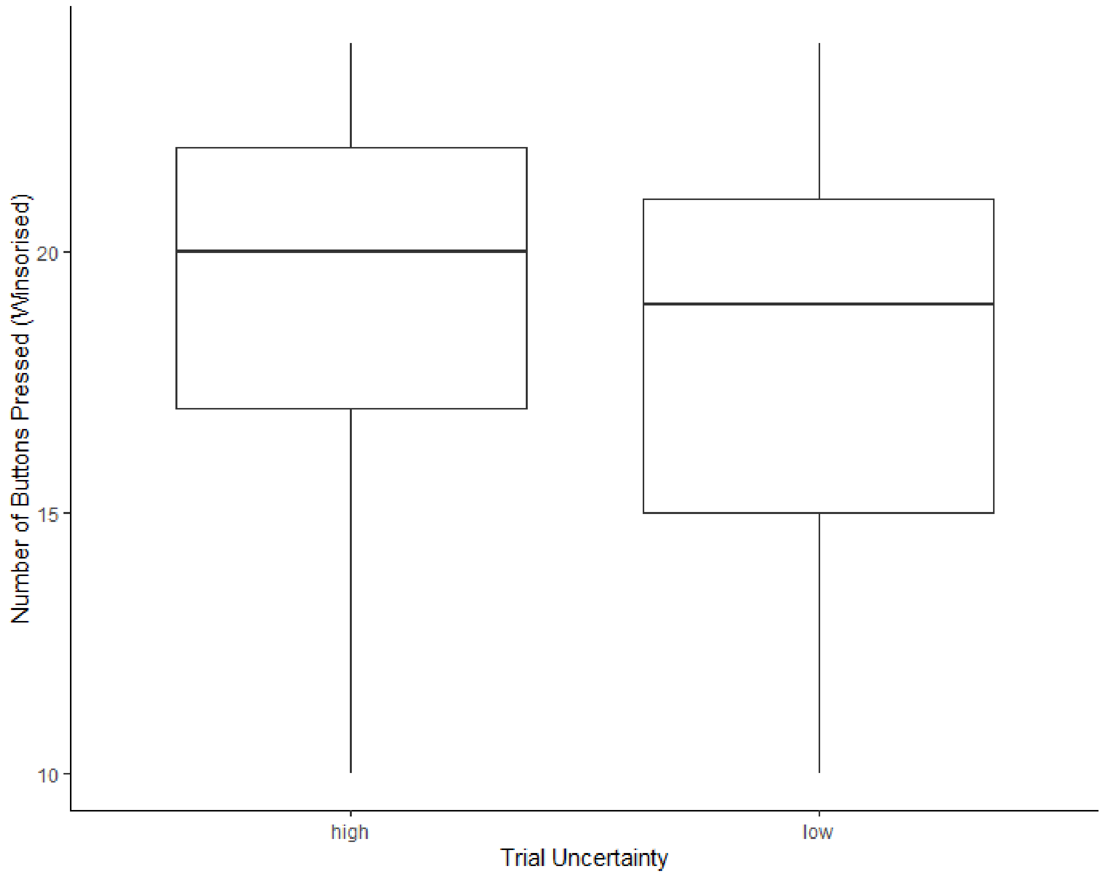


Figure 3: Effect of trial uncertainty on button presses (Winsorised). The lines show the median, whiskers represent scores outside the middle 50% and extend to the minimum and maximum scores, and the box shows the interquartile range (IQR).

3.2.4 Exploratory analysis: The influence of uncertainty, IU, and curiosity on type of button pressed

The descriptive statistics suggest that children may have had asymmetrical patterns of pressing the certain and uncertain types of buttons across the high and low uncertainty trials. To investigate this, while accounting for the different numbers of each type of button across trial uncertainties, we calculated the proportion of the minority button pressed and used this as the dependent variable. On high uncertainty trials, the minority buttons are certain (labelled with an “ok” or a “thumbs down” hand gesture) and on low uncertainty trials, the minority buttons are uncertain (labelled with a “?”). There was a main effect of trial uncertainty (b = 0.04, 95% CI [0.03, 0.06], p < .001), suggesting that children are more likely to press the minority button on high uncertainty trials than on low uncertainty trials. Importantly, this suggests that children press more *certain* buttons on high uncertainty trials than they press *uncertain* buttons on low uncertainty trials. This main effect was qualified by an interaction with IU (b = 0.02, 95% CI [0.00, 0.03], p = .032). Inspection of the marginal effects suggests that asymmetry in button presses is stronger for those who are high in IU (see Figure 4). No other main effects or interactions were significant. The full model table is available in Supplementary Table S11.

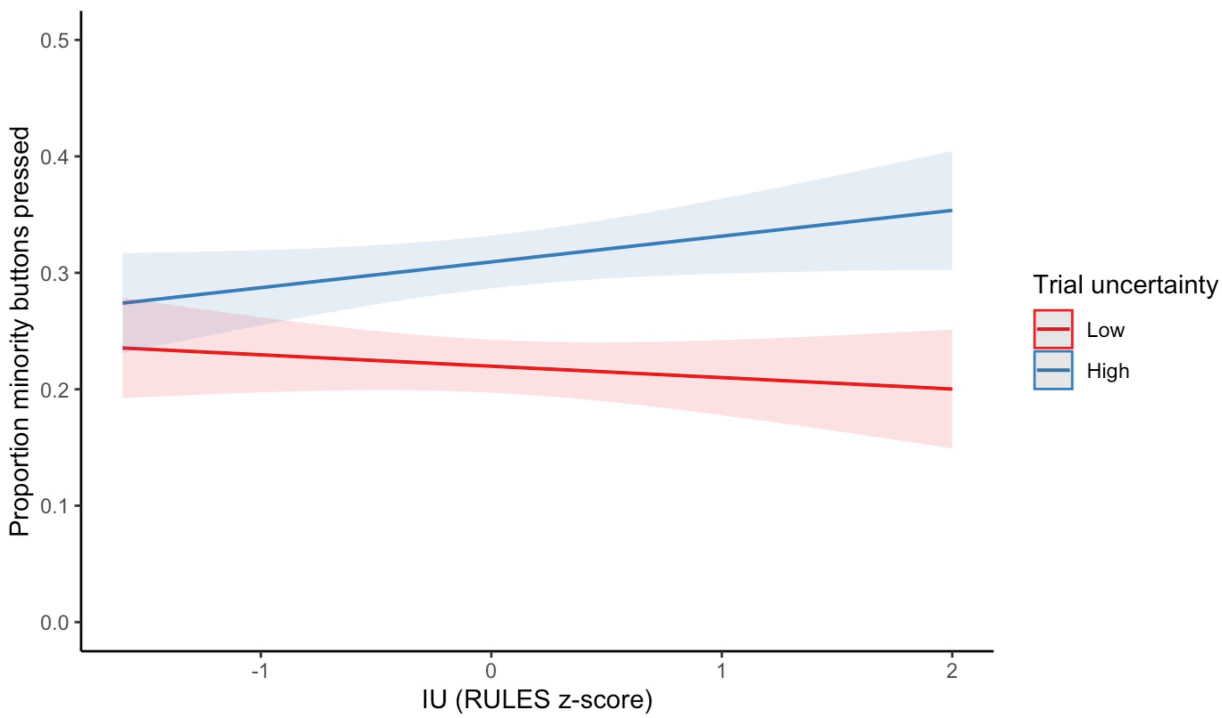


Figure 4. Marginal estimated effects of trial uncertainty and IU on the proportion of minority buttons pressed (certain buttons on high uncertainty trials [blue]/uncertain buttons on low uncertainty trials[red]). Ribbons represent 95% confidence intervals around the estimated effects.

3.2.5 The influence of uncertainty, IU and curiosity on facial affect

We hypothesised that higher curiosity would be associated with positive facial expressions and that higher IU would be associated with negative facial expressions in response to uncertain situations, reflected in interactions between trial uncertainty and each individual differences measure. There was a trend towards an effect of trial uncertainty on facial affect score (b = -0.06, 95% CI [-0.13, 0.00], p = .066). Participants appeared marginally less happy in high uncertainty trials than in low uncertainty trials. IU did not predict facial affect (b = -0.05, 95% CI [-0.18, 0.07], p = .404). Curiosity also did not predict facial affect (b = 0.06, 95% CI [-0.07, 0.19], p = .385). Crucially for our hypotheses, neither IU (b = -0.02, 95% CI [-0.09, 0.04], p = .501) nor curiosity (b = 0.05, 95% CI [-0.02, 0.12], p = .169) significantly interacted with trial uncertainty to predict facial affect. See Table 4 for LMM results. An exploratory analysis including age did not change the pattern or significance of these effects and no two- or three-way interactions with age were significant, see Supplementary Table S10 for the LMM results.

3.2.6 The influence of uncertainty, IU and curiosity on self-reported emotional valence

We hypothesised that higher curiosity would be associated with positive self-reported emotional responses and that higher IU would be associated with negative self-reported emotional responses to uncertain situations, reflected in interactions between trial uncertainty and each individual differences measure. There was a trend towards an effect of trial uncertainty on self-reported emotional valence (b = -0.06, 95% CI [-0.13, 0.00], p = .055), although this was not robust after the rating score was binarised (see Supplementary Table S5). Participants felt marginally less happy on high uncertainty trials than low uncertainty trials. IU did not predict self-reported emotional valence (b = -.07, 95% CI [-0.19, 0.05], p = .266). There was a significant effect of curiosity on self-reported emotional valence score (b = 0.20, 95% CI [0.07, 0.32], p = .002). More curious children reporting feeling happier than less curious children. Crucially for our hypotheses, neither IU (*b* = 0.00, 95% CI [-0.06, 0.07], *p* = .895) nor curiosity (*b* = -0.03, 95% CI [-0.09, 0.04], *p* = .385) significantly interacted with trial uncertainty to predict self-reported emotional valance. See Table 4 for LMM results.

An exploratory analysis including age did not change the pattern or significance of these effects. One significant three-way interaction with age was identified between age, trial uncertainty, and IU (*b* = -0.05, 95% CI [-0.10, -0.01], *p* = .030). Visual inspection of the estimated marginal effects suggests that for younger children, higher IU was related to lower happiness on low uncertainty trials, and for older children, higher IU was related to lower happiness on high uncertainty trials (see Figure 5). However, overlapping confidence intervals suggest caution should be taken interpreting this three-way interaction. See Supplementary Table S10 for the LMM results.

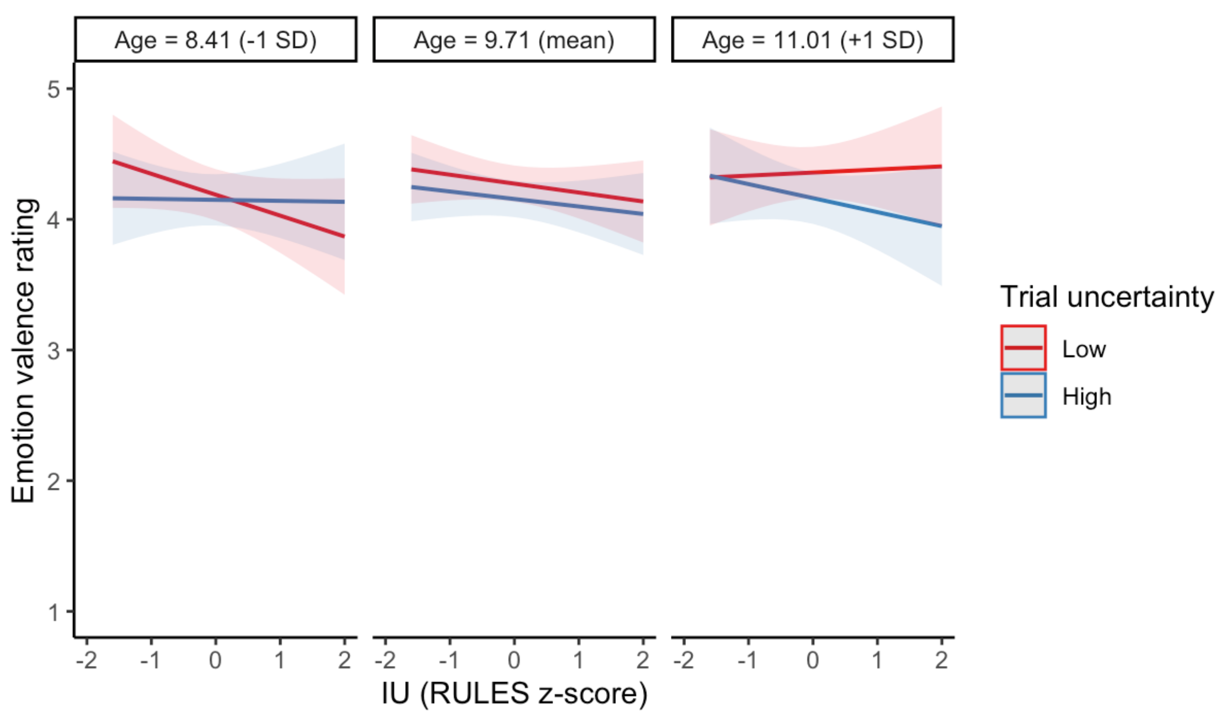


Figure 5. Marginal estimated effects of age, trial uncertainty, and IU on self-reported emotion valence. Ribbons represent 95% confidence intervals around the estimated effects.

3.2.7 The influence of uncertainty, IU and curiosity on self-reported worry

We hypothesised that higher IU would be associated with negative self-reported emotional responses to uncertain situations, reflected in an interaction between trial uncertainty and IU. There was no effect of trial uncertainty on self-reported worry (b = 0.04, 95% CI [-0.01, 0.05], p = .145). IU did not predict self-reported worry score (b = 0.06, 95% CI [-0.03, 0.15], p = .176). Curiosity did not predict self-reported worry score (b = -0.05 , 95% CI [-0.14, 0.04], p = .269). Crucially for our hypothesis, IU (b = -0.00, 95% CI [-0.05, 0.05], p = .953) did not interact with trial uncertainty. Curiosity (b = -0.03, 95% CI [-0.08, 0.02], p = .262) also did not interact with trial uncertainty. See Table 4 for LMM results.

An exploratory analysis including age did not change the pattern or significance of these effects. There was a main effect of age such that children became less worried with age (b = -0.08, 95% CI [-0.15, -0.01], p = .020). A significant three-way interaction with age was identified between age, trial uncertainty, and IU (b = 0.04, 95% CI [0.01, 0.08], p = .021). Visual inspection of the estimated marginal effects suggests that for younger children, higher IU was related to more worry on low uncertainty trials, and for older children, higher IU was related to more worry on high uncertainty trials (see Figure 6). However, overlapping confidence intervals suggest caution should be taken interpreting this three-way interaction. See Supplementary Table S10 for the LMM results.

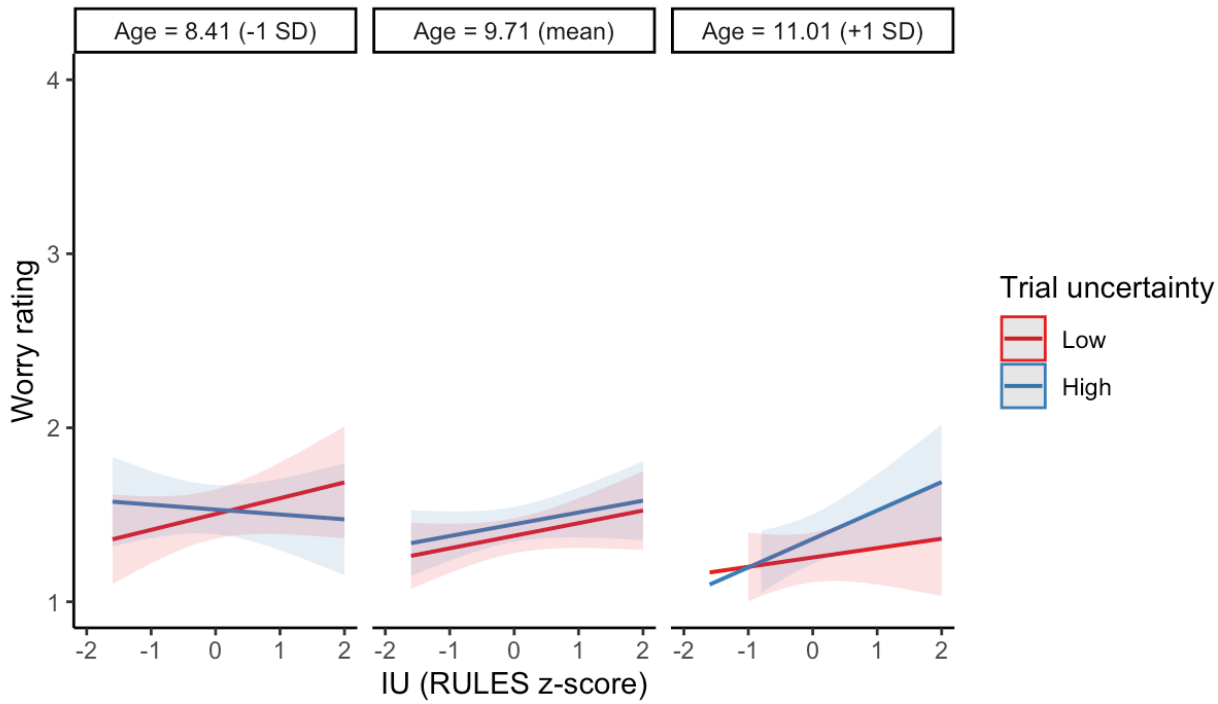


Figure 6. Marginal estimated effects of age, trial uncertainty, and IU on self-reported worry.

Ribbons represent 95% confidence intervals around the estimated effects.

Table 4. LMM results across dependent variables

Fixed effects												
		Button presses			**Facial affect**			**Self-report emotion valance**			**Self-report worry**	
Predictors	*b*	*CI*	*p*	*b*	*CI*	*p*	*b*	*CI*	*p*	*b*	*CI*	*p*
(Intercept)	**18.53**	**18.01 – 19.05**	**<.001**	0.01	-0.12 – 0.14	.872	**4.21**	**4.09 – 4.33**	**<.001**	**1.41**	**1.32 – 1.50**	**<0.001**
Trial uncertainty	0.25	0.01 – 0.49	**.039**	*-0.06*	*-0.13 – 0.00*	*.066*	*-0.06*	*-0.13 – 0.00*	*.055*	0.04	-0.01 – 0.08	0.145
IU (RULES total)	-0.30	-0.82 – 0.23	.268	-0.05	-0.18 – 0.07	.404	-0.07	-0.19 – 0.05	.266	0.06	-0.03 – 0.15	0.176
Curiosity (I/D-YC total)	0.10	-0.43 – 0.62	.716	0.06	-0.07 – 0.19	.385	**0.20**	**0.07 – 0.32**	**.002**	-0.05	-0.14 – 0.04	0.269
Trial uncertainty * IU	0.08	-0.16 – 0.32	.509	-0.02	-0.09 – 0.04	.501	0.00	-0.06 – 0.07	.895	0.00	-0.05 – 0.05	0.953
Trial uncertainty * Curiosity	-0.07	-0.31 – 0.17	.554	0.05	-0.02 – 0.12	.169	-0.03	-0.09 – 0.04	.385	-0.03	-0.08 – 0.02	0.262
Random Effects												
σ^2	0.02			0.62			0.55			0.32		
τ_{00}	0.02 $_{id}$			0.39 $_{id}$			0.37 $_{id}$			0.19 $_{id}$		
ICC	0.48			0.39			0.4			0.38		
N	133 $_{id}$			127 $_{id}$			133 $_{id}$			133 $_{id}$		
Observations	532			503			532			532		
Marginal R^2 / Conditional R^2	0.012 / 0.487			0.014 / 0.394			0.053 / 0.432			0.017 / 0.387		

Note. Trial uncertainty is effect coded, RULES total and I/D-YC total are *z*-scored, Button presses and RULES total are Winsorised. Effects significant at the *p* < .05 level are displayed in bold text, trends at *p* < .10 are displayed in italics.

3.2.8 *Exploratory analyses: Differential effects of Interest-type and Deprivation-type curiosity*

All of the pre-registered analyses were replicated, replacing the full I/D-YC scale score with subscale scores for Interest-type and Deprivation-type curiosity respectively. These were modelled separately to avoid issues of multicollinearity. The pattern and significance of the reported effects did not change as a result of including each subscale. Notably, the main effect of curiosity on self-reported emotion valance was seen for both Interest- (b = 0.18, 95% CI [0.05, 0.30], p = .006) and Deprivation-type (b = 0.17, 95% CI [0.04, 0.29], p = .009) curiosity. More curious children on both subscales reported feeling happier than less curious children. See Supplementary Tables S8 and S9 for LMM results.

3.3 Discussion

This is the first study to examine IU and curiosity together in a child sample. Furthermore, it is one of the first studies to examine how either IU or curiosity, as separate constructs relate to behaviour and affective responses to uncertainty in children. We hypothesised that children higher in IU and higher in curiosity would engage in more information seeking by pressing more buttons during the task. We also hypothesised that IU would be associated with more negative affect in relation to higher uncertainty and that curiosity would be associated with more positive affect in relation to higher uncertainty. Overall, these hypotheses were not supported; children's general behaviour under uncertainty in this task was not clearly associated with trait differences in IU or curiosity. However, further exploratory analyses point towards some nuanced effects, especially with respect to IU. The findings are now discussed in relation to each aim.

Our first aim was to evaluate whether children's information seeking is related to curiosity and IU by examining associations between the number of buttons pressed in the game and parent-reported IU and curiosity. Contrary to our expectations, the number of buttons pressed was not related to IU nor curiosity, however participants overall pressed more buttons in high uncertainty trials than low. Similar to our findings for IU, Osmanağaoğlu et al. (2021) found that pre-adolescent children's information seeking behaviour increased as uncertainty increased, but this was not related to IU. We also expected curious children to seek more information to plug the information gap but no effect of curiosity was found. Children tended to press more buttons in higher uncertainty trials irrespective of parent-reported trait curiosity, which suggests that children are generally driven to resolve uncertainty, with little influence of these individual difference variables.

Exploratory investigation of the types of buttons pressed within each trial suggests slightly more nuanced findings. Although children pressed more buttons in the high uncertainty trials than low uncertainty trials, there was asymmetry in the types of buttons children pressed across the uncertainty conditions. In the high uncertainty trials there were only four certain buttons and in low uncertainty trials there were only four uncertain buttons. Interestingly, children pressed the certain buttons on the high uncertainty trials more often than they pressed the uncertain buttons on low uncertainty trials. Furthermore, this effect was moderated by IU such that the asymmetry was greatest for children high in IU. This increased pressing of the certain buttons in high uncertainty trials could be a checking or safety-seeking behaviour – behaviours that are used to manage the stress of an uncertain or threatening situation (Rachman, 1976; Thwaites & Freeston, 2005). Importantly, this interaction suggests that although IU was not related to quantitative differences in overall button pressing, it was related to qualitative differences in which buttons were pressed. In adults, IU is known to be related to checking and safety seeking behaviours (Fourtounas & Thomas, 2016; Freeston & Komes, 2023; Hebert & Dugas, 2019), but to our knowledge, this is the first tentative evidence of such a behavioural manifestation of IU in children.

Our second aim was to evaluate whether curiosity was related to positive emotional responses to uncertainty by examining associations between parent-reported curiosity and both the child's facial affect and self-reported emotional valence during the game. We expected curiosity would be related to positive affect as per Jovanovic and Brdaric (2012) and Kashdan et al. (2004)'s findings in adolescents and adults respectively. We indeed found a small association between curiosity and self-reported positive emotional responses to uncertainty. This effect was robust across both Interest- and Deprivation-type curiosity, suggesting that these sub-types may not have differential associations with affect in childhood. The effect of curiosity on emotion valence was not moderated by level of uncertainty and was not observable in the facial expression data. Whilst this result may support a direct link between curiosity as a trait and positive affect, it is also possible that this link might be driven by the wording of items on the I/D-YC curiosity measure. For example, some questions such as "My child shows visible enjoyment when discovering something new" and "My child has fun learning about new topics or subjects" may capture expression of positive affect. This would explain why curiosity was related to overall happiness, rather than to more positive responses under higher uncertainty. An alternative explanation is that both the high and low uncertainty conditions led to uncertainty-related positive affect because both conditions involve some uncertainty. Having a condition with no uncertainty would have aided interpretation and allowed us to clarify whether the presence of some uncertainty is sufficient to make the more curious children happier or whether they are happier than those low in curiosity even when there is no uncertainty present.

Our final aim was to evaluate whether IU was associated with negative emotional responses to uncertainty. Contrary to our expectations, there were no significant associations or interactions between IU and negative facial affect, self-reported emotional valence or worry. Aligning with our findings about worry, Osmanağaoğlu et al. (2021) found the same lack of worry during a lab-based task in children who were high in parent-reported IU, although they did find associations between child-reported IU and worry. It seems possible given these findings that parent-report IU may not relate to internal states associated with uncertainty, perhaps because they are harder to observe. Thus, it will be important for future research to include child-report measures to further explore this question.

Overall, our findings related to IU were unexpected; for those high in IU, uncertainty elicited neither a negative emotional response, nor increased information seeking. This could be because the parent-report IU questionnaire does not effectively capture associations between IU and affective and behavioural responses to uncertain situations. An alternative explanation is that behavioural and affective responses that are linked to IU are only elicited when sufficient threat is present. It has been theorised that IU is an aversion to uncertainty itself (Carleton, 2016b), however previous research has suggested that the presence of threat may be important (Osmanağaoğlu et al., 2018; Tanovic et al., 2018). Our task may not have included enough threat to stimulate these negative responses. Although participants found the aversive sounds to be relatively negative, they may not have been unpleasant enough to elicit threat-related responses. Future research could address this by introducing a condition with uncertainty but no threat whatsoever, and additional conditions with varying levels of threat (cf., Morriss et al. (2021)'s work with adults).

A further alternative explanation is that, given that children could choose whether or not to press buttons during each of the four trials, they may have felt control over their exposure to the sounds. Indeed, our exploratory analyses suggest that children with high IU operated this control by pressing proportionally more certain buttons on uncertain trials. Having this control may have influenced the children's self-reported worry or affect and may not have induced IU. Future research could address this by manipulating level of control. Control could also be given by allowing children to decide when to end of the trial, rather than having a fixed time interval in which button presses are measured. This would ensure that the number of button presses truly reflects each individuals' desire for information.

Another possibility is that the relationship between IU and affective responses to uncertainty emerges during middle childhood and would be more prevalent in an older sample. In a series of exploratory analyses, we investigated interactions with age and found that for both self-reported emotion valence and worry, the interaction between trial uncertainty and IU varies by age, with the oldest children in the sample appearing to show the hypothesised pattern of results; IU was related to less happiness and more worry in high uncertainty trials but not in low uncertainty trials. We interpret these exploratory findings with extreme caution because of their exploratory nature and because of overlapping confidence intervals around the marginal estimated effects. We also note that a previous meta-analysis found that age did not moderate the relationship between IU and worry more generally (Osmanağaoğlu et al., 2018). Future research should investigate whether the specific relationship between uncertainty and worry in children with high IU emerges developmentally between the ages of 8 and 12 years, as this may have clinical relevance.

As the first study to examine relationships between curiosity, IU, and behavioural and affective responses to uncertainty in children, this study has several strengths. An important strength is that our manipulation check showed that the task design was successful at manipulating children's feelings of uncertainty; children reported feeling less sure in high uncertainty trials than low uncertainty trials. This is in line with recent findings suggesting that children's understanding of terms relating to uncertainty reaches adult levels at around 9 years of age (Meder et al., 2022). Children also sought more information in the uncertain trials, as expected, and their facial affect and self-reported emotion trended towards children feeling less happy in uncertain trials. Furthermore, the aversive sounds were rated more negatively than the neutral sounds. There was also a significant correlation between our measure of facial affect and children's self-reported emotion valence. Thus, we can be confident that the lack of support for some of our hypotheses does not indicate a design issue with the task; but instead suggests that effects of individual differences in curiosity and IU may not universally affect children's behavioural or affective responses to uncertainty. A further strength to this study is that it investigates the rarely examined behavioural and affective correlates of IU and curiosity in children. We took an approach that extended the current literature by examining information seeking alongside individual differences in children.

There are however some limitations to the study. One limitation that the uncertainty manipulation check revealed is that while children reported feeling more unsure in the higher uncertainty trials than low, overall they reported feeling quite sure, and the difference between high and low uncertainty trials was small, and was reduced to a trend when the ratings were binarised. Children's reported lack of uncertainty is particularly surprising since before each trial, children did not know what sounds they were going to hear in either condition. It is possible that children's interpretation of uncertainty is biased such that they are more confident in the face of uncertainty than adults. Previous research has found that young children tend to be overconfident in relation to their performance in a task (Newman & Wick, 1987; Roebers, 2002) and in the face of uncertainty (Beck et al., 2011; Lapidow et al., 2022). As children have so much uncertainty in their lives as they learn and develop, overconfidence in the face of uncertainty may be an adaptive strategy for coping. The limited number of sounds used in each trial may also have led to a limited sense of uncertainty. Increasing the number of sounds so that each button produces a different sound could increase children's perceived uncertainty in the task.

A further limitation is that due to the Covid-19 pandemic, the task was run from participants own homes, therefore we could not control the environment in which the child participated, and we could not control the volume of the sounds the buttons made when clicked. Video coding facial affect was particularly challenging, possibly because the design may not be leading to a strong enough emotional response in children. Additionally, the inter-rater reliability for the facial affect coding was only modest and facial affect scores were only weakly correlated with children's self-reported affect and not correlated with self-reported worry, therefore these results need to be interpreted with caution. The children had a relatively flat affect during the anticipation phase, however recent work argues that facial expressions do not correspond well to emotional states (Barrett et al., 2019) so it may not be a reliable or appropriate method for evaluating affect. Using and refining creative measures to examine affect however should be continued to be explored. For example, Outters et al. (2023) have used body posture change as an indicator of positive affect and task engagement.

Although there are adult behavioural measures to examine reactions to uncertainty (e.g., (Jacoby et al., 2016)), there is little convincing evidence yet that IU, as measured by questionnaires, predicts behaviour in children. More generally, a limiting factor in research of this kind is the lack of validated questionnaires that can reliably capture individual differences in children's responses to uncertainty, making it difficult to tease apart the contributions of different constructs such as IU, curiosity, and other related constructs such as tolerance of ambiguity. Since this study was conducted, a new measure of IU, the Youth Intolerance of Uncertainty – Parent-Report (YIU-PR) (Wong & Caporino, 2023) has been developed which is intended as a developmentally sensitive measure of IU in children and adolescents and may be a more suitable measure of IU in young people going forward. It showed excellent internal consistency and evidenced convergent and discriminant validity. It would be informative to determine whether this new measure is related to Deprivation-type curiosity in children as has been found in adults (Jach et al., 2022; Jach & Smillie, 2021), since we did not replicate this relationship with the RULES as a measure of IU.

Additionally, future research would benefit from focusing on children's thoughts and behaviour in relation to uncertainty and uncertain situations in real life, perhaps using qualitative methods, observational or diary measures. This could inform further experimental work with children. As there is an increasing interest in developing treatments for child anxiety that target reactions to uncertainty specifically, we need a much clearer idea about how responses to uncertainty in children high in IU are distinct to ensure these interventions target the right mechanisms. Understanding curiosity and responses to uncertainty further would also inform educational policies, approaches and interventions, especially that focus on building motivation for learning.

3.3.1 Conclusion

IU did not predict children's emotional responses or the quantity of information seeking during an uncertain task. Exploratory analyses suggest that IU may be associated with the nature of children's information seeking, with children who are high in IU engaging in more information seeking that reflects checking or safety-seeking than those who are low in IU. Additionally, our findings suggest that there may be age-related change in the effects of IU on worry, with IU more strongly related to worry in uncertain situations for older children than younger children. Children higher in curiosity reported feeling happier whilst completing the task but more uncertainty did not increase happiness in these children. In general children sought more information under higher uncertainty, but this was not related to curiosity or IU. Future research should focus on establishing how IU manifests in children, monitoring for qualitative as well as quantitative differences in behaviour, and how curiosity can be harnessed to support motivation and learning.

3.3.2 Acknowledgements

The authors would like to thank all of the families that took part in the study. Thanks also to Chris Morea for his help in developing the coding scheme for facial affect and for all of his help coding the videos, to Dr Anthony Haffey and Dr Dan Brady for their help writing the code for the first version of the game, and to Dr Bowen Ruan for his help when we began development of this task.

3.3.3 Declaration of Conflicting Interests

The Authors declare that there is no conflict of interest.

3.3.4 Funding

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by the Experimental Psychology Society (EPS) Small Grant Scheme, awarded to LF.

3.4 References

Barrett, L. F., Adolphs, R., Marsella, S., Martinez, A. M., & Pollak, S. D. (2019). Emotional expressions reconsidered: Challenges to inferring emotion from human facial movements. *Psychological science in the public interest*, *20*(1), 1-68.

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2014). Fitting linear mixed-effects models using lme4. *arXiv preprint arXiv:1406.5823*.

Beck, S. R., McColgan, K. L. T., Robinson, E. J., & Rowley, M. G. (2011). Imagining what might be: Why children underestimate uncertainty. *Journal of Experimental Child Psychology*, *110*(4), 603-610. https://doi.org/https://doi.org/10.1016/j.jecp.2011.06.010

Bennett, D., Sutcliffe, K., Tan, N. P. J., Smillie, L. D., & Bode, S. (2020). Anxious and obsessive-compulsive traits are independently associated with valuation of noninstrumental information. *Journal of Experimental Psychology: General*, *150*(4), 739-755. https://doi.org/10.1037/XGE0000966

Bradley, M. M., & Lang, P. J. (1994). MEASURING EMOTION: THE SELF-ASSESSMENT MANIKIN AND THE SEMANTIC DIFFERENTIAL. *I. B&w Thu. & Exp. Psvchrar*, *25*(I), 49-59.

Bradley, M. M., & Lang, P. J. (2007). The International Affective Digitized Sounds (2nd Edition; IADS-2): Affective ratings of sounds and instruction manual. Technical report B-3. *University of Florida, Gainesville, Fl.*

Cacioppo, J. T., Petty, R. E., Losch, M. E., & Kim, H. S. (1986). Electromyographic activity over facial muscle regions can differentiate the valence and intensity of affective reactions. *Journal of personality and social psychology*, *50*(2), 260.

Callanan, M. A., & Oakes, L. M. (1992). Preschoolers' questions and parents' explanations: Causal thinking in everyday activity. *Cognitive Development*, *7*(2), 213-233. https://doi.org/10.1016/0885-2014(92)90012-G

Carleton, R. N. (2016a). Fear of the unknown: One fear to rule them all? *Journal of Anxiety Disorders*, *41*, 5-21. https://doi.org/https://doi.org/10.1016/j.janxdis.2016.03.011

Carleton, R. N. (2016b). Into the unknown: A review and synthesis of contemporary models involving uncertainty. *Journal of Anxiety Disorders*. https://doi.org/10.1016/j.janxdis.2016.02.007

de Leeuw, J. R. (2014). jsPsych: A JavaScript library for creating behavioral experiments in a Web browser. *Behavior Research Methods 2014 47:1*, *47*(1), 1-12. https://doi.org/10.3758/S13428-014-0458-Y

Dugas, M. J., Gagnon, F., Ladouceur, R., & Freeston, M. H. (1998). Generalized anxiety disorder: a preliminary test of a conceptual model. *Behaviour Research and Therapy*, *36*(2), 215-226. https://doi.org/10.1016/S0005-7967(97)00070-3

Dugas, M. J., Gosselin, P., & Ladouceur, R. (2001). Intolerance of uncertainty and worry: Investigating specificity in a nonclinical sample. *Cognitive Therapy and Research*, *25*(5), 551-558.

Ekman, P., & Friesen, W. V. (1978). Facial action coding system. *Environmental Psychology & Nonverbal Behavior*. 1(1), 56-75.

FitzGibbon, L., Komiya, A., & Murayama, K. (2021). The lure of counterfactual curiosity: People incur a cost to experience regret. *Psychological Science*, *32*(2), 241-255.

Fourtounas, A., & Thomas, S. J. (2016). Cognitive factors predicting checking, procrastination and other maladaptive behaviours: Prospective versus Inhibitory Intolerance of Uncertainty. *Journal of Obsessive-Compulsive and Related Disorders*, *9*, 30-35. https://doi.org/https://doi.org/10.1016/j.jocrd.2016.02.003

Frazier, B. N., Gelman, S. A., & Wellman, H. M. (2009). Preschoolers' search for explanatory information within adult-child conversation. *Child Development*, *80*(6), 1592-1611. https://doi.org/10.1111/j.1467-8624.2009.01356.x

Freeston, M., & Komes, J. (2023). Revisiting uncertainty as a felt sense of unsafety: The somatic error theory of intolerance of uncertainty. *Journal of Behavior Therapy and Experimental Psychiatry*, *79*, 101827. https://doi.org/https://doi.org/10.1016/j.jbtep.2022.101827

Gottfried, A. E., Preston, K. S. J., Gottfried, A. W., Oliver, P. H., Delany, D. E., & Ibrahim, S. M. (2016). Pathways from parental stimulation of children’s curiosity to high school science course accomplishments and science career interest and skill. *International Journal of Science Education*, *38*(12), 1972-1995.

Grossnickle, E. M. (2016). Disentangling curiosity: Dimensionality, definitions, and distinctions from interest in educational contexts. *Educational Psychology Review*, *28*(1), 23-60.

Gruber, Matthias J., Gelman, Bernard D., & Ranganath, C. (2014). States of Curiosity Modulate Hippocampus-Dependent Learning via the Dopaminergic Circuit. *Neuron*, *84*(2), 486-496. https://doi.org/https://doi.org/10.1016/j.neuron.2014.08.060

Grupe, D. W., & Nitschke, J. B. (2011). Uncertainty is associated with biased expectancies and heightened responses to aversion. *Emotion*, *11*(2), 413-424. https://doi.org/10.1037/a0022583

Hebert, E. A., & Dugas, M. J. (2019). Behavioral Experiments for Intolerance of Uncertainty: Challenging the Unknown in the Treatment of Generalized Anxiety Disorder. *Cognitive and Behavioral Practice*, *26*(2), 421-436. https://doi.org/10.1016/J.CBPRA.2018.07.007

Hillen, M. A., Gutheil, C. M., Strout, T. D., Smets, E. M. A., & Han, P. K. J. (2017). Tolerance of uncertainty: Conceptual analysis, integrative model, and implications for healthcare. *Social Science and Medicine*, *180*, 62-75. https://doi.org/10.1016/j.socscimed.2017.03.024

Hsee, C. K., & Ruan, B. (2016). The Pandora Effect: The Power and Peril of Curiosity. *Psychological Science*, *27*(5), 659-666. https://doi.org/10.1177/0956797616631733

Jach, H. K., DeYoung, C. G., & Smillie, L. D. (2022). Why do people seek information? The role of personality traits and situation perception. *Journal of Experimental Psychology: General*, *151*(4), 934.

Jach, H. K., & Smillie, L. D. (2021). Testing the Information-Seeking Theory of Openness/Intellect. *European Journal of Personality*, *35*(1), 103-119. https://doi.org/10.1002/per.2271

Jacoby, R. J., Abramowitz, J. S., Buck, B. E., & Fabricant, L. E. (2014). How is the Beads Task related to intolerance of uncertainty in anxiety disorders? *Journal of Anxiety Disorders*, *28*(6), 495-503. https://doi.org/10.1016/J.JANXDIS.2014.05.005

Jacoby, R. J., Abramowitz, J. S., Reuman, L., & Blakey, S. M. (2016). Enhancing the ecological validity of the Beads Task as a behavioral measure of intolerance of uncertainty. *J Anxiety Disord*, *41*, 43-49. https://doi.org/10.1016/j.janxdis.2016.02.003

Jansen, B., Dekkers, T., & van Schijndel, T. (2021). A novel approach to the assessment of curiosity. PsyArXiv. https://doi.org/10.31234/osf.io/zesbw

Jirout, J., & Klahr, D. (2012). Children's scientific curiosity: In search of an operational definition of an elusive concept. In *Developmental Review* (Vol. 32, pp. 125-160).

Jovanovic, V., & Brdaric, D. (2012). Did curiosity kill the cat? Evidence from subjective well-being in adolescents. *Personality and Individual Differences*, *52*(3), 380-384. https://doi.org/https://doi.org/10.1016/j.paid.2011.10.043

Kashdan, T. B., Rose, P., & Fincham, F. D. (2004). Curiosity and Exploration: Facilitating Positive Subjective Experiences and Personal Growth Opportunities. *Journal of Personality Assessment*, *82*(3), 291-305. https://doi.org/10.1207/s15327752jpa8203_05

Kidd, C., & Hayden, B. Y. (2015). The Psychology and Neuroscience of Curiosity. *Neuron*, *88*(3), 449-460. https://doi.org/10.1016/J.NEURON.2015.09.010

Kidd, C., Piantadosi, S. T., & Aslin, R. N. (2012). The Goldilocks effect: Human infants allocate attention to visual sequences that are neither too simple nor too complex. *PLOS ONE*, *7*(5), e36399.

Koerner, N., & Dugas, M. J. (2008). An investigation of appraisals in individuals vulnerable to excessive worry: the role of intolerance of uncertainty. *Cognitive Therapy and Research*, *32*(5), 619-638. https://doi.org/10.1007/s10608-007-9125-2

Krain, A. L., Gotimer, K., Hefton, S., Ernst, M., Castellanos, F. X., Pine, D. S., & Milham, M. P. (2008). A Functional Magnetic Resonance Imaging Investigation of Uncertainty in Adolescents with Anxiety Disorders. *Biological Psychiatry*, *63*(6), 563-568. https://doi.org/10.1016/j.biopsych.2007.06.011

Krain, A. L., Hefton, S., Pine, D. S., Ernst, M., Xavier Castellanos, F., Klein, R. G., & Milham, M. P. (2006). An fMRI examination of developmental differences in the neural correlates of uncertainty and decision-making. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *47*(10), 1023-1030. https://doi.org/10.1111/j.1469-7610.2006.01677.x

Kruglanski, A. W., Jasko, K., & Friston, K. (2020). All Thinking is 'Wishful' Thinking. *Trends in Cognitive Sciences*, *24*(6), 413-424. https://doi.org/10.1016/j.tics.2020.03.004

Lapidow, E., Killeen, I., & Walker, C. M. (2022). Learning to recognize uncertainty vs. recognizing uncertainty to learn: Confidence judgments and exploration decisions in preschoolers. *Developmental science*, *25*(2), e13178.

Litman, J. (2005). Curiosity and the pleasures of learning: Wanting and liking new information. *Cognition & emotion*, *19*(6), 793-814.

Litman, J. A. (2008). Interest and deprivation factors of epistemic curiosity. *Personality and Individual Differences*, *44*, 1585-1595. https://doi.org/10.1016/j.paid.2008.01.014

Litman, J. A., & Silvia, P. J. (2006). The latent structure of trait curiosity: Evidence for interest and deprivation curiosity dimensions. *Journal of Personality Assessment*, *86*(3), 318-328.

Meder, B., Mayrhofer, R., & Ruggeri, A. (2022). Developmental Trajectories in the Understanding of Everyday Uncertainty Terms. *Topics in Cognitive Science*, *14*(2), 258-281. https://doi.org/https://doi.org/10.1111/tops.12564

Morriss, J., Bennett, K. P., & Larson, C. L. (2021). I told you it was safe: Associations between intolerance of uncertainty and different parameters of uncertainty during instructed threat of shock. *Journal of Behavior Therapy and Experimental Psychiatry*, *70*, 101620. https://doi.org/https://doi.org/10.1016/j.jbtep.2020.101620

Newman, R. S., & Wick, P. L. (1987). Effect of age, skill, and performance feedback on children's judgments of confidence. *Journal of Educational Psychology*, *79*(2), 115-119. https://doi.org/10.1037/0022-0663.79.2.115

Osmanağaoğlu, N., Creswell, C., & Dodd, H. F. (2018). Intolerance of Uncertainty, anxiety, and worry in children and adolescents: A meta-analysis. *Journal of Affective Disorders*, *225*, 80-90. https://doi.org/10.1016/J.JAD.2017.07.035

Osmanağaoğlu, N., Creswell, C., & Dodd, H. F. (2021). Development of a behavioural measure of Intolerance of Uncertainty in preadolescent children: Adaptation of the beads task. *Journal of Behavior Therapy and Experimental Psychiatry*, *72*, 101654-101654. https://doi.org/10.1016/J.JBTEP.2021.101654

Outters, V., Hepach, R., Behne, T., & Mani, N. (2023). Children’s affective involvement in early word learning. *Scientific reports*, *13*(1), 7351. https://doi.org/10.1038/s41598-023-34049-3

Piotrowksi, J. T., Litman, J. A., & Valkenburg, P. (2014). Measuring Epistemic Curiosity in Young Children. *Infant and Child Development*, *23*(5), 542-553. https://doi.org/10.1002/icd.1847

R Core Team. (2022). *R: A language and environment for statistical computing.* . In R Foundation for Statistical Computing. https://www.R-project.org/

Rachman, S. (1976). Obsessional-compulsive checking. *Behaviour Research and Therapy*, *14*(4), 269-277.

Roebers, C. M. (2002). Confidence judgments in children's and adult's event recall and suggestibility. *Developmental psychology*, *38*(6), 1052.

Rosen, N. O., & Knäuper, B. (2009). A little uncertainty goes a long way: State and trait differences in uncertainty interact to increase information seeking but also increase worry. *Health communication*, *24*(3), 228-238.

Sanchez, A. L., Cornacchio, D., Chou, T., Leyfer, O., Coxe, S., Pincus, D., & Comer, J. S. (2017). Development of a scale to evaluate young children's responses to uncertainty and low environmental structure. *Journal of Anxiety Disorders*, *45*, 17-23. https://doi.org/10.1016/J.JANXDIS.2016.11.006

Schulz, L. E., & Bonawitz, E. B. (2007). Serious fun: Preschoolers engage in more exploratory play when evidence is confounded. *Developmental psychology*, *43*(4), 1045-1050. https://doi.org/10.1037/0012-1649.43.4.1045

Shah, P. E., Weeks, H. M., Richards, B., & Kaciroti, N. (2018). Early childhood curiosity and kindergarten reading and math academic achievement. *Pediatric Research*, *84*(3), 380-386. https://doi.org/10.1038/s41390-018-0039-3

Shoshani, A. (2019). Young children's character strengths and emotional well-being: Development of the Character Strengths Inventory for Early Childhood (CSI-EC). *The Journal of Positive Psychology*, *14*(1), 86-102. https://doi.org/10.1080/17439760.2018.1424925

Stewart, J. L., Mishel, M. H., Lynn, M. R., & Terhorst, L. (2010). Test of a Conceptual Model of Uncertainty in Children and Adolescents With Cancer. *Research in Nursing & Health*, *33*, 179-191. https://doi.org/10.1002/nur.20374

Syed, M., & Nelson, S. C. (2015). Guidelines for establishing reliability when coding narrative data. *Emerging Adulthood*, *3*(6), 375-387.

Tanovic, E., Gee, D. G., & Joormann, J. (2018). Intolerance of uncertainty: Neural and psychophysiological correlates of the perception of uncertainty as threatening. *Clinical Psychology Review*, 1-0. https://doi.org/10.1016/j.cpr.2018.01.001

Thwaites, R., & Freeston, M. H. (2005). Safety-seeking behaviours: fact or function? How can we clinically differentiate between safety behaviours and adaptive coping strategies across anxiety disorders? *Behavioural and Cognitive Psychotherapy*, *33*(2), 177-188.

van Lieshout, L. L., de Lange, F. P., & Cools, R. (2021). Uncertainty increases curiosity, but decreases happiness. *Scientific reports*, *11*(1), 1-10.

van Schijndel, T. J. P., Jansen, B. R. J., & Raijmakers, M. E. J. (2018). Do individual differences in children's curiosity relate to their inquiry-based learning? *International Journal of Science Education*, *40*(9), 996-1015. https://doi.org/10.1080/09500693.2018.1460772

von Stumm, S., Hell, B., & Chamorro-Premuzic, T. (2011). The Hungry Mind:Intellectual Curiosity Is the Third Pillar of Academic Performance. *Perspectives on Psychological Science*, *6*(6), 574-588. https://doi.org/10.1177/1745691611421204

Whitecross, W. M., & Smithson, M. (2023). Curiously different: Interest-curiosity and deprivation-curiosity may have distinct benefits and drawbacks. *Personality and Individual Differences*, *213*, 112310. https://doi.org/https://doi.org/10.1016/j.paid.2023.112310

Wong, J. X., & Caporino, N. E. (2023). Youth Intolerance of Uncertainty – Parent-Report (YIU-PR): A Developmentally Sensitive Measure of Intolerance of Uncertainty in Children and Adolescents. *Journal of Psychopathology and Behavioral Assessment*, *45*(1), 194-206. https://doi.org/10.1007/s10862-022-10016-6

Joining Statement for Chapters 3 and 4

The surprising and unexpected results in the Uncertain World child study where children's individual differences in IU and curiosity did not influence their behaviour and affect under uncertainty provided motivation to conduct the same task with adults. There is limited research examining curiosity and IU together, and also limited research exploring how IU is related to behaviour and affect in adults. We therefore felt that a paper using the Uncertain World task with adult participants would make a standalone contribution to the adult literature on IU. We kept the task the same to facilitate comparison with the child study. The third aim of the adult study therefore is to consider how findings relate to those found for children in Study 2.

Chapter 4. Study 3: Uncertain World: How Adults' Curiosity and Intolerance of Uncertainty Relate to their Behaviour and Emotion under Uncertainty, and how it compares with children.

Manuscript in preparation for submission to Cognition and Emotion

Ryan, Z.J., Dodd, H.F., Morriss, J. & FitzGibbon, L. Uncertain World: How Adults' Curiosity and Intolerance of Uncertainty Relate to their Behaviour and Emotion under Uncertainty. Manuscript in preparation.

Appendices Associated with this Chapter:

Abstract

Those who experience uncertainty may respond to it positively or negatively, and may be motivated to seek information to deal with the associated information gap. Those who are curious may find uncertainty rewarding and may enjoy filling that information gap, however those who experience intolerance of uncertainty (IU) may find the uncertainty unpleasant and may fill the information gap to reduce their discomfort. There is limited research examining IU and curiosity together in conjunction with emotional and behavioural responses to uncertainty. We have taken an existing task designed for children and have used it with adults, aiming to examine how individual differences in IU and curiosity relate to behavioural and emotional responses to uncertainty, and how these responses differ in children and adults. 133 university students self-reported IU and curiosity measures, and completed the game where participants were presented with an array of buttons which played sounds when pressed. Each button played an aversive or neutral sound, and was labelled as either certain neutral, certain aversive, or uncertain. The game consisted of four trials which together gave an index of information seeking. Participants self-reported affect and worry during an anticipation period. Analyses revealed that more curious adults sought more information than the less curious, and those with higher interest-type curiosity were marginally happier than those with lower interest-type curiosity. Those with higher IU were less happy and more worried during the game, particularly in high uncertainty trials but did not seek more information. In general, participants were less happy but did not seek more information under higher uncertainty. Adult results mostly differed from child results, however both children and adults were happier in low uncertainty trials than in high and the more curious children and the higher the interest-type curiosity in adults were, the happier they were. Findings suggest that individual differences are more closely related to greater emotional responses to

uncertainty than behavioural reactions in adults, and that the impact of IU and curiosity on responses to uncertainty may change with age.

4 Introduction

Everyday life is filled with uncertainty. We all respond to this uncertainty differently and responses can be positive or negative (Hillen et al., 2017). Some individuals respond to uncertainty with curiosity, wishing to learn and increase their knowledge (Gruber et al., 2014; von Stumm et al., 2011). Others feel anxious and worried in response to uncertainty (Buhr & Dugas, 2002; Counsell et al., 2017; Holaway et al., 2006; Sexton & Dugas, 2009). These individuals can be described as having high intolerance of uncertainty (IU). Both IU and curiosity are individual difference factors that are associated with responses to uncertainty but there is little research examining the two constructs together in relation to behavioural or emotional responses to uncertainty.

Curiosity has been defined as ‘the threshold of desired uncertainty in the environment which leads to exploratory behavior’ (Jirout & Klahr, 2012, p. 150), placing uncertainty as a precursor to curiosity (Loewenstein, 1994). Following this definition, curious people tend to seek information in order to plug an information gap and the resulting knowledge acquisition is rewarding (Kang et al., 2009; Murayama et al., 2019). This reward is salient enough that curious individuals will seek information even if the outcome is negative (Hsee & Ruan, 2016). Associations between information seeking behaviour and curiosity have been examined experimentally by van Lieshout, Traast, et al. (2021) using a lottery task. They found that curiosity increased as uncertainty increased, that curiosity was higher for gains than for losses and that individuals in general were willing to seek information even if it was costly in order to satisfy their curiosity. They concluded that there are two motives behind curiosity; one being to reduce uncertainty (regardless of whether the expected outcome is negative or positive), and one being to maximise positive information (for gains moreso than losses in the lottery task). Hsee and Ruan

(2016) also explored curiosity by examining information seeking in the face of uncertainty through a series of tasks. For example, in one of their tasks participants were presented with an array comprising buttons labelled as “certain” or “uncertain”. “Certain” labelled buttons were labelled as positive or negative and, when pressed, they played aversive or neutral sounds predictably. In contrast “uncertain” buttons played either a neutral sound or an aversive sound, when pressed, with the sound unpredictable. There were two conditions. In the certain condition the array comprised 44 certain and 4 uncertain buttons, and vice versa for the uncertain condition. Hsee and Ruan (2016) found that participants pressed more buttons in the uncertain condition than the certain condition. Furthermore, the more buttons the participants pressed, the less happy they reported feeling, and participants in the uncertain condition were significantly less happy than those in the certain condition. Thus, it appears that uncertainty may lead individuals to seek information to reduce the uncertainty, even when there is a possibility of a negative outcome and when it comes at a cost emotionally. It is unclear whether and how individual differences such as curiosity and IU influence information seeking behaviours and affect under uncertainty.

Litman (2008) suggested that information seeking acts as a reward in two different dimensions of curiosity, interest and deprivation types. In interest-type curiosity, individuals find discovering something new enjoyable, and in deprivation-type curiosity, gaining information where they feel it is lacking brings reward. These dimensions suggest some nuance with regards to affect accompanying curiosity, as interest-type has been related to happiness (Whitecross & Smithson, 2023) and is likely to be associated with positive feelings about information. In contrast, deprivation type is associated with unpleasant feelings until information is gained. In addition to this, Bar-Anan et al. (2009) theorised that uncertainty makes positive affect stronger. In fact, Kashdan et al. (2004) posit that curious adults have more positive affect and better life satisfaction. In contrast, van Lieshout, de Lange, et al. (2021) have argued, based on their research, that state curiosity increases with uncertainty but happiness decreases. This discrepancy regarding the affective response to uncertainty in people high in curiosity requires further exploration.

Although some find uncertainty positive, others may find uncertainty aversive, even if the outcome is not likely to be negative (Carleton, 2016a). IU is defined as a "dispositional incapacity to endure the aversive response triggered by the perceived absence of salient, key, or sufficient information, and sustained by the associated perception of uncertainty" (Carleton, 2016b, p. 32). In those high in IU the aversive response triggered by uncertainty is often anxiety and worry, with high IU robustly associated with worry across adults and children (Buhr & Dugas, 2002; Koerner & Dugas, 2008; Osmanağaoğlu et al., 2018; Sexton & Dugas, 2009). This aversive response likely occurs because of dysfunctional processing of uncertainty (Grupe & Nitschke, 2011). The behaviour of those high in IU in response to uncertainty may appear to be like that of those who are curious, however the motivations may well be different; in curiosity information seeking could be driven by a motivation to increase knowledge and in IU, it may be driven by a desire to decrease discomfort. Indeed, the desire for information is so strong in those who find uncertainty aversive that they seek it even at a cost (Bennett et al., 2020). Those who find uncertainty aversive or are high in IU may be hypervigilant to threat under uncertainty, and may practice safety behaviours (Hebert & Dugas, 2019; Mathews & MacLeod, 2002) such as information seeking to reduce the discomfort associated with uncertainty (Krohne, 1993), however these certainty-seeking behaviours only provide relief on a temporary basis (Jacoby, 2020). As previously discussed, Bar-Anan et al. (2009) theorised that uncertainty makes positive affect stronger, however they also theorized that it makes negative affect stronger, so within a negative context uncertainty may be aversive and lead to increased negative affect. In further support of this, Einstein (2014) has also suggested that people high in IU can have increased negative affect under uncertainty.

There has been limited research examining behaviour and emotion together in relation to IU. In one such study, Jacoby et al. (2014) examined IU and its associations with anxiety and information seeking through a probabilistic inference task (The Beads Task) where participants selected beads one by one from an unseen jar and had to guess which of a variety of jars they came from. Each jar had coloured beads with differing ratios, providing different levels of uncertainty. They found that self-reported IU was related to increased levels of distress in the game, however there were no significant associations between information seeking and IU. This suggests that it may be a person's emotions rather than behavior that can differentiate between high and low IU. In another study examining IU and behavioural responses to uncertainty, but not affect, uncertainty was manipulated experimentally via an aptitude test, which was claimed to be either excellent or poor at predicting outcomes (high and low relevance conditions respectively). Bartoszek et al. (2022) gave participants the opportunity to ask questions and request feedback. They found that in a high relevance condition (with the test being an excellent predictor of outcomes), both those high and low in IU sought information, however in the low relevance condition (where the test is a poor predictor of outcomes), those low in IU sought less information than those high in IU. This suggests that despite the fact that the test was not likely to have an impact or importance to those high in IU, they still wished to seek information to fill the information gap, potentially to soothe their discomfort with the uncertainty. One of these studies showed no indication that IU is related to behaviour under uncertainty, but shows IU being related to emotion, whereas the other study shows IU being related to information seeking behaviour.

The relationship between IU, behaviour and affect is therefore unclear and further research is required.

Although curiosity and IU are both linked to responses to uncertainty, to our knowledge there are currently only two papers examining the relationship between them in relation to responses to uncertainty (Jach & Smillie, 2021; Ryan et al., 2023). Jach and Smillie (2021) conducted two studies examining the relationship between information seeking, IU and curiosity in adults. In the first study, there were five guessing games where, for example, participants were shown pictures of fruit and were asked to choose which piece of fruit was secretly rotten. Participants were then asked if they would like to see which piece of fruit was indeed rotten. Once they had completed all of the games, they were informed that they had won a bonus, and were asked if they would like to see which game led them to winning this bonus. Participants' responses across tasks were combined to create an information seeking variable. A relationship was found between information seeking and curiosity, although it was relatively weak, and no significant relationship was found between information seeking and IU. Jach's second study had a similar design but at the end of each of the five games, participants could choose to know straight away if they had won the bonus, providing an immediate reduction in uncertainty, and giving a further information seeking measure. Clear associations between curiosity and information seeking were not apparent in the second study, whereas IU was related to both measures of information seeking. The study authors indicated that curiosity was more likely to be related to arbitrary information seeking and IU to seeking information regarding reward outcomes.

In the second paper to have examined curiosity and IU together in relation to uncertainty, Ryan et al. (2023) conducted a task with children, based on Hsee and Ruan (2016)'s array task described earlier, where participants were presented with an array of buttons that played neutral or aversive sounds when pressed. In Ryan and colleagues' study, buttons were labelled to indicate the type of sound they would play (neutral or aversive), or they were labelled to indicate uncertainty (with a "?"). Button pressing was recorded to index information seeking behaviour, and affective responses were recorded via emotional valence and worry self-report. Ryan et al. (2023) found that children sought more information in high uncertainty trials than low. They also found that curious children reported feeling happier during the task. In contrast to expectations, neither curiosity nor IU were associated with information seeking and no associations were found between worry and uncertainty, curiosity or IU. Further nuance to the findings was discovered through exploratory analysis suggesting that children high in IU may display subtly different patterns of button pressing relative to those high in IU.

Due to the limited research examining IU and curiosity together in relation to behaviour and emotion under uncertainty, we used an existing task to examine how individual differences in IU and curiosity related to information seeking behaviour, affect and worry under high and low uncertainty. There were three aims to this study. The first was to examine whether information seeking behavior (characterized by button pressing) was related to self-reported IU and curiosity. Our hypothesis was that those who were more curious and higher in IU would press more buttons, indicating greater information seeking. The second aim was to examine whether self-reported IU and curiosity were associated with emotional responses to uncertainty (by way of self-reported emotional valence and worry). Our hypothesis was that those who were more curious would report more positive affect in high uncertainty trials than those who were less curious. In relation to IU our hypothesis was that those with higher IU would report more negative emotional responses on high uncertainty trials than those lower in IU. The third aim was to explore the consistency of findings across adult and child samples; by using an identical task to that used in our previous research with children (Ryan et al., 2023) we were able to further contribute to the literature by comparing findings across these different age groups.

4.1 Method

4.1.1 Pre-registration

For this paper we followed the pre-registration for the child version of the study, which can be found here. This study follows the same design, sample size, hypotheses and analysis plan but with some minor variations to account for this sample being adults. Details of these variations were pre-registered here. See this link for task code, analysis code and analysis output for the Uncertain World project.

4.1.2 Participants

There were 133 participants who were recruited from the University of Reading's School of Psychology and Clinical Language Sciences student participation panel, where students receive course credit for participating, who completed the questionnaires and game. We followed the a priori power calculation which determined that a sample size of 132 participants would be sufficient to reach 80% power for a small interaction effect (standardised beta = 0.02 - 0.05) based on the variance in pilot data. Of the participants, 113 identified as female, 16 male, 3 classified their gender as "other" and one opted not to provide their gender. The age range was from 18 to 48 years (M = 21.00, SD = 4.35). The majority of participants identified as White (90) and the remaining as Asian (n=24), Black (n=3), Mixed Race (n=11), or "Other" (n=4); one person opted not to provide this information. All participants met the inclusion criteria of living in the UK. Further information regarding demographics of the sample can be found in the Supplementary Materials (Table S1). Participants were provided with 0.5 credits for completing the 30 minute study. The study was approved by the University of Reading School of Psychology and Clinical Language Sciences Research Ethics Committee (2021-194-JM).

4.1.3 Self-report Measures

4.2.3.1 Curiosity. Participants self-reported curiosity through the 10-item Interest and Deprivation-Type Epistemic Curiosity (ID-EC) Scale (Litman, 2008; Litman et al., 2010; Litman & Mussel, 2013). This scale uses a four point Likert scale where 1 indicates “almost never”, 2 ”sometimes”, 3 “often” and 4 “almost always”, and the questionnaire captures interest-type and deprivation-type subscales of curiosity (Litman, 2008). The interest scale measures interest in acquiring knowledge and includes questions such as “I find it fascinating to learn new information” and the deprivation scale measures interest in acquiring knowledge to reduce information deprivation through questions such as “I brood for a long time in an attempt to solve some fundamental problem”. Litman (2008) found that alphas were acceptable for all scales ($\alpha > 0.70$). Internal consistency for the full scale for our sample was good ($\alpha = 0.81$). Internal consistency for the interest scale was adequate ($\alpha = 0.78$) and for the Deprivation scale was good ($\alpha = 0.87$). Litman and Mussel (2013) reported that the subscales were highly correlated (Study 1, $r = .70$; Study 2, $r = .60$), and we have primarily treated the ID-EC as a single scale for our analysis. We did however choose to explore each subscale as well, because they may differ in predicting responses to uncertainty. We found the subscales are correlated, although not strongly $r(131) = 0.28$, $p = 0.001$ (see Table 1).

4.2.3.2 Intolerance of Uncertainty. IU was measured using the 27-item self-report Intolerance of Uncertainty Scale (IUS) (Buhr & Dugas, 2002). This scale uses a five-point Likert scale where 1 is “not at all characteristic of me”, 3 is “somewhat characteristic of me” and 5 is “entirely characteristic of me”, including questions such as “Unforeseen events upset me greatly” and “When I am uncertain, I can’t go forward”. Buhr and Dugas (2002) report excellent internal consistency for the scale ($\alpha = 0.94$) and Khawaja and Yu (2010) confirmed that the 27-item scale had higher test-retest reliability ($r = .83$) than the 12-item scale ($r = .77$) , that there was moderate concurrent validity with other anxiety and worry scales (all $p < .05$) and there was discriminant validity between clinical and non-clinical samples. Internal consistency for the scale in our sample was excellent ($\alpha = 0.95$).

4.1.4 Task Procedure

The Uncertain World task was adapted from Hsee and Ruan (2016)’s button pressing task. We originally developed the task for children, with a space theme to make it appealing. To support comparison across studies, we chose to keep the task the same in this study. The game was built in html using javascript in jsPsych (de Leeuw, 2014) and run from a University of Reading hosted web server. The programme and materials for the game can be found in the child game pre-registration GitHub directory (here) with materials for the adult game being suffixed by “_a”. Participants were required to allow the browser to access the computer’s webcam and microphone for the game. In order to check computer audio, participants were asked to input a word that was played through the speakers. Sounds were chosen from the International Affective Digitized Sounds-2 (IADS-2) database (Bradley & Lang, 2007) (see Supplementary Materials for further information).

Participants were informed by a computerized voice that they would go through a practice phase. They were taught how a symbol of an “ok” hand gesture represented a neutral sound and a “thumbs down” represented an aversive sound, and a question mark represented a neutral sound or an aversive sound. Participants were required to press these buttons in the practice phase and to confirm that they had indeed heard the sounds. They were also asked to confirm that they wished to proceed with the game. If these checks were completed successfully, they then proceeded on to the test trials.

There were four test trials, counterbalanced with two being high uncertainty and two being low uncertainty. Further information can be found in Trial Design below. Each trial consisted of a camera check, an anticipatory phase, self-report questions and a button pressing phase (see Figure 1). Participants were shown the feed from their webcam in a spaceship window on the screen; they were asked if they could see their face in the spaceship window, and if so, to click "next" (or to move their camera until they could see their face). This moved them to the anticipation phase of the game. During this phase, an array of 48 buttons for the trial ahead was shown on screen for 10 seconds. Whilst this screen was displayed, participants were instructed to look at the buttons but not press them, while the webcam recorded their face (note that facial affect was not coded or analysed for this study due to problems achieving reliability and practical considerations). Participants were then asked to complete a self-report measure of emotional valence, worry and uncertainty (see Self-reported emotion valence, worry and uncertainty section) before moving on to the button pressing phase. During the button pressing phase, the 48 buttons were activated for one minute and participants could press as many or as few buttons as they liked. When buttons were pressed, relevant sounds were played. Each of the four trials had one neutral and one aversive sound allocated to the respective buttons (see Trial Design section).

Once the four trials were complete, participants were asked to rate how each sound made them feel as a manipulation check. Participants were asked to confirm consent for the webcam video to be uploaded, and were then provided with a project debrief on screen, with the option to download it.

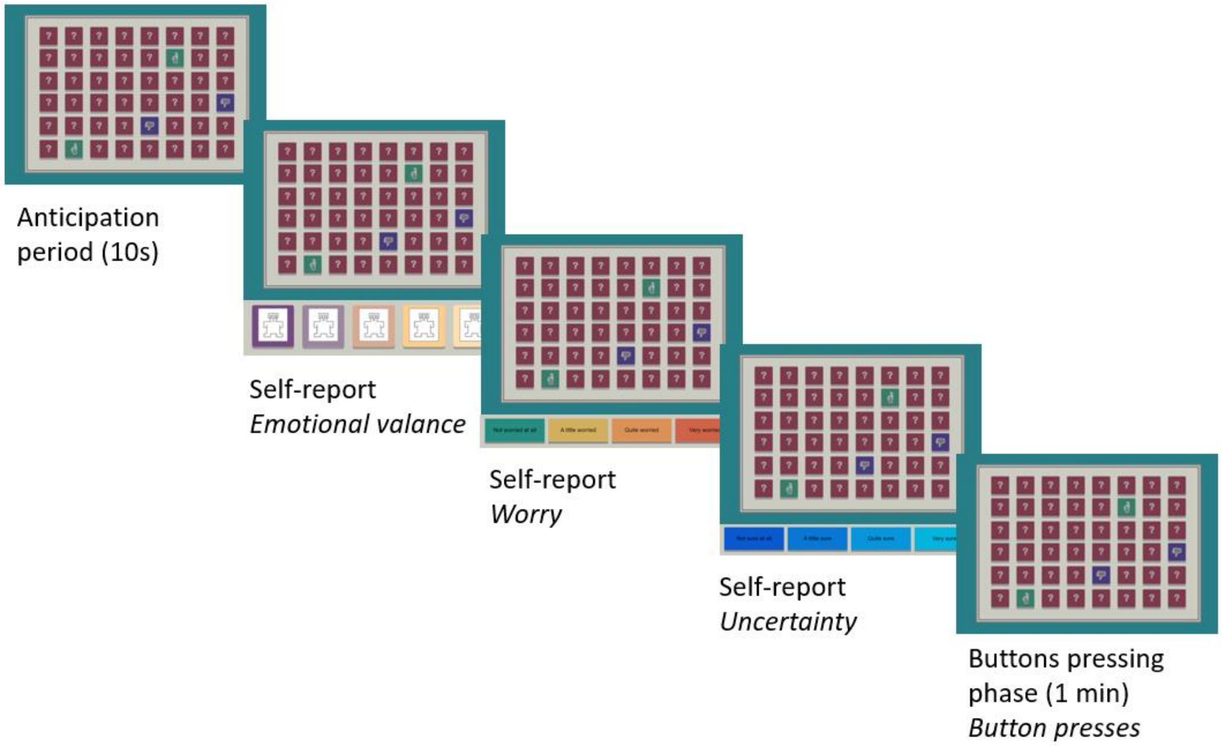
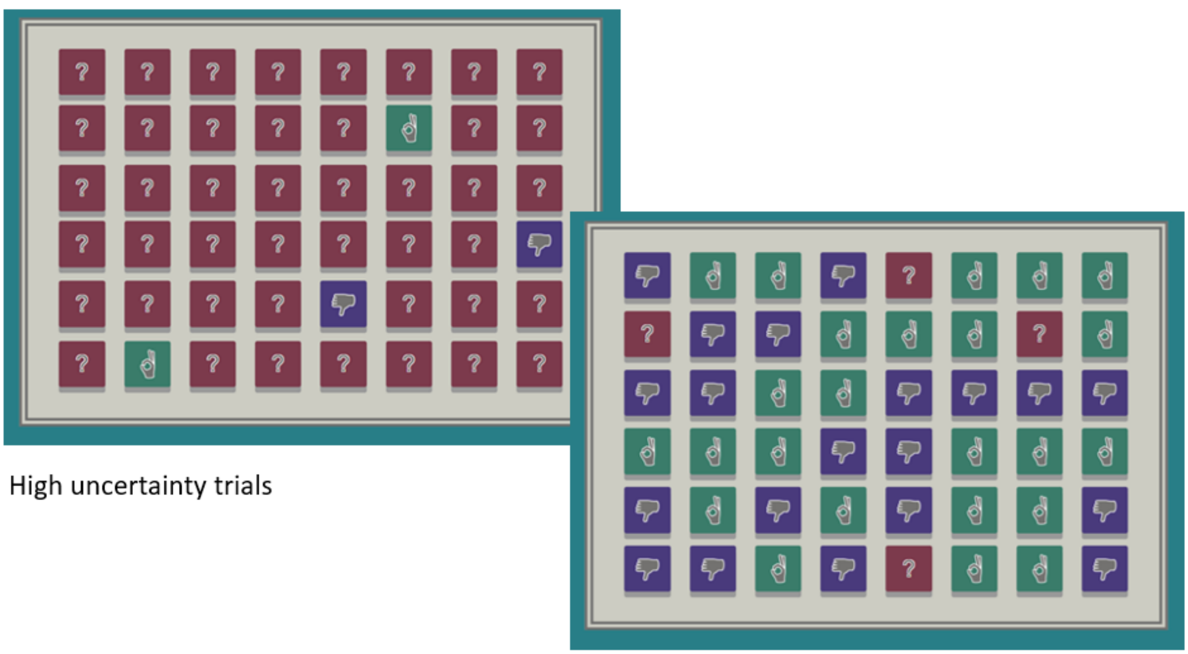


Figure 1. This trial procedure shows a high uncertainty trial. Self-report measures remained on screen until a response was made. Buttons only responded to presses in the Button pressing phase. Trial measures are shown in italics. Note: Please refer to the online version of the article for the colour version of this figure.

4.2.4.1 Trial Design. Each of the four trials consisted of 48 buttons on the screen. In the two low uncertainty trials, 44 buttons were certain and four were uncertain. A total of 22 buttons were labelled to show they would play neutral sounds and 22 aversive sounds, with 4 buttons labelled as being uncertain with a question mark. In the two high uncertainty trials, 44 buttons were uncertain and labelled with question marks, two labelled to show they would play neutral sounds and two to play aversive sounds. (see Figure 2). There was an equal chance of hearing a neutral or aversive sound with uncertain buttons. Each of the four trials was allocated one neutral and one aversive sound, and those sounds were repeated across relevant buttons for that trial, therefore there were a total of four neutral and four aversive sounds played throughout the game. Participants were not aware which of the neutral or aversive sounds they would hear the first time they pressed a button in a specific trial, however each button retained that sound for the full trial (i.e. the same sound played each time the button was pressed). Trials were one minute long and participants were invited to press as many or as few buttons as they liked. Sounds lasted 2 seconds and participants were unable to press a button until the previous sound had finished resulting in a maximum number of button presses being 30 during each trial.



High uncertainty trials

Low uncertainty trials

Figure 2. Example of high and low uncertainty trial button arrays. Note: please refer to online version of article for colour version of the figure.

4.1.5 Task Measures

4.2.5.1 Button presses. Participants were invited to press as many or as few buttons as they liked during the button pressing phase. Numbers of button presses were recorded during each button pressing phase of a trial and the total number of buttons pressed per trial was used in the analyses (following Hsee & Ruan, 2016). We also conducted exploratory analysis through calculating the proportion of unique, certain, and uncertain buttons pressed on each trial.

4.2.5.2 Self-reported emotion valence, worry and uncertainty. Participants self-reported their emotional valence (“very unhappy” to “very happy”) using a five-point Self Assessment Mannikin (SAM) (Bradley & Lang, 1994). They self-reported worry (from “Not worried at all” to “Very worried”) using a four-point scale.

As a manipulation check, participants were asked to self-report “how sure or not sure do you feel about the sounds in this round?” for each trial on a four-point scale from “Not sure at all” to “Very sure”. We reversed the responses to give a rating of uncertainty.

4.2.5.3 Self-reported sound ratings. Once they had completed all four trials, as a manipulation check, participants were asked to report how each of the sounds played made them feel on a five-point SAM scale (from “very unhappy” to “very happy”).

4.1.6 Data analysis

4.2.6.1 Missing data and data cleaning. We collected data from 147 participants. We could not include data for 14 participants as there was no data, incomplete, or missing data. Of these, 10 had technical problems and four started the study but did not complete it. We contacted them but they did not reply and they did not cancel. A further 28 participants signed up but then cancelled their participation via the online student participant panel platform (see Exclusions in

Supplementary Material). The 133 participants described previous had complete data and the analyses are based on these data.

Data for all variables was visualized, and the self-report measure for worry was skewed with the majority of responses at one end of the scale. This skew could not be corrected by transformation, and we had not preregistered a plan for dealing with skewed data. A binary variable was created taking the most frequent response which was “Not at all worried” as one value and any other response as the second value in order to assess the robustness of the results with this variable. The planned analysis was repeated using the binarised version of the variable. This did not affect the pattern or significance of the main findings, so the planned analysis is reported and analysis with the binary variable is reported in Supplementary Table S5. Where differences in findings were noted, these are reported alongside the reported results.

4.2.6.2 Analysis Plan. The following analysis plan was pre-registered. We aimed to establish if curiosity (ID-EC) and intolerance of uncertainty (IUS) predicted adult’s behavioural and emotional responses to uncertainty, including number of buttons pressed and self-reported emotion and worry. The effects of IU and curiosity and their interactions with trial uncertainty were modelled for each dependent variable. Effects of IU and curiosity were modelled separately (see Supplementary Materials Tables 3- 5) and then together (see Table 3), with limited difference in the model estimates with the two approaches.

Linear mixed effects models were run in R (R Core Team, 2022) using the package lme4 (Bates et al., 2014). Random effects for participants (intercepts and random slopes for uncertainty) were initially included in all models, but in the model examining the influence of trial uncertainty and IU on self-reported worry the random effects structure was simplified to deal with convergence and singular fit errors (see preregistration for details). The syntax for each of the models reported in this paper can be seen below:

Number of buttons pressed on high and low uncertainty trials models:

- buttons ~ (ID-EC + IUS) * uncertainty + (uncertainty | participant)

Self-reported valence models:

- sr_valence ~ (ID-EC + IUS) * uncertainty + (uncertainty | participant)

Self-report worry models:

- sr_worry ~ (ID-EC + IUS) * uncertainty + (uncertainty | participant)

We effect coded trial uncertainty, with low uncertainty coded as -1 and high uncertainty was coded as +1. Scores for ID-EC and IUS were converted to z-scores to make scores comparable. No outliers were detected in both either ID-EC and IUS data using boxplots. Data for all other variables were visualised and no outliers were found.

4.2.6.3 Additional exploratory analysis. We ran an additional model to investigate asymmetry in selection of certain and uncertain buttons across high and low uncertainty trials and whether this could be explained by curiosity and IU. In high uncertainty trials, certain buttons were in the minority with 44 buttons being uncertain and 4 certain. In low uncertainty trials, uncertain buttons were in the minority with 44 buttons being certain and 4 uncertain. We calculated the proportion of minority buttons pressed and used this as the dependent variable in a new model, allowing us to establish if there is asymmetry in certain and uncertain button pressing that is not related to the different number of each type of button available within a trial. The syntax for this model is as follows:

prop_minority_buttons_pressed ~ (ID-EC + IUS) * trial_uncertainty + (1 | participant)

To investigate differential effects of Interest- and Deprivation-type curiosity, models were repeated with each curiosity type. Model syntax follows that of the main analysis but the total ID-

EC score was replaced with the subscale scores. The results of these additional models are summarised below and reported in full in the Supplementary Table S6.

4.2 Results

4.2.1 Descriptive statistics

Descriptive statistics for IU (IUS score) and curiosity (ID-EC total raw scores, Interest-type subscale scores and Deprivation type subscale scores) and their correlations are shown in Table 1. IU was only related to Deprivation-type curiosity, Both Interest-type and Deprivation-type scores were strongly related to the curiosity total score, as would be expected, and weakly related to each other.

Table 1. Means, standard deviations, and correlations with 95% confidence intervals of IU (IUS score) and curiosity (ID-EC score; interest-type subscale score; and deprivation-type subscale score).

Variable	*M*	*SD*	1	2	3
1. IU (IUS Score)	72.65	19.19			
2. Curiosity (ID-EC Score)	26.10	4.15	.11		
			[-.06, .27]		
3. Interest-type curiosity (I-type subscale score)	14.55	2.21	-.16	.73**	
			[-.32, .01]	[.64, .80]	
4. Deprivation-type curiosity (D-type subscale score)	11.55	2.95	.27**	.86**	.28**
			[.11, .42]	[.81, .90]	[.11, .43]

Note. ***p < .001.

Descriptive statistics for button presses across high and low uncertainty trials are found in Table 2. This table shows the number of buttons pressed, and the proportion that were unique, certain and uncertain buttons. In our analyses, all button presses, including those that have been pressed previously by the participant, are included in the total.

Table 2. Means, standard deviations, and correlations with confidence intervals of number of buttons pressed in trials, number of unique buttons pressed, number of certain buttons pressed, number of certain aversive and certain neutral buttons pressed, and number of uncertain buttons pressed, by high and low uncertainty trials.

Trial Uncertainty	Number of buttons	Proportion unique	Proportion certain	Proportion uncertain
High	16.53 (5.71)	0.87 (0.13)	0.29 (0.20)	0.71 (0.20)
Low	16.10 (5.76)	0.90 (0.10)	0.73 (0.14)	0.27 (0.14)

Note. Means and standard deviations are calculated by first summarising across trials within participants and then across participants to account for clustering.

Descriptive statistics and correlations between affect and worry are shown in Table 3. Self-reported emotion valence was strongly negatively related to self-reported worry ratings.

Table 3. Means, standard deviations, and correlations with 95% confidence intervals of affective responses at the trial level.

Variable	M (SD)	1

1. Emotion-valence rating	3.60 (0.82)	
2. Worry rating	1.49 (0.48)	-.60*** [-.65, -.54]

Note. Standard deviations are calculated at the participant level. Correlations are adjusted for participant-level clustering.

4.2.2 Manipulation checks

To check that participants recognized that some trials were more uncertain than others, a linear mixed effect model was used to examine high or low trial uncertainty effects on self-reported uncertainty ratings. Trial uncertainty had a small but significant effect on trial uncertainty (b = 0.14, 95% CI [0.11-0.17], p<.001), with participants being less certain with high uncertainty trials. See Table S2 of Supplementary Materials for further information.

To check that participants found that the aversive sounds were indeed unpleasant, a linear mixed effects model was used to examine effects of valence of sound ratings taken at the end of the trial. There was a significant effect of sound valence on emotional valence ratings (b=0.47, 95% CI [0.43, 0.51], p <0.001) with the aversive sounds rated more negatively than the neutral sounds. Rating score distributions can be found in Supplementary Materials Figure S1.

4.2.3 The influence of uncertainty, IU and curiosity on the number of button presses.

We hypothesised that there would be a positive relationship between both curiosity and IU and information seeking under uncertainty (total button presses). We also explored the extent to which any associations varied by trial uncertainty. There was not an effect of trial uncertainty on button presses (*b* = 0.01, 95% CI [-0.01, 0.03], *p* =.250); participants did not press significantly more buttons in high uncertainty trials than in low uncertainty trials. IU did not predict button presses (*b* = -0.03, 95% CI [-0.08, 0.02], *p* = .229). In contrast, curiosity was a significant predictor of button presses (*b* = 0.07, 95% CI [0.02, 0.12], *p* = .011). Neither IU (*b* = -0.01, 95% CI [-0.03, 0.01], *p* = .358) nor curiosity (*b* = 0.00, 95% CI [-0.02, 0.03], *p* = .667) significantly interacted with trial uncertainty to predict button presses. See Table 3 for full LMM results and see Table S3 in Supplementary Materials for models with button pressing including IU and Curiosity separately and combined.

4.2.4 Exploratory analysis: The influence of uncertainty, IU, and curiosity on type of button pressed

As outlined previously, each trial had a minority button (4 buttons versus 44). The button type that was the minority varied by trial uncertainty. To examine whether IU and curiosity were associated with different patterns of responding in relation to these minority buttons, an exploratory analysis was conducted. The proportion of the minority buttons pressed was calculated and used as the dependent variable while accounting for the different numbers of each type of button across trial uncertainties. There was no main effect of trial uncertainty (*b* = 0.00, 95% CI [-0.01, 0.02], *p* = .626), but there was a marginal effect of IU (*b* = 0.02, 95% CI [-0.00, 0.03], *p* = .068). There was no interaction between trial uncertainty and IU (*b* = 0.01, 95% CI [-0.00, 0.03], *p* = .119), however there was an interaction with curiosity (*b* = -0.02, 95% CI [-0.03, 0.00], *p* = .046). Visual inspection of these effects (see Figure 3) suggests that those with higher curiosity are pressing a larger proportion of minority buttons in low uncertainty trials (uncertain buttons) than in high uncertainty trials (certain buttons) (see Figure 3). No other main effects or interactions were significant. The full model table is available in Supplementary Table S7.

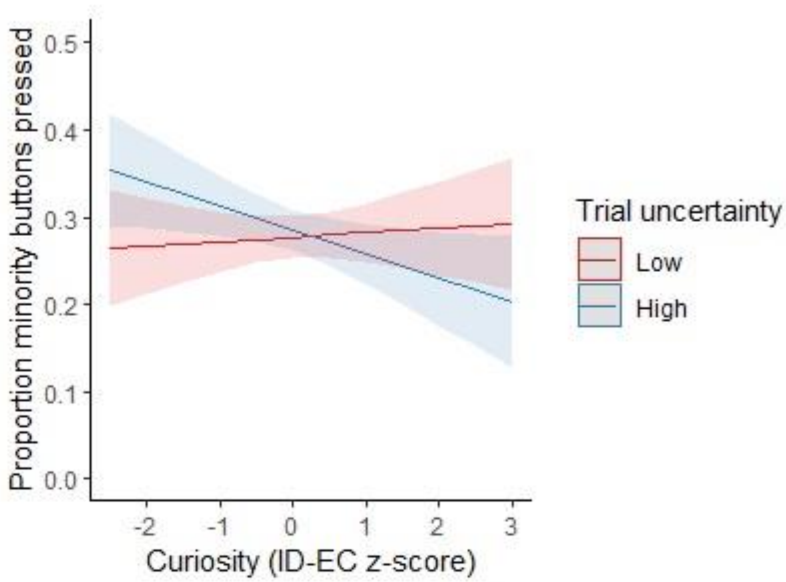


Figure 3. Significant estimated effects of trial uncertainty and curiosity on the proportion of minority buttons pressed (certain buttons on high uncertainty trials [blue]/uncertain buttons on low uncertainty trials[red]). Ribbons represent 95% confidence intervals around the estimated effects.

4.2.5 The influence of uncertainty, IU and curiosity on self-reported emotional valence.

Our hypothesis was that those who were more curious would report more positive affect in high uncertainty trials than those who were less curious. In relation to IU our hypothesis was that those with higher IU would report more negative emotional responses, including emotional valence, on high uncertainty trials than those lower in IU. There was an effect of trial uncertainty on self-reported emotional valence (b =-0.34, 95% CI [-0.43, -0.24], p < .001); in high uncertainty trials participants were significantly less happy than in low uncertainty trials. IU was significant in predicting self-reported emotional valence (*b* =-0.17, 95% CI [-0.31, -0.03], *p* = .016); the higher the IU score, the less happy the participants were. In contrast, curiosity was not significant in predicting self-reported emotional valence score (*b* = 0.07, 95% CI [-0.07, 0.21], *p* =.336). Note that when models were run separately for interest and deprivation-type curiosity, the effect of interest-type curiosity on emotional valence score was marginally significant (*b* = 0.13, 95% CI [0.01, 0.27], *p* =.062) (see Table S6 of Supplementary Materials). IU (*b* = -0.14, 95% CI [-0.24, -0.05], *p* = .003) significantly interacted with trial uncertainty to predict self-reported emotional valence but curiosity (*b* = -0.02, 95% CI [-0.12, 0.07], *p* = .601) did not. Visual inspection of this significant interaction suggests that the higher the IU, the less happy participants were in high uncertainty trials, whereas IU was not clearly associated with emotion ratings on low uncertainty trials (see Figure 4). See Table 3 for combined LMM results and see Table S4 in Supplementary Materials for models with emotion valence including IU and Curiosity separately.

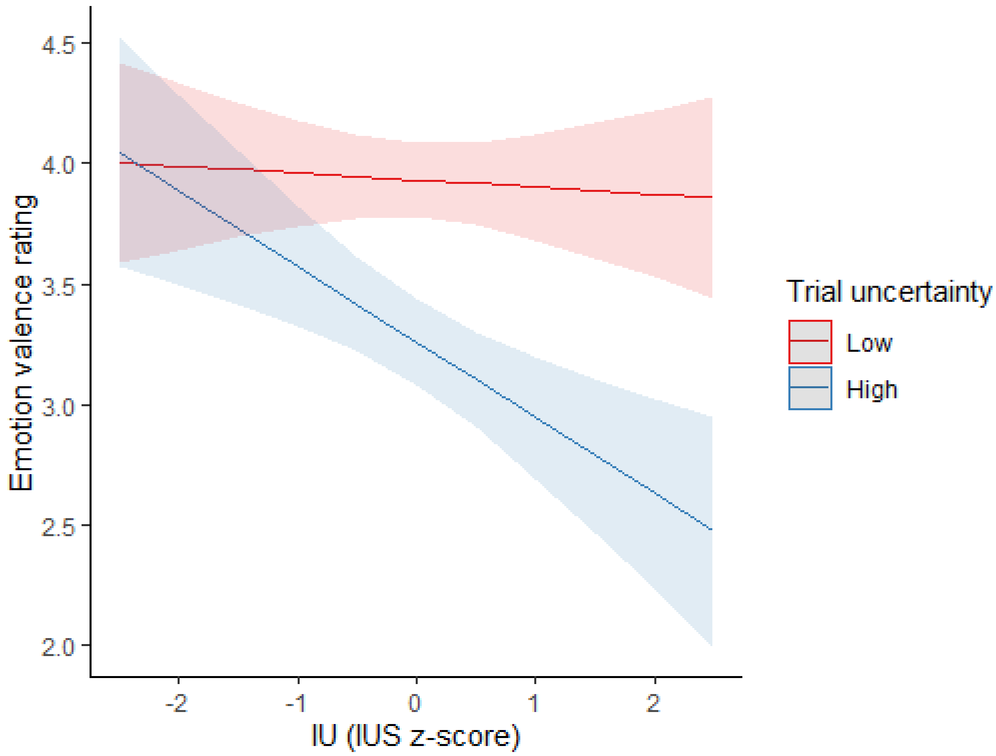


Figure 4. Significant estimated effects of trial uncertainty and IU on the self-reported emotion valence rating. Ribbons represent 95% confidence intervals around the estimated effects.

4.2.6 The influence of uncertainty, IU and curiosity on self-reported worry

We hypothesised that those with higher IU would report more negative emotional responses, including self-reported worry, on high uncertainty trials than those lower in IU. This model indicates that there was an effect of trial uncertainty on self-reported worry (b = 0.18, 95% CI [0.13, 0.23], p < .001); in high uncertainty trials, participants were significantly more worried than in low uncertainty trials. IU was a significant predictor of self-reported worry score (b = 0.11, 95% CI [0.03, 0.19], p = .007), suggesting that those with higher IU were more worried during the game than those with lower IU scores. Curiosity was not significant in predicting self-reported worry (b = 0.04, 95% CI [-0.04, 0.12], p = .336), and curiosity did not interact with trial uncertainty to predict self-reported worry scores (b = 0.04, 95% CI [-0.01, 0.09], p = .113)[1]. In addition, IU significantly interacted with trial uncertainty in predicting self-reported worry scores (b =0.07, 95% CI [0.02, 0.12], p = .010). Visual inspection of the interaction suggests that participants were more worried in high uncertainty trials than low, and this effect was greatest for those high in IU (see Figure 5). See Table 3 for LMM results and see Table S5 in Supplementary Materials for models with worry rating including IU and Curiosity separately and combined and GLM with binarized rating scores.

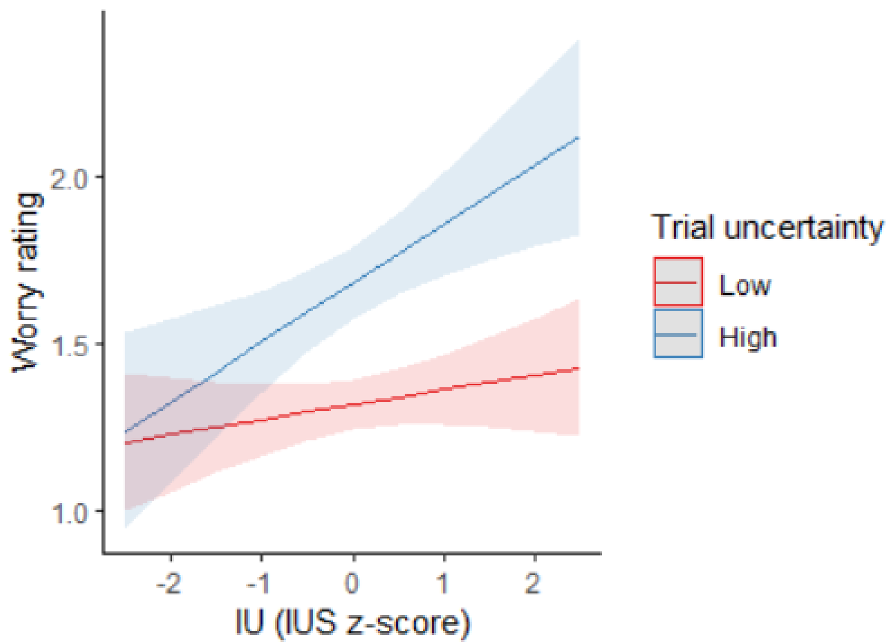


Figure 5. Significant estimated effects of trial uncertainty and IU on the self-reported worry rating. Ribbons represent 95% confidence intervals around the estimated effects.

[1] When the worry score was made into a binary variable and the model was run, this interaction was significant (OR = 1.34, 95% CI [1.05, 1.72], p = .020

Table 3: LMM results across dependent variables

Fixed effects	**Button presses**			**Emotional Valence**			**Worry**		
Predictors	*b*	*CI*	*p*	*b*	*CI*	*p*	*b*	*CI*	*p*
Intercept	0.93	0.88 – 0.98	**<0.001**	3.60	3.46 – 3.73	**<0.001**	1.50	1.42 – 1.58	**<0.001**
Trial uncertainty	0.01	-0.01 – 0.03	0.250	-0.34	-0.43 – -0.24	**<0.001**	0.18	0.13 – 0.23	**<0.001**
IU (IUS total)	-0.03	-0.08 – 0.02	0.229	-0.17	-0.31 – -0.03	**0.016**	0.11	0.03 – 0.19	**0.007**
Curiosity (IDEC total)	0.07	0.02 – 0.12	**0.011**	0.07	-0.07 – 0.21	0.336	0.04	-0.04 – 0.12	0.336
Trial uncertainty * IU	-0.01	-0.03 – 0.01	0.358	-0.14	-0.24 – -0.05	**0.003**	0.07	0.02 – 0.12	**0.010**
Trial uncertainty * Curiosity	0.00	-0.02 – 0.03	0.667	-0.02	-0.12 – 0.07	0.601	0.04	-0.01 – 0.09	0.113
Random Effects									
σ^2	0.05			0.58			0.25		
τ_{00}	0.07 $_{id}$			0.51 $_{id}$			0.16 $_{id}$		
τ_{11}	0.00 $_{id.trial\_uncertainty\_ec}$			0.15 $_{id.trial\_uncertainty\_ec}$			0.02 $_{id.trial\_uncertainty\_ec}$		
ρ_{01}	-0.05 $_{id}$			0.23 $_{id}$			0.88 $_{id}$		
ICC	0.58			0.53			0.42		
N	133 $_{id}$			133 $_{id}$			133 $_{id}$		
Observations	536			536			536		
Marginal R^2 / Conditional R^2	0.038 / 0.599			0.119 / 0.586			0.112 / 0.487		

Note. Trial uncertainty is effect coded, IUS total and IDEC total are *z*-scored. Effects significant at the $p <$ .05 level are displayed in bold text, trends at $p <$ .01 are displayed in italics.

4.3 Discussion

This is one of the first studies to examine IU and curiosity together in relation to information seeking behaviour and emotional responses under uncertainty. We hypothesised that both higher IU and higher curiosity would be associated with more information seeking during the task. This hypothesis was partially supported; higher curiosity, but not IU, was linked to more information seeking during the game. Next, we hypothesised that higher IU and higher curiosity would be associated with affect under high uncertainty trials, with curiosity linked to more positive affect and IU linked to more negative affect. Some support for this hypothesis was found; higher IU was associated with less happiness and more worry, especially on high uncertainty trials, and higher interest type curiosity was associated with more happiness during the game. These findings are now discussed in the context of the three study aims.

Our first aim was to examine if information seeking (operationalized as button presses during the game) was related to IU and curiosity. Consistent with Loewenstein (1994)'s theory that curious individuals seek information to plug the knowledge gap, individuals with higher curiosity sought more information on the task (they pressed more buttons) than those lower in curiosity. This was not moderated by trial uncertainty which indicates that high levels of uncertainty aren't required to motivate more information seeking in highly curious individuals. IU was not related to information seeking during the task, irrespective of uncertainty level, suggesting that IU may not be associated with information seeking behaviour, at least within a task like this.

We conducted exploratory analyses examining the types of buttons pressed in each trial and found that participants high in curiosity pressed more uncertain buttons during low uncertainty trials than certain buttons during high uncertainty trials, although there were only 4 of each within their respective trials. This suggests a motivation to explore the uncertain buttons in participants high in curiosity, further supporting the main finding of curiosity being linked to information seeking. Plugging this information gap may be rewarding, in accordance with Kang et al. (2009) and Murayama et al. (2019), even if the outcome is negative (Hsee & Ruan, 2016). It is important to note that we did not have a condition where there was no uncertainty so it is not possible to attribute the button pressing observed in high curiosity to uncertainty per se; these participants may also have also pressed more buttons on a trial where all buttons were certain.

Our second aim was to examine whether curiosity and IU were associated with emotional responses to uncertainty, through self-report questionnaires and self-reported emotional valence and worry during the game. Taking curiosity first, participants were generally happier in low uncertainty trials as would be expected (van Lieshout, de Lange, et al., 2021), however more curious individuals were not happier in general whilst playing the game and the association between curiosity and positive affect did not vary across trial uncertainty. When interest and deprivation type curiosity were examined separately however, those with higher interest-type curiosity were marginally happier than those with lower interest-type curiosity. This relationship between interest-type curiosity and happiness was also found in (Whitecross & Smithson, 2023). A possible explanation for the lack of association found for curiosity is ceiling effects; most participants reported being on the happier end of the rating scale in general. It also may be that the resolution of uncertainty within the game was not sufficiently informative to be rewarding for highly curious individuals.

Focusing on IU, we found that IU was related to negative emotional responses to uncertainty. This is in keeping with Einstein (2014) who suggested that those with high IU are vulnerable to negative affect. Participants higher in IU were less happy and more worried than those with lower IU in anticipation of the task, particularly in high uncertainty trials. As expected because of the work of Koerner and Dugas (2008), those who were higher in IU were more worried in general than those with lower IU, and were more worried in high uncertainty trials than low. The overall pattern of results for IU suggests that IU may be more closely related to emotional responses than to behaviour. Whilst this is consistent with some previous work (Jacoby et al., 2014), Krohne (1993), Hebert and Dugas (2019) and Mathews and MacLeod (2002) suggest that those who find uncertainty aversive may undertake safety behaviours such as information seeking to reduce discomfort, so we had expected to see more information seeking in higher IU in addition to more negative affect. It is possible that this task did not involve sufficiently aversive stimuli to lead to discomfort at a level that would engage safety behaviours. Indeed, worry scores were low overall.

Our third aim was to explore the consistency of findings across adult and child samples by using an identical task to that used in our previous research with children (Ryan et al., 2023). There were consistent findings with regards to positive affect and its relationship with trial uncertainty and to some extent, curiosity. Both children and adults were happier in low uncertainty trials than in high uncertainty trials (marginally so in children), providing further support to van Lieshout, de Lange, et al. (2021)'s findings that happiness decreases with higher uncertainty. Further to this, the more curious children were, the happier they were, and adults with higher interest-type curiosity were marginally happier than those with lower interest-type curiosity, offering some support to previous findings regarding associations between curiosity and happiness (Kashdan et al., 2004; Whitecross & Smithson, 2023). No associations between IU and happiness were found for either adults or children. Similarly, IU was not associated with overall button pressing in either adults or children.

There were two clear differences in findings between adults and children. In relation to information seeking, children pressed more buttons in high uncertainty trials than low, and this was not associated with curiosity. In contrast, no overall effect of uncertainty on button pressing was found in adults, but those higher in curiosity pressed more buttons during the task than those lower in curiosity. Thus, curious adults in the present study behaved in a similar way to how children behaved in our previous study. This is in keeping with the idea that children are inherently curious (Jirout & Klahr, 2012). The second clear difference in findings relates to emotional responses to uncertainty. Trial uncertainty and IU were not associated with worry in children and there was no association between IU and happiness. In contrast, adults higher in IU were less happy and more worried than those lower in IU, particularly on high uncertainty trials. This difference in findings could indicate that IU is more closely related to emotions in adults, which is entirely plausible given that the construct of IU was initially developed based on clinical observations of adults. Alternatively, differences in findings could be due to the reliance on parent-report in the child study, which may not link so closely to the child's internal emotional experience as self-report. Overall, our findings suggest that adult individual differences in IU are related more closely to emotional responses to uncertainty than behavioural. Comparing findings with our previous study with child participants, there is some indication that the impact of IU and curiosity on responses to uncertainty may change with age. Future research examining different developmental stages within the same study would help to extend this work further.

Although our study aims related entirely to individual differences, we recognize that the overall group effects may also be of interest, particularly in relation to Hsee and Ruan (2016)'s findings. Hsee and Ruan (2016) found that participants in general sought more information in the high uncertainty condition, but we found no effect of trial uncertainty on information seeking in adults. Participants in their uncertain condition (the equivalent of our high uncertainty trials) were significantly less happy than those in the certain condition (the equivalent of our low uncertainty trials), which is consistent with our findings. Through participants seeking more information in high uncertainty trials both Hsee and Ruan (2016) and Ryan et al. (2023)'s studies support the concept that individuals will seek information even when the outcome could be negative.

There are a number of strengths with this study. It carefully builds the evidence base regarding responses under uncertainty, with the task being based on that designed by Hsee and Ruan (2016) and then a replication of Ryan et al. (2023)'s study with children; this allows easy comparisons across findings in what is an emerging area of research interest. A further strength is our inclusion of manipulation checks that demonstrate that participants felt more sure (less uncertain) in low uncertainty trials than high uncertainty trials, and that aversive sounds were rated more negatively than neutral sounds. Where hypothesized effects have not been found, we can therefore be confident that it wasn't due to issues with the trial manipulations. A further strength is the novelty of this work; literature examining individual differences, behaviour and affect under uncertainty is scarce, and to our knowledge there are only two previous studies examining IU and curiosity together in relation to these factors (Jach & Smillie, 2021; Ryan et al., 2023).

There are however some limitations to the study. We used a task that was initially developed for children, which may not be sufficiently engaging or aversive for adults. We only recruited university students for the study, and of those, the majority were female, therefore we cannot be certain that the effects would hold for other age ranges or demographic groups. Due to issues with reliability and practical constraints, we were unable to code and analyse facial affect, which could have potentially highlighted further affective differences in dealing with uncertainty. In future studies, using psychophysiological measures such as facial electromyography and galvanic skin response would be helpful to examine the body's responses to uncertainty and links with individual differences, behaviour and affect under uncertainty. It could be beneficial to examine whether uncertainty needs to be aversive to elicit responses, or whether the uncertainty itself is sufficient, therefore future work could also include a condition with uncertainty but no threat whatsoever, in addition to conditions with varying levels of threat e.g. (Morriss et al., 2021).

4.3.1 Conclusion

IU predicted negative emotional responses, specifically more worry and less happiness particularly when uncertainty was high, however IU did not predict behavioural responses during an uncertain task. Curiosity did not predict positive emotional responses per se, however higher interest-type curiosity marginally predicted more happiness than lower interest-type curiosity. Curiosity predicted information seeking, where more curious individuals pressed more buttons than those with lower curiosity, but this was not related to trial uncertainty. Participants did not seek more information on high uncertainty trials than low during the game and were generally less happy and more worried in high uncertainty trials. Adults' emotional and behavioural responses to uncertainty mostly differed from children's on this task, however there were similarities where both children and adults were happier in low uncertainty trials than in high uncertainty trials and the more curious children were and the higher the interest-type curiosity in adults, the happier they were. Future research should focus on varying the level of threat in the task to establish if uncertainty requires threat to elicit a response, and also to include physiological measures to further examine individual differences and affect under uncertainty.

4.4 References

Bar-Anan, Y., Wilson, T. D., & Gilbert, D. T. (2009). The feeling of uncertainty intensifies affective reactions. *Emotion*, *9*(1), 123.

Bartoszek, G., Ranney, R. M., Curanovic, I., Costello, S. J., & Behar, E. (2022). Intolerance of uncertainty and information-seeking behavior: Experimental manipulation of threat relevance. *Behaviour Research and Therapy*, *154*, 104125. https://doi.org/https://doi.org/10.1016/j.brat.2022.104125

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2014). Fitting linear mixed-effects models using lme4. *arXiv preprint arXiv:1406.5823*.

Bennett, D., Sutcliffe, K., Tan, N. P. J., Smillie, L. D., & Bode, S. (2020). Anxious and obsessive-compulsive traits are independently associated with valuation of noninstrumental information. *Journal of Experimental Psychology: General*, *150*(4), 739-755. https://doi.org/10.1037/XGE0000966

Bradley, M. M., & Lang, P. J. (1994). Measuring emotion: the self-assessment manikin and the semantic differential. *Journal of Behavior Therapy and Experimental Psychiatry*, *25*(1), 49-59.

Bradley, M. M., & Lang, P. J. (2007). The International Affective Digitized Sounds (2nd Edition; IADS-2): Affective ratings of sounds and instruction manual. Technical report B-3. *University of Florida, Gainesville, Fl.*

Buhr, K., & Dugas, M. J. (2002). The intolerance of uncertainty scale: Psychometric properties of the English version. *Behaviour Research and Therapy*, *40*(8), 931-945.

Carleton, R. N. (2016a). Fear of the unknown: One fear to rule them all? *Journal of Anxiety Disorders*, *41*, 5-21. https://doi.org/https://doi.org/10.1016/j.janxdis.2016.03.011

Carleton, R. N. (2016b). Into the unknown: A review and synthesis of contemporary models involving uncertainty. *Journal of Anxiety Disorders*, *39*, 30-43. https://doi.org/https://doi.org/10.1016/j.janxdis.2016.02.007

Counsell, A., Furtado, M., Iorio, C., Anand, L., Canzonieri, A., Fine, A., Fotinos, K., Epstein, I., & Katzman, M. A. (2017). Intolerance of uncertainty, social anxiety, and generalized anxiety: Differences by diagnosis and symptoms. *Psychiatry research*, *252*, 63-69.

de Leeuw, J. R. (2014). jsPsych: A JavaScript library for creating behavioral experiments in a Web browser. *Behavior Research Methods 2014 47:1*, *47*(1), 1-12. https://doi.org/10.3758/S13428-014-0458-Y

Einstein, D. A. (2014). Extension of the transdiagnostic model to focus on intolerance of uncertainty: a review of the literature and implications for treatment. *Clinical Psychology: Science and Practice*, *21*(3), 280.

Gruber, Matthias J., Gelman, Bernard D., & Ranganath, C. (2014). States of Curiosity Modulate Hippocampus-Dependent Learning via the Dopaminergic Circuit. *Neuron*, *84*(2), 486-496. https://doi.org/https://doi.org/10.1016/j.neuron.2014.08.060

Grupe, D. W., & Nitschke, J. B. (2011). Uncertainty is associated with biased expectancies and heightened responses to aversion. *Emotion*, *11*(2), 413-424. https://doi.org/10.1037/a0022583

Hebert, E. A., & Dugas, M. J. (2019). Behavioral Experiments for Intolerance of Uncertainty: Challenging the Unknown in the Treatment of Generalized Anxiety Disorder. *Cognitive and Behavioral Practice*, *26*(2), 421-436. https://doi.org/10.1016/J.CBPRA.2018.07.007

Hillen, M. A., Gutheil, C. M., Strout, T. D., Smets, E. M. A., & Han, P. K. J. (2017). Tolerance of uncertainty: Conceptual analysis, integrative model, and implications for healthcare. *Social Science and Medicine*, *180*, 62-75. https://doi.org/10.1016/j.socscimed.2017.03.024

Holaway, R. M., Heimberg, R. G., & Coles, M. E. (2006). A comparison of intolerance of uncertainty in analogue obsessive-compulsive disorder and generalized anxiety disorder. *Journal of Anxiety Disorders*, *20*(2), 158-174.

Hsee, C. K., & Ruan, B. (2016). The Pandora Effect: The Power and Peril of Curiosity. *Psychological Science*, *27*(5), 659-666. https://doi.org/10.1177/0956797616631733

Jach, H. K., & Smillie, L. D. (2021). Testing the Information-Seeking Theory of Openness/Intellect. *European Journal of Personality*, *35*(1), 103-119. https://doi.org/10.1002/per.2271

Jacoby, R. J. (2020). Intolerance of uncertainty. In *Clinical handbook of fear and anxiety: Maintenance processes and treatment mechanisms.* (pp. 45-63). American Psychological Association. https://doi.org/10.1037/0000150-003

Jacoby, R. J., Abramowitz, J. S., Buck, B. E., & Fabricant, L. E. (2014). How is the Beads Task related to intolerance of uncertainty in anxiety disorders? *Journal of Anxiety Disorders*, *28*(6), 495-503. https://doi.org/10.1016/J.JANXDIS.2014.05.005

Jirout, J., & Klahr, D. (2012). Children's scientific curiosity: In search of an operational definition of an elusive concept. In *Developmental Review* (Vol. 32, pp. 125-160).

Kang, M. J., Hsu, M., Krajbich, I. M., Loewenstein, G., McClure, S. M., Wang, J. T.-y., & Camerer, C. F. (2009). The wick in the candle of learning: Epistemic curiosity activates reward circuitry and enhances memory. *Psychological Science*, *20*(8), 963-973.

Kashdan, T. B., Rose, P., & Fincham, F. D. (2004). Curiosity and Exploration: Facilitating Positive Subjective Experiences and Personal Growth Opportunities. *Journal of Personality Assessment*, *82*(3), 291-305. https://doi.org/10.1207/s15327752jpa8203_05

Khawaja, N. G., & Yu, L. N. H. (2010). A comparison of the 27-item and 12-item intolerance of uncertainty scales. *Clinical psychologist*, *14*(3), 97-106.

Koerner, N., & Dugas, M. J. (2008). An investigation of appraisals in individuals vulnerable to excessive worry: the role of intolerance of uncertainty. *Cognitive Therapy and Research*, *32*(5), 619-638. https://doi.org/10.1007/s10608-007-9125-2

Krohne, H. W. (1993). Vigilance and cognitive avoidance as concepts in coping research.

Litman, J. A. (2008). Interest and deprivation factors of epistemic curiosity. *Personality and Individual Differences*, *44*, 1585-1595. https://doi.org/10.1016/j.paid.2008.01.014

Litman, J. A., Crowson, H. M., & Kolinski, K. (2010). Validity of the Interest- and Deprivation-type epistemic curiosity distinction in non-students. *Personality and Individual Differences*, *49*(5), 531-536. https://doi.org/https://doi.org/10.1016/j.paid.2010.05.021

Litman, J. A., & Mussel. (2013). Validity of the Interest-and Deprivation-Type Epistemic Curiosity Model in Germany. *Epistemic Curiosity Journal of Individual Differences*, *34*(2), 59-68. https://doi.org/10.1027/1614-0001/a000100

Loewenstein, G. (1994). The Psychology of Curiosity: A Review and Reinterpretation. *Psychological Bulletin*, *116*(1), 75-98.

Mathews, A., & MacLeod, C. (2002). Induced processing biases have causal effects on anxiety. *Cognition & emotion*, *16*(3), 331-354.

Morriss, J., Bennett, K. P., & Larson, C. L. (2021). I told you it was safe: Associations between intolerance of uncertainty and different parameters of uncertainty during instructed threat of shock. *Journal of Behavior Therapy and Experimental Psychiatry*, *70*, 101620. https://doi.org/https://doi.org/10.1016/j.jbtep.2020.101620

Murayama, K., Fitzgibbon, L., & Sakaki, M. (2019). Process Account of Curiosity and Interest: A Reward-Learning Perspective. *Educational Psychology Review*, *31*(4), 875-895. https://doi.org/10.1007/s10648-019-09499-9

Osmanağaoğlu, N., Creswell, C., & Dodd, H. F. (2018). Intolerance of Uncertainty, anxiety, and worry in children and adolescents: A meta-analysis. *Journal of Affective Disorders*, *225*, 80-90. https://doi.org/10.1016/J.JAD.2017.07.035

R Core Team. (2022). *R: A language and environment for statistical computing.* . In R Foundation for Statistical Computing. https://www.R-project.org/

Ryan, Z. J., Dodd, H. F., & FitzGibbon, L. (2023). Uncertain World: How Children's Curiosity and Intolerance of Uncertainty Relate to their Behaviour and Emotion under Uncertainty. (Manuscript submitted for publication).

Sexton, K. A., & Dugas, M. J. (2009). Defining distinct negative beliefs about uncertainty: validating the factor structure of the Intolerance of Uncertainty Scale. *Psychological assessment*, *21*(2), 176.

van Lieshout, L. L., de Lange, F. P., & Cools, R. (2021). Uncertainty increases curiosity, but decreases happiness. *Scientific reports*, *11*(1), 1-10.

van Lieshout, L. L., Traast, I. J., de Lange, F. P., & Cools, R. (2021). Curiosity or savouring? Information seeking is modulated by both uncertainty and valence. *PLOS ONE*, *16*(9), e0257011.

von Stumm, S., Hell, B., & Chamorro-Premuzic, T. (2011). The Hungry Mind:Intellectual Curiosity Is the Third Pillar of Academic Performance. *Perspectives on Psychological Science*, *6*(6), 574-588. https://doi.org/10.1177/1745691611421204

Whitecross, W. M., & Smithson, M. (2023). Curiously different: Interest-curiosity and deprivation-curiosity may have distinct benefits and drawbacks. *Personality and Individual Differences*, *213*, 112310. https://doi.org/https://doi.org/10.1016/j.paid.2023.112310

Chapter 5 General discussion

Due to the limited knowledge and literature regarding how and when IU affects emotions and behaviours, particularly in childhood, the research undertaken for this thesis aimed to further explore the construct of IU through behavioural, cognitive and emotional responses to uncertainty, and developmental associations with anxiety. This thesis had two overarching aims:

1) to examine the association between IU and worry using both a longitudinal study design and a behavioural task.
2) to examine the relationship between IU and both information seeking behaviour and affect, under uncertainty, after controlling for any effects of curiosity.

These aims were realised across three studies. This chapter begins with an overview of findings for each of the studies followed by sections focusing on how these findings relate to the two aims of the thesis. This is followed by consideration of strengths and challenges, reflections and limitations across the studies and priorities for future work. Clinical implications of these findings are then discussed.

5 Overview of Findings

5.1 Study 1: Does Intolerance of Uncertainty predict child anxiety? A longitudinal study

Better understanding the causes or correlates of anxiety in children is important because earlier identification can lead to earlier treatment, reducing the chance of future mental health problems. Further to this, finding constructs that may be risk factors or relate to anxiety provides potential targets for future interventions or treatments. Associations between IU and anxiety are poorly understood in children; it is unclear whether IU plays a causal role or is a risk factor for future anxiety, or whether it acts as a maintenance mechanism. The majority of previous research has been cross-sectional and conducted across broad age ranges, so it has not been possible to examine trajectories and changes in the relationship between IU and anxiety over development. It is also currently not feasible to measure IU in younger children, therefore we cannot examine the relationship with anxiety in children's very early years. Also, it is unclear whether IU is a transdiagnostic factor and what the nature of associations with internalising and externalising symptoms are. Study 1 was a longitudinal study examining the relationship of IU with generalised anxiety, internalising and externalising symptoms at three timepoints across six years (from pre-school age to middle childhood). Parents of 179 children completed questionnaires regarding their child's IU, anxiety, internalising and externalising symptoms at the first timepoint, 162 at the second and 148 at the third.

Hierarchical growth curve analyses were run to establish how IU moderated trajectories of generalised anxiety scores and internalising and externalising symptoms over time. IU was found to be positively associated with generalised anxiety, internalising symptoms and externalising symptoms at each timepoint; those with higher IU had higher symptoms than those with lower IU. IU predicted trends in generalised anxiety over time, however contrary to expectations, higher IU was linked to a decrease in generalised anxiety symptoms over time, and in those with lower IU, generalised anxiety symptoms were relatively stable over time. For internalising symptoms, lower IU was associated with an increase over time, but there were no effects of time for those with higher IU. IU predicted unusual trends in externalising symptoms over time with externalising symptoms increasing between time point 1 and time point 2 and decreasing between time point 2 and time point 3 for those with higher IU, whereas for those with lower IU, externalising scores remained relatively stable over the three time points.

These findings suggest that IU is associated with generalised anxiety symptoms across early and middle childhood but that IU may not play a causal role in the onset of generalised anxiety in children because high IU was not associated with a trajectory of increasing anxiety over time, although it is possible that the association between IU and anxiety existed prior to our baseline assessment. Lastly these findings suggest that IU is associated with a range of mental health conditions and not just worry/generalised anxiety.

5.2 Study 2: Uncertain World: How Children's Curiosity and Intolerance of Uncertainty Relate to their Behaviour and Emotion under Uncertainty.

Information seeking behaviour under uncertainty may be linked to IU and curiosity; those who are curious may fill an information gap because it is rewarding, whereas those who are high in IU may do so to reduce the discomfort associated with the uncertainty. Uncertainty in those high in IU may be associated with negative affect and in those with higher curiosity, with positive affect. The constructs of IU and curiosity have not been examined together in children and may be important in understanding how children respond to uncertainty. Study 2 therefore aimed to examine how individual differences in IU and curiosity were associated with behavioural and emotional responses to uncertainty.

Study 2 participants were 133 8-12 year old children who played an online game which was based on an information seeking task originally created for adults. Children were shown an array of buttons, each of which played a neutral or aversive sound. Uncertainty was manipulated through button labelling; certain neutral sounds were labelled with a symbol of an "okay" hand gesture, certain aversive sounds had a symbol of a "thumbs down" hand gesture and uncertain buttons had a question mark label (and could play either neutral or aversive sounds). Children completed four trials; two high uncertainty trials (with 44 uncertain buttons and 4 certain) and two low (with 44 certain buttons and 4 uncertain). Children were asked to rate their emotion valence, worry and uncertainty in anticipation of each trial.

Children's facial expressions were recorded through their webcam during this period and their affect was coded. During trials, children had a minute to press as many or as few buttons as they liked. Parents reported their child's IU and epistemic curiosity via questionnaires.

Linear mixed effects models were run, examining the effects of curiosity and IU on numbers of buttons pressed, self-reported emotional valence and worry and facial affect by trial uncertainty. Button pressing was not related to IU or curiosity, however children pressed more buttons in high than low uncertainty trials suggesting that children in general wanted to resolve uncertainty. Exploratory findings in high uncertainty conditions suggest that children high in IU may press the certain buttons as a regulatory or checking behaviour in high uncertainty trials. Curious children reported being happier than low curiosity children when playing the game, but this was not related to trial uncertainty, and was not found through facial affect. There were no associations or interactions between IU and negative facial affect, self-reported emotional valence or worry. Study 2 concluded that, contrary to expectations, IU did not predict children's emotional responses and that children sought more information under higher uncertainty, but this was not related to either IU or curiosity.

5.3 Study 3: Uncertain World: How Adult's Curiosity and Intolerance of Uncertainty Relate to their Behaviour and Emotion under Uncertainty, and how it compares with children

As the findings of study 2 were not as expected, and because the original task by Hsee and Ruan (2016) was conducted with adults, an identical task to study 2 was run with adults. Study 3 aimed to examine how individual differences in IU and curiosity related to behavioural and emotional responses to uncertainty in adults. Furthermore, by comparing findings with Study 2, it was also possible to explore how responses might differ between children and adults. Participants were 133 adults who completed measures of IU and epistemic curiosity, before completing a game identical to that used in Study 2.

Again, linear mixed effects models were run, examining the effects of curiosity and IU on numbers of buttons pressed, self-reported emotional valence and worry by trial uncertainty. The pattern of results differed from those of children. Those with higher IU were more worried and less happy than those with lower IU during the game, particularly in high uncertainty trials, but they did not seek more information. Adults with higher curiosity sought more information than the less curious, and those with higher interest-type curiosity were marginally happier than those with lower interest-type curiosity. In general, participants were less happy but did not seek more information under higher uncertainty.

When comparing children and adults, both were happier in low uncertainty trials than in high and the more curious the children and the higher the interest-type curiosity in adults were, the happier they were. It was concluded that individual differences are associated more with emotional responses to uncertainty than behavioural in adults, and that the relationship of IU and curiosity with responses to uncertainty may change with age.

5.4 Integration of Findings

5.4.1 IU and worry

The studies in this thesis aimed to examine the relationship between IU and worry within a longitudinal task (Study 1) and a behavioural task (Studies 2 and 3). Existing literature has examined the relationship between IU, anxiety and worry for both adults and children (Counsell et al., 2017; Holaway et al., 2006; Osmanağaoğlu et al., 2018; Sexton & Dugas, 2009), however there has been limited research examining IU and anxiety or worry in children. In particular there is a lack of research examining: how IU is related to behavioural responses in children; associations between IU and worry in young children; and how IU is related to worry developmentally.

There are mixed findings with regards to the relationship between IU and worry across the studies in this thesis. Study 1 showed that IU was related to generalised anxiety in children at multiple timepoints, with children higher in IU having higher generalised anxiety over time. This association was found even when participants were preschoolers, which extends the current literature that shows strong associations between IU and worry in young people (Osmanağaoğlu et al., 2018). There was also evidence that IU predicted trajectories of anxiety over time but not in the expected direction. Based on Dugas et al. (2012) who found a bidirectional and reciprocal association between IU and worry over time in adolescence, we expected that high IU might be associated with a trajectory of increasing anxiety over time. In fact, Study 1 showed anxiety *decreasing* over time in children high in IU. IU may not play a causal role in the onset of worry in children but may be a consistent correlate of generalised anxiety. Alternatively, causality may occur prior to preschool age.

The findings of Study 2 did not support the hypothesis that IU was related to increased worry in a behavioural task. This is similar to Osmanağaoğlu et al.'s (2021) findings that parent-reported IU was not related to increased worry, but contrary to Krain et al. (2006) and Krain et al. (2008)'s findings that higher IU was related to higher anxiety in a HiLo task with adolescents and Osmanağaoğlu et al. (2021) findings where pre-adolescent children's self-reported IU was related to increased worry especially under higher uncertainty in a Beads task. Contrary to Study 2, in Study 3 (where participants were adults), those higher in IU reported more worry during the uncertain task, particularly under higher uncertainty, which is consistent with Koerner and Dugas (2008) who found that in those high in IU the aversive response triggered by uncertainty is often anxiety and worry. It is noteworthy that no associations are found when IU is reported by parents; this may suggest that parent-report IU may not be capturing the internal states associated with uncertainty.

When considering this aim of the thesis regarding IU and worry, it is important to also consider broader psychopathology such as the construct of internalising problems (which brings together anxiety and depression), but also externalising problems (capturing impulsive and conduct related problems; Achenbach, 1966). This helps to further explore Gramszlo et al. (2018)'s suggestion that IU may be a transdiagnostic construct. In Study 1, IU was related to internalising and externalising problems in children at multiple timepoints and those with higher IU had higher internalising and externalising problems over time. This suggests that IU is a construct that may not specifically be related to worry but may sit across a range of broader psychopathologies. Although there have been no theoretical links between IU and externalising symptoms previously, speculatively, high IU may be contributing to externalizing problems because children's feelings of distress in the face of uncertainty may manifest in a negative emotional response (Buhr & Dugas, 2002). Daughters et al. (2009) posit that those who do not tolerate distress well are motivated to escape negative affect through risky behaviours, suggesting that this distress can be expressed through externalising behaviours. This may allow them to regain some certainty and control.

Furthermore, in Study 3, in addition to being associated with worry in adults, IU was associated with more negative affect, further supporting the theory that IU is not uniquely related to worry. Overall, we found consistent associations between IU and worry across childhood, and we found that adults were more worried under uncertainty when they were high in IU, compared to low. We did not find any association between IU and children's self-reported worry, which may be due to issues with measurement, or may indicate that the construct of IU is not predictive of state emotions in children. Importantly, IU does not appear to be uniquely associated with worry, with associations to externalising and internalising problems found more broadly.

5.4.2 IU and behaviour and affect under uncertainty

The studies in this thesis also aimed to examine the relationship between IU and both information seeking behaviour and affect, under uncertainty, after controlling for any effects of curiosity. This second aim was addressed via a behavioural task with children (Study 2) and adults (Study 3). Existing literature has examined information seeking behaviour under uncertainty in children with high IU (Osmanağaoğlu et al., 2021) and found that IU was not related to information seeking behaviour. Information seeking under uncertainty and high IU in adults (Bartoszek et al., 2022; Jacoby et al., 2014) has also been examined, however there have been mixed findings, countering expectations that those high in IU may undertake safety behaviours to reduce the discomfort associated with the uncertainty. It has also been suggested that those higher in IU would experience more negative affect in response to uncertainty, relative to low IU (Einstein, 2014; Jacoby et al., 2014). Jacoby et al. (2014) found this relationship in adults, but there is limited research, particularly in children. Osmanağaoğlu et al. (2021) found a relationship between negative affect and IU when IU was child self-reported, but not with parent-reported IU. The studies in this thesis aimed to extend current research by further exploring these contradictions in the literature. Whilst the primary focus of the thesis was IU, curiosity has also been linked to information seeking (Frazier et al., 2009; Murayama et al., 2019) and positive affect (Jovanovic & Brdaric, 2012; Kashdan et al., 2004) therefore to ensure robustness of effects, this was controlled for.

The thesis led to mixed findings with regards IU and behaviour under uncertainty, with particular inconsistencies between children and adults. In Study 2, children sought more information under higher uncertainty than lower uncertainty trials, but this was not related to IU, supporting Osmanağaoğlu et al. (2021)'s findings. In Study 3, adults with higher IU did not seek more information in the game than those with lower IU, similar to Jacoby et al. (2014)'s findings, but contrary to Bartoszek et al. (2022)'s findings where those high in IU wished to fill an information gap. Curious adults however sought more information than less curious adults, indicating that curiosity is linked to information seeking despite IU not being related.

There are distinct findings with regards IU and affect under uncertainty between children and adults. In Study 2, there was no association between IU and affect, similar to Osmanağaoğlu et al. (2021)'s findings. Further exploration however found with younger children, higher IU was related to more negative affect on low uncertainty trials, and for older children, higher IU was related to more negative affect on high uncertainty trials, however these findings need to be interpreted with caution. In Study 3, IU was found to be related to affect in adults; adults with higher IU had more negative affect and were more worried, particularly in high uncertainty, similar to Jacoby et al. (2014)'s findings. The only significant relationship with affect came with children's curiosity in Study 2 where more curious children rated their affect more positively; this was not related to trial uncertainty. Similar to Jovanovic and Brdaric (2012), the more curious children reported more positive affect than less curious children.

To summarise, IU was not related to information seeking behaviour in children, nor in adults, however children did seek more information in general on high uncertainty trials, perhaps suggesting a general curiosity. Further to this, curious children also reported more positive affect. In children, IU was not related to affect, however in adults, it was. These findings together present a mixed picture with regards to the hypothesis. IU does not clearly lead to increased information seeking, although the exploratory findings suggest there may be a subtle relationship with behaviour in children, which requires replication. In adults, IU appears to be related to more negative affect, but this same association is not found in children. The findings therefore suggest that there may be developmental differences in how IU, behaviour and affect under uncertainty are related.

5.5 Strengths

This thesis has several strengths. Study 1 is the first research to examine IU and generalised anxiety over time in early to middle childhood, which is important because associations between IU and worry may change as children develop. Study 2 and 3 present some of the first research to examine the construct of IU and curiosity together in relation to behaviour and affect. Novel methods, with careful controls, were used to capture information seeking, worry and affect in response to uncertainty on a 'lab-based task' which was actually conducted remotely by participants' at home (due to COVID-19 lockdowns). This study also trialled recording and coding children's facial affect through their webcam as an alternative to being unable to use physiological measures in the lab due to the COVID-19 lockdowns. Lastly, the design of Study 2 was based on an adult study, which was adapted for children, and then replicated with adults. This approach builds the evidence base in the field, allowing easy comparisons across findings.

5.6 Limitations, reflections and future directions

Despite the strengths of this thesis, there are several limitations, many of which have been discussed in individual papers. There are however some broader limitations that need to be considered in relation to the findings and conclusions of this thesis. In this next section, these limitations are discussed within the context of broader reflections on the processes and learning that has taken place as this thesis was conducted. Opportunities for future research are also included.

5.6.1 Research through a pandemic

When reflecting on the pathway and development of plans for this thesis, the COVID-19 pandemic needs to be considered. A full body of work was designed, programmed and piloted in 2019, and data collection had just begun as the lockdown was announced. All activities were lab based and included computerised tasks examining decision making under uncertainty and psychophysiological measures to examine the body's response to uncertainty in children, along with an observation task to examine behavioural responses to uncertainty. For an overview of the original research questions and methods see Appendix 14. When it was clear that the return to the lab was not imminent, a new body of work needed to be developed to address the research questions as best as possible using methods that would work remotely. This allowed the introduction of novel methods such as recording and coding facial affect, but also created challenges. As participants were in their own home rather than in the lab, there was limited control over the environment around them when completing the task. I trialled collecting and coding facial affect but this was not very reliable, despite considered effort to improve reliability. Thus, a limitation of the thesis is that the studies are not as carefully controlled as they would have been in a lab setting and it was not possible to include psychophysiological measures, which may have provided further insights into children's behaviour under uncertainty.

Following on from the studies in this thesis, the relationship between behaviour and IU in children remains unclear, with little evidence so far that IU directly affects behaviour. Further investigation is therefore required to examine different types of behaviour and some of the subtle aspects of the relationship. Next steps may include a battery of measures, potentially similar to the originally planned "Uncertainty Room" (see Appendix 14; where behaviour under uncertainty can be observed, including physiological measures to examine skin conductance and pupil dilation under uncertainty in conjunction with a number of questionnaire measures of uncertainty.

Lastly, in the longitudinal study (Study 1), the unexpected stressor of the lockdown may have impacted the trajectory of mental health symptoms over time. It would therefore be beneficial to follow up with the cohort again to give a fourth timepoint. It also could be interesting to see the relationship between IU and generalised anxiety in early adolescence, as the children transition into puberty and to high school, as anxiety can emerge at this time.

5.6.2 Conducting research with children

There are many complexities in doing research and experimental work with children, particularly research that addresses complex and potentially developmentally-sensitive constructs such as IU. There are difficulties with designing tasks and capturing responses to uncertainty and there appear to be nuances in how children behave and feel throughout different ages of development. Children may be overconfident in the face of uncertainty as they face it all the time, thus, confidence may differ depending on stage of development (Lapidow et al., 2022). It may also be only specific types of uncertainty, under specific situations that influences children's emotional and behavioural responses. For example, perhaps only uncertainty in situations that are important to children might affect their emotions and behaviour (e.g. a child who is really committed to playing football and their team winning might particularly react to uncertainty in the context of their football games).

One challenge when working with young children is that they cannot easily provide self-report. The thesis results suggest that parent-reported IU may not accurately reflect the potentially developmental aspects of IU and the internal state of children, especially when compared to child self-report IU. It is therefore important to establish an effective way of capturing IU in children. Further to this, existing measures of IU in children may not take any changes through development into account. One possibility addressing the latter concern is the new measure Youth Intolerance of Uncertainty – Parent Report (YIU-PR) (Wong & Caporino, 2023) which claims to be a developmentally sensitive measure of IU in children and adolescents. This was not yet available when the thesis work began so it was not possible to include it. A further consideration with regards to behavioural tasks with children, is that they have mainly been designed based on adult behavioural studies. As we have seen in this thesis, the manifestation of IU may differ between children and adults, therefore novel designs should be developed specifically with children in mind.

Another developmental consideration is what the profile of IU in adolescence looks like. Tymula et al. (2012) suggests that adolescents are better at tolerating uncertainty than adults and may therefore take risks where adults may not. However their relationship with uncertainty is not straightforward. They can tolerate the uncertainty within ambiguous conditions (such as when it is unclear if they will win or lose), but they are more averse to clearly stated risk (Tymula et al., 2012)s. This further illustrates the potential developmental changes in responses to uncertainty that occur between childhood and adolescence and that further research examining developmental trajectories of IU into adolescence is warranted.

5.6.3 Qualitative work with young people

The importance of doing qualitative work to capture children's voices cannot be understated. Understanding children's thoughts and behaviour in relation to uncertainty and uncertain situations in real life could further inform experimental work. It could also help to develop interventions that target reactions to uncertainty specifically in those with high IU. As part of the work conducted for this PhD, I conducted initial interviews with young people and parents where children were high in IU. Unfortunately it was not possible to conduct a full qualitative analysis of these interviews due to time constraints. Initial reflections following from interviews with young people high in IU are that they can feel uncertain in any number of situations, ranging from taking a test, going on holiday, to being bullied. Most young people seem to experience physical feelings of uncertainty (such as stomach aches, butterflies and sweaty palms), and tend to have some kind of physical manifestation such as having slower physical movements and staying quiet. Interestingly, many young people also reported some kinds of uncertainty being positive (such as birthday surprises, holidays, seeing old friends), and reported that in that situation their behaviour would be energetic and chatty. This suggests that not all uncertainty might be negative for young people high in IU. Individuals reported that adding new uncertain things when they are already in a situation they do not like, adding pressure, or having lots of people talking about the uncertainty made it worse. What was clear however is that what creates a sense of uncertainty, and how children respond, is very idiosyncratic; what is unpleasant and uncertain for one person who is high in IU may be positive and uncertain for another. Initial reflections suggest that conducting this kind of qualitative work is an important direction for future research in further understanding how IU manifests in children and the nuance of children’s personal relationship with uncertainty

5.6.4 General reflections

My general reflections from the past six years of working on this body of work is that young people’s feelings and behaviours surrounding uncertainty are very much situational. I also believe that thresholds are very important when it comes to young people being able (or not able) to deal with uncertainty. The more uncertainties are stacked up, the less able the children are to deal with it. Children higher in IU may therefore have a lowered threshold for the point at which they feel there is too much uncertainty. It may be that isolated uncertainty studies are not effective because they do not offer real-life situations where outcomes are valued. It is also possible that, because there is typically only one uncertainty that they face in a lab-based task, it is not enough for most participants to push them over their threshold. It may be sensible to try to build tasks that more closely reflect real life, where the outcome is related to participants’ own values and goals and also to manipulate levels of uncertainty in different domains to test the hypothesis that the more uncertainty there is, the less able participants high in IU are to cope.

5.6.5 Future research summary

Priorities for future research include designing experimental tasks specifically for children, based on current research, and including psychophysiological measures. In anxiety research, some commonly used psychophysiological measures are heart rate variation, skin conductance response, pupillometry and facial EMG (Hyde et al., 2019). Altering the stimuli when examining physiological responses in experimental tasks by, for example, removing threat or introducing positive uncertainty could help to further elucidate physiological responses under uncertainty. Physiological characteristics may indeed look different under uncertainty than under anxiety and exploring this further may help to disentangle anxiety from IU. A further consideration is whether there are any novel physiological measures of reactions to uncertainty that are separate to measures of anxiety.

As previous research examining the relationship between children's behaviour and IU is sparse and has had mixed findings, and as parent-reported IU does not necessarily seem to be capturing IU in children, further understanding the differential patterns of children's behaviour in response to uncertainty through behavioural observation work would be helpful in establishing if changes in behaviour are observable and are related to IU. The Uncertain World game could be modified, with a focus on conditions under which emotional and behavioural differences may be elicited, for example, manipulating levels of threat and adding more variations of uncertainty, including a condition with 50% certain and 50% uncertain buttons, and another condition where all of the buttons are certain. Further to this, we could establish each child's personal threshold of acceptable levels of uncertainty and manipulate uncertainty based on this baseline per child. Manipulating reward or salience could also help to further understand children's behaviour under uncertainty potentially by way of adding an incentive or goal through instruction e.g. gaining points for pressing as many buttons as possible in a minute or by removing the reward. "Removing the reward" could involve the child having to pay to engage with uncertainty i.e. the child is given a pound and has to pay 10 pence to press each button. Manipulating these various parameters could help towards getting a more sensitive measure of responses to uncertainty. In order to increase sensitivity with regards to curiosity, it is worth considering including positive noises and varying the game instructions to attempt to elicit curiosity.

There are various different developmental stages of childhood which would be helpful to explore with regards to IU. As it is unclear at what point IU may begin in childhood, it is important to be able to measure IU in younger children, however no measures currently exist. As behaviour is difficult to see when it comes to IU in children, it is necessary to further explore of the manifestation of IU through games using different types of uncertainty. Childhood transitions can lead to a sense of uncertainty, and as there is a lack of clarity with regards to IU through development, it is important to examine these periods. Examining IU in children in years 6 and Year 7 who are transitioning to secondary school, and concurrently examining IU in a control group of middle school pupils who are not transitioning could further help our understanding of IU at these times of change. Extending the longitudinal study into adolescence would also be beneficial in understanding further the trajectory of generalised anxiety and IU. Of note, the adult IU/GAD data from the Uncertain World game looked similar to that of the older children, therefore examining this further through cross-sectional work may provide some interesting insight.

Due to the potential fluctuations in IU through development, and as parent-report could be considered an unsatisfactory measure of IU, it would be beneficial to develop a developmentally sensitive child-report measure of IU. Lastly, qualitative work would be beneficial to understanding children’s thoughts and feelings surrounding uncertainty and in developing a child self-report measure.

5.7 Clinical Implications

There is increased interest in developing treatments for generalised anxiety in children, targeting uncertainty specifically. This is in part motivated by research showing that, in adults, treatment targeting tolerating uncertainty has been found to be successful in reducing social phobia and GAD (Miller & McGuire, 2023). There is also interest in developing alternative treatments for children with anxiety as CBT is not effective in a large percentage of young people (James et al., 2020).

This thesis aimed to further understanding of the relationship between IU and anxiety as well as responses to uncertainty with a view to informing future research or interventions, ensuring that the correct mechanisms are targeted. Unfortunately, due to research in children lagging behind that of adults, there has not yet been sufficient evidence to develop IU-focused treatments for children, however this thesis has extended the literature, and the understanding of the nature of IU in children, providing future directions for necessary research.

The results of Study 1 showed that IU may be a core feature of anxiety in young children through to middle childhood, but there was no evidence that it was playing a causal role in the onset of generalised anxiety. Preschool children with higher IU actually showed a decrease in generalised anxiety over time. It is not therefore clear whether targeting IU in interventions with younger children would be useful for reducing future generalised anxiety. Further to this, in Study 2, a complex relationship between IU and behaviour emerged, suggesting that those with higher IU may be using regulatory or checking behaviours under high uncertainty. This requires further investigation, however this is clinically of interest as could be a potential focus for treatment. The lack of relationship between IU and worry needs to be interpreted with caution, as the parent-report measure of IU may not be representing the internal thoughts of the children.

The efficacy of treatment targeting tolerating uncertainty in adults (Miller & McGuire, 2023) is logical, following the results in Study 3 where adults are less happy and more worried under uncertainty. However, as the pattern of results appear differently in children in Study 2, it is worth considering that our expectations of behaviour and affect in children with IU may not be correct. It may be that targeting uncertainty in therapy for adults with IU may act as a means of reducing anxiety/worry, but these therapies for adults may not be effective with children due to their differing response to uncertainty. It is clear that IU may present differently in children than adults, and that more research needs to be done to understand the intricacies of the relationship between IU and anxiety in children over development before evidence-based interventions can be effectively developed.

5.8 Conclusions

The studies in this thesis aimed to examine the association between IU and worry using a longitudinal study design and a behavioural task. The thesis fulfilled this aim and established that, through early and middle childhood, IU was associated with generalised anxiety symptoms, but that IU did not appear to cause the onset of generalised anxiety in children.

The studies in this thesis also aimed to examine the relationship between IU and information seeking behaviour and affect under uncertainty in both children and in adults, after controlling for the effect of curiosity. The thesis fulfilled this aim; IU and information seeking behaviour in children were not related in general, however in specific circumstances, those high in IU may seek very particular information. IU and information seeking behaviour in adults were not found to be related at all. IU was not related to affect in children, however in adults, it was.

These findings advance current understanding of the construct of IU and how it relates to behavioural, cognitive and emotional responses to uncertainty. Furthermore, the thesis provides new knowledge about developmental associations between IU and generalised anxiety. Priorities for future work include further psychophysiological, observational and qualitative work with children.

5.9 References

Achenbach, T. M. (1966). The classification of children's psychiatric symptoms: A factor-analytic study. *Psychological Monographs: General and Applied*, *80*(7), 1-37. https://doi.org/10.1037/h0093906

Bartoszek, G., Ranney, R. M., Curanovic, I., Costello, S. J., & Behar, E. (2022). Intolerance of uncertainty and information-seeking behavior: Experimental manipulation of threat relevance. *Behaviour Research and Therapy*, *154*, 104125. https://doi.org/https://doi.org/10.1016/j.brat.2022.104125

Buhr, K., & Dugas, M. J. (2002). The intolerance of uncertainty scale: Psychometric properties of the English version. Behaviour Research and Therapy, 40(8), 931-945.

Counsell, A., Furtado, M., Iorio, C., Anand, L., Canzonieri, A., Fine, A., Fotinos, K., Epstein, I., & Katzman, M. A. (2017). Intolerance of uncertainty, social anxiety, and generalized anxiety: Differences by diagnosis and symptoms. *Psychiatry research*, *252*, 63-69.

Daughters, S. B., Reynolds, E. K., MacPherson, L., Kahler, C. W., Danielson, C. K., Zvolensky, M., & Lejuez, C. W. (2009). Distress tolerance and early adolescent externalizing and internalizing symptoms: The moderating role of gender and ethnicity. Behaviour research and therapy, 47(3), 198-205.

Dugas, M. J., Laugesen, N., & Bukowski, W. M. (2012). Intolerance of uncertainty, fear of anxiety, and adolescent worry. *Journal of Abnormal Child Psychology*, *40*(6), 863-870. https://doi.org/10.1007/s10802-012-9611-1

Einstein, D. A. (2014). Extension of the transdiagnostic model to focus on intolerance of uncertainty: a review of the literature and implications for treatment. *Clinical Psychology: Science and Practice*, *21*(3), 280.

Frazier, B. N., Gelman, S. A., & Wellman, H. M. (2009). Preschoolers' search for explanatory information within adult-child conversation. *Child Development*, *80*(6), 1592-1611. https://doi.org/10.1111/j.1467-8624.2009.01356.x

Gramszlo, C., Fogleman, N. D., Rosen, P. J., & Woodruff-Borden, J. (2018). Intolerance of uncertainty in children with attention-deficit/hyperactivity disorder. *ADHD Attention Deficit and Hyperactivity Disorders*, *10*(3), 189-197. https://doi.org/10.1007/s12402-017-0244-7

Grupe, D. W., & Nitschke, J. B. (2013). Uncertainty and anticipation in anxiety: an integrated neurobiological and psychological perspective. *Nature Reviews Neuroscience*, *14*(7), 488-501. https://doi.org/10.1038/nrn3524

Holaway, R. M., Heimberg, R. G., & Coles, M. E. (2006). A comparison of intolerance of uncertainty in analogue obsessive-compulsive disorder and generalized anxiety disorder. *Journal of Anxiety Disorders*, *20*(2), 158-174.

Hsee, C. K., & Ruan, B. (2016). The Pandora Effect: The Power and Peril of Curiosity. *Psychological Science*, *27*(5), 659-666. https://doi.org/10.1177/0956797616631733

Hyde, J., Ryan, K. M., & Waters, A. M. (2019). Psychophysiological markers of fear and anxiety. Current Psychiatry Reports, 21, 1-10.

Jacoby, R. J., Abramowitz, J. S., Buck, B. E., & Fabricant, L. E. (2014). How is the Beads Task related to intolerance of uncertainty in anxiety disorders? *Journal of Anxiety Disorders*, *28*(6), 495-503. https://doi.org/10.1016/J.JANXDIS.2014.05.005

James, A. C., Reardon, T., Soler, A., James, G., & Creswell, C. (2020). Cognitive behavioural therapy for anxiety disorders in children and adolescents. *Cochrane database of systematic reviews*(11).

Jovanovic, V., & Brdaric, D. (2012). Did curiosity kill the cat? Evidence from subjective well-being in adolescents. *Personality and Individual Differences*, *52*(3), 380-384. https://doi.org/https://doi.org/10.1016/j.paid.2011.10.043

Kashdan, T. B., Rose, P., & Fincham, F. D. (2004). Curiosity and Exploration: Facilitating Positive Subjective Experiences and Personal Growth Opportunities. *Journal of Personality Assessment*, *82*(3), 291-305. https://doi.org/10.1207/s15327752jpa8203_05

Koerner, N., & Dugas, M. J. (2008). An investigation of appraisals in individuals vulnerable to excessive worry: the role of intolerance of uncertainty. *Cognitive Therapy and Research*, *32*(5), 619-638. https://doi.org/10.1007/s10608-007-9125-2

Krain, A. L., Gotimer, K., Hefton, S., Ernst, M., Castellanos, F. X., Pine, D. S., & Milham, M. P. (2008). A Functional Magnetic Resonance Imaging Investigation of Uncertainty in Adolescents with Anxiety Disorders. *Biological Psychiatry*, *63*(6), 563-568. https://doi.org/10.1016/j.biopsych.2007.06.011

Krain, A. L., Hefton, S., Pine, D. S., Ernst, M., Xavier Castellanos, F., Klein, R. G., & Milham, M. P. (2006). An fMRI examination of developmental differences in the neural correlates of uncertainty and decision-making. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *47*(10), 1023-1030. https://doi.org/10.1111/j.1469-7610.2006.01677.x

Lapidow, E., Killeen, I., & Walker, C. M. (2022). Learning to recognize uncertainty vs. recognizing uncertainty to learn: Confidence judgments and exploration decisions in preschoolers. *Developmental science*, *25*(2), e13178.

Miller, M. L., & McGuire, J. F. (2023). Targeting intolerance of uncertainty in treatment: A meta-analysis of therapeutic effects, treatment moderators, and underlying mechanisms.

Journal of Affective Disorders, *341*, 283-295. https://doi.org/https://doi.org/10.1016/j.jad.2023.08.132

Murayama, K., Fitzgibbon, L., & Sakaki, M. (2019). Process Account of Curiosity and Interest: A Reward-Learning Perspective. *Educational Psychology Review*, *31*(4), 875-895. https://doi.org/10.1007/s10648-019-09499-9

Osmanağaoğlu, N., Creswell, C., & Dodd, H. F. (2018). Intolerance of Uncertainty, anxiety, and worry in children and adolescents: A meta-analysis. *Journal of Affective Disorders*, *225*, 80-90. https://doi.org/10.1016/J.JAD.2017.07.035

Osmanağaoğlu, N., Creswell, C., & Dodd, H. F. (2021). Development of a behavioural measure of Intolerance of Uncertainty in preadolescent children: Adaptation of the beads task. *Journal of Behavior Therapy and Experimental Psychiatry*, *72*, 101654-101654. https://doi.org/10.1016/J.JBTEP.2021.101654

Sexton, K. A., & Dugas, M. J. (2009). Defining distinct negative beliefs about uncertainty: validating the factor structure of the Intolerance of Uncertainty Scale. *Psychological assessment*, *21*(2), 176.

Tymula, A., Rosenberg Belmaker, L. A., Roy, A. K., Ruderman, L., Manson, K., Glimcher, P. W., & Levy, I. (2012). Adolescents' risk-taking behavior is driven by tolerance to ambiguity. *Proceedings of the National Academy of Sciences*, *109*(42), 17135-17140.

Wong, J. X., & Caporino, N. E. (2023). Youth Intolerance of Uncertainty – Parent-Report (YIU-PR): A Developmentally Sensitive Measure of Intolerance of Uncertainty in Children and Adolescents. *Journal of Psychopathology and Behavioral Assessment*, *45*(1), 194-206. https://doi.org/10.1007/s10862-022-10016-6

6 Appendices

6.1 Appendix 1a) Supplementary Materials for Study 1

Demographic Information

Table S1. Demographic characteristics of the sample used in the analyses at baseline, time point 2 and time point 3

	Baseline	TP2	TP3
Characteristic	*N* (%)	*N* (%)	*N* (%)
Child gender	180	162	148
Male	90 (50%)	79 (49%)	69 (47%)
Female	90 (50%)	83 (51%)	79 (53%)
Child ethnicity			
White	159 (88%)	145 (90%)	129 (87%)
Non-white	21 (12%)	17 (10%)	19 (13%)
Child birth order			
First born	93 (52%)	82 (51%)	75 (51%)
Second born	61 (34%)	55 (34%)	50 (34%)
Third	16 (9%)	15 (9%)	13 (9%)
Other	10 (6%)	10 (6%)	10 (7%)
Diagnosed learning difficulty, mental health problem or atypical development			
Yes	3 (2%)	13 (8%)	31 (21%)
No	177 (98%)	149 (92%)	117 (79%)
Caregiver marital status			
One parent at home (Single,	18 (10%)	17 (10%)	18 (12%)
Separated, Divorced)	142 (79%)	132 (81%)	119 (80%)
Two parents at home	20 (11%)	13 (8%)	11 (7%)
(Married)			
Other			
Parent employment status			
Employed full-time	25 (14%)	34 (21%)	46 (31%)
Employed part-time	76 (42%)	74 (46%)	69 (47%)
Self-employed	Not option at TP1	17 (10%)	19 (13%)
Full-time home-maker	48 (27%)	22 (14%)	11 (7%)
Unemployed	6 (3%)	3 (2%)	1 (1%)
Other	25 (14%)	12 (7%)	2 (1%)
Parent level of education			
Primary School	2 (1%)	3 (2%)	3 (2%)
GCSE	15 (8%)	13 (8%)	9 (6%)
A-levels	11 (6%)	12 (7%)	8 (5%)
College/apprenticeship	21 (12%)	17 (10%)	20 (14%)
Certificate/Diploma	84 (47%)	74 (46%)	61 (41%)
Undergraduate Degree	29 (16%)	23 (14%)	26 (18%)
Postgraduate Degree	18 (10%)	20 (12%)	21 (14%)
Child attending school in first lockdown			

Yes	32 (20%)
No	130 (80%)
Parent essential worker	
Yes	67 (41%)
No	95 (59%)
Child in vulnerable group re COVID	
Yes	3 (2%)
No	159 (98%)
Member of family in vulnerable group re COVID	
Yes	35 (22%)
No	127 (78%)

Methods

Power analysis

With regards to power analysis, we were restricted by our baseline sample size (180 participants). In our previous longitudinal work, a drop out at follow up of approximately 20% has been typical. This leaves an approximate sample size of 144 participants. We conducted a post hoc power analysis using G*Power3.1 (Faul, Erdfelder, Lang, & Buchner, 2007) to evaluate what effect size we would be able to detect with at least 80% power given this sample size. Using multiple regression to evaluate an R^2 increase with one tested predictor (IU) and either 1, 2 or 3 predictors total (IU, baseline GA/internalising problems/or externalising problems (and) parental anxiety), and an alpha of 0.05, the smallest f^2 effect size we would detect using $p < .05$ would be $f^2 = 0.06$ and this would be detected at 83% power. We were satisfied that the sample is large enough to provide a robust test of the hypotheses. A small effect size would be missed, but as the clinical utility of a predictor with a small effect size is limited, the study was adequately powered to detect clinically relevant predictors of generalized anxiety. Following on from this approach to power, we chose to analyse the data using mixed effects models and growth curve analysis.

We have not conducted any analysis of the IU baseline data and therefore have no bias by prior observation.

Results

Descriptive statistics

The descriptive statistics for certain PAS/SCAS subscales (Social Anxiety (SA), Separation Anxiety (Sep), Generalised Anxiety (GA)) and RULES scores can be found in Table S2 below, as well as bivariate correlations between the variables. As shown in Table S2, all variables were correlated apart from TP1 Social Anxiety and TP3 Generalised Anxiety.

Table S2. Means, standard deviations, and correlations with confidence intervals for certain PAS/SCAS subscales (Social Anxiety (SA), Separation Anxiety (Sep), Generalised Anxiety (GA)) and RULES scores at each time point.

Variable	*M*	*SD*	1	2	3	4	5	6	7	8	9	10	11
1. TP1 SA	6.40	4.75											
2. TP2 SA	4.90	3.11	.38** [.23, .50]										
3. TP3 SA	5.18	3.20	.23** [.08, .38]	.52** [.39, .63]									
4. TP1 Sep	4.09	3.21	.56** [.45, .65]	.42** [.29, .54]	.30** [.14, .44]								
5. TP2 Sep	5.49	3.57	.25** [.10, .39]	.60** [.49, .69]	.53** [.40, .64]	.45** [.32, .57]							
6. TP3 Sep	4.82	3.53	.16* [.00, .32]	.41** [.27, .54]	.58** [.46, .68]	.39** [.25, .52]	.61** [.50, .71]						
7. TP1 GA	3.94	3.41	.63** [.53, .71]	.46** [.33, .58]	.39** [.25, .52]	.72** [.64, .79]	.50** [.37, .61]	.35** [.20, .48]					
8. TP2 GA	3.38	2.23	.22** [.06, .36]	.61** [.50, .69]	.50** [.36, .61]	.45** [.32, .57]	.65** [.55, .73]	.45** [.31, .57]	.56** [.44, .66]				
9. TP3 GA	3.83	2.79	.11 [-.06, .26]	.42** [.28, .55]	.59** [.47, .68]	.34** [.19, .48]	.52** [.39, .63]	.74** [.65, .80]	.38** [.23, .51]	.57** [.45, .67]			
10. TP1 RULES	35.01	11.48	.56** [.45, .65]	.47** [.34, .58]	.37** [.23, .51]	.63** [.53, .71]	.40** [.26, .52]	.30** [.14, .44]	.74** [.67, .80]	.46** [.32, .57]	.34** [.19, .48]		
11. TP2 RULES	34.38	14.95	.25** [.10, .39]	.71** [.63, .78]	.53** [.40, .64]	.38** [.24, .50]	.62** [.52, .71]	.45** [.30, .57]	.53** [.41, .63]	.68** [.59, .76]	.45** [.31, .58]	.62** [.52, .71]	
12. TP3 RULES	35.76	15.62	.20* [.04, .35]	.57** [.44, .67]	.63** [.52, .71]	.30** [.15, .44]	.51** [.38, .62]	.62** [.51, .71]	.42** [.28, .55]	.53** [.40, .64]	.60** [.48, .69]	.51** [.38, .62]	.78** [.70, .84]

Note. M and *SD* are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. The confidence interval is a plausible range of population correlations that could have caused the sample correlation (Cumming, 2014). * indicates p < .05. ** indicates p < .01.

Growth curve models not controlling for STAI or marital status

Models were run without controlling for STAI or marital status. These revealed very similar results to the models 1b, 2b and 3b of supplementary materials where controls and outliers were included (see Table S4).

Model 1a: RULES and GA subscale score models, not controlling for STAI or marital status

RULES was a significant predictor of GA subscale score [F[1] = 105.93 $p < .001$], and there was no significant linear effect of time [F[1] = 0.58, $p = .446$], but there was a significant quadratic effect of time [F[1] = 5.71, $p = .017$]. There was, a significant interaction between RULES and linear time [F[1] = 12.36, $p < .001$]. Further probing of this interaction using the Johnson-Neyman technique showed that a greater RULES score was linked to a decrease in GA subscale score over time (Fig 1aS(A)) (i.e. where RULES was ≥ 1.01, there was a linear decrease in GA subscale score over time). Additionally, a low RULES score was also linked to an increase in GA subscale score over time (i.e. where RULES was ≤ -0.37, there was a linear increase in GA subscale score over time), however this was predominantly outside the range of observed data. There was no significant interaction between RULES and the quadratic effect of time [F[1] = 2.57, $p = .110$]. All of these effects and interactions (or lack of) follow the same pattern as the main manuscript where outliers were removed, except that there was a linear effect of time and a significant interaction between RULES and the quadratic effect of time (see Model 1 in the main manuscript).

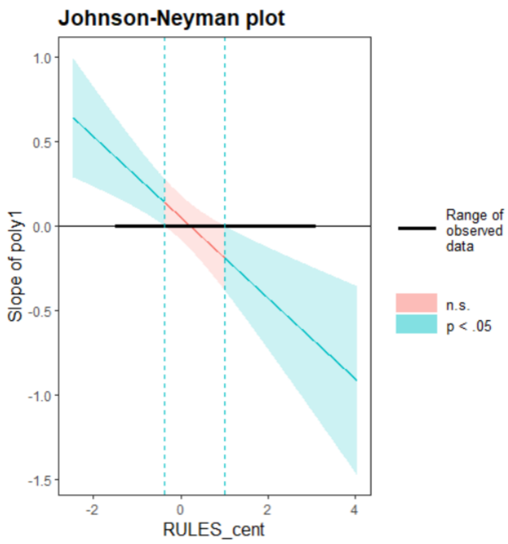


Fig 1aS. RULES and GA subscale score, not controlling for STAI or marital status. This figure shows a Johnson-Neyman plot illustrating the significant interaction effects. 1aS shows the relation between RULES scores and linear slope of GA subscale score over time. The range of observed data is shown by the bold black horizontal line, the blue shaded areas show where the slopes were significant (p < .05), and the red shaded areas show where the slopes were not significant (n.s). RULES moderated a decrease in GA subscale score over time; when RULES scores were ≥ 1. 01, the linear decrease of GA subscale score over time differed significantly from zero. The higher the RULES, the stronger the linear decrease of GA subscale score over time. The opposite was found for low RULES scores. Where RULES ≤ -0.37, there was a linear increase in GA subscale score over time, however this predominantly lay outside the range of observed data.

Model 2a: RULES and HBQ Internalising models, not controlling for STAI or marital status

RULES was a significant predictor of HBQ Internalising [F[1] = 115.46, p < .001], and there was a significant linear effect of time [F[1] = 62.96, p < .001] however there was no significant quadratic effect of time [F[1] = 1.02, p = .312]. There was a significant interaction between RULES and linear effects of time [F[1] = 6.48, p = .011], however there was no interaction between RULES and quadratic effects of time [F[1] = 0.13, p = .717]. Further probing of the significant interaction using Johnson-Neyman technique showed that a lower RULES score was linked to an increase in HBQ Internalising scores over time (Fig 2aSA) (i.e. where RULES was ≤ 1.61, there was a linear increase in HBQ internalising over time). Additionally, a high RULES score was also linked to a decrease in HBQ internalising over time (i.e. where RULES was ≥ 13.62, there was a linear decrease in HBQ internalising over time), however this was predominantly outside the range of observed data. The pattern of these results matches the main manuscript where controls are included and outliers removed, except that in the main model, there was in fact a marginal quadratic effect of time (see Model 2 in the main manuscript).

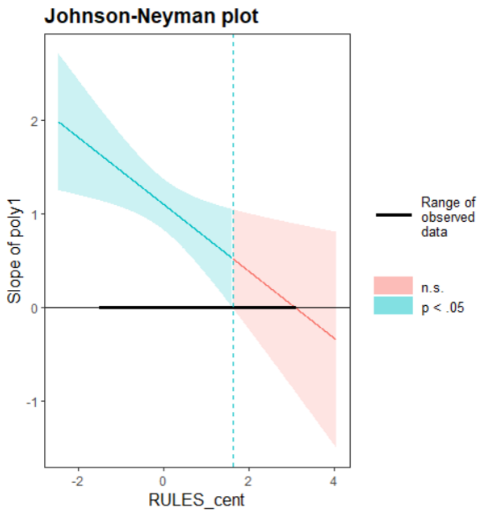


Fig 2aS. RULES and HBQ Internalising, not controlling for STAI and marital status. This figure shows a Johnson-Neyman plot illustrating the significant interaction effects. 2aS shows the relation between RULES scores and linear slope of HBQ Internalising over time. The range of observed data is shown by the bold black horizonal line, the blue shaded areas show where the slopes were significant (p < .05), and the red shaded areas show where the slopes were not significant (n.s). RULES moderated an increase of HBQ internalising over time; when RULES scores were ≤ 1.61, the linear increase of HBQ internalising over time differed significantly from zero. The lower the RULES, the stronger the linear increase of HBQ internalising over time. The opposite was found with high RULES scores. Where RULES ≥13.62, there was a linear decrease in HBQ internalising over time, however this lay predominantly outside of the range of observed data.

Model 3a: RULES and HBQ Externalising models, not controlling for STAI or marital status

RULES was a significant predictor of HBQ Externalising [F[1] = 26.79, p < .001] and there was a significant quadratic effect of time [F[1] = 5.53, p = .019]. However, there was not a significant linear effect of time [F[1] = 0.35, p = .557], and there was no significant interaction between RULES and quadratic effects of time [F[1] = 1.11, p = .294]. There was however an interaction between RULES and linear effects of time [F[1] = 4.30, p = .039]. Further probing of this interaction using the Johnson-Neyman technique showed that a greater RULES score was linked to a decrease in HBQ Externalising over time (Fig 3aSA) (i.e. where RULES was ≥ 1.22, there was a linear decrease in HBQ Externalising over time). Additionally, a low RULES score was also linked to an increase in HBQ Externalising over time (i.e. where RULES was ≤ -6.34, there was a linear increase in HBQ Externalising over time), however this was predominantly outside the range of observed data.

When controls were included and outliers removed (in the main manuscript), the pattern of results differed as there was not a significant effect of quadratic time, and there was not a significant interaction between RULES and the linear effect of time, however there was a significant interaction between RULES and the quadratic effect of time.

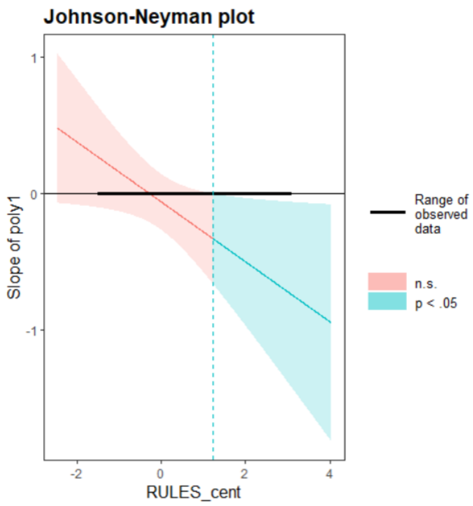


Fig 3aS. RULES and HBQ Externalising, not controlling for STAI and marital status. This figure shows a Johnson-Neyman plot illustrating the significant interaction effects. 3aS shows the relation between RULES scores and linear slope of HBQ Externalising over time. The range of observed data is shown by the bold black horizonal line, the blue shaded areas show where the slopes were significant (*p* < .05), and the red shaded areas show where the slopes were not significant (n.s). RULES moderated an increase of HBQ externalising over time; when RULES scores were ≥ 1. 22, the linear decrease of HBQ Externalising over time differed significantly from zero. The higher the RULES, the stronger the linear decrease of HBQ Externalising over time. The opposite was found for low RULES scores. Where RULES ≤ -6.34, there was a linear increase in HBQ Externalising over time, however this predominantly lay outside the range of observed data.

Table S3: LMM Results with no controlling variables

	GA Subscale Score			HBQ Internalising			HBQ Externalising		
Predictors	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*
Intercept	0.32	0.20 – 0.43	**<0.001**	3.50	3.22 – 3.77	**<0.001**	3.17	2.90 – 3.44	**<0.001**
RULES	0.61	0.49 – 0.73	**<0.001**	1.50	1.23 – 1.78	**<0.001**	0.71	0.44 – 0.99	**<0.001**
Linear Time	0.05	-0.08 – 0.18	0.446	1.10	0.82 – 1.37	**<0.001**	-0.06	-0.26 – 0.14	0.557
Quadratic Time	0.16	0.03 – 0.29	**0.017**	-0.14	-0.41 – 0.13	0.312	-0.24	-0.44 – -0.04	**0.019**
RULES x Linear Time	-0.24	-0.37 – -0.11	**<0.001**	-0.36	-0.63 – -0.08	**0.011**	-0.22	-0.43 – -0.01	**0.039**
RULES x Quadratic Time	0.11	-0.02 – 0.24	0.109	-0.05	-0.33 – 0.22	0.717	-0.11	-0.32 – 0.10	0.293
Random Effects									
σ^2	0.70			2.98			1.66		
τ_{00}	0.35 $_{child\_ID}$			2.28 $_{child\_ID}$			2.71 $_{child\_ID}$		
ICC	0.33			0.43			0.62		
N	179 $_{child\_ID}$			179 $_{child\_ID}$			179 $_{child\_ID}$		
Observations	487			487			486		
Marginal R^2 / Conditional R^2	0.282 / 0.519			0.339 / 0.626			0.112 / 0.664		

Note: RULES scores are centred.

Model 1b: RULES and GA subscale score models controlling for STAI and marital status, including outliers

RULES was a significant predictor of GA subscale score [F[1] = 94.21, p < .001], and there was a significant quadratic effect of time [F[1] = 7.18, p = .008]. There was no significant linear effect of time [F[1] = 0.11, p = .740]. Marital status was not a significant predictor of generalised anxiety [F[2] = 1.00, p = .370, however parent STAI was [F[1] = 8.24, p = .004. There were significant interactions between RULES and the linear effect of time [F[1] = 11.12, p = .001]. Further probing of this interaction using Johnson-Neyman technique showed that a greater RULES score was linked to a decrease in GA subscale score over time (Fig 1bSA) (i.e. where RULES was ≥ 0.88, there was a linear decrease in GA subscale score over time). Additionally, a low RULES score was also linked to an increase in GA subscale score over time (i.e. where RULES was ≤ -0.58, there was a linear increase in GA subscale score over time), however this was predominantly outside the range of observed data. There was no interaction between RULES and the quadratic effect of time[F[1] = 2.10, p = .149].

When covariates (parent STAI and marital status) were removed from the model, the model results were consistent (see Model 1a in Supplementary Materials). When outliers were removed from the model, there was in fact a linear effect of time, and in addition to there being an interaction between RULES and the linear effect of time, there was also an interaction between RULES and the quadratic effect of time (see Model 1 in the main manuscript); when RULES was high there was a slight decline in GA subscale score between TP1 and TP2, and then a slight increase between TP2 and TP3, whereas when RULES was low, there was a steady increase over time.

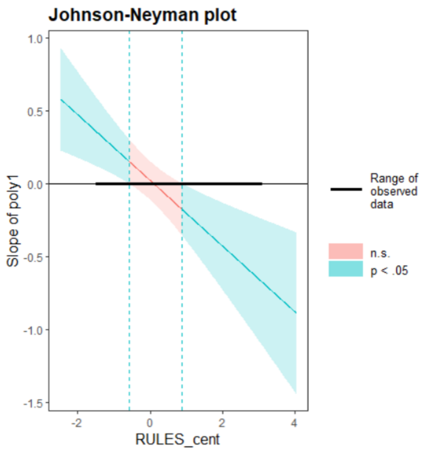


Fig 1bS. RULES and GA subscale score controlling for STAI and marital status. This figure shows a Johnson-Neyman plot illustrating the significant interaction effects; the relation between RULES scores and linear slope of GA subscale score over time. The range of observed data is shown by the bold black horizonal line, the blue shaded areas show where the slopes were significant ($p < .05$), and the red shaded areas show where the slopes were not significant (n.s). RULES moderated a decrease of GA subscale score over time; when RULES scores were ≥ 0.88, the linear decrease of GA subscale score over time differed significantly from zero. The higher the RULES, the stronger the linear decrease of GA subscale score over time. The opposite was found with low RULES scores. Where RULES ≤ -0.58, there was a linear increase in GA subscale score over time, however this lay predominantly outside of the range of observed data.

Model 2b RULES and HBQ Internalising models controlling for STAI and marital status

RULES was a significant predictor of HBQ Internalising scores [F[1] = 100.60 $p < .001$], and there was a significant linear effect of time [F[1] = 53.23, $p < .001$] but no significant quadratic effect of time [F[1] = 0.29, $p = .593$]. There was also a significant effect of STAI [F[1] = 22.79, $p < .001$] but no significant effect of marital status [F[2] = 1.49, $p = .229$]. There was a significant interaction between RULES and linear effects of time [F[1] = 5.10, $p = .025$], however there was no significant interaction between RULES and quadratic effects of time [F[1] = 0.41, $p = .520$]. Further probing of this interaction using Johnson-Neyman technique showed that a lower RULES score was linked to an increase in HBQ Internalising scores over time (Fig 2b) (i.e. where RULES was ≤ 1.58, there was a linear increase in HBQ internalising over time). Additionally, a high RULES score was also linked to a decrease in HBQ internalising over time (i.e. where RULES was ≥ 24.71, there was a linear decrease in HBQ internalising over time), however this was predominantly outside the range of observed data. When outliers were included and confounds were removed from the models, the pattern of results was consistent (see Model 2 in the main manuscript and Model 2a in Supplementary Materials). When outliers were removed from the main model the quadratic effect of time approached significance (see Model 2 in the main manuscript).

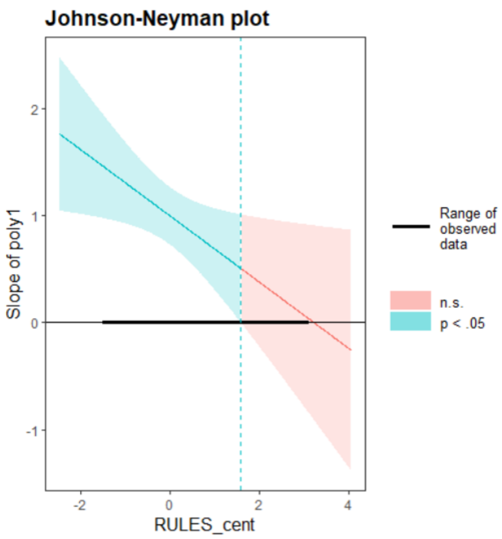


Fig 2bS. RULES and HBQ Internalising controlling for parental anxiety and marital status. This figure shows a Johnson-Neyman plot illustrating the significant interaction effects. 2bS shows the relation between RULES scores and linear slope of HBQ Internalising over time. The range of observed data is shown by the bold black horizonal line, the blue shaded areas show where the slopes were significant (*p* < .05), and the red shaded areas show where the slopes were not significant (n.s). RULES moderated an increase of HBQ internalising over time; when RULES scores were ≤ 1.58, the linear increase of HBQ internalising over time differed significantly from zero. The lower the RULES, the stronger the linear increase of HBQ internalising over time. The opposite was found with high RULES scores. Where RULES ≥24.71, there was a linear decrease in HBQ internalising over time, however this lay predominantly outside of the range of observed data.

Model 3b RULES and HBQ Externalising models controlling for STAI and marital status

RULES was a significant predictor of HBQ Externalising scores [F[1] = 19.95, $p < .001$] but there was no significant linear effect of time [F[1] = 1.70, $p = .193$ and no significant quadratic effect of time [F[1] = 3.61, $p = .058$]. There was a significant effect of STAI [F[1] = 16.57, $p < .001$] and of marital status [F[2] = 4.45, $p = .013$]. However, there was a marginal significant interaction between RULES and linear[F[1] = 3.16, $p = .076$] but no significant interaction with quadratic [F[1] = 1.72, $p = .190$] effects of time.

When controlling variables were removed from the model, the results were similar however there was a significant quadratic effect of time, and a significant interaction between RULES and the linear effect of time (see Model 3a in Supplementary Materials). When outliers were removed, results were similar but there was no significant interaction between RULES and linear effects of time, and there was a significant interaction between RULES and quadratic effects of time (see Model 3 in the main manuscript).

Table S4. LMM Results.

	GA Subscale Score			HBQ Internalising			HBQ Externalising			GA Subscale Score no controls		
Predictors	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*
Intercept	0.51	0.15 – 0.87	**0.006**	4.17	3.33 – 5.01	**<0.001**	4.33	3.51 – 5.15	**<0.001**	0.32	0.20 – 0.43	**<0.001**
RULES	0.58	0.46 – 0.70	**<0.001**	1.39	1.12 – 1.66	**<0.001**	0.60	0.33 – 0.86	**<0.001**	0.61	0.49 – 0.73	**<0.001**
Linear Time	0.02	-0.11 – 0.15	0.740	0.99	0.73 – 1.26	**<0.001**	-0.14	-0.34 – 0.07	0.193	0.05	-0.08 – 0.18	0.446
Quadratic Time	0.18	0.05 – 0.31	**0.008**	-0.07	-0.34 – 0.19	0.593	-0.19	-0.40 – 0.01	0.058	0.16	0.03 – 0.29	**0.017**
STAI	0.15	0.05 – 0.26	**0.004**	0.55	0.33 – 0.78	**<0.001**	0.40	0.21 – 0.59	**<0.001**			
Marital Status - Two Parents at home	-0.24	-0.62 – 0.15	0.230	-0.78	-1.67 – 0.12	0.088	-1.29	-2.16 – -0.42	**0.004**			
Marital Status - Other	-0.07	-0.57 – 0.44	0.798	-0.58	-1.74 – 0.58	0.327	-1.40	-2.53 – -0.26	**0.016**			
RULES x Linear Time	-0.22	-0.36 – -0.09	**0.001**	-0.31	-0.58 – -0.04	**0.024**	-0.19	-0.39 – 0.02	0.076	-0.24	-0.37 – -0.11	**<0.001**

RULES x Quadratic Time	0.10	-0.03 – 0.23	0.148	-0.09	-0.36 – 0.18	0.520	-0.14	-0.34 – 0.07	0.190	0.11	-0.02 – 0.24	0.109
Random Effects												
σ^2	0.69			2.83			1.62			0.70		
τ_{00}	0.34 $_{child\_ID}$			2.14 $_{child\_ID}$			2.42 $_{child\_ID}$			0.35 $_{child\_ID}$		
ICC	0.33			0.43			0.60			0.33		
N	179 $_{child\_ID}$			179 $_{child\_ID}$			179 $_{child\_ID}$			179 $_{child\_ID}$		
Observations	487			487			486			487		
Marginal R^2 / Conditional R^2	0.301 / 0.532			0.381 / 0.648			0.177 / 0.670			0.282 / 0.519		

Note: RULES scores and parent anxiety are centred

6.2 Appendix 1b) Supplementary Materials for Study 2

Participants

Table S1. Demographic characteristics of full sample

Characteristic	*N* (%)
Child gender	
Male	68 (51%)
Female	64 (48%)
Describe their gender differently	1 (1%)
Prefer not to say	0
Child age	
8	47 (35%)
9	31 (23%)
10	29 (22%)
11	19 (14%)
12	7 (5%)
Child ethnicity	
White British	102 (77%)
White Irish	0
White European	6 (5%)
White Other	3 (2%)
Asian or Asian British (Indian origin)	8 (6%)
Asian or Asian British (Pakistani origin)	1 (1%)
Asian or Asian British (Bangladeshi origin)	1 (1%)
Asian or Asian British (Chinese origin)	0
Asian or Asian British (Other Asian origin)	1 (1%)
Black or Black British	2 (2%)
Mixed Race	8 (6%)
Prefer not to say	0
Other	1 (1%)
Number of children in household	
1	23 (17%)
2	75 (56%)
3	30 (23%)
4	5 (4%)
Child’s birth order	
First born	78 (59%)
Second born	38 (29%)
Third born	11 (8%)
Other	6 (5%)
Child’s handedness	
Left-handed	13 (10%)
Right-handed	120 (90%)
Is the child colourblind	

Yes	1 (1%)
No	132 (99%)
Respondent's relationship to child	
Mother	126 (95%)
Father	7 (5%)
Grandmother	0
Grandfather	0
Other	0
Child's Primary Caregiver?	
Yes	96 (72%)
No	1 (1%)
Shared	36 (27%)
Parent age	
<30	0
30-40	52 (39%)
41-50	73 (55%)
50+	7(1%)
Parent marital status	
Single	8 (6%)
Married	108 (81%)
Separated	1 (1%)
Divorced	7 (5%)
Prefer not to say	0
Other	9 (7%)
Parent employment status	
Employed full-time	49 (37%)
Employed part-time	51 (38%)
Full-time home-maker	15 (11%)
Unemployed	3 (2%)
Other	15 (11%)
Parent level of education	
Primary School	0
GCSEs	3 (2%)
A' Levels	3 (2%)
College Course Certificate	10 (8%)
Bachelors Degree	49 (37%)
Masters Degree	34 (26%)
Postgraduate Degree	33 (25%)
Prefer not to say	1 (1%)

Exclusions

24 parents completed the questionnaires but did not meet the inclusion criteria: nine lived outside of the UK, two did not have a webcam, one child was too old, four children did not have normal or corrected hearing or vision and eight were siblings of children who had

already taken part. 12 additional responses were flagged as suspicious: 11 had an address error (i.e. address, city, county, post code not matching) and one had an error with the child's name (note that addresses were taken as part of the safeguarding procedure for the study).

Neutral and aversive sounds

Sounds for the game were selected from the International Affective Digitized Sounds-2 (IADS-2) database (Bradley & Lang, 2007). Neutral sounds were shortlisted if they had a medium affective valence rating (quite pleasant) and a medium arousal rating (between calm and excited) and were aversive sounds were shortlisted if they had lower affective valence rating (less pleasant) and higher arousal rating (more excited). These shortlisted sounds were then played to four children within the target age range and they each voted for the four neutral sounds and four sounds they found most aversive. The aversive and neutral sounds with the most votes were chosen for the game. The sounds used as examples in the task were the sound of a rattle (neutral) and an air raid siren (aversive); sounds 134 and 624 of the IADs-2 respectively. In the game itself, the neutral sounds were night, country night, jet and rain; sounds 170, 171, 400 and 627 of the IADS-2 respectively. The aversive sounds used in the game were a rollercoaster, a jackhammer, a buzzer and a dentist drill; sounds 30, 380, 712 and 719 of the IADS-2 respectively. The assignment of the sounds to each trial was randomized between participants so that the order and pairings of the sounds varied.

Objective facial affect recording, coding and scoring

The FACS Action Unit (AU)12 (lip corner puller) was coded for smiles and AU4 (brow lower) for frown (Ekman et al., 2002; Ekman & Friesen, 1978), in an attempt to mimic facial electromyography (fEMG) recordings for zygomatic major and corrugator supercilii respectively. ELAN software was used for coding of facial expressions in the anticipation period of the videos. Because we were unable to code some portions of the anticipation period due to children covering their face or not facing the camera, time spent smiling and frowning during the anticipation period was converted into two proportion variables and a difference score was calculated to create an objective facial affect score ranging from -1 to 1, where -1 represents the entire codable time spent frowning, and 1 represents the entire codable time spent smiling (M = .09, SD = .27, range = -1-1). The coders were blind to uncertainty condition. Composite scores were calculated by summing subjective and objective facial affect scores (M = .32, SD = .79, range = -1.96-2).

Supplementary results

Manipulation checks

Table S2. LMM testing effect of trial uncertainty on self-reported uncertainty ratings and repeated using binarised ratings (logistic regression).

Fixed Effects						
		Uncertainty rating			**Uncertainty rating (Binarised rating)**	
Predictors	*b*	*CI*	*p*	*Odds Ratio*	*CI*	*p*
(Intercept)	**0.89**	**0.83 – 0.94**	**<.001**	0.97	0.70 – 1.34	.844
Trial uncertainty	**0.04**	**0.01 – 0.07**	**.010**	*1.22*	*0.99 – 1.49*	*.057*
Random Effects						
σ^2		0.13			3.29	
τ_{00}		0.08 $_{id}$			2.19 $_{id}$	
ICC		0.38			0.4	
N		133 $_{id}$			133 $_{id}$	
Observations		532			532	
Marginal R^2 / Conditional R^2		0.008 / 0.385			0.007 / 0.404	

Note. Trial uncertainty is effect coded. Effects significant at the $p < .05$ level are displayed in bold text, trends at $p < .01$ are displayed in italics.

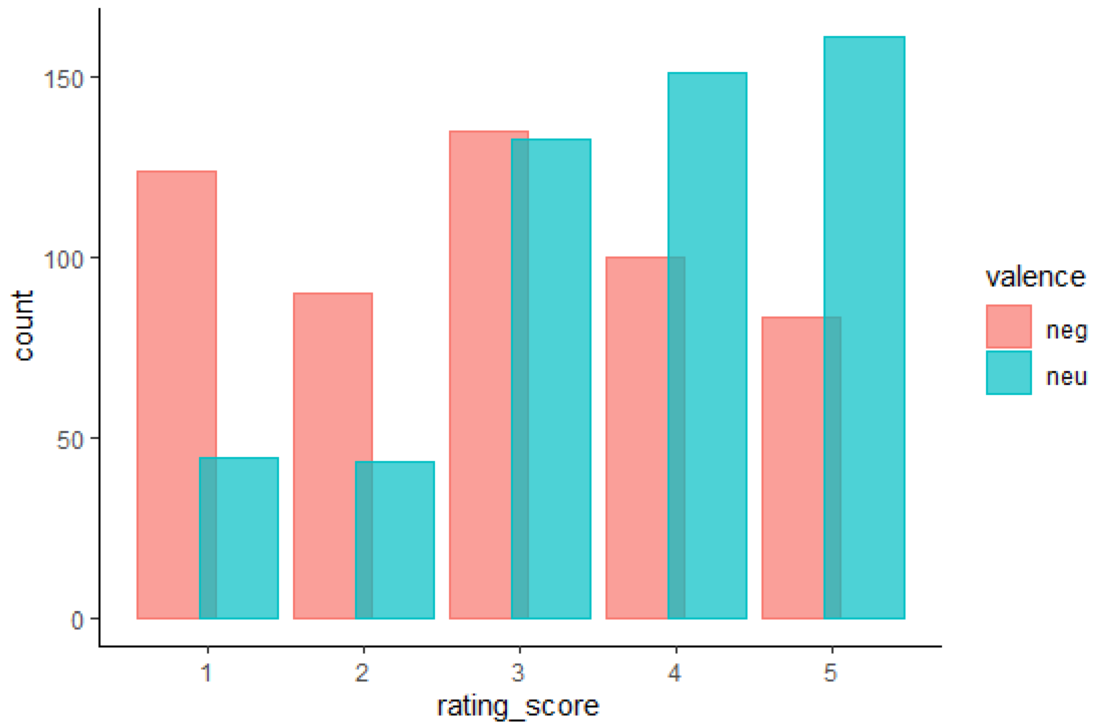


Figure S1: Distribution of children's self-reported emotion valence scores (1 being very unhappy and 5 being very happy) for negative and neutral sounds

Main analyses: Robustness checks

In our preregistered data analysis plan, we proposed to conduct separate models for IU and Curiosity before combining them in a combined model. There was negligible difference between the model estimates, so only the combined models were presented in the manuscript. Tables of separate and combined model parameters for each dependent variable are presented below (see Tables S3-S6). For models of self-reported emotion valence and self-reported worry, logistic regression models were run with binarised rating scores to test the robustness of the results given the skewed ratings. These are presented alongside the above models for comparison. As an additional robustness check, we present models for the three measures of facial affect for comparison (see Table S7).

Table S3. LMMs for button pressing including IU and Curiosity separately and combined

	Button presses (I/D-YC only)	Button presses (RULES only)	Button presses (Combined)

Predictors	*b*	*CI*	*p*	*b*	*CI*	*p*	*b*	*CI*	*p*
(Intercept)	18.53	18.01 – 19.05	**<0.001**	18.53	18.02 – 19.05	**<0.001**	18.53	18.01 – 19.05	**<0.001**
Trial uncertainty	0.25	0.01 – 0.49	**0.039**	0.25	0.01 – 0.49	**0.039**	0.25	0.01 – 0.49	**0.039**
Curiosity (I/D-YC score)	0.13	-0.39 – 0.65	0.625				0.10	-0.43 – 0.62	0.716
Trial uncertainty * Curiosity	-0.08	-0.32 – 0.16	0.503				-0.07	-0.31 – 0.17	0.554
IU (RULES score)				-0.31	-0.83 – 0.21	0.246	-0.30	-0.82 – 0.23	0.268
Trial uncertainty * IU				0.09	-0.15 – 0.33	0.464	0.08	-0.16 – 0.32	0.509
Random Effects									
σ^2	7.88			7.88			7.89		
τ_{00}	7.34 $_{id}$			7.26 $_{id}$			7.32 $_{id}$		
ICC	0.48			0.48			0.48		
N	133 $_{id}$			133 $_{id}$			133 $_{id}$		
Observations	532			532			532		
Marginal R^2 / Conditional R^2	0.006 / 0.485			0.011 / 0.485			0.012 / 0.487		

Note. Trial uncertainty is effect coded, RULES total and I/D-YC total are z-scored, Button presses and RULES total are Winsorised. Effects significant at the p < .05 level are displayed in bold text, trends at p < .01 are displayed in italics.

Table S4. LMMs for facial affect including IU and Curiosity separately and combined

	Facial affect (I/D-YC only)			Facial affect (RULES only)			Facial affect (Combined)		
Predictors	*b*	*CI*	*p*	*b*	*CI*	*p*	*b*	*CI*	*p*
(Intercept)	0.01	-0.12 – 0.14	0.877	0.01	-0.12 – 0.14	0.877	0.01	-0.12 – 0.14	0.872
Trial uncertainty	*-0.06*	*-0.13 – 0.00*	*0.065*	*-0.07*	*-0.13 – 0.00*	*0.064*	*-0.06*	*-0.13 – 0.00*	*0.066*
Curiosity (I/D-YC score)	0.06	-0.07 – 0.19	0.341				0.06	-0.07 – 0.19	0.385
Trial uncertainty * Curiosity	0.05	-0.02 – 0.12	0.148				0.05	-0.02 – 0.12	0.169
IU (RULES score)				-0.06	-0.19 – 0.07	0.356	-0.05	-0.18 – 0.07	0.404
Trial uncertainty * IU				-0.03	-0.10 – 0.04	0.422	-0.02	-0.09 – 0.04	0.501
Random Effects									
σ^2	0.62			0.62			0.62		
τ_{00}	0.39 $_{id}$			0.38 $_{id}$			0.39 $_{id}$		
ICC	0.38			0.38			0.39		
N	127 $_{id}$			127 $_{id}$			127 $_{id}$		
Observations	503			503			503		
Marginal R^2 / Conditional R^2	0.011 / 0.392			0.009 / 0.389			0.014 / 0.394		

Note. Trial uncertainty is effect coded, RULES total and I/D-YC total are z-scored, RULES total is Winsorised. Effects significant at the p < .05 level are displayed in bold text, trends at p < .01 are displayed in italics.

Table S5. LMMs for self-reported emotion valence including IU and Curiosity separately and combined and with binarised rating scores

	Emotion valence (I/D-YC only)			**Emotion valence (RULES only)**			**Emotion valence (Combined)**			**Emotion valence (Combined and binarised rating)**		
Predictors	*b*	*CI*	*p*	*b*	*CI*	*p*	*b*	*CI*	*p*	*b*	*CI*	*p*
(Intercept)	4.21	4.09 – 4.33	**<0.001**	4.21	4.08 – 4.33	**<0.001**	4.21	4.09 – 4.33	**<0.001**	1.03	0.70 – 1.51	0.883
Trial uncertainty	-0.06	-0.13 – 0.00	0.055	-0.06	-0.13 – 0.00	0.055	-0.06	-0.13 – 0.00	0.055	0.84	0.67 – 1.05	0.119
Curiosity (I/D-YC score)	0.21	0.08 – 0.33	**0.001**				0.20	0.07 – 0.32	**0.002**	1.78	1.20 – 2.66	**0.004**
Trial uncertainty * Curiosity	-0.03	-0.09 – 0.03	0.373				-0.03	-0.09 – 0.04	0.385	0.93	0.74 – 1.17	0.530
IU (RULES score)				-0.09	-0.22 – 0.03	0.155	-0.07	-0.19 – 0.05	0.266	0.91	0.62 – 1.34	0.632
Trial uncertainty * IU				0.01	-0.06 – 0.07	0.818	0.00	-0.06 – 0.07	0.895	0.93	0.75 – 1.16	0.533
Random Effects												
σ^2	0.55			0.55			0.55			3.29		
τ_{00}	0.37 $_{id}$			0.41 $_{id}$			0.37 $_{id}$			3.18 $_{id}$		
ICC	0.40			0.42			0.40			0.49		
N	133 $_{id}$			133 $_{id}$			133 $_{id}$			133 $_{id}$		

Observations	532	532	532	532
Marginal R^2 / Conditional R^2	0.048 / 0.430	0.013 / 0.430	0.053 / 0.432	0.057 / 0.521

Note. Trial uncertainty is effect coded, RULES total and I/D-YC total are z-scored, RULES total is Winsorised. Effects significant at the p < .05 level are displayed in bold text, trends at p < .01 are displayed in italics.

Table S6. LMMs for self-reported worry including IU and Curiosity separately and combined and with binarised rating scores

	Worry (I/D-YC only)			**Worry (RULES only)**			**Worry (Combined)**			**Worry (Combined and binarised rating)**		
Predictors	*b*	*CI*	*p*	*b*	*CI*	*p*	*b*	*CI*	*p*	*Odds Ratio*	*CI*	*p*
(Intercept)	0.30	0.24 – 0.35	**<0.001**	0.30	0.24 – 0.35	**<0.001**	1.41	1.32 – 1.50	**<0.001**	0.23	0.14 – 0.38	**<0.001**
Trial uncertainty	0.02	-0.01 – 0.05	0.150	0.02	-0.01 – 0.05	0.152	0.04	-0.01 – 0.08	0.145	1.18	0.93 – 1.50	0.163
Curiosity (I/D-YC score)	-0.02	-0.07 – 0.04	0.562				-0.05	-0.14 – 0.04	0.269	0.92	0.59 – 1.41	0.693
Trial uncertainty * Curiosity	-0.03	-0.06 – 0.00	0.079				-0.03	-0.08 – 0.02	0.262	0.80	0.63 – 1.03	0.086
IU (RULES score)				0.03	-0.03 – 0.08	0.389	0.06	-0.03 – 0.15	0.176	1.21	0.79 – 1.85	0.378
Trial uncertainty * IU				0.01	-0.02 – 0.04	0.522	-0.00	-0.05 – 0.05	0.953	1.05	0.83 – 1.32	0.699
Random Effects												
σ^2	0.13			0.13			0.32			3.29		
τ_{00}	0.08 $_{id}$			0.08 $_{id}$			0.19 $_{id}$			3.70 $_{id}$		
ICC	0.38			0.37			0.38			0.53		
N	133 $_{id}$			133 $_{id}$			133 $_{id}$			133 $_{id}$		

Observations	532	532	532	532
Marginal R^2 / Conditional R^2	0.007 / 0.381	0.006 / 0.377	0.017 / 0.387	0.018 / 0.538

Note. Trial uncertainty is effect coded, RULES total and I/D-YC total are z-scored, RULES total is Winsorised. Effects significant at the $p < .05$ level are displayed in bold text, trends at $p < .01$ are displayed in italics.

Table S7. LMMs for facial affect for comparison of subjective facial affect scores, objective facial affect scores, and composite facial affect scores

	Subjective facial affect			**Objective facial affect**			**Composite facial affect**		
Predictors	*b*	*CI*	*p*	*b*	*CI*	*p*	*b*	*CI*	*p*
(Intercept)	0.35	0.23 – 0.47	**<0.001**	0.33	0.22 – 0.44	**<0.001**	0.01	-0.12 – 0.14	0.872
Trial uncertainty	*-0.06*	*-0.12 – 0.00*	*0.062*	-0.04	-0.11 – 0.03	0.264	*-0.06*	*-0.13 – 0.00*	*0.066*
IU (RULES score)	-0.05	-0.17 – 0.07	0.406	-0.02	-0.13 – 0.09	0.695	-0.05	-0.18 – 0.07	0.404
Curiosity (I/D-YC score)	0.08	-0.04 – 0.20	0.211	0.04	-0.07 – 0.15	0.483	0.06	-0.07 – 0.19	0.385
Trial uncertainty * IU	-0.02	-0.09 – 0.04	0.435	0.03	-0.04 – 0.10	0.434	-0.02	-0.09 – 0.04	0.501
Trial uncertainty * Curiosity	0.03	-0.04 – 0.09	0.403	0.04	-0.03 – 0.11	0.279	0.05	-0.02 – 0.12	0.169
Random Effects									
σ^2	0.50			0.66			0.62		
τ_{00}	0.37 $_{id}$			0.24 $_{id}$			0.39 $_{id}$		
ICC	0.42			0.27			0.39		
N	127 $_{id}$			127 $_{id}$			127 $_{id}$		
Observations	503			503			503		
Marginal R^2 / Conditional R^2	0.017 / 0.434			0.007 / 0.275			0.014 / 0.394		

Note. Trial uncertainty is effect coded, RULES total and I/D-YC total are z-scored, RULES total is Winsorised. Effects significant at the p < .05 level are displayed in bold text, trends at p < .01 are displayed in italics.

Exploratory analyses: Differential effects of Interest-type and Deprivation-type curiosity

Table S8. Models examining dependent variables with Interest (IYC) and Deprivation (DYC) subscales of the I/D-YC separately for button presses and facial affect

	Button Presses (IYC)			**Button Presses (DYC)**			**Facial Affect (IYC)**			**Facial Affect (DYC)**		
Predictors	*b*	*CI*	*p*	*b*	*CI*	*p*	*b*	*CI*	*p*	*b*	*CI*	*p*
(Intercept)	18.53	18.02 – 19.05	**<0.001**	18.53	18.01 – 19.05	**<0.001**	0.01	-0.12 – 0.14	0.871	0.01	-0.12 – 0.14	0.878
Trial uncertainty	0.25	0.01 – 0.49	**0.039**	0.25	0.01 – 0.49	**0.039**	*-0.07*	*-0.13 – 0.00*	*0.064*	*-0.06*	*-0.13 – 0.00*	*0.067*
IU (RULES score)	-0.27	-0.80 – 0.25	0.308	-0.31	-0.83 – 0.21	0.247	-0.05	-0.17 – 0.08	0.489	-0.06	-0.19 – 0.07	0.359
I-type Curiosity (Interest subscale score)	0.20	-0.33 – 0.73	0.463				0.09	-0.04 – 0.22	0.161			
Trial uncertainty * IU	0.09	-0.16 – 0.33	0.493	0.09	-0.15 – 0.33	0.479	-0.02	-0.09 – 0.05	0.495	-0.03	-0.10 – 0.04	0.429
Trial uncertainty * I-type Curiosity	-0.03	-0.27 – 0.22	0.835				0.02	-0.04 – 0.09	0.487			
D-type Curiosity (Deprivation subscale score)				-0.02	-0.54 – 0.50	0.946				0.01	-0.12 – 0.14	0.876

Trial uncertainty * D-type Curiosity				-0.10	-0.34 – 0.14	0.435				0.06	-0.01 – 0.12	0.106
Random Effects												
σ^2	7.90			7.88			0.62			0.61		
τ_{00}	7.29 $_{id}$			7.33 $_{id}$			0.38 $_{id}$			0.39 $_{id}$		
ICC	0.48			0.48			0.38			0.39		
N	133 $_{id}$			133 $_{id}$			127 $_{id}$			127 $_{id}$		
Observations	532			532			503			503		
Marginal R^2 / Conditional R^2	0.013 / 0.487			0.011 / 0.488			0.017 / 0.391			0.012 / 0.395		

Note. Trial uncertainty is effect coded, RULES total and I/D-YC subscale scores are z-scored, Button presses RULES total are Winsorised. Effects significant at the p < .05 level are displayed in bold text, trends at p < .01 are displayed in italics.

Table S9. Models examining dependent variables with Interest (IYC) and Deprivation (DYC) subscales of the I/D-YC separately for self-reported emotion valence and worry

	Emotion valence (IYC)			**Emotion valence (DYC)**			**Worry (IYC)**			**Worry (DYC)**		
Predictors	*b*	*CI*	*p*	*b*	*CI*	*p*	*b*	*CI*	*p*	*b*	*CI*	*p*
(Intercept)	4.21	4.09 – 4.33	**<0.001**	4.21	4.09 – 4.33	**<0.001**	1.41	1.32 – 1.50	**<0.001**	1.41	1.32 – 1.50	**<0.001**
Trial uncertainty	*-0.06*	*-0.13 – 0.00*	*0.055*	*-0.06*	*-0.13 – 0.00*	*0.055*	0.04	-0.01 – 0.08	0.145	0.04	-0.01 – 0.08	0.145

IU (RULES score)	-0.06	-0.19 – 0.06	0.327	-0.09	-0.21 – 0.04	0.169	0.06	-0.03 – 0.15	0.169	0.07	-0.02 – 0.15	0.148
I-type Curiosity (Interest subscale score)	0.18	0.05 – 0.30	**0.006**				-0.02	-0.11 – 0.07	0.627			
Trial uncertainty * IU	0.00	-0.06 – 0.07	0.925	0.01	-0.06 – 0.07	0.834	-0.00	-0.05 – 0.05	0.933	0.00	-0.05 – 0.05	0.972
Trial uncertainty * I-type Curiosity	-0.03	-0.09 – 0.04	0.424				-0.02	-0.07 – 0.03	0.370			
D-type Curiosity (Deprivation subscale score)				0.17	0.04 – 0.29	**0.009**				-0.06	-0.15 – 0.03	0.171
Trial uncertainty * D-type Curiosity				-0.02	-0.09 – 0.04	0.485				-0.03	-0.07 – 0.02	0.305
Random Effects												
σ^2	0.56			0.56			0.32			0.32		
τ_{00}	0.38 $_{id}$			0.38 $_{id}$			0.19 $_{id}$			0.19 $_{id}$		
ICC	0.41			0.41			0.38			0.37		
N	133 $_{id}$			133 $_{id}$			133 $_{id}$			133 $_{id}$		
Observations	532			532			532			532		

Marginal R^2 / Conditional R^2	0.044 / 0.432	0.041 / 0.432	0.013 / 0.387	0.020 / 0.387

Note. Trial uncertainty is effect coded, RULES total and I/D-YC subscale scores are z-scored, RULES total is Winsorised. Effects significant at the p < .05 level are displayed in bold text, trends at p < .01 are displayed in italics.

Exploratory analyses including age as an interactive predictor

Table 10. Exploratory LMMs including age as an additional interactive predictor

	Button presses			**Facial Affect**			**Emotion valence**			**Worry**		
Predictors	*b*	*CI*	*p*	*b*	*CI*	*p*	*b*	*CI*	*p*	*b*	*CI*	*p*
(Intercept)	18.55	18.03 – 19.08	**<0.001**	0.01	-0.10 – 0.13	0.820	4.21	4.09 – 4.34	**<0.001**	1.41	1.32 – 1.50	**<0.001**
Age	0.10	-0.31 – 0.51	0.629	-0.06	-0.15 – 0.03	0.193	0.04	-0.06 – 0.13	0.468	-0.08	-0.15 – -0.01	**0.020**
Trial uncertainty	0.24	0.00 – 0.48	**0.049**	*-0.05*	*-0.11 – 0.01*	*0.081*	*-0.06*	*-0.12 – 0.00*	*0.070*	0.03	-0.02 – 0.08	0.178
IU (RULES score)	-0.28	-0.82 – 0.25	0.296	-0.04	-0.16 – 0.07	0.437	-0.06	-0.19 – 0.06	0.322	0.07	-0.02 – 0.16	0.121
Curiosity (I/D-YC score)	0.07	-0.47 – 0.61	0.811	0.04	-0.07 – 0.16	0.475	0.19	0.07 – 0.32	**0.003**	-0.06	-0.15 – 0.03	0.157
Trial uncertainty * IU	0.07	-0.17 – 0.32	0.562	-0.02	-0.08 – 0.04	0.584	0.01	-0.06 – 0.07	0.867	-0.00	-0.05 – 0.05	0.926
Trial uncertainty * Curiosity	-0.05	-0.30 – 0.20	0.702	0.04	-0.02 – 0.10	0.168	-0.04	-0.11 – 0.02	0.187	-0.02	-0.07 – 0.03	0.517
Age * Trial uncertainty	0.05	-0.14 – 0.23	0.628	0.00	-0.04 – 0.05	0.850	-0.03	-0.08 – 0.02	0.230	0.02	-0.02 – 0.05	0.415
Age * IU (RULES score)	-0.11	-0.52 – 0.29	0.584	0.02	-0.06 – 0.11	0.588	0.02	-0.08 – 0.11	0.740	0.03	-0.04 – 0.10	0.390
Age * Curiosity (I/D-YC score)	0.12	-0.30 – 0.54	0.565	0.02	-0.07 – 0.11	0.687	0.05	-0.05 – 0.15	0.321	0.04	-0.03 – 0.11	0.220
Age * Trial uncertainty * IU	0.03	-0.15 – 0.22	0.730	0.03	-0.02 – 0.07	0.219	-0.05	-0.10 – -0.01	**0.030**	0.04	0.01 – 0.08	**0.021**
Age * Trial uncertainty * Curiosity	-0.07	-0.26 – 0.13	0.508	0.02	-0.03 – 0.07	0.391	0.01	-0.04 – 0.06	0.624	-0.01	-0.05 – 0.03	0.587
Random Effects												
σ^2	7.93			0.47			0.55			0.32		
τ_{00}	7.45_{id}			0.29_{id}			0.38_{id}			0.18_{id}		
ICC	0.48			0.39			0.41			0.37		
N	133_{id}			127_{id}			133_{id}			133_{id}		
Observations	532			503			532			532		
Marginal R^2 / Conditional R^2	0.017 / 0.493			0.026 / 0.401			0.064 / 0.446			0.055 / 0.402		

Note. Trial uncertainty is effect coded, RULES total and I/D-YC subscale scores are z-scored, Button presses RULES total are Winsorised. Effects significant at the p < .05 level are displayed in bold text, trends at p < .01 are displayed in italics.

Exploratory analysis: The influence of uncertainty, IU, and curiosity on type of button pressed

Table S11. Exploratory LMM with proportion minority buttons pressed as the dependent variable

	Proportion minority buttons pressed		
Predictors	*b*	*CI*	*p*
(Intercept)	0.26	0.25 – 0.28	**<0.001**
Trial uncertainty	0.04	0.03 – 0.06	**<0.001**
IU (RULES score)	0.01	-0.01 – 0.02	0.492
Curiosity (I/D-YC score)	0.00	-0.01 – 0.02	0.657
Trial uncertainty * IU	0.02	0.00 – 0.03	**0.032**
Trial uncertainty * Curiosity	-0.00	-0.02 – 0.01	0.571
Random Effects			
σ^2	0.03		
$\tau_{00\ id}$	0.00		
ICC	0.10		
N_{id}	133		
Observations	531		
Marginal R^2 / Conditional R^2	0.068 / 0.166		

References

Bradley, M. M., & Lang, P. J. (2007). The International Affective Digitized Sounds (2nd Edition; IADS-2): Affective ratings of sounds and instruction manual. Technical report B-3. *University of Florida, Gainesville, Fl.*

Ekman, P., Friesen, W., & Hager, J. (2002). Facial action coding system [E-book]. *Salt Lake City, UT: Research Nexus*.

Ekman, P., & Friesen, W. V. (1978). Facial action coding system. *Environmental Psychology & Nonverbal Behavior*.

6.3 Appendix 1c) Supplementary Materials for Study 3

Participants

Table S1. Demographic characteristics of full sample

Characteristic	*N* (%)
Gender	
Male	16 (12%)
Female	113 (85%)
Other	3(2%)
Withheld	1 (1%)
Age	
<20	96 (72%)
20-30	30 (23%)
31-40	6 (5%)
41-50	1 (1%)
50+	0
Child ethnicity	
White British	75 (56%)
White Irish	1 (1%)
White European	8 (6%)
White Other	6 (5%)
Asian or Asian British (Indian origin)	6 (5%)
Asian or Asian British (Pakistani origin)	4 (3%)
Asian or Asian British (Bangladeshi origin)	1 (1%)
Asian or Asian British (Chinese origin)	8 (6%)
Asian or Asian British (Other Asian origin)	5 (4%)
Black or Black British	3 (2%)
Mixed Race	11 (8%)
Prefer not to say	1 (1%)
Other	4 (3%)
Colourblind?	
Yes	0
No	132 (99%)
N/A	1 (1%)
Problems with hearing/vision	
Yes	0 (%)
No	131 (98%)
N/A	2 (2%)
Neurodivergent?	
Yes	30 (23%)
No	103 (77%)
ADHD & Dyslexia	1(1%)
ADHD, Dyspraxia, depression	1 (1%)
ADHD	1 (1%)
Anxiety	7 (5%)
Anxiety and PTSD	1 (1%)

Anxiety and depression	4 (3%)
Autistic	1 (1%)
Depression	6 (5%)
Depression, anxiety, suspected neurodiversity	1 (1%)
Dyslexia	4 3(%)
Dyslexia and ADHD	1 (1%)
Dyslexia and dyspraxia	1 (1%)
PTSD	1 (1%)

Exclusions

In addition to the 133 participants who completed the questionnaires and game, 28 participants cancelled their participation via the online student participant panel platform. Of these, some only looked at the information sheet but did not consent (n = 6), some provided consent then did not carry on with the questionnaires or game (n = 9), some part completed the questionnaires but did not move on to the game (n = 2), some completed the questionnaires but did not play the game (n = 3), some completed consent and questionnaires but only part completed the game (n = 7) and one participant completed the game but asked to be withdrawn.

Neutral and aversive sounds

Sounds for the game were selected from the International Affective Digitized Sounds-2 (IADS-2) database (Bradley & Lang, 2007). Neutral sounds were shortlisted if they had a medium affective valence rating (quite pleasant) and a medium arousal rating (between calm and excited) and aversive sounds were shortlisted if they had lower affective valence rating (less pleasant) and higher arousal rating (more excited). These shortlisted sounds were then played to four children within the target age range for the original study by Ryan et al. (2023) and they each voted for the four neutral sounds and four sounds they found most aversive. The aversive and neutral sounds with the most votes were chosen for the game. The sounds used as examples in the task were the sound of a rattle (neutral) and an air raid siren (aversive); sounds 134 and 624 of the IADs-2 respectively. In the game itself, the neutral sounds were night, country night, jet and rain; sounds 170, 171, 400 and 627 of the IADS-2 respectively. The aversive sounds used in the game were a rollercoaster, a jackhammer, a buzzer and a dentist drill; sounds 30, 380, 712 and 719 of the IADS-2 respectively. The assignment of the sounds to each trial was randomized between participants so that the order and pairings of the sounds varied.

Supplementary results

Manipulation checks

Table S12. LMM testing effect of trial uncertainty on self-reported uncertainty ratings and repeated using binarised ratings (logistic regression).

	Uncertainty rating		
Predictors	*Estimates*	*CI*	*p*
(Intercept)	0.92	0.87 – 0.96	**<0.001**
trial uncertainty ec	0.14	0.11 – 0.17	**<0.001**
Random Effects			
σ^2	0.07		
$\tau_{00\ id}$	0.06		
$\tau_{11\ id.trial\_uncertainty\_ec}$	0.02		
$\rho_{01\ id}$	0.33		
ICC	0.54		
N_{id}	134		
Observations	540		
Marginal R^2 / Conditional R^2	0.114 / 0.595		

Note. Trial uncertainty is effect coded. Effects significant at the $p < .05$ level are displayed in bold text, trends at $p < .01$ are displayed in italics.

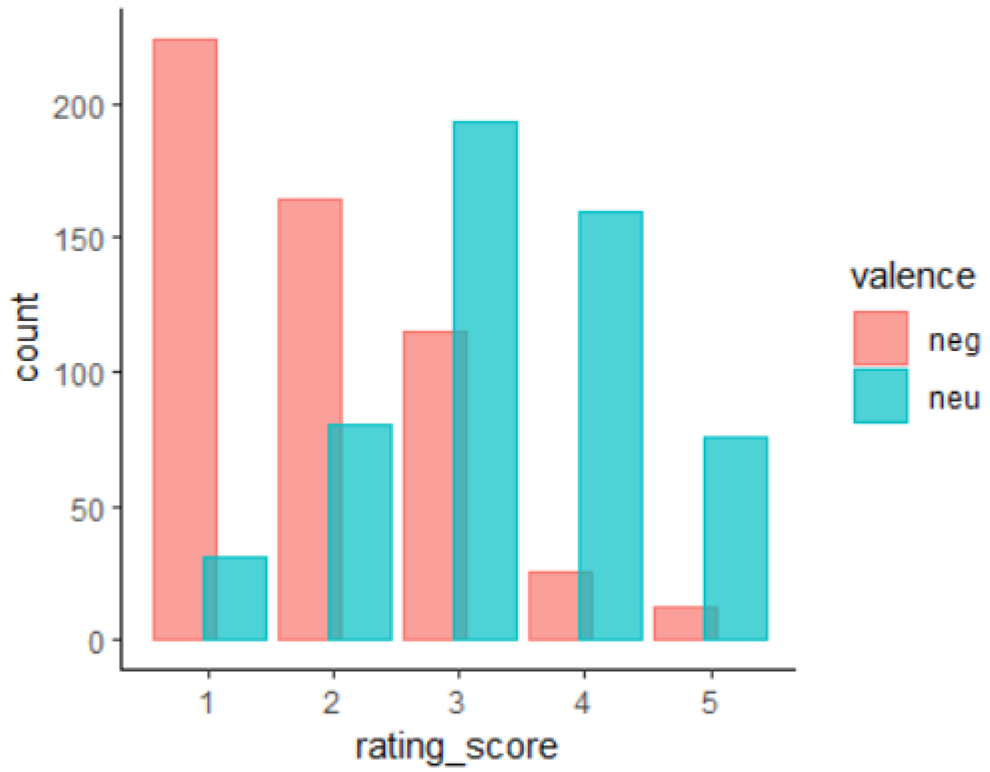


Figure S1: Distribution of participant's self-reported emotion valence scores (1 being very unhappy and 5 being very happy) for negative and neutral sounds

Main analyses: Robustness checks

In our preregistered data analysis plan, we proposed to conduct separate models for IU and Curiosity before combining them in a combined model. There was negligible difference between the model estimates, so only the combined models were presented in the manuscript. Tables of separate and combined model parameters for each dependent variable are presented below (see Tables S3-S6). For models of self-reported worry, a logistic regression models was run with binarized rating scores to test the robustness of the results given the skewed ratings. These are presented alongside the above models for comparison.

Table S13. LMMs for button pressing including IU and Curiosity separately and combined

	Button presses (IDEC only)			Button presses (IUS only)			Button presses (Combined)		
Predictors	*b*	*CI*	*p*	*b*	*CI*	*p*	*b*	*CI*	*p*
(Intercept)	0.93	0.88 – 0.98	**<0.001**	0.93	0.88 – 0.98	**<0.001**	0.93	0.88 – 0.98	**<0.001**
Trial uncertainty	0.01	-0.01 – 0.03	0.252	0.01	-0.01 – 0.03	0.250	0.01	-0.01 – 0.03	0.250
Curiosity (IDEC score)	0.06	0.01 – 0.11	**0.015**				0.07	0.02 – 0.12	**0.011**
Trial uncertainty * Curiosity	0.00	-0.02 – 0.03	0.737				0.00	-0.02 – 0.03	0.667
IU (IUS score)				-0.02	-0.08 – 0.03	0.362	-0.03	-0.08 – 0.02	0.229
Trial uncertainty * IU				-0.01	-0.03 – 0.01	0.378	-0.01	-0.03 – 0.01	0.358
Random Effects									
σ^2	0.05			0.05			0.05		
τ_{00}	0.07 id			0.08 id			0.07 id		
τ_{11}	0.00 id.trial_uncertainty_ec			0.00 id.trial_uncertainty_ec			0.00 id.trial_uncertainty_ec		
ρ_{01}	-0.03 id			-0.03 id			-0.05 id		
ICC	0.58			0.59			0.58		
N	133 id			133 id			133 id		
Observations	536			536			536		
Marginal R^2 / Conditional R^2	0.030 / 0.597			0.006 / 0.597			0.038 / 0.599		

Note. Trial uncertainty is effect coded, IUS total and IDEC total are z-scored. Effects significant at the p < .05 level are displayed in bold text, trends at p < .01 are displayed in italics.

Table S4. LMMs for self-reported emotion valence including IU and Curiosity separately and combined

	Emotion valence (IDEC only)			**Emotion valence (IUS only)**			**Emotion valence (Combined)**		
Predictors	*b*	*CI*	*p*	*b*	*CI*	*p*	*b*	*CI*	*p*
(Intercept)	3.60	3.46 – 3.74	**<0.001**	3.60	3.46 – 3.73	**<0.001**	3.60	3.46 – 3.73	**<0.001**
Trial uncertainty	-0.34	-0.43 – -0.24	**<0.001**	-0.34	-0.43 – -0.24	**<0.001**	-0.34	-0.43 – -0.24	**<0.001**
Curiosity (IDEC score)	0.05	-0.09 – 0.19	0.490				0.07	-0.07 – 0.21	0.336
Trial uncertainty * Curiosity	-0.04	-0.14 – 0.06	0.408				-0.02	-0.12 – 0.07	0.601
IU (IUS score)				-0.16	-0.30 – -0.03	**0.020**	-0.17	-0.31 – -0.03	**0.016**
Trial uncertainty * IU				-0.15	-0.24 – -0.05	**0.002**	-0.14	-0.24 – -0.05	**0.003**
Random Effects									
σ^2	0.58			0.58			0.58		
τ_{00}	0.53 id			0.51 id			0.51 id		
τ_{11}	0.17 id.trial_uncertainty_ec			0.15 id.trial_uncertainty_ec			0.15 id.trial_uncertainty_ec		
ρ_{01}	0.29 id			0.22 id			0.23 id		
ICC	0.55			0.53			0.53		

N	133 id	133 id	133 id
Observations	536	536	536
Marginal R^2 / Conditional R^2	0.084 / 0.583	0.116 / 0.584	0.119 / 0.586

Note. Trial uncertainty is effect coded, IUS total and IDEC total are z-scored. Effects significant at the p < .05 level are displayed in bold text, trends at p < .01 are displayed in italics.

Table S5. LMMs for self-reported worry including IU and Curiosity separately and combined and GLM with binarized rating scores

	Worry (IDEC only)			**Worry (IUS only)**			**Worry (Combined)**			**Worry (Combined and binarised rating)**		
Predictors	*b*	*CI*	*p*	*b*	*CI*	*p*	*b*	*CI*	*p*	*Odds Ratio*	*CI*	*p*
(Intercept)	1.50	1.42 – 1.58	**<0.001**	1.50	1.42 – 1.58	**<0.001**	1.50	1.42 – 1.58	**<0.001**	0.47	0.31 – 0.71	**<0.001**
Trial uncertainty	0.18	0.13 – 0.23	**<0.001**	0.18	0.13 – 0.23	**<0.001**	0.18	0.13 – 0.23	**<0.001**	2.33	1.80 – 3.02	**<0.001**
Curiosity (IDEC score)	0.05	-0.03 – 0.13	0.217				0.04	-0.04 – 0.12	0.336	1.00	0.67 – 1.50	0.981
Trial uncertainty * Curiosity	0.05	-0.00 – 0.10	0.067				0.04	-0.01 – 0.09	0.113	1.34	1.05 – 1.72	**0.020**
IU (IUS score)				0.12	0.03 – 0.20	**0.005**	0.11	0.03 – 0.19	**0.007**	1.66	1.10 – 2.51	**0.016**
Trial uncertainty * IU				0.07	0.02 – 0.12	**0.006**	0.07	0.02 – 0.12	**0.010**	1.33	1.04 – 1.70	**0.025**
Random Effects												
σ^2	0.25			0.25			0.25			3.29		
τ_{00}	0.17 id			0.16 id			0.16 id			3.37 id		
τ_{11}	0.03 id.trial_uncertainty_ec			0.02 id.trial_uncertainty_ec			0.02 id.trial_uncertainty_ec					

ρ_{01}	0.90 id	0.89 id	0.88 id	
ICC	0.44	0.42	0.42	0.51
N	133 id	133 id	133 id	133 id
Observations	536	536	536	536
Marginal R^2 / Conditional R^2	0.079 / 0.485	0.107 / 0.485	0.112 / 0.487	0.148 / 0.579

Note. Trial uncertainty is effect coded, IUS total and IDEC total are z-scored. Effects significant at the p < .05 level are displayed in bold text, trends at p < .01 are displayed in italics.

Exploratory analyses: Differential effects of Interest-type and Deprivation-type curiosity

Table S6. Models examining dependent variables with Interest (I-EC) and Deprivation (D-EC) subscales of the ID-EC separately for button presses, self-reported emotion valence and worry.

	Button presses (IEC)			**Button presses (DEC)**			**Emotion valence (IEC)**			**Emotion valence (DEC)**			**Worry (IEC)**			**Worry (DEC)**		
Predictors	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*
Intercept	0.93	0.88 – 0.98	**<0.001**	0.93	0.88 – 0.98	**<0.001**	3.60	3.46 – 3.73	**<0.001**	3.60	3.46 – 3.73	**<0.001**	1.50	1.42 – 1.58	**<0.001**	1.50	1.42 – 1.58	**<0.001**
Trial uncertainty	0.01	-0.01 – 0.03	0.249	0.01	-0.01 – 0.03	0.251	-0.34	-0.43 – -0.24	**<0.001**	-0.34	-0.43 – -0.24	**<0.001**	0.18	0.13 – 0.23	**<0.001**	0.18	0.14 – 0.23	**<0.001**

IUS total	-0.02	-0.07 – 0.04	0.523	-0.04	-0.09 – 0.01	0.126	-0.14	-0.28 – -0.01	**0.042**	-0.16	-0.31 – -0.02	**0.026**	0.11	0.03 – 0.19	**0.007**	0.10	0.01 – 0.18	**0.024**
I-EC total	0.05	-0.01 – 0.10	0.086				0.13	-0.01 – 0.27	0.062				-0.02	-0.10 – 0.06	0.661			
Trial uncertainty * IUS total	-0.01	-0.03 – 0.01	0.458	-0.01	-0.03 – 0.01	0.396	-0.15	-0.24 – -0.06	**0.002**	-0.14	-0.24 – -0.04	**0.004**	0.08	0.02 – 0.13	**0.004**	0.06	0.01 – 0.11	**0.011**
Trial uncertainty * I-EC total	0.01	-0.01 – 0.03	0.422				-0.02	-0.11 – 0.07	0.672				0.03	-0.02 – 0.08	0.226			
D-EC total				0.06	0.01 – 0.12	**0.019**				-0.00	-0.15 – 0.14	0.982				0.07	-0.01 – 0.16	0.080
Trial uncertainty * D-EC total				0.00	-0.02 – 0.02	0.992				-0.02	-0.12 – 0.07	0.663				0.04	-0.01 – 0.08	0.134

Random Effects

σ^2	0.05	0.05	0.58	0.58	0.25	0.28
τ_{00}	0.08 $_{id}$	0.07 $_{id}$	0.50 $_{id}$	0.51 $_{id}$	0.16 $_{id}$	0.15 $_{id}$
τ_{11}	0.00 $_{id.trial\_uncertainty\_ec}$	0.00 $_{id.trial\_uncertainty\_ec}$	0.15 $_{id.trial\_uncertainty\_ec}$	0.15 $_{id.trial\_uncertainty\_ec}$	0.02 $_{id.trial\_uncertainty\_ec}$	
ρ_{01}	-0.06 $_{id}$	-0.03 $_{id}$	0.23 $_{id}$	0.22 $_{id}$	0.90 $_{id}$	
ICC	0.59	0.59	0.53	0.53	0.42	0.35
N	133 $_{id}$	133 $_{id}$	133 $_{id}$	133 $_{id}$	133 $_{id}$	133 $_{id}$

Observations	536	536	536	536	536	536
Marginal R^2 / Conditional R^2	0.021 / 0.599	0.033 / 0.599	0.127 / 0.586	0.115 / 0.586	0.109 / 0.487	0.119 / 0.423

Note. Trial uncertainty is effect coded, IUS total and IDEC subscale scores are z-scored. Effects significant at the $p < .05$ level are displayed in bold text, trends at $p < .01$ are displayed in italics.

Exploratory analysis: The influence of uncertainty, IU, and curiosity on type of button pressed

Table S7. Exploratory LMM with proportion minority buttons pressed as the dependent variable

	Proportion minority buttons pressed		
Predictors	*b*	*CI*	*p*
(Intercept)	0.28	0.26 – 0.30	**<0.001**
Trial uncertainty	0.00	-0.01 – 0.02	0.626
IU (IUS score)	0.02	-0.00 – 0.03	0.068
Curiosity (ID-EC score)	-0.01	-0.03 – 0.01	0.221
Trial uncertainty * IU	0.01	-0.00 – 0.03	0.119
Trial uncertainty * Curiosity	-0.02	-0.03 – -0.00	**0.046**
Random Effects			
σ^2	0.03		
$\tau_{00\ id}$	0.00		
ICC	0.07		
N_{id}	132		
Observations	525		
Marginal R^2 / Conditional R^2	0.021 / 0.087		

References

Bradley, M. M., & Lang, P. J. (2007). The International Affective Digitized Sounds (2nd Edition; IADS-2): Affective ratings of sounds and instruction manual. Technical report B-3. *University of Florida, Gainesville, Fl.*

Ryan, Z. J., Dodd, H. F., & FitzGibbon, L. (2023). Uncertain World: How Children's Curiosity and Intolerance of Uncertainty Relate to their Behaviour and Emotion under Uncertainty. [Manuscript submitted for publication].

6.4 Appendix 2a) Ethics approval for Study 1

Longitudinal study Wave 2 Ethics approval email
From: PCLS Ethics <pclsethics@reading.ac.uk>
Sent: Tuesday, March 31, 2020 3:34 PM
To: Helen Dodd <h.f.dodd@reading.ac.uk>
Cc: Zoe Ryan <z.j.ryan@pgr.reading.ac.uk>
Subject: RE: New ethics application 2019-080-HD
Hi Helen
I am pleased to inform you that changes to this project (2019-080-HD) have been reviewed by the School Research Ethics Committee and given a favourable ethical opinion for conduct. The project may proceed.
Many thanks
Liz
Longitudinal study Wave 3 Ethics approval email
From: PCLS Ethics <pclsethics@reading.ac.uk>
Sent: Tuesday, November 29, 2022 3:54 PM
To: PCLS Ethics <pclsethics@reading.ac.uk>; Rachel McCloy <r.a.mccloy@reading.ac.uk>
Cc: Zoe Ryan <z.j.ryan@pgr.reading.ac.uk>; Dodd, Helen <h.dodd@exeter.ac.uk>
Subject: RE: New ethics application - 2022-172-RM
Hi Rachel
I am pleased to inform you that this project (2022-172-RM) has been reviewed by the School Research Ethics Committee and has been given a favourable ethical opinion for conduct. The project may proceed.

(If this project is going through SONA, please could you make all the necessary arrangements as early as possible)

Many thanks
Liz

6.5 Appendix 2b) Ethics approval for Study 2

Uncertain World Child Ethics Approval
From: PCLS Ethics <pclsethics@reading.ac.uk>
Sent: 23 March 2021 08:07
To: Zoe Ryan <z.j.ryan@pgr.reading.ac.uk>
Cc: Helen Dodd <h.f.dodd@reading.ac.uk>; Lily Fitzgibbon <l.t.fitzgibbon@reading.ac.uk>
Subject: RE: Uncertain World Project Ethics Application 2020-072-HD
Hi Zoe
I am pleased to inform you that changes to this project (2020-072-HD) have been reviewed by the School Research Ethics Committee and given a favourable ethical opinion for conduct. The project may proceed.
Many thanks
Liz
From: PCLS Ethics <pclsethics@reading.ac.uk>
Sent: 10 November 2020 15:06
To: Zoe Ryan <z.j.ryan@pgr.reading.ac.uk>
Cc: Helen Dodd <h.f.dodd@reading.ac.uk>; Lily Fitzgibbon <l.t.fitzgibbon@reading.ac.uk>
Subject: RE: Uncertain World Project Ethics Application 2020-072-HD
Hi Zoe
I am pleased to inform you that changes to this project (2020-072-HD) have been reviewed by the School Research Ethics Committee and given a favourable ethical opinion for conduct. The project may proceed.
The reviewer has added – as there have been a lot of revisions, it would make life easier if these were highlighted.
Many thanks
Liz
From: PCLS Ethics <pclsethics@reading.ac.uk>
Sent: 29 October 2020 15:32
To: Zoe Ryan <z.j.ryan@pgr.reading.ac.uk>
Cc: Helen Dodd <h.f.dodd@reading.ac.uk>; Lily Fitzgibbon <l.t.fitzgibbon@reading.ac.uk>
Subject: RE: Uncertain World Project Ethics Application 2020-072-HD
Hi Zoe
I am pleased to inform you that changes to this project (2020-072-HD) have been reviewed by the School Research Ethics Committee and given a favourable ethical opinion for conduct. The project may proceed.
Many thanks
Liz
From: PCLS Ethics [mailto:pclsethics@reading.ac.uk]
Sent: 11 August 2020 09:26
To: Zoe Ryan <z.j.ryan@pgr.reading.ac.uk>
Cc: Helen Dodd <h.f.dodd@reading.ac.uk>; Lily Fitzgibbon <l.t.fitzgibbon@reading.ac.uk>
Subject: RE: Uncertain World Project Ethics Application 2020-072-HD
Hi Zoe
I am pleased to inform you that changes to this project (2020-072-HD) have been reviewed by the School Research Ethics Committee and given a favourable ethical opinion for conduct. The project may proceed.
Many thanks
Liz
From: PCLS Ethics <pclsethics@reading.ac.uk>
Sent: 17 June 2020 15:20

To: Zoe Ryan <z.j.ryan@pgr.reading.ac.uk>
Cc: Helen Dodd <h.f.dodd@reading.ac.uk>; Lily Fitzgibbon <l.t.fitzgibbon@reading.ac.uk>
Subject: RE: Uncertain World Project Ethics Application 2020-072-HD

Hi Zoe
I am pleased to inform you that this project (2020-072-HD) has been reviewed by the School Research Ethics Committee and has been given a favourable ethical opinion for conduct. The project may proceed.
Many thanks
Liz

6.6 Appendix 2c) Ethics approval for Study 3

Uncertain World Adult Ethics Approval
From: PCLS Ethics <pclsethics@reading.ac.uk>
Sent: Thursday, December 9, 2021 1:34 PM
To: Zoe Ryan <z.j.ryan@pgr.reading.ac.uk>
Cc: Lily Fitzgibbon <l.t.fitzgibbon@reading.ac.uk>; Jayne Morriss <j.e.morriss@reading.ac.uk>; Dodd, Helen <h.dodd@exeter.ac.uk>; Fitzgibbon, Lily <L.Fitzgibbon@exeter.ac.uk>
Subject: RE: Uncertain World Project Ethics Application 2021-194-JM
Hi Zoe
I am pleased to inform you that this project (2021-194-JM) has been reviewed by the School Research Ethics Committee and has been given a favourable ethical opinion for conduct. The project may proceed.
(If this project is going through SONA, please could you make all the necessary arrangements as early as possible)
Many thanks
Liz

6.7 Appendix 2d) Ethics approval for originally planned PhD study

Originally planned PhD study - Watch Them Grow Follow Up Ethics Approval
From: PCLS Ethics <pclsethics@reading.ac.uk>
Sent: Tuesday, August 13, 2019 11:40 AM
To: Zoe Ryan <z.j.ryan@pgr.reading.ac.uk>; Helen Dodd <h.f.dodd@reading.ac.uk>
Subject: RE: New ethics application 2019-080-HD
Hi Helen and Zoe
I am pleased to inform you that this project (2019-080-HD) has been reviewed by the School Research Ethics Committee and has been given a favourable ethical opinion for conduct. The project may proceed.
Many thanks
Liz

6.8 Appendix 3. Questionnaires for Studies 1, 2 and 3

The Spence Children's Anxiety Scale – Parent report (SCAS-P; Nauta et al., 2004).

Health Behaviour Questionnaire (HBQ) (Armstrong & Goldstein, 2003).)

Health and Behavior Questionnaire (HBQ-P 1.0) Page 11

Below is a list of more behaviors that some children exhibit during middle childhood. Please keep in mind that this questionnaire is intended to cover a wide range of behaviors and behavior problems that may occur during this period of development, and that, therefore, you may or may not find many items applicable to your child. For each of the following behaviors, please place a check (✓) next to the statement that best describes how often or true the behavior is of your child ***within the past six months***.

67. Fidgets.

0 ____ Never or not true
1 ____ Sometimes or somewhat true
2 ____ Often or very true

68. Worries about things in the future.

0 ____ Never or not true
1 ____ Sometimes or somewhat true
2 ____ Often or very true

69. Has temper tantrums or hot temper.

0 ____ Never or not true
1 ____ Sometimes or somewhat true
2 ____ Often or very true

70. When mad at a peer, keeps that peer from being in the play group.

0 ____ Never or not true
1 ____ Sometimes or somewhat true
2 ____ Often or very true

71. Worries that something bad will happen to people s/he is close to.

0 ____ Never or not true
1 ____ Sometimes or somewhat true
2 ____ Often or very true

72. Steals; takes things that don't belong to him/her.

0 ____ Never or not true
1 ____ Sometimes or somewhat true
2 ____ Often or very true

73. Has trouble sleeping.

0 ____ Never or not true
1 ____ Sometimes or somewhat true
2 ____ Often or very true

74. Can't stay seated when required to do so.

0 ____ Never or not true
1 ____ Sometimes or somewhat true
2 ____ Often or very true

75. Worries about past behavior.

0 ____ Never or not true
1 ____ Sometimes or somewhat true
2 ____ Often or very true

76. Is a solitary child.
    - 0 ____ Never or not true
    - 1 ____ Sometimes or somewhat true
    - 2 ____ Often or very true

77. Argues a lot with adults.
    - 0 ____ Never or not true
    - 1 ____ Sometimes or somewhat true
    - 2 ____ Often or very true

78. Argues a lot with peers.
    - 0 ____ Never or not true
    - 1 ____ Sometimes or somewhat true
    - 2 ____ Often or very true

79. Worries about being separated from loved ones.
    - 0 ____ Never or not true
    - 1 ____ Sometimes or somewhat true
    - 2 ____ Often or very true

80. Lies or cheats.
    - 0 ____ Never or not true
    - 1 ____ Sometimes or somewhat true
    - 2 ____ Often or very true

81. Sleeps more than most children during the day and/or night.
    - 0 ____ Never or not true
    - 1 ____ Sometimes or somewhat true
    - 2 ____ Often or very true

82. Impulsive or acts without thinking.
    - 0 ____ Never or not true
    - 1 ____ Sometimes or somewhat true
    - 2 ____ Often or very true

83. Tries to get others to dislike a peer.
    - 0 ____ Never or not true
    - 1 ____ Sometimes or somewhat true
    - 2 ____ Often or very true

84. Distractible, has trouble sticking to any activity.
    - 0 ____ Never or not true
    - 1 ____ Sometimes or somewhat true
    - 2 ____ Often or very true

85. Taunts and teases other children.
    - 0 ____ Never or not true
    - 1 ____ Sometimes or somewhat true
    - 2 ____ Often or very true

86. Worries about doing better at things.
    - 0 ____ Never or not true
    - 1 ____ Sometimes or somewhat true
    - 2 ____ Often or very true

87. Defiant, talks back to adults.
    - 0 ____ Never or not true
    - 1 ____ Sometimes or somewhat true
    - 2 ____ Often or very true

88. Avoids school to stay home.
    - 0 ____ Never or not true
    - 1 ____ Sometimes or somewhat true
    - 2 ____ Often or very true

89. Vandalizes.
    - 0 ____ Never or not true
    - 1 ____ Sometimes or somewhat true
    - 2 ____ Often or very true

90. Wets the bed.
    - 0 ____ Never or not true
    - 1 ____ Sometimes or somewhat true
    - 2 ____ Often or very true

91. Poor appetite, not hungry.
    - 0 ____ Never or not true
    - 1 ____ Sometimes or somewhat true
    - 2 ____ Often or very true

92. Prefers to play alone.
    - 0 ____ Never or not true
    - 1 ____ Sometimes or somewhat true
    - 2 ____ Often or very true

93. Has difficulty awaiting turn in games or groups.
    - 0 ____ Never or not true
    - 1 ____ Sometimes or somewhat true
    - 2 ____ Often or very true

94. Sets fires.
    - 0 ____ Never or not true
    - 1 ____ Sometimes or somewhat true
    - 2 ____ Often or very true

95. Physical problems *without* known medical cause:

95a. Aches and pains

0 ____ Never or not true
1 ____ Sometimes or somewhat true
2 ____ Often or very true

95b. Headaches

0 ____ Never or not true
1 ____ Sometimes or somewhat true
2 ____ Often or very true

95c. Nausea, feels sick

0 ____ Never or not true
1 ____ Sometimes or somewhat true
2 ____ Often or very true

95d. Stomach aches or cramps

0 ____ Never or not true
1 ____ Sometimes or somewhat true
2 ____ Often or very true

96. Tells others not to play with or be a peer's friend.

0 ____ Never or not true
1 ____ Sometimes or somewhat true
2 ____ Often or very true

97. Does things that annoy others.

0 ____ Never or not true
1 ____ Sometimes or somewhat true
2 ____ Often or very true

98. Scared to go to sleep without parents being near.

0 ____ Never or not true
1 ____ Sometimes or somewhat true
2 ____ Often or very true

99. Cruel to animals.

0 ____ Never or not true
1 ____ Sometimes or somewhat true
2 ____ Often or very true

100. Likes to be alone.

0 ____ Never or not true
1 ____ Sometimes or somewhat true
2 ____ Often or very true

101. Interrupts, blurts out answers to questions too soon.
   0 ____ Never or not true
   1 ____ Sometimes or somewhat true
   2 ____ Often or very true

102. Self-conscious or easily embarrassed.
   0 ____ Never or not true
   1 ____ Sometimes or somewhat true
   2 ____ Often or very true

103. Blames others for his/her own mistakes.
   0 ____ Never or not true
   1 ____ Sometimes or somewhat true
   2 ____ Often or very true

104. Avoids being alone.
   0 ____ Never or not true
   1 ____ Sometimes or somewhat true
   2 ____ Often or very true

105. Physically attacks people.
   0 ____ Never or not true
   1 ____ Sometimes or somewhat true
   2 ____ Often or very true

106. Shy with other children.
   0 ____ Never or not true
   1 ____ Sometimes or somewhat true
   2 ____ Often or very true

107. Has difficulty following directions or instructions.
   0 ____ Never or not true
   1 ____ Sometimes or somewhat true
   2 ____ Often or very true

108. Tells a peer that s/he won't play with that peer or be that peer's friend unless that peer does what s/he asks.
   0 ____ Never or not true
   1 ____ Sometimes or somewhat true
   2 ____ Often or very true

109. Needs to be told over and over that things are OK.
   0 ____ Never or not true
   1 ____ Sometimes or somewhat true
   2 ____ Often or very true

110. Is easily annoyed by others.
   0 ____ Never or not true
   1 ____ Sometimes or somewhat true
   2 ____ Often or very true

111. Has nightmares about being abandoned.
    0 ____ Never or not true
    1 ____ Sometimes or somewhat true
    2 ____ Often or very true

112. Threatens people.
    0 ____ Never or not true
    1 ____ Sometimes or somewhat true
    2 ____ Often or very true

113. Shy with unfamiliar adults.
    0 ____ Never or not true
    1 ____ Sometimes or somewhat true
    2 ____ Often or very true

114. Can't concentrate, can't pay attention for long.
    0 ____ Never or not true
    1 ____ Sometimes or somewhat true
    2 ____ Often or very true

115. Nervous, high strung, or tense.
    0 ____ Never or not true
    1 ____ Sometimes or somewhat true
    2 ____ Often or very true

116. Angry and resentful.
    0 ____ Never or not true
    1 ____ Sometimes or somewhat true
    2 ____ Often or very true

117. Avoids peers.
    0 ____ Never or not true
    1 ____ Sometimes or somewhat true
    2 ____ Often or very true

118. Complains of feeling sick before separating from those s/he is close to.
    0 ____ Never or not true
    1 ____ Sometimes or somewhat true
    2 ____ Often or very true

119. Destroys his or her own things.
    0 ____ Never or not true
    1 ____ Sometimes or somewhat true
    2 ____ Often or very true

120. Feels worthless or inferior.
    0 ____ Never or not true
    1 ____ Sometimes or somewhat true
    2 ____ Often or very true

121. Jumps from one activity to another.
   0 ____ Never or not true
   1 ____ Sometimes or somewhat true
   2 ____ Often or very true

122. Overly upset when leaving someone s/he is close to.
   0 ____ Never or not true
   1 ____ Sometimes or somewhat true
   2 ____ Often or very true

123. Gets back at people.
   0 ____ Never or not true
   1 ____ Sometimes or somewhat true
   2 ____ Often or very true

124. Unhappy, sad, or depressed.
   0 ____ Never or not true
   1 ____ Sometimes or somewhat true
   2 ____ Often or very true

125. Destroys things belonging to his/her family or other children.
   0 ____ Never or not true
   1 ____ Sometimes or somewhat true
   2 ____ Often or very true

126. Underactive, slow-moving, or lacks energy.
   0 ____ Never or not true
   1 ____ Sometimes or somewhat true
   2 ____ Often or very true

127. Verbally threatens to keep a peer out of the play group if the peer doesn't do what s/he wants.
   0 ____ Never or not true
   1 ____ Sometimes or somewhat true
   2 ____ Often or very true

128. Has difficulty playing quietly.
   0 ____ Never or not true
   1 ____ Sometimes or somewhat true
   2 ____ Often or very true

129. Overly upset while away from someone s/he is close to.
   0 ____ Never or not true
   1 ____ Sometimes or somewhat true
   2 ____ Often or very true

130. Swears or uses obscene language.
   0 ____ Never or not true
   1 ____ Sometimes or somewhat true
   2 ____ Often or very true

131. Keeps peers at a distance.
   0 ____ Never or not true
   1 ____ Sometimes or somewhat true
   2 ____ Often or very true

132. Disobedient at school.
   0 ____ Never or not true
   1 ____ Sometimes or somewhat true
   2 ____ Often or very true

133. Is afraid of being away from home.
   0 ____ Never or not true
   1 ____ Sometimes or somewhat true
   2 ____ Often or very true

134. Talks excessively.
   0 ____ Never or not true
   1 ____ Sometimes or somewhat true
   2 ____ Often or very true

135. Kicks, bites, or hits other children.
   0 ____ Never or not true
   1 ____ Sometimes or somewhat true
   2 ____ Often or very true

136. Is afraid of strangers.
   0 ____ Never or not true
   1 ____ Sometimes or somewhat true
   2 ____ Often or very true

137. Cries a lot.
   0 ____ Never or not true
   1 ____ Sometimes or somewhat true
   2 ____ Often or very true

138. Cruel, bullies, or mean to others.
   0 ____ Never or not true
   1 ____ Sometimes or somewhat true
   2 ____ Often or very true

139. Tells a peer that they won't be invited to their birthday party unless that peer does what s/he wants.
   0 ____ Never or not true
   1 ____ Sometimes or somewhat true
   2 ____ Often or very true

140. Seems lonely.
   0 ____ Never or not true
   1 ____ Sometimes or somewhat true
   2 ____ Often or very true

Health and Behavior Questionnaire (HBQ-P 1.0) Page 19

141. Wets self during the day.
0 ____ Never or not true
1 ____ Sometimes or somewhat true
2 ____ Often or very true

142. Interrupts or butts in on others.
0 ____ Never or not true
1 ____ Sometimes or somewhat true
2 ____ Often or very true

143. Gets in many fights.
0 ____ Never or not true
1 ____ Sometimes or somewhat true
2 ____ Often or very true

144. Withdraws from peer activities.
0 ____ Never or not true
1 ____ Sometimes or somewhat true
2 ____ Often or very true

145. Uses a weapon when fighting.
0 ____ Never or not true
1 ____ Sometimes or somewhat true
2 ____ Often or very true

146. Doesn't smile or laugh much.
0 ____ Never or not true
1 ____ Sometimes or somewhat true
2 ____ Often or very true

147. Does not seem to listen.
0 ____ Never or not true
1 ____ Sometimes or somewhat true
2 ____ Often or very true

148. Loses things.
0 ____ Never or not true
1 ____ Sometimes or somewhat true
2 ____ Often or very true

149. Does dangerous things without thinking.
0 ____ Never or not true
1 ____ Sometimes or somewhat true
2 ____ Often or very true

The Responses to Uncertainty and Low Environmental Structure (RULES) questionnaire (Sanchez et al., 2017).

Responses to Uncertainty and Low Environmental Structure (RULES)
For each of the following statements, please rate how well the statement describes your child by selecting among one of five responses and circling the number corresponding to that response.
Not at all Somewhat Very much

1. My child gets tense when unexpected events or transitions occur in his/her environment	1	2	3	4	5
2. My child has a hard time coping with even minor changes	1	2	3	4	5
3. My child says, “It is unfair” when he/she cannot	1	2	3	4	5

know what will happen next					
4. My child always wants to know ahead of the time what the plan is	1	2	3	4	5
5. My child becomes upset if he/she has to enter a new situation	1	2	3	4	5
6. My child seeks reassurance prior to entering an unfamiliar situation	1	2	3	4	5
7. My child cries when he/she finds him/herself in an unfamiliar situation	1	2	3	4	5
8. My child gets down on himself if he does not know what will happen next.	1	2	3	4	5
9. My child performs best in highly structured environments.	1	2	3	4	5
10. My child tantrums when an unexpected event occurs	1	2	3	4	5
11. My child avoids unstructured situations	1	2	3	4	5
12. My child cannot relax if he/she does not know what will happen next	1	2	3	4	5
13. My child cannot sleep if he anticipates	1	2	3	4	5

an upcoming change					
14. My child becomes fidgety during transitions	1	2	3	4	5
15. My child freezes up in the face of unexpected events	1	2	3	4	5
16. Transitions are difficult for my child	1	2	3	4	5
17. My child complains of physical symptoms (e.g., headaches, stomachaches) when he/she is about to enter a new situation	1	2	3	4	5

Trait scale of Y2 State-Trait Anxiety Inventory (STAI-Y2; Speilberger et al., 1983).

Interest/Deprivation-Young Children (I/D-YC) scale (Litman, 2005; Piotrowksi et al., 2014)

1	My child has fun learning about new topics or subjects.
2	My child is attracted to new things in his/her environment.
3	My child enjoys talking about topics that are new to him/her.
4	My child devotes considetable effort trying to figure out things that are confusing or unclear.
5	My child is bothered when he/she does not understand something and tries to make sense of it.
6	My child shows visible enjoyment when discovering something new.
7	When my child is learning something new, he/she asks many questions about it.
8	When presented with a tough problem, my child focuses all of his/her attention on how to solve it.
9	My child will work for a long time to solve a problem because he/she wants to know the answer.
10	My child examines things by turning them around and looking at them from all sides.
	indicate how frequently their child expresses the characteristics or behaviours described
	(1) almost never, (2) sometimes, (3) often and (4) almost always.
	Below added after ethics approval.
	i-type - sum the item scores for 1, 2, 3, 6, 7
	d-type - sum the item scores for 4, 5, 8, 9, 10

Interest and Deprivation-Type Epistemic Curiosity (ID-EC) Scale (Litman, 2008; Litman et al., 2010; Litman & Mussel, 2013)
Please report how you generally feel regarding each statement below on the following 4-point

frequency scale

1. I enjoy exploring new ideas.
2. I can spend hours on a single problem because I just can't rest without knowing the answer.
3. I find it fascinating to learn new information
4. I brood for a long time in an attempt to solve some fundamental problem
5. I enjoy learning about subjects that are unfamiliar to me
6. Difficult conceptual problems can keep me awake all night thinking about solutions.
7. I enjoy discussing abstract concepts
8. I feel frustrated if I can't figure out the solution to a problem, so I work even harder to solve it.
9. When I learn something new, would like to find out more about it
10. I work like a fiend at problems that I feel must be solved

1 = Almost Never, 2 = Sometimes, 3 = Often, 4 = Almost Always

I-type score is established by averaging items odd-numbered items (1, 3, 5, 7, 9).

D-type score is established by averaging items even-numbered items (2, 4, 6, 8, 10).

Intolerance of Uncertainty Scale (IUS) (Buhr & Dugas, 2002)
IUS

You will find below a series of statements which describe how people may react to the uncertainties of life. Please use the scale below to describe to what extent each item is characteristic of you. Please circle a number (1 to 5) that describes you best.

Not at all characteristic of me	Somewhat characteristic of me	Entirely characteristic of me

1. Uncertainty stops me from having a firm opinion. ....1....................2....................3....................4...................5...........
2. Being uncertain means that a person is disorganized. ....1....................2....................3....................4...................5...........
3. Uncertainty makes life intolerable. ....1....................2....................3....................4...................5...........
4. It's unfair not having any guarantees in life. ....1....................2....................3....................4...................5...........
5. My mind can't be relaxed if I don't know what will happen tomorrow. ....1....................2....................3....................4...................5...........
6. Uncertainty makes me uneasy, anxious, or stressed. ....1....................2....................3....................4...................5...........
7. Unforeseen events upset me greatly. ....1....................2....................3....................4...................5............
8. It frustrates me not having all the information I need. ....1....................2....................3....................4...................5...........
9. Uncertainty keeps me from living a full life. ....1....................2....................3....................4...................5...........
10. One should always look ahead so as to avoid surprises. ....1....................2....................3....................4...................5...........

11. A small unforeseen event can spoil everything, even with the best of planning. ....1....................2....................3....................4...................5...........

12. When it's time to act, uncertainty paralyses me. ....1....................2....................3....................4...................5...........

13. Being uncertain means that I am not first rate. ....1....................2....................3....................4...................5...........

14. When I am uncertain, I can't go forward. ....1....................2....................3....................4...................5...........

15. When I am uncertain I can't function very well. ....1....................2....................3....................4...................5...........

16. Unlike me, others always seem to know where they are going with their lives. ....1....................2....................3....................4...................5...........

17. Uncertainty makes me vulnerable, unhappy, or sad. ....1....................2....................3....................4...................5...........

18. I always want to know what thefuture has in store for me. ....1....................2....................3....................4...................5...........

19. I can't stand being taken by surprise. ....1....................2....................3....................4...................5...........

20. The smallest doubt can stop me from acting. ....1....................2....................3....................4...................5...........

21. I should be able to organize everything in advance. ....1....................2....................3....................4...................5...........

22. Being uncertain means that I lack confidence. ....1....................2....................3....................4...................5...........

23. I think it's unfair that other people seem sure about their future. ....1....................2....................3....................4....................5 ....

24. Uncertainty keeps me from sleeping soundly. ....1....................2....................3....................4...................5...........

25. I must get away from all uncertain situations. ....1....................2....................3....................4...................5...........

26. The ambiguities in life stress me ....1....................2....................3....................4...................5...........

27. I can't stand being undecided about my future. ....1....................2....................3....................4...................5...........

Original French Version: Freeston, M.H., Rhéaume, J., Letarte, H., Dugas, M.J., & Ladouceur, R. (1994): Why do people worry? *Personality and Individual Differences, 17* (6), 791-802.

English Version: Buhr, K., Dugas, M. J. (2002). The intolerance of uncertainty scale: psychometric properties of the English version.

Behavior Research and Therapy, 40 , 931-945.

Scoring Instructions

The IUS may be used as a unifactorial or a bifactorial assessment tool.

To score the IUS as a unifactorial tool, add up the responses for each of the items.

As a bifactorial tool, the IUS is used to assess the following two factors:

Factor 1: Uncertainty has negative behavioural and self-referent implications
Factor 2: Uncertainty is unfair and spoils everything

To score Factor 1, add up the responses for items 1, 2, 3, 9, 12, 13, 14, 15, 16, 17, 20, 22, 23, 24, and 25
To score Factor 2, add up the responses for items 4, 5, 6, 7, 8, 10, 11,

18,19, 21, 26, and 27

A discussion on the 2-factor IUS scale may be found here:

Sexton, K. A., & Dugas, M. J. (2009). Defining Distinct Negative Beliefs about Uncertainty: Validating the Factor Structure of the Intolerance of Uncertainty Scale. *Psychological Assessment, 21* , 176-186.

6.9 Appendix 4 Information sheet for parents for Study 1

Timepoint 2:

Watch them Grow Project Follow-up Questionnaires

Thank you for your interest in taking part in the next follow-up of the Watch them Grow Project. This stage of the project focuses on how children deal with uncertainty and is being led by Zoe Ryan as part of her PhD research under the supervision of Prof. Helen Dodd.

Project Information

The University of Reading's 'Watch them Grow' project has already tracked the journey of 180 local children through their entry into primary school. We are currently going through an unprecedented period of uncertainty, with the situation regarding the Coronavirus changing on a day to day basis. We would like to now ask all families to help us to examine how this is affecting anxiety in young children and their parents.

This part of the project will involve completing some questionnaires online regarding your 5-7 year old child and yourself.

As a thank you for your time and support families will be given a £5 voucher for taking part.

On the next few pages we answer frequently asked questions about the project. Please get in touch
if you have any other questions or would like to discuss any aspect of the project, we'd love to hear
from you. If you are happy to take part in the research you can use The link to the questionnaires which can be found at the end of the FAQs.

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.

Thank you for your time and interest in our project - we hope to hear from you soon!

Zoe Ryan
(University of Reading Doctoral Researcher)
Contact info:
z.j.ryan@pgr.reading.ac.uk
Mobile:

What's the point of the project?

On average one child in every UK classroom experiences anxiety that significantly affects their daily
life. The Watch them Grow project focuses on understanding what causes and maintains anxiety in children broadly. At this stage we have chosen to focus on uncertainty. There is a theory that people who find uncertainty difficult are those who are most likely to have

problems with anxiety. At the moment we know very little about whether reactions to uncertainty are linked to anxiety in children. The aim is that we can use the information from this project to work out how reactions to uncertainty and anxiety are linked in children and how anxiety is affected over time in people who struggle with uncertainty . This could be helpful for developing treatments for anxiety in the future.

We are interested in how the whole group of children cope with uncertainty and will only be looking at overall patterns for the group, not individuals in detail.

What exactly will happen when we complete the questionnaire?

You will complete a series of questionnaires which measure your child's emotions and behaviour and your own anxiety.

You will be emailed a link to redeem a £5 voucher once we have closed the questionnaire in approximately two weeks time.

What will happen to the information about me and my child?

We appreciate the importance of keeping your information safe. All the information we collect and
that you share with us will be kept confidential. We will use a unique code known only to the project team to identify any information relating to you and your child. That way, all of the information is anonymous. We have to keep the form you sign to say that you are happy to take part
and this will be stored in a locked filing cabinet in the University. Electronic data including any videos will be stored on secure servers and password protected. Only the researchers working on
this project will have access to these stored files. De-identified electronic data for the whole group will be deposited to the UK Data Service; no personal or identifiable information will be included.

Will you want to see my child again when they are older?

We will be asking your child to come back to the University at some point when they are in Year 2 (some children may have already taken part in this stage). This stage of the testing will run until the summer of 2021. We will contact you once we have run the analysis and written up our findings. You may be asked back to the university to help us again in the future so that we can continue to see how children's emotions are developing. You are not be obliged to take part in any further research.

I'm worried about anxiety – where can I go for more information?
Some of our questionnaires ask about worries and fears you and your child might have.
If these raise any concerns you can contact any member of the research team or see
https://research.reading.ac.uk/andy/resources/resources-parents/

Please find below a helpful link with advice for parents, carers and people that work with children and young people put together by our team together with colleagues at Oxford University:

https://emergingminds.org.uk/wp-content/uploads/2020/03/COVID19_advice-for-parents-and-carers_20.3_.pdf

You may also be interested in the below link about how to talk to your child about coronavirus:

https://www.unicef.org/coronavirus/how-talk-your-child-about-coronavirus-covid-19

And how to calm coronavirus anxiety in children:

https://www.specialneedsjungle.com/calming-coronavirus-anxiety-children-everyone-else/

Who is doing the research?

The project is managed by Zoe Ryan, Doctoral Researcher from the University of Reading, under the supervision of Prof. Helen Dodd and Dr Jayne Morriss. All researchers working on the project have enhanced Disclosure and Barring Service (DBS) checks.

If you have read this information and are happy to take part in the next stage of the project, please feel free to click the link below to complete the questionnaires:

https://www.surveymonkey.co.uk/r/WTGSpring2020

If you have any questions you can contact Zoe on:
z.j.ryan@pgr.reading.ac.uk
mobile:

or Helen on:
h.f.dodd@reading.ac.uk
Phone: 0118 378 6331

Many thanks for your time and interest in our project! We look forward to seeing you again soon!

Zoe

Timepoint 3:

Watch them Grow Project Follow-up Questionnaires

Thank you for your interest in taking part in the next follow-up of the Watch them Grow Project. This stage of the project focuses on how children deal with uncertainty and is being led by Zoe Ryan as part of her PhD research under the supervision of Prof. Helen Dodd.

Project Information

The University of Reading's 'Watch them Grow' project has already tracked the journey of 180 local children through their entry into primary school. In 2020 we asked all of the Watch them Grow families to help us examine how the unprecedented period of uncertainty in the

Coronavirus pandemic affected anxiety in young children and their parents. We would like to ask you the same questions again, to see how everyone is getting on now. We are particularly interested in whether intolerance of uncertainty predicts child anxiety over time.

This part of the project will involve completing some questionnaires online regarding your 8-10 year old child and yourself.

Families will be given a £5 voucher as reimbursement for their time.

On the next few pages we answer frequently asked questions about the project. Please get in touch
if you have any other questions or would like to discuss any aspect of the project, we'd love to hear
from you. If you are happy to take part in the research you can use the link to the questionnaires which can be found at the end of the FAQs.

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.

Thank you for your time and interest in our project - we hope to hear from you soon!

Zoe Ryan
(University of Reading Doctoral Researcher)
Contact info:
z.j.ryan@pgr.reading.ac.uk

What's the point of the project?

On average one child in every UK classroom experiences anxiety that significantly affects their daily
life. The Watch them Grow project focuses on understanding what causes and maintains anxiety in children broadly. At this stage we have chosen to focus on uncertainty. There is a theory that people who find uncertainty difficult are those who are most likely to have problems with anxiety. At the moment we know very little about whether reactions to uncertainty are linked to anxiety in children. The aim is that we can use the information from this project to work out how reactions to uncertainty and anxiety are linked in children and how anxiety is affected over time in people who struggle with uncertainty. This could be helpful for developing treatments for anxiety in the future.

We are interested in how the whole group of children cope with uncertainty and will only be looking at overall patterns for the group, not individuals in detail.

What exactly will happen when we complete the questionnaire?

You will complete a series of questionnaires which measure your child's emotions and behaviour and your own anxiety.

You will be emailed a link to redeem a £5 voucher once we have closed the questionnaire in approximately two weeks time.

What will happen to the information about me and my child?

We appreciate the importance of keeping your information safe. All the information we collect and
that you share with us will be kept confidential. We will use a unique code known only to the project team to identify any information relating to you and your child. That way, all of the information is anonymous. Electronic data will be stored on secure servers and password protected. Only the researchers working on this project will have access to these stored files. De-identified electronic data for the whole group will be deposited to the UK Data Service; no personal or identifiable information will be included.

Will you want to see my child again when they are older?

We are hoping to do some follow-on research in the future to see how children's emotions are developing, hopefully in person at the University again! You are not be obliged to take part in any further research.

In the meantime, we will contact you once we have run the analysis and written up our findings of this study.

I'm worried about anxiety – where can I go for more information?
Some of our questionnaires ask about worries and fears you and your child might have.
If these raise any concerns you can contact any member of the research team or see https://research.reading.ac.uk/andy/resources/resources-parents/

Who is doing the research?

The project is managed by Zoe Ryan, Doctoral Researcher from the University of Reading, under the supervision of Prof. Helen Dodd and Dr Rachel McCloy. All researchers working on the project have enhanced Disclosure and Barring Service (DBS) checks.

If you have read this information and are happy to take part in the next stage of the project, please feel free to click the link below to complete the questionnaires:

https://www.surveymonkey.co.uk/r/WTGAutumn2022

If you have any questions you can contact Zoe on:
z.j.ryan@pgr.reading.ac.uk

or Helen on:
h.dodd@exeter.ac.uk

Many thanks for your time and interest in our project! We look forward to seeing you again soon!
Zoe

6.10 Appendix 5 Parent Debrief for Study 1

Parent debrief – Questionnaires

Thank you for taking the time to complete the questionnaires for us. Here is a bit more information about why we are interested in the things we have asked about.

- One of the questionnaires measures your child's anxiety levels. We are looking at these levels at three different timepoints. When you first came in to the lab, when you completed the questionnaires early on in the COVID pandemic, and now.
- We have asked questions about your child's responses to uncertainty, also at these three timepoints. We would like to see if these responses are related to anxiety, and if their responses to uncertainty predict future anxiety
- Other questionnaires ask about other factors that are sometimes related to anxiety, including parent anxiety and children's mood.

It is important to keep in mind that we are interested in scores for these questionnaires for all of the children taking part in this project as a group; we don't look at scores or behaviours for specific individuals so we aren't able to give you feedback about your child's scores.

If you have any concerns about your child resources for parents can be found on our website: https://research.reading.ac.uk/andy/resources/resources-parents/

Thank you again for your time today. Do let us know if you have any questions, comments or feedback (z.j.ryan@pgr.reading.ac.uk).

6.11 Appendix 6 Consent form for Study 2

University of Reading

Consent form: Uncertain World

Thank you for supporting our project. On the next few pages you will be asked to answer a series of questions about you and your child. In total it should take about 5-10 minutes to complete the questions. When you have submitted the questionnaire responses, you will be sent an email with details of how to access the online game that your child will play.

You can save your questionnaire and come back to it later if you wish.

Many thanks,

Zoe

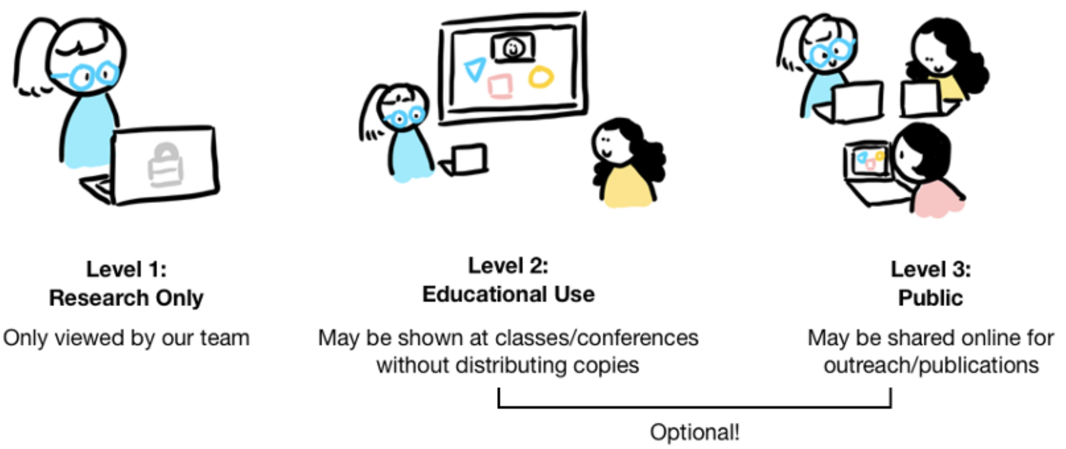
(z.j.ryan@pgr.reading.ac.uk)

- ☐ I agree to participating in this questionnaire portion of the project and to my child taking part in the webcam-recorded computer game, being conducted by Professor Helen Dodd, Dr Lily Fitzgibbon and Zoe Ryan at The University of Reading.
- ☐ I have seen and read a copy of the Parent Information Sheet and have been given the opportunity to ask questions about the study and these have been answered to my satisfaction.
- ☐ I understand that all personal information will remain confidential to the project team and arrangements for the storage of any identifiable material have been made clear to me.
- ☐ I understand that this data will be stored against a number identifier on secure servers and password protected.
- ☐ I understand that de-identified data will be shared using a secure data repository service.
- ☐ I understand that participation in this study is voluntary and that my child and I can withdraw at any time without having to give an explanation.

As part of the game, your child's facial expressions will be recorded by your computer's webcam. You will be instructed how to get this set up when you decide to start the computer game with your child By giving consent for your child to participate, you are allowing us to view the video-recordings of the study. The video will remain on your computer until the end of the game and we won't be able to see anything via your webcam until you upload the video. If at this point, you decide that you no longer want to share the video with us, then you can simply decline to upload the video file.

I am happy to proceed with my participation and for the video to be viewed and stored by the research team as detailed above. Y/N

In addition, you can also authorize us to use the video for educational purposes, for example, to show to other scientists and students or for public sharing, for example, for the purpose of further scientific research or to go on our website. These additional levels of consent help us teach students and communicate our research to others, but they are optional. You will be asked if you wish to consent to these when you upload the video file after the game but there is absolutely no requirement to do so. Please let us know if you need further explanation about these levels or if you have any other questions.



This application has been reviewed by the University Research Ethics Committee and has been given a favourable ethical opinion for conduct.

6.12 Appendix 7 Information Sheet for Study 2

Uncertain World Project

Thank you for your interest in taking part in the University of Reading's "Uncertain World" Project. This project focuses on how children respond to the unknown and is being led by Zoe Ryan as part of her PhD research under the supervision of Prof. Helen Dodd. After this initial information and FAQs, there is a short questionnaire for you to complete.

Project Information

We are looking for 170 children **between the ages of 8 and 12** to take part in this exciting project about how children respond to the unknown. We aim to discover why children explore things that are unknown or uncertain; because of curiosity or because they are uncomfortable with not knowing.

In total the project will take approximately **10 minutes of your time** and **10 minutes of your child's time**. In the first part we will ask you to complete some **short questionnaires** about your child, which should take about 5-10 minutes. In the second part, your child will **play a game** on a computer at home. To play the game your child will need to have access to a **computer that can play sounds, has a webcam, and access to Google Chrome**. The game needs to be completed within one week of you completing the questionnaires.

The questionnaires for you to complete are available after you have read this information and agreed to take part. Once you have completed them we will send you a link by email that you can use to get the game set-up for your child. The game is designed for 8 - 12 year old children and should only take about 10 minutes. It will involve your child pressing buttons that make sounds while their face is being recorded by your computer's webcam. Due to the nature of the game, your child will need to have normal or corrected hearing and vision.
Families will be given a £5 voucher as a contribution to your reasonable expenses incurred in taking part in the research. This.

Unfortunately, at this stage we're not able to include children who have significant Special Educational Needs (SEN) because their reactions to uncertainty are likely to be different to that of other children. In the future we may look to carry out a similar study with children who have SEN. On the next few pages, we answer some frequently asked questions about the project. Please get in touch if you have any other questions or would like to discuss any aspect of the project. If you are happy to take part in the research, please continue through to provide your consent and complete the questionnaires.

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.

Thank you for your time and interest in our project!

Zoe Ryan
(University of Reading Doctoral Researcher)
Contact info:
z.j.ryan@pgr.reading.ac.uk
Mobile:

What's the point of the project?

We seek out information in our daily lives, and this can be driven by a range of factors. We can be curious, and our thirst for information can lead us to try to find out more. We can also be driven to seek information because we don't like uncertainty and want to decrease it. At the moment we know very little about what drives children's reactions to uncertainty so that is what we are investigating in this project.

The information from the project could be helpful in thinking about how to treat anxiety around uncertainty and for understanding how to stimulate curiosity in education.

We are interested in what drives the behaviour of the whole group of children and will only be looking at overall patterns for the group, not individuals in detail.

What exactly will happen when we take part?

Once you have finished reading this information sheet, we will ask for you to complete some questionnaires about you and your child which should take 5 – 10 minutes. Once we have confirmed your child's eligibility to take part, we will send you a link to the computer game.

We would appreciate it if you could assist your child with the setup of the game. You will be asked to allow the web browser to start recording on the webcam and then check that the sound is working and at an appropriate level on the computer. Your child will be shown a brief instruction video which explains what they have to do. Your child will then be shown a number of buttons on the screen which are linked to different sounds. Each button shows an image relating to the sound, or a "?". Your child's reaction to the buttons will be video recorded via the webcam in anticipation of the game and during the game. They will be asked to rate how they feel, and then will be given the opportunity to press as many or as few buttons as they like. Each round lasts around a minute. They will be given the opportunity to play the game with different sounds several times..

After your child completes the game, you will be asked if you are happy to upload the video to our secure servers by pressing a button – you will be able to choose who is allowed to view the videos at this point. You will then be provided with some further information about the project.

You will be sent a £5 voucher once you have completed the session as a contribution to your reasonable expenses incurred in taking part in the research.

What will happen to the information about me and my child?

We are committed to keeping your information safe. All the information we collect and that you share with us will be kept confidential, unless something we observe makes us concerned for your safety, your child's safety or someone else's safety. We may then need to share information to make sure you are kept safe. We will use a unique code known only to the project team to identify any information relating to you and your child. That way, all of the information is anonymous. Electronic data including any videos will be stored on secure servers and password protected. Only the researchers working on this project will have access to these stored files. De-identified electronic data for the whole group will be deposited to the

University of Reading data archive; no videos, personal or identifiable information will be included.

What if my child gets upset or doesn't want to do some of the games?

We of course hope that the game is not upsetting and that your child enjoys taking part. We have
designed the game so that it is suitable for children and we have done lots of work with young children in the past. However, if your child does show any signs of getting upset, says that they don't want to take part, or if you don't feel comfortable at any stage, please tell them that they can stop the game. Taking part is voluntary and you are free to withdraw from the research at any point. Withdrawing won't affect the contribution to your reasonable expenses incurred in taking part in the research..

Who is doing the research?

The project is managed by Zoe Ryan, Doctoral Researcher from the University of Reading, under the supervision of Prof. Helen Dodd, Dr Lily Fitzgibbon and Dr Jayne Morriss. All researchers working on the project have enhanced DBS checks.

If you have read this information and are happy to take part in the project, please feel free to continue on to the consent form and questionnaires.

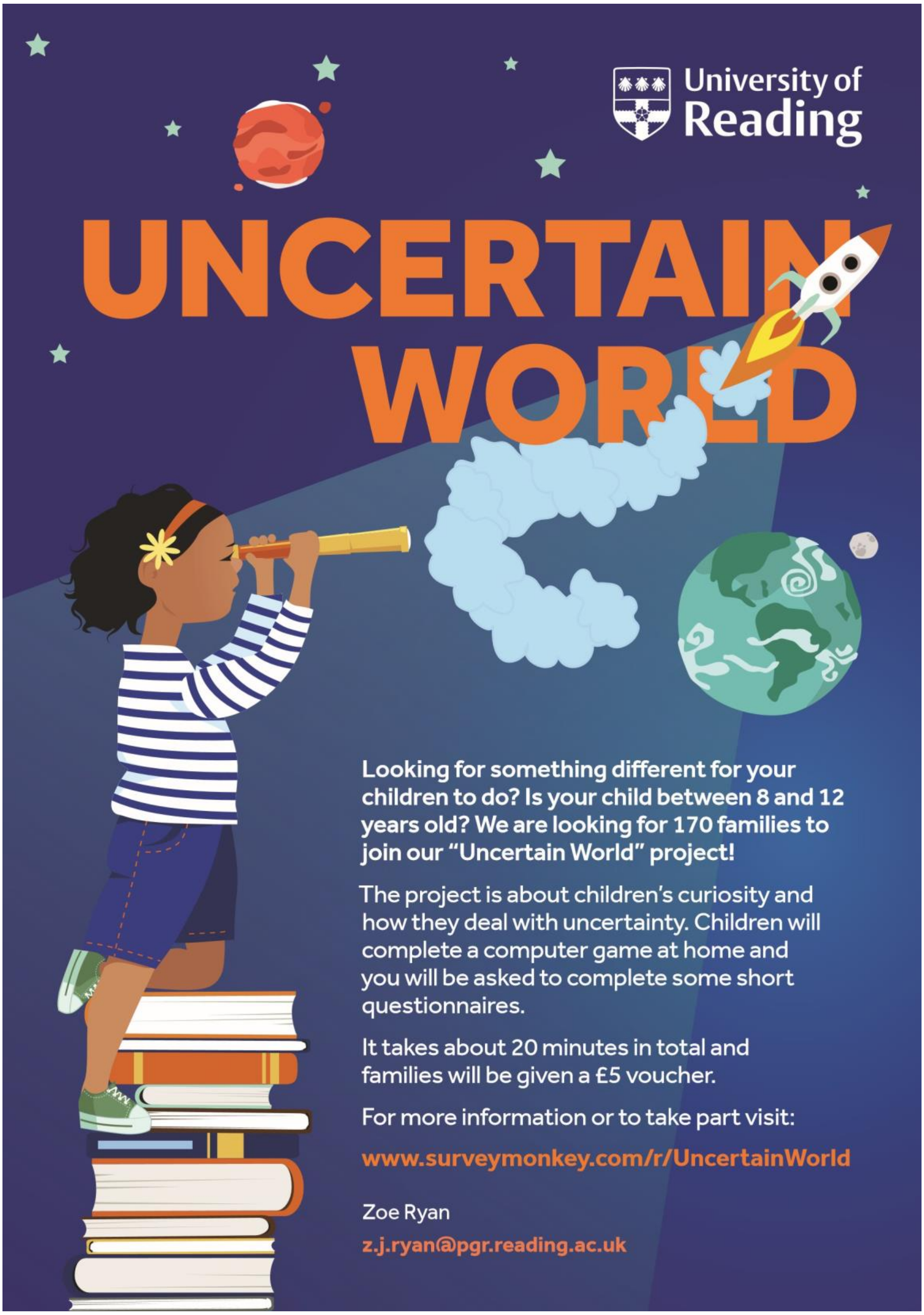
If you have any questions you can contact Zoe on:
z.j.ryan@pgr.reading.ac.uk
mobile:

or Helen on:
h.f.dodd@reading.ac.uk
Phone: 0118 378 6331

Many thanks for your time and interest in our project!

Zoe

6.13 Appendix 8 Advertising Flyer for Study 2



6.14 Appendix 9 Parent Debrief for Study 2

Parent debrief

Thank you for taking the time to complete the questionnaires, and for your child taking part in the computer games today. We hope that you both enjoyed the experience.

Here is a bit more information about what your child did today and why we are interested in these things. Please let us know if you have any questions, either by emailing z.j.ryan@pgr.reading.ac.uk or by leaving a question in the free text box at the end of this debrief.

- Your child played a game where they could choose to press buttons. The buttons had pictures on them relating to the sound they played when pressed, or a "?". Some of the buttons played the sound of rain, a jet planeor nightime noises, while others played a dentist drill, a rollercoaster, a jackhammer or a buzzer and some were uncertain (could be any of these). This tells us whether children seek out information or avoid it by not pressing any "?" buttons.
- Through the webcam recording, we will observe your child's emotional response to the buttons at the beginning of the game. We will aim to see whether your child is feeling positively or negatively about the game ahead. This tells us how children feel about uncertainty.
- We have also asked your child to rate how they felt about each of the screens they saw (on a scale from positive to negative). This allows your child to report whether they are feeling positively or negatively about the uncertainty.

It is important to keep in mind that we are interested in scores on these games for all of the children taking part in this project as a group; we don't look at scores or behaviours for specific individuals so we aren't able to give you feedback about your child's scores.

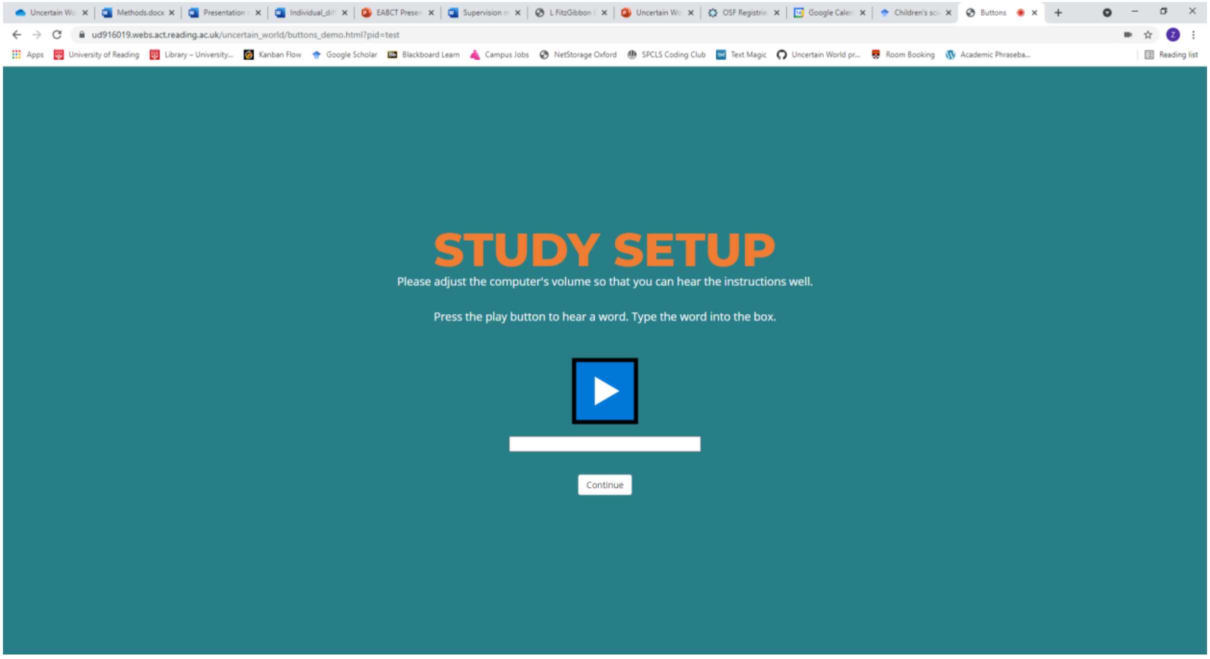
If you have any concerns about your child, resources for parents can be found on our website: https://research.reading.ac.uk/andy/resources/resources-parents/

Thank you again for your time today. Do let us know if you have any questions, comments or feedback.

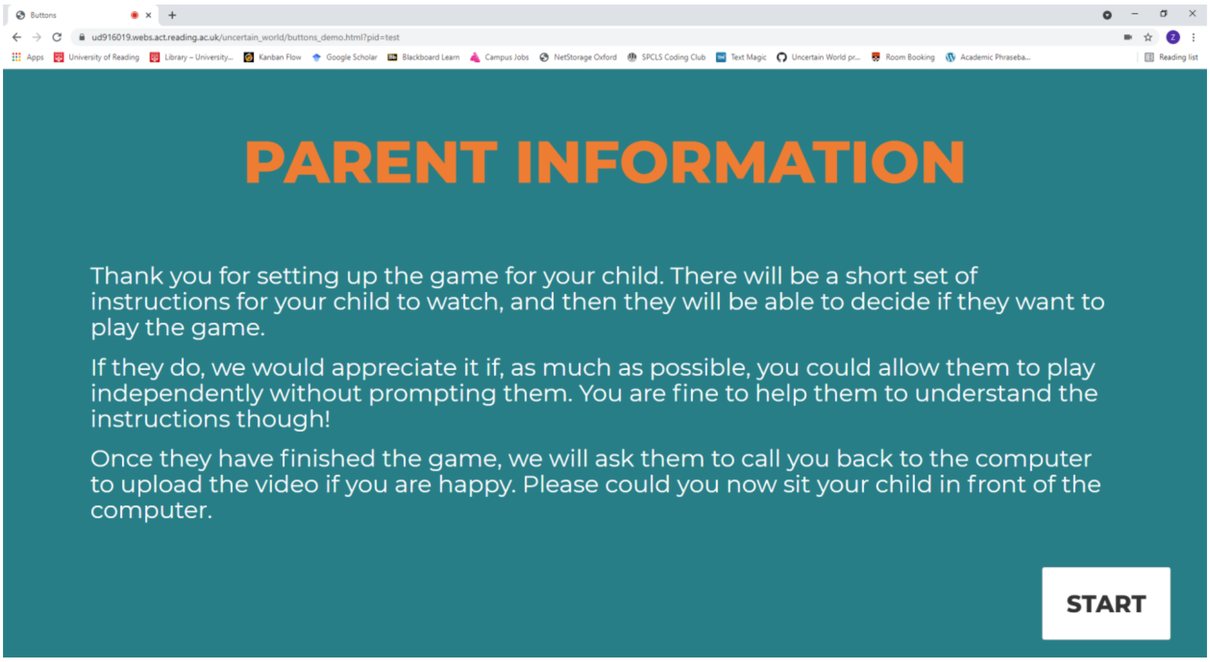
You can download a copy of this page by clicking here. We will also send you a copy by email with a giftcard as a contribution to your reasonable expenses incurred in taking part in the research and your child's certificate.

<<FREE TEXT BOX>>

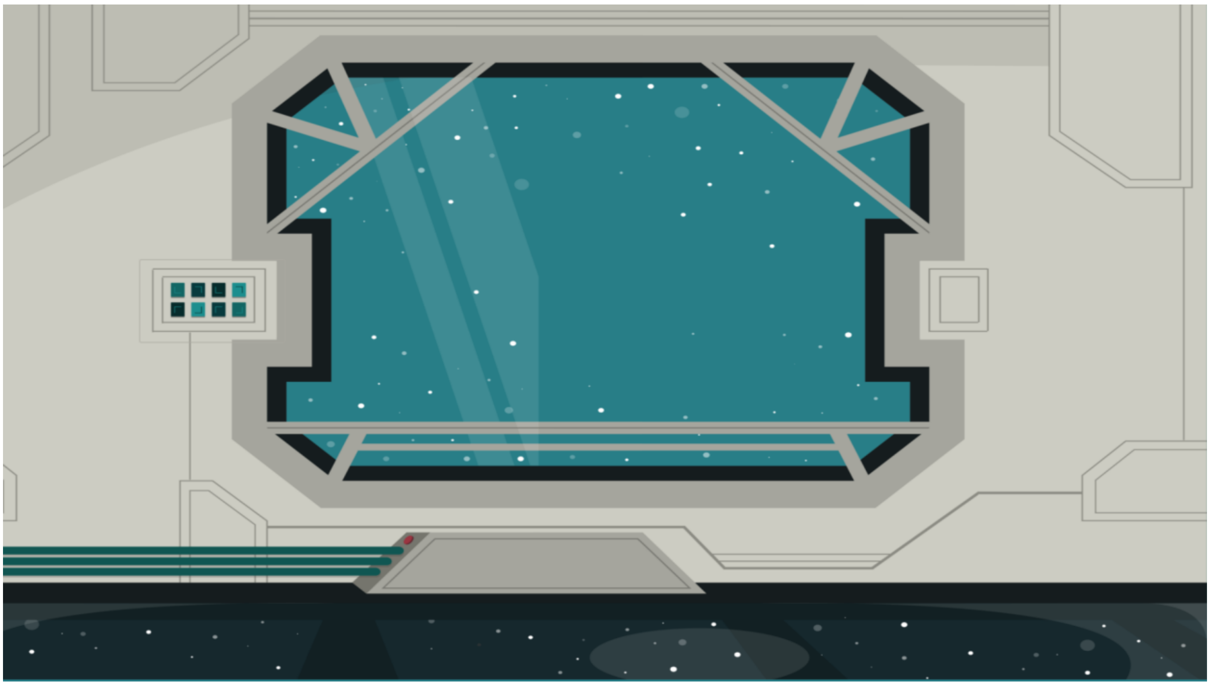
6.15 Appendix 10 Screenshots of game in Study 2 and 3

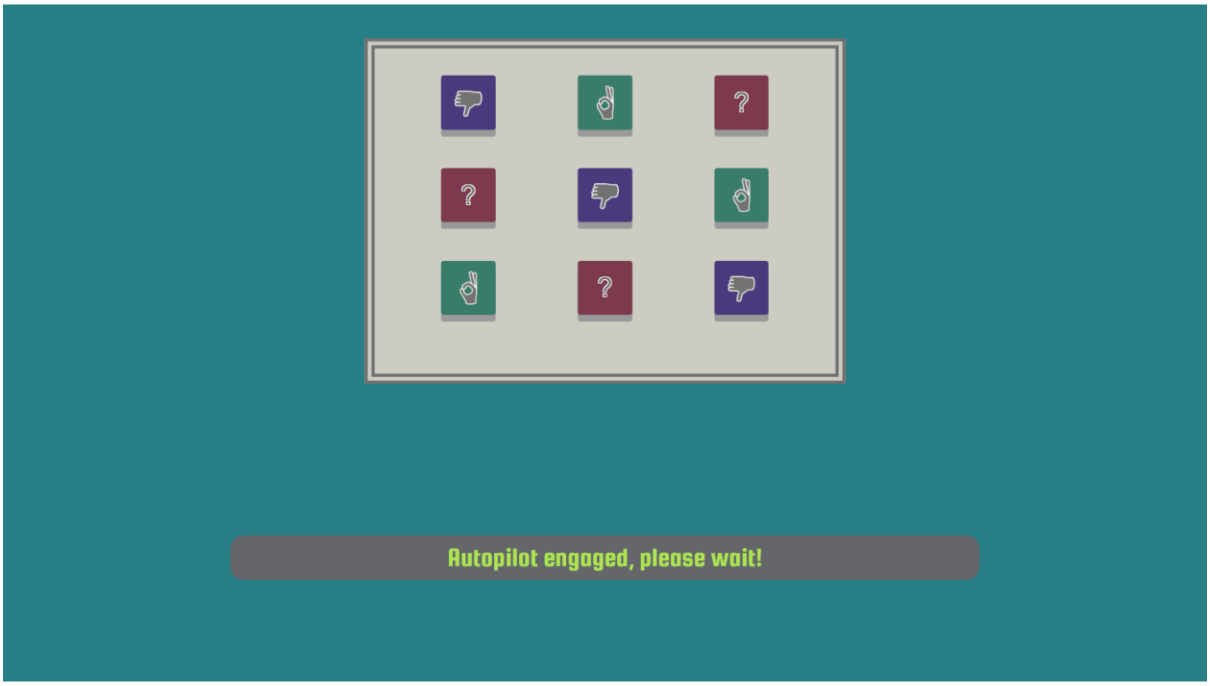


To check sound is working on participants' computer, they were asked to press the button which plays a sound and type it into the box

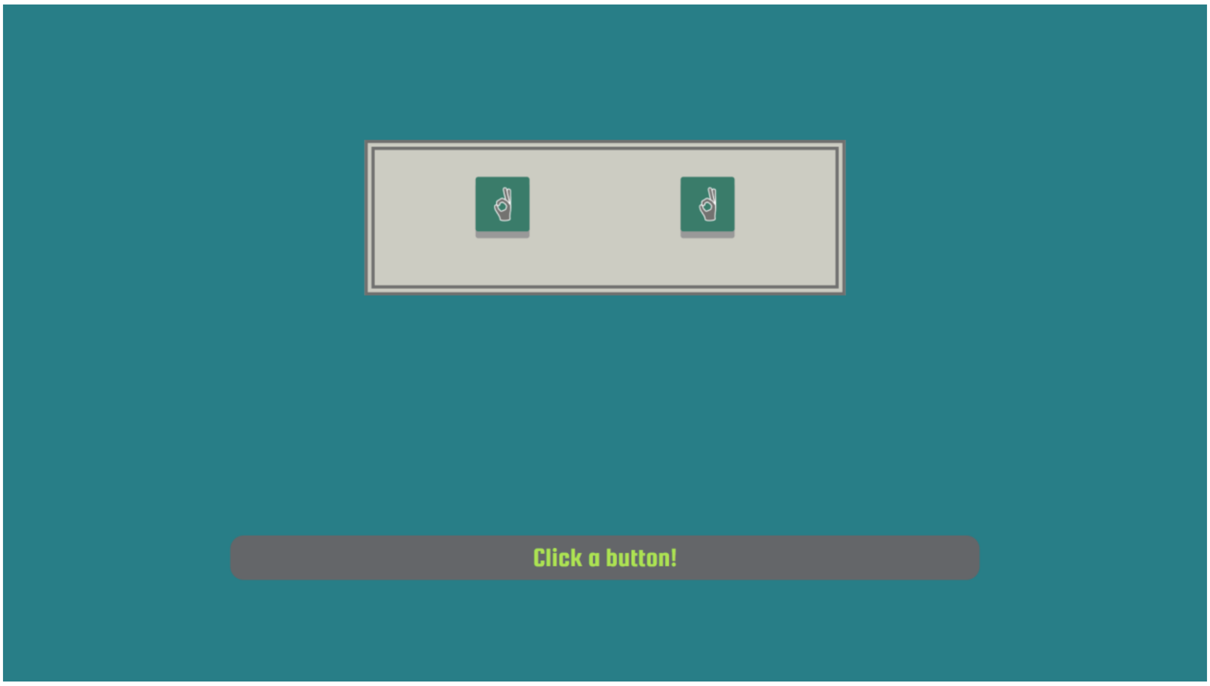


Participants are asked to seat themselves so that they can see their face in the spaceship window. This ensures their face will be in the correct position to be recorded on the webcam

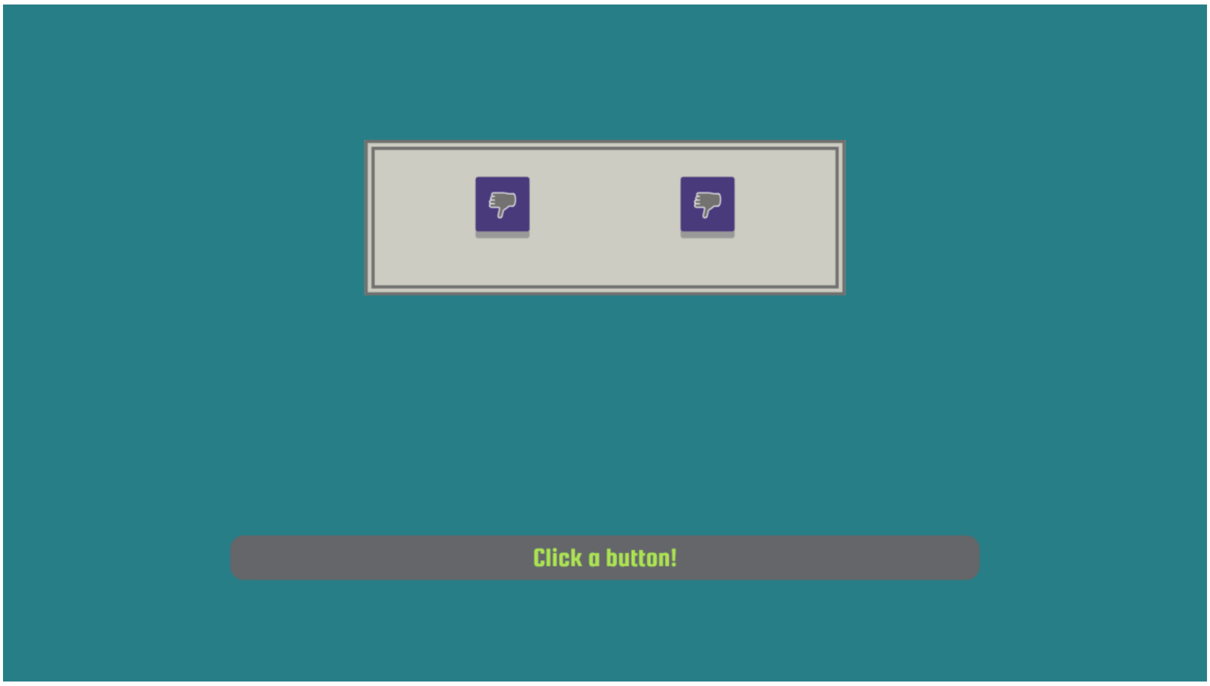




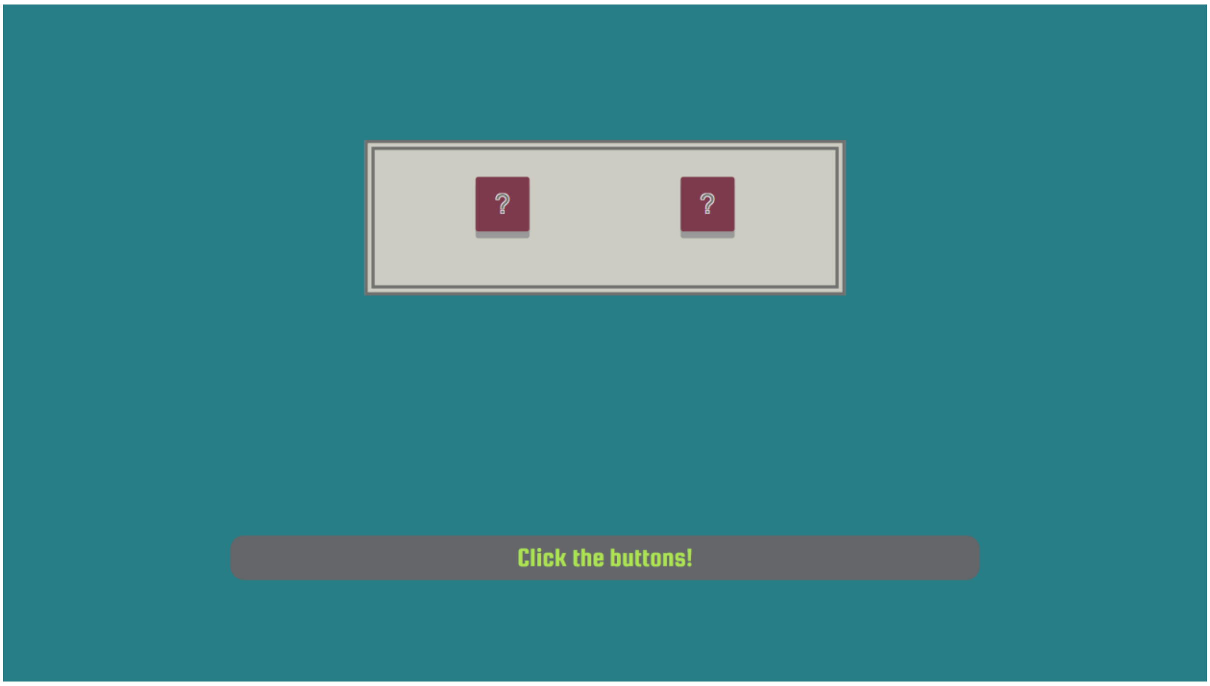
Practice Screen. Uncertain button “?”, Certain neutral sound button “okay hand gesture”, Certain aversive sound “thumbs down hand gesture”.



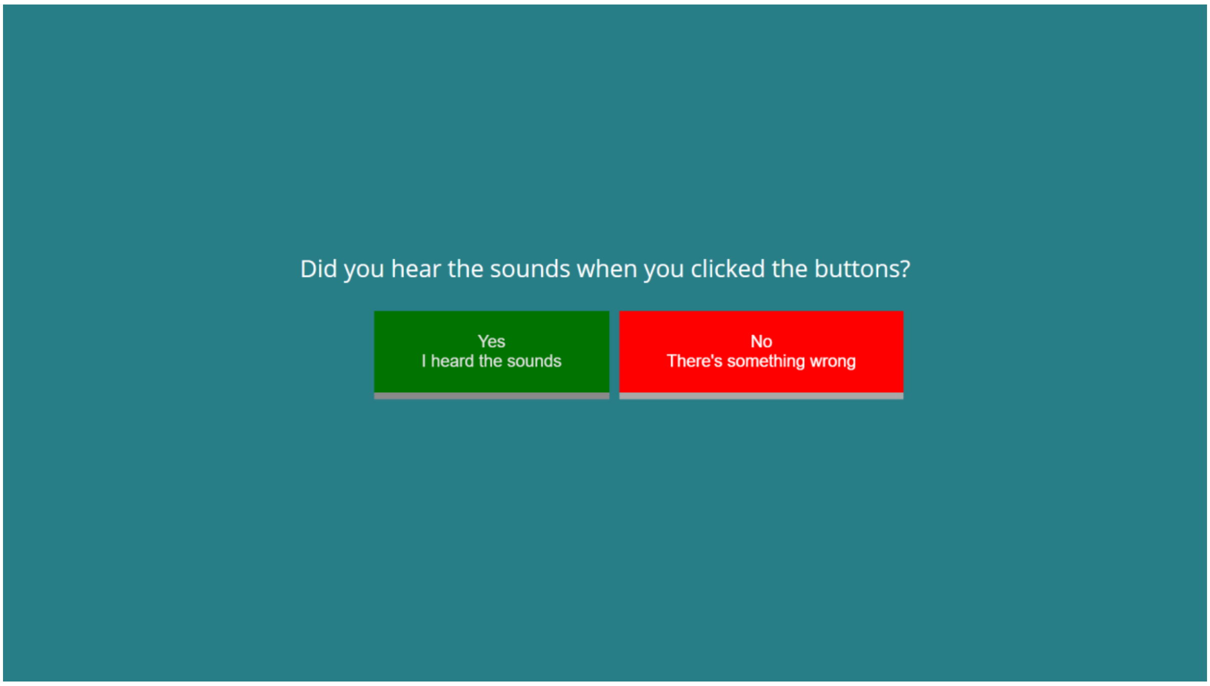
Practice Screen.



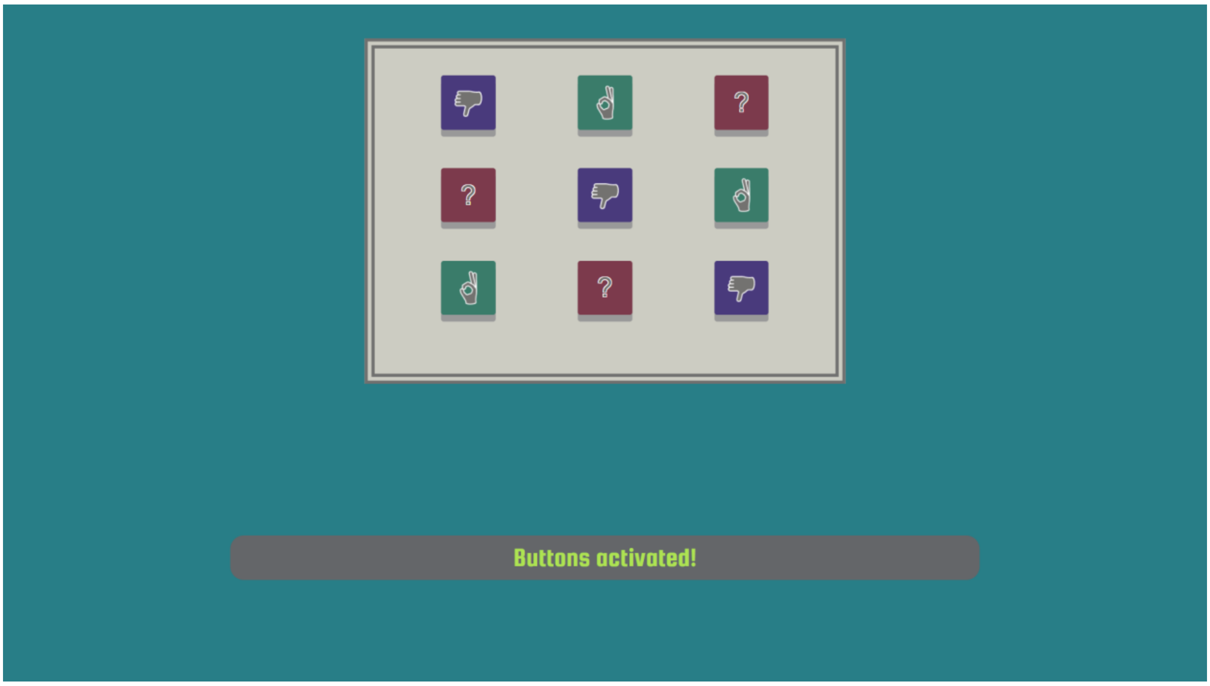
Practice Screen.

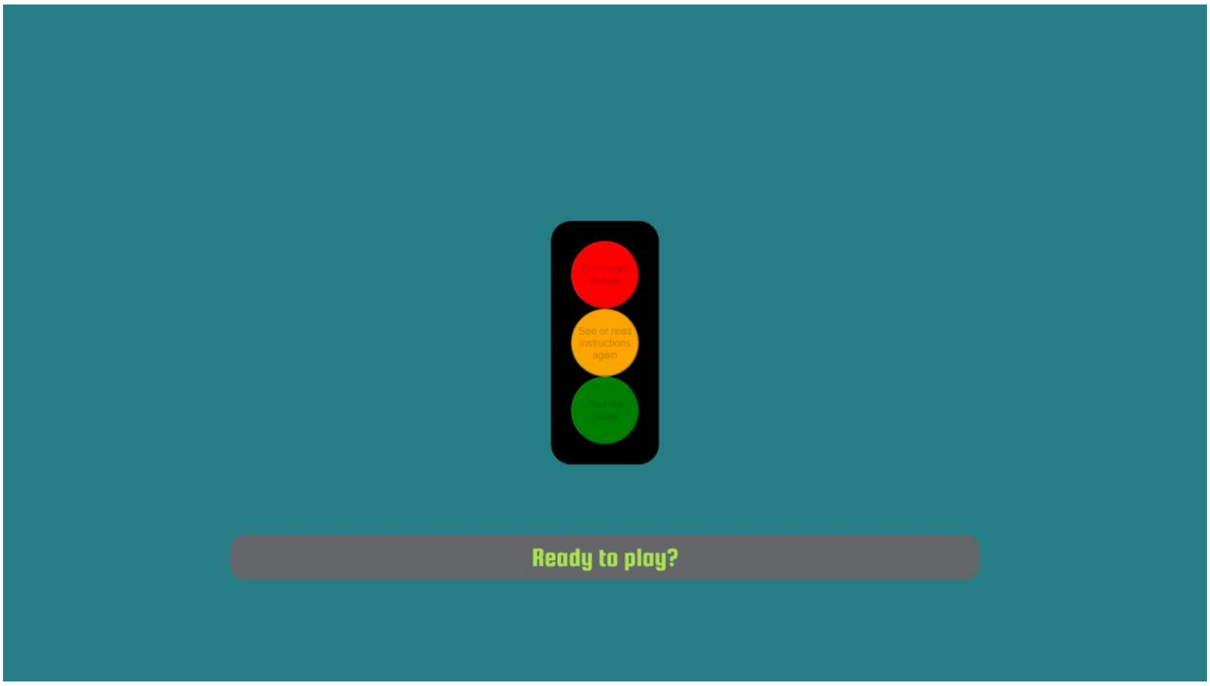


Practice Screen.

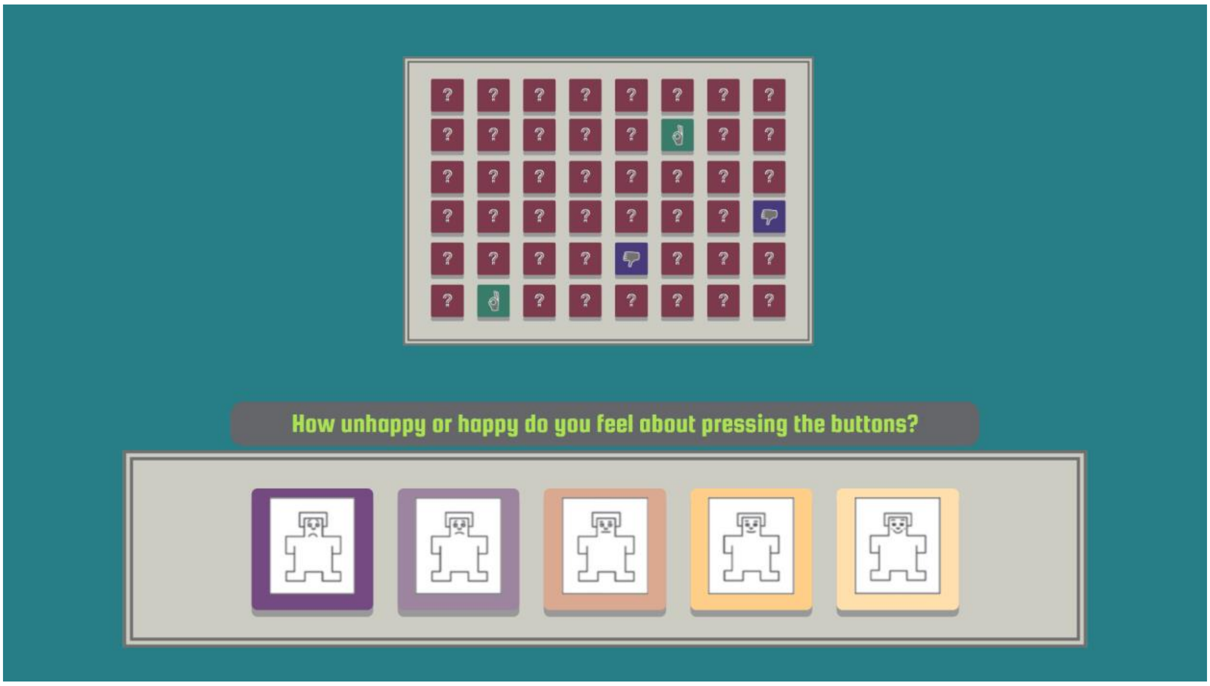


Checking to see if participants heard sounds when clicking buttons

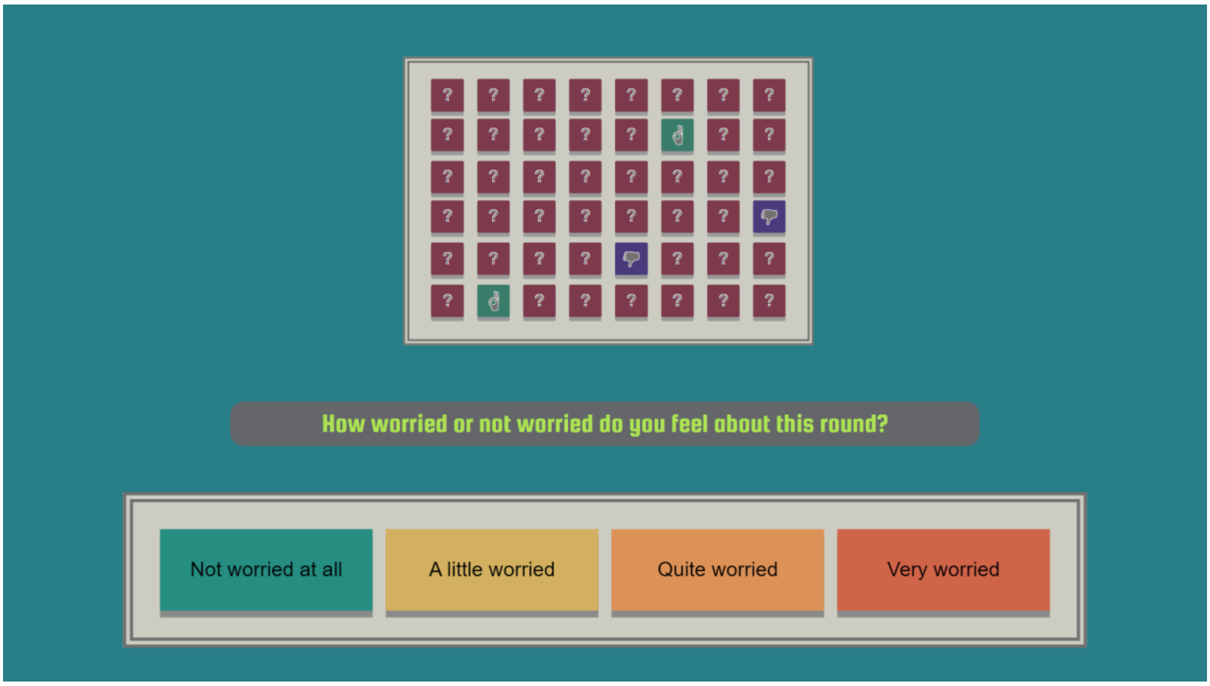

Buttons activated!


See or read instructions again
Ready to play?

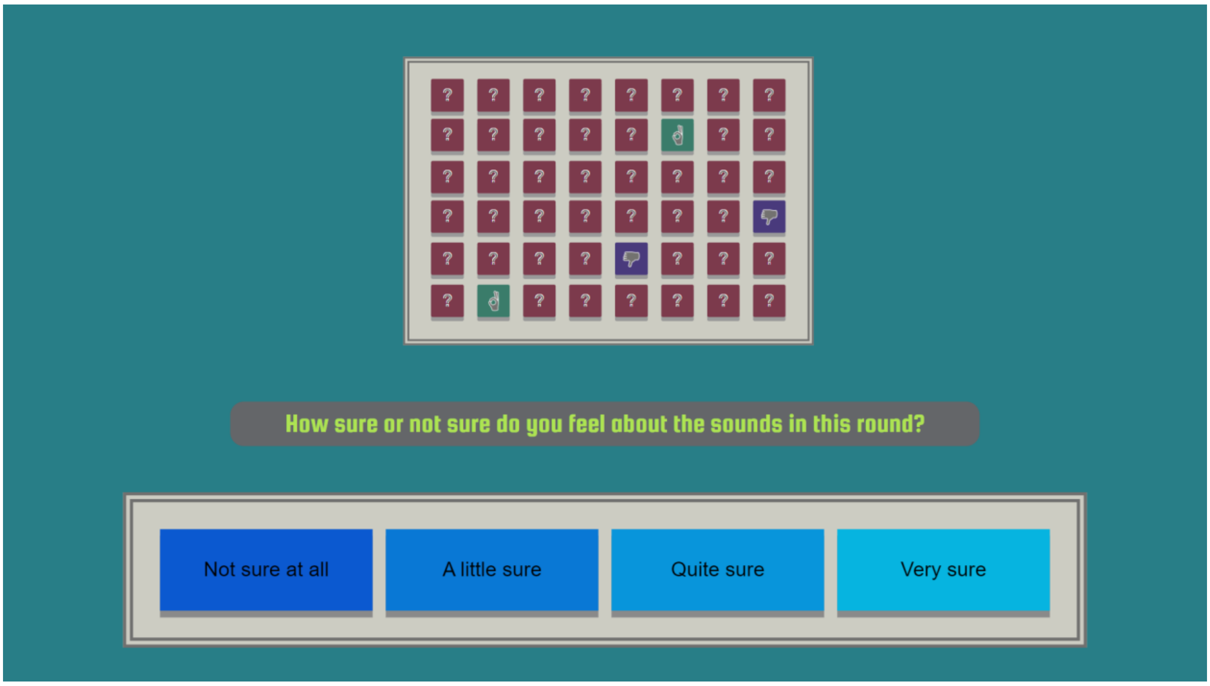
Checking again to see if participant can see themselves in window (for recording via webcam)



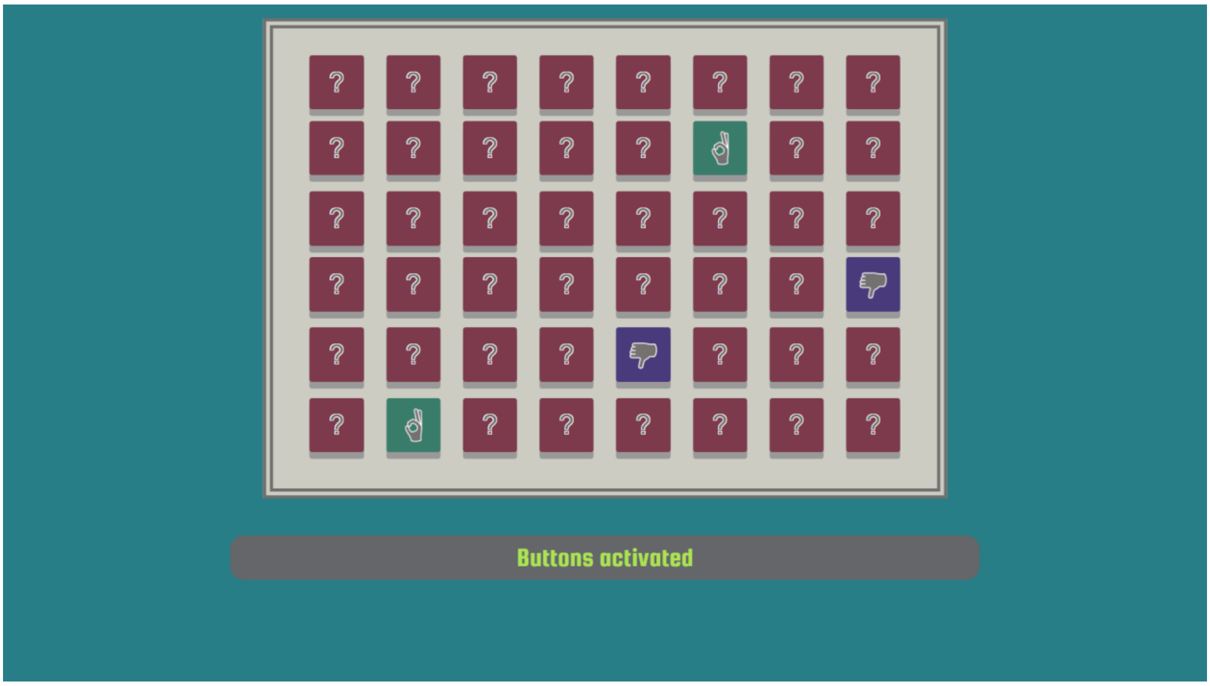
Emotion rating after 10 second anticipation period. From very unhappy to very happy



Worry rating after anticipation period and emotion rating. From not at all worried to very worried

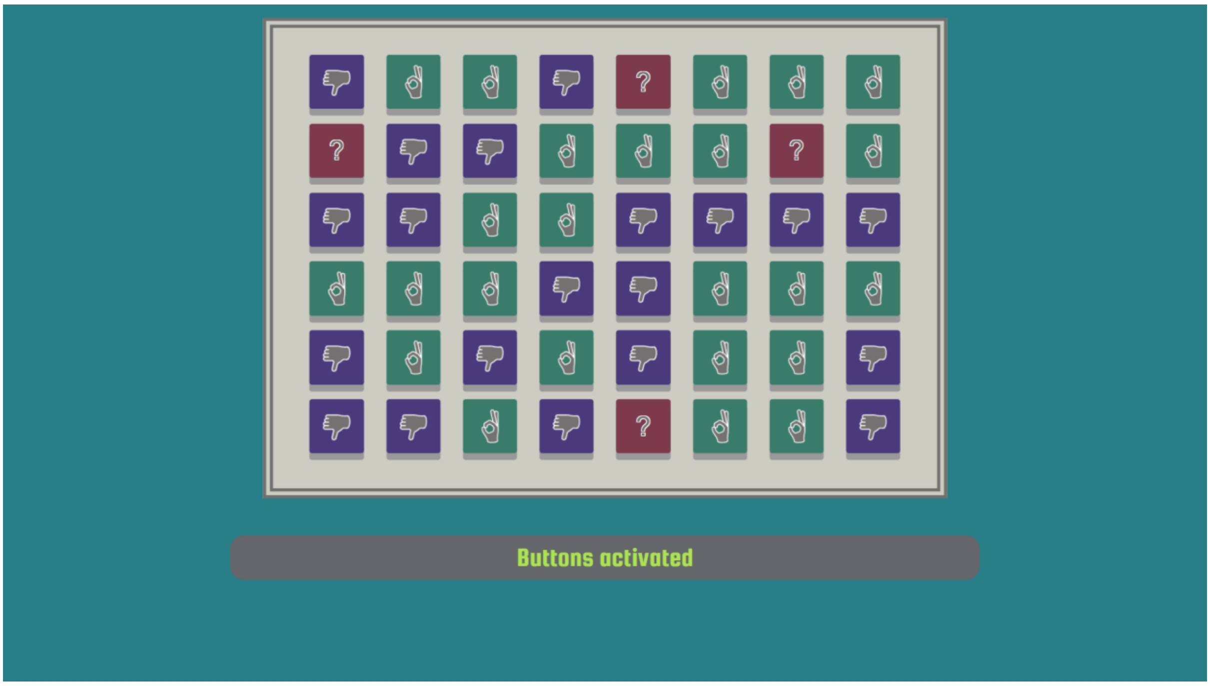


Uncertainty rating after worry rating as manipulation check. From not sure at all to very sure.

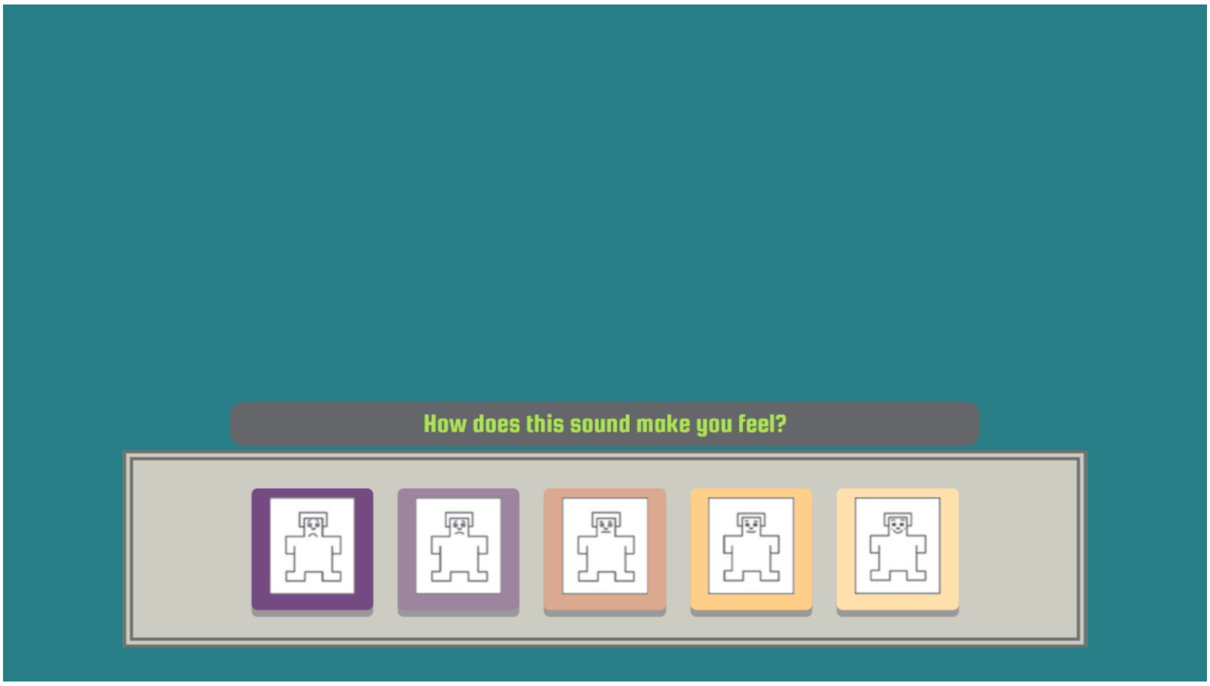


Example of high uncertainty trials

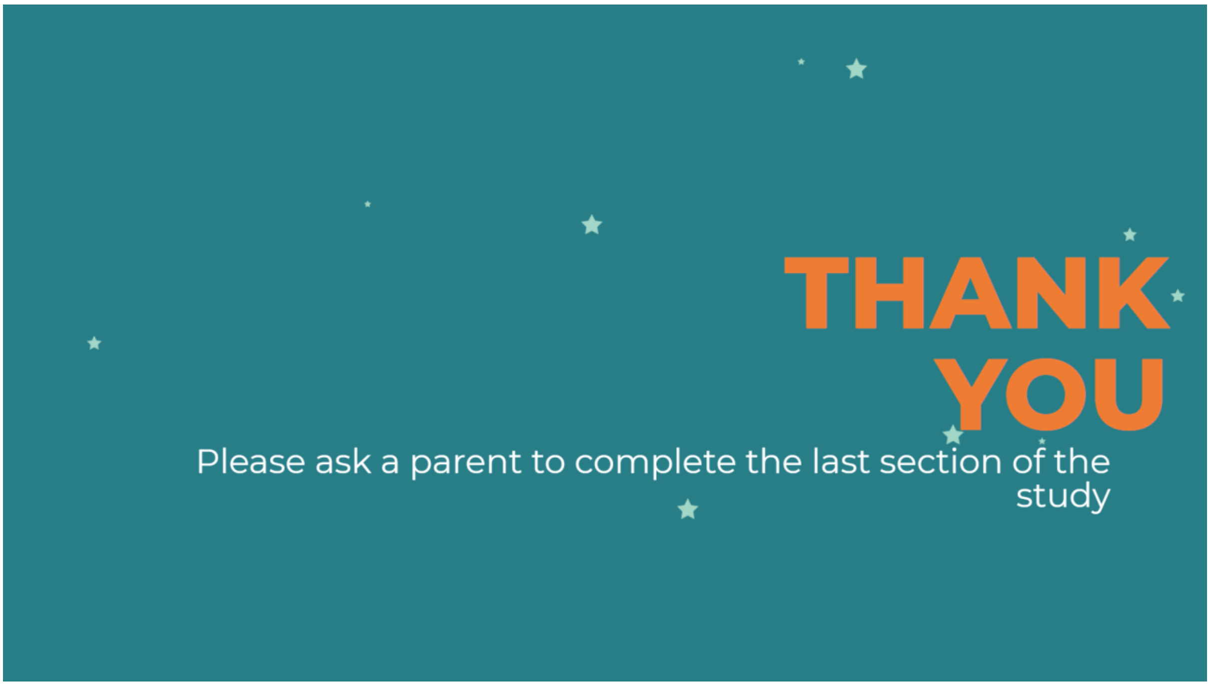
44 Uncertain “?” Buttons, 2 certain neutral buttons and 2 certain aversive buttons

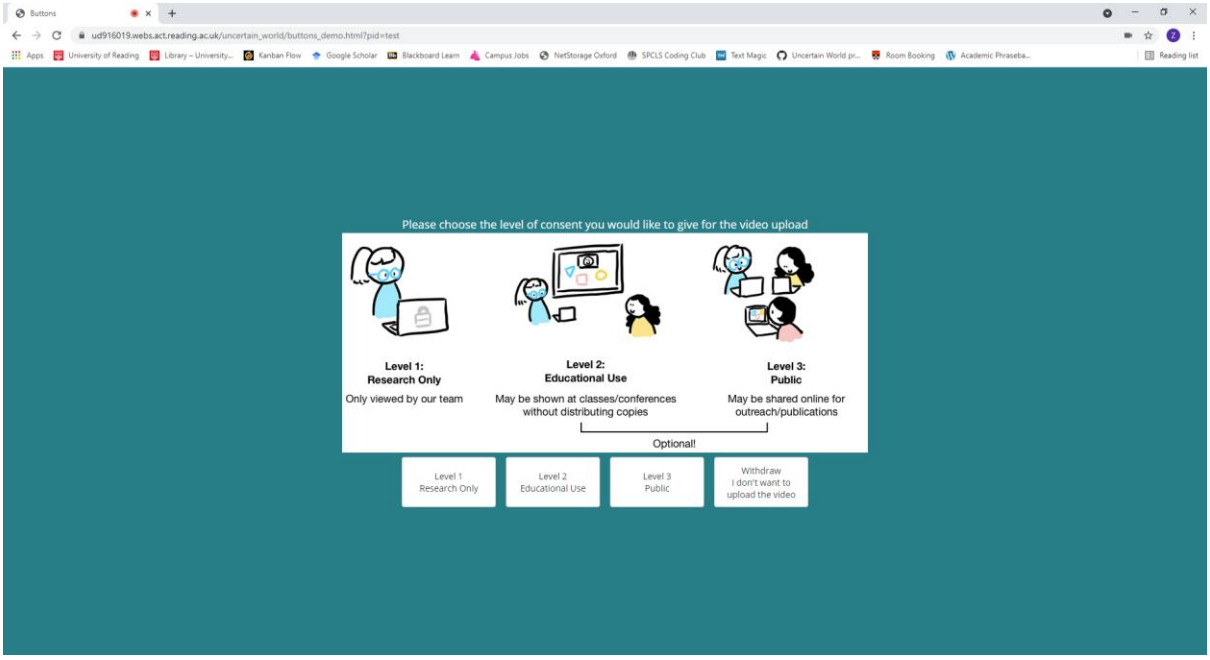


Low uncertainty trials 44 Certain Buttons (22 neutral buttons and 22 aversive buttons) and four uncertain buttons “?”

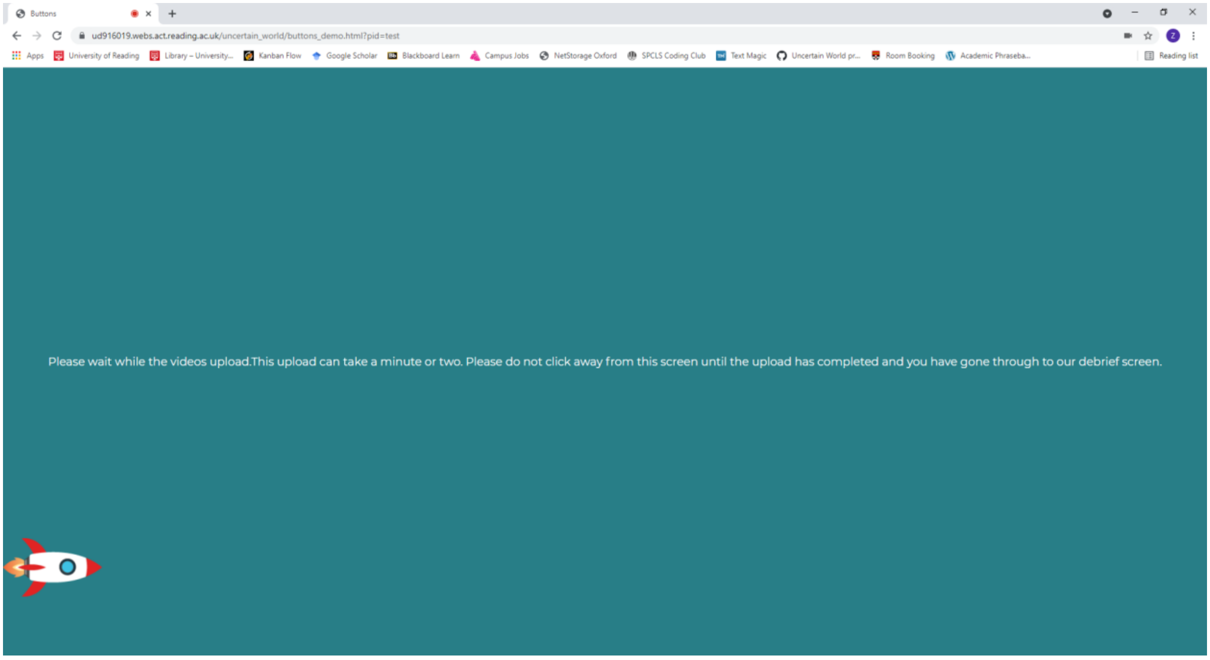


As a manipulation check, participants rated how each sound played in the game made them feel





Parents provided level of consent for video upload



Parents are then provided with debrief on screen and option to download

6.16 Appendix 11 Consent form for Study 3

University of Reading

Consent form: Uncertain World

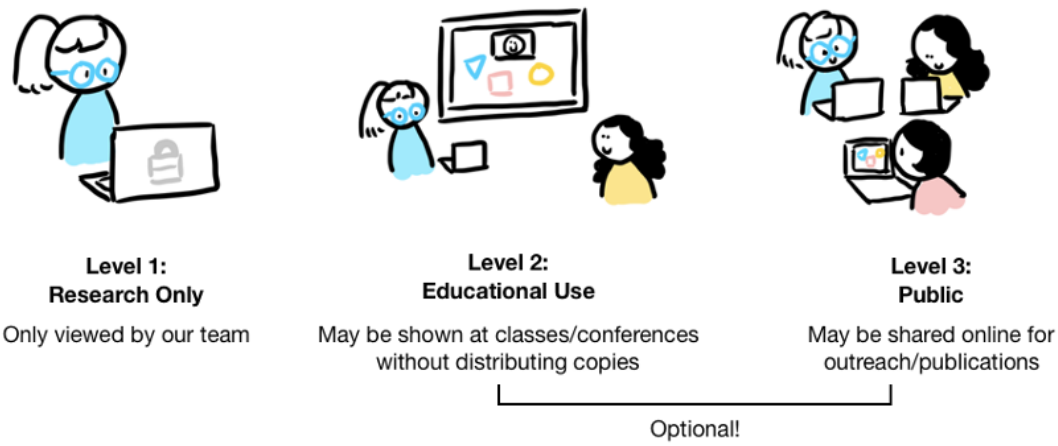
Thank you for supporting our project. On the next few pages you will be asked to answer a series of questions about yourself. In total it should take about 5-10 minutes to complete the questions. At the end of the questionnaire responses, you will begin the online game. You will need to complete both parts of the study together. Please do not close the browser window once you have started as your progress will be lost.
Many thanks,
Zoe
(z.j.ryan@pgr.reading.ac.uk)

- ☐ I agree to participate in this study being conducted by Zoe Ryan, Dr Jayne Morriss, Professor Helen Dodd and Dr Lily Fitzgibbon at The University of Reading and the University of Exeter.
- ☐ I have seen and read a copy of the Information Sheet and have been given the opportunity to ask questions about the study and these have been answered to my satisfaction.
- ☐ I understand that all personal information will remain confidential to the project team and arrangements for the storage of any identifiable material have been made clear to me.
- ☐ I understand that this data will be stored against a number identifier on secure servers and password protected.
- ☐ I understand that de-identified data will be shared using a secure data repository service.
- ☐ I understand that participation in this study is voluntary and that I can withdraw at any time without having to give an explanation.

As part of the game, your facial expressions will be recorded by your computer's webcam. You will be instructed how to get this set up when you decide to start the computer game. By giving consent to participate, you are allowing us to view the video-recordings of the study. The video will remain on your computer until the end of the game and we won't be able to see anything via your webcam until you upload the video. If at this point, you decide that you no longer want to share the video with us, then you can simply decline to upload the video file.

- ❑ I am happy to proceed with my participation and for the video to be viewed and stored by the research team as detailed above.

In addition, you can also authorise us to use the video for educational purposes, for example, to show to other scientists and students or for public sharing, for example, for the purpose of further scientific research or to go on our website. These additional levels of consent help us teach students and communicate our research to others, but they are optional. You will be asked if you wish to consent to these when you upload the video file after the game but there is absolutely no requirement to do so. Please let us know if you need further explanation about these levels or if you have any other questions.



This application has been reviewed by the University Research Ethics Committee and has been given a favourable ethical opinion for conduct.

6.17 Appendix 12 Information Sheet for Study 3

Uncertain World Project

Thank you for your interest in taking part in the University of Reading's "Uncertain World" Project. This project focuses on how children and adults respond to the unknown and is being led by Zoe Ryan as part of her PhD research under the supervision of Dr Jayne Morriss. This task was originally designed for adults, however we adapted it so that it was suitable for children. We then ran the study with 132 children and found surprising results. We therefore now want to see what happens when adults complete the task using the child version.

After this initial information and FAQs, there is a short questionnaire for you to complete.

Project Information

We are looking for 150 **adults** to take part in this project about how people respond to the unknown. We aim to discover why people explore things that are unknown or uncertain; because of curiosity or because they are uncomfortable with not knowing.

In total the project will take approximately **20 minutes of your time**. We will ask you to complete some **short questionnaires**, which should take about 5-10 minutes and then you will **play a game** on a computer at home. To play the game you will need to have access to a **computer that can play sounds, has a webcam, and access to Google Chrome**.

As you have signed up on SONA, you have accessed this information sheet and questionnaires via the link provided and will continue to the game at the end of the questionnaires. The game was originally designed for children and should only take about 10 minutes. It will involve you pressing buttons that make sounds while **your face is being recorded by your computer's webcam**. Due to the nature of the game, you will need to have normal or corrected hearing and vision.

On the next few pages, we answer some frequently asked questions about the project. Please get in touch if you have any other questions or would like to discuss any aspect of the project. If you are happy to take part in the research, please continue through to provide your consent and complete the questionnaires.

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.

Thank you for your time and interest in our project!

Zoe Ryan
(University of Reading Doctoral Researcher)
Contact info:
z.j.ryan@pgr.reading.ac.uk

What's the point of the project?

We seek out information in our daily lives, and this can be driven by a range of factors. We can be curious, and our thirst for information can lead us to try to find out more. We can also be driven to seek information because we don't like uncertainty and want to decrease it. At the moment we know very little about what drives people's reactions to uncertainty so that is what we are investigating in this project.

The information from the project could be helpful in thinking about how to treat anxiety around uncertainty and for understanding how to stimulate curiosity in education.

We are interested in what drives the behaviour of the whole group and will only be looking at overall patterns for the group, not individuals in detail.

What exactly will happen when I take part?

Once you have finished reading this information sheet, we will ask for you to complete some questionnaires which should take 5 – 10 minutes. Once you have completed the questionnaires, you will start the game.

You will be asked to allow the web browser to start recording on the webcam and then check that the sound is working and at an appropriate level on the computer. You will be shown a brief instruction video which explains what you have to do. You will then be shown a number of buttons on the screen which are linked to different sounds. Each button shows an image relating to the sound, or a "?". Your reaction to the buttons will be video recorded via the webcam in anticipation of the game and during the game. You will be asked to rate how you feel, and then will be given the opportunity to press as many or as few buttons as you like. Each round lasts around a minute. You will be given the opportunity to play the game with different sounds several times.

After you complete the game, you will be asked if you are happy to upload the video to our secure servers by pressing a button – you will be able to choose who is allowed to view the videos at this point. You will then be provided with some further information about the project.

You will be given 0.5 SONA credits for taking part in the research.

What will happen to the information about me?

We are committed to keeping your information safe. All the information we collect and that you share with us will be kept confidential, unless something we observe makes us concerned for your safety, or someone else's safety. We may then need to share information to protect you/someone else. We will use a unique code known only to the project team to identify any information relating to you. That way, all of the information is anonymous. Electronic data including any videos will be stored on secure servers and password protected. Only the researchers working on this project will have access to these stored files. De-identified electronic data for the whole group will be deposited to the University of Reading data archive; no videos, personal or identifiable information will be included.

What if I get upset or don't want to do some of the games?

We of course hope that the game is not upsetting and that you enjoy taking part. We have designed the game so that it is suitable for children and adults. However, if you get upset, decide you don't want to take part, or if you don't feel comfortable at any stage, please stop the game. Taking part is voluntary and you are free to withdraw from the research at any point. Withdrawing won't affect the allocation of SONA credits to you.

Who is doing the research?

The project is managed by Zoe Ryan, Doctoral Researcher, under the supervision of Dr Jayne Morriss, Prof. Helen Dodd and Dr Lily Fitzgibbon from the University of Reading and the University of Exeter. All researchers working on the project have enhanced DBS checks.

If you have read this information and are happy to take part in the project, please feel free to continue on to the consent form and questionnaires.

If you have any questions you can contact Zoe on:
z.j.ryan@pgr.reading.ac.uk

or Jayne on:

j.e.morriss@reading.ac.uk

Many thanks for your time and interest in our project!

Zoe

6.18 Appendix 13 Debrief for Study 3

Debrief

Thank you for taking the time to complete the questionnaires, and for taking part in the computer games today. We hope that you enjoyed the experience.

Here is a bit more information about what you did today and why we are interested in these things. Please let us know if you have any questions, either by emailing z.j.ryan@pgr.reading.ac.uk or by leaving a question in the free text box at the end of this debrief.

- You played a game where you could choose to press buttons. The buttons had pictures on them relating to the sound they played when pressed, or a "?". Some of the buttons played the sound of rain, a jet plane or nighttime noises, while others played a dentist drill, a rollercoaster, a jackhammer or a buzzer and some were uncertain (could be any of these). This tells us whether people seek out information or avoid it by not pressing any "?" buttons.
- Through the webcam recording, we will observe your emotional response to the buttons at the beginning of the game. We will aim to see whether you are feeling positively or negatively about the game ahead. This tells us how people feel about uncertainty.
- We have also asked you to rate how you felt about each of the screens you saw (on a scale from positive to negative). This allows you to report whether you are feeling positively or negatively about the uncertainty.
- We have conducted this study with children, and in running it with adults, we hope to see if there is a difference in behaviour and emotional responses to uncertainty in children and adults.

It is important to keep in mind that we are interested in scores on these games for everyone taking part in this project as a group; we don't look at scores or behaviours for specific individuals so we aren't able to give you feedback about your scores.

If you have any concerns about your fears and worries, you can contact your GP or https://www.nhs.uk/mental-health/talking-therapies-medicine-treatments/talking-therapies-and-counselling/nhs-talking-therapies/

Thank you again for your time today. Do let us know if you have any questions, comments or feedback.

6.19 Appendix 14 Brief overview of originally planned PhD studies

Watch Them Grow Follow Up

Zoe Ryan

Research Questions

- Q1: Is anxiety associated with children's physiological and behavioural reactions to uncertainty?
- Q2: Does IU predict anxiety over time in children?
- Q3: Is parent report of IU related to children's physiological and behavioural reactions to uncertainty?
- Secondary:
- Q4: Does baseline sensory processing predict anxiety over time and is this moderated by IU?

Methods

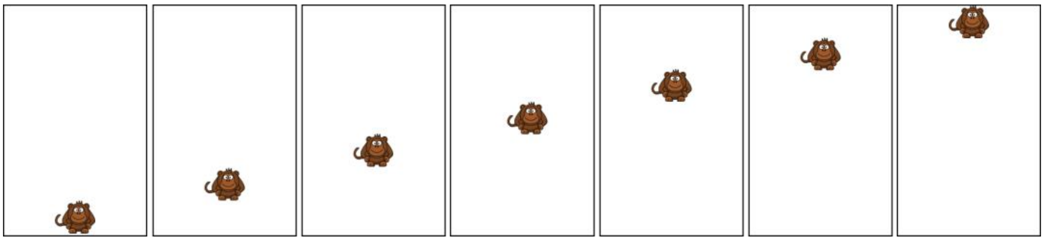
- Participants
  - Recruiting from 180 6 – 7 year old children who took part in Watch Them Grow project at 3-4 years old
  - At first time point, had examined whether attention bias predicts anxiety when children start school
- Lab based tasks
  - HiLo
  - 48 Buttons
  - Pandora's Box
- Behavioural observation
  - Battery

Parent Questionnaires

- *Spence Child Anxiety Scale (SCAS), which measures child's anxiety levels*
- *State Trait Anxiety Inventory (STAI), measuring the parents own levels of trait anxiety*
- *Responses to Uncertainty and Low Environmental Structure (RULES), measuring a child's responses to uncertainty*
- *Interest/Deprivation-Young Children (ID-YC) which measures epistemic curiosity*
- *Sections from Child Sensory Profile2 Caregiver Questionnaire which measure a child's processing of visual and auditory stimuli*
- *Health Behaviour Questionnaire (HBQ) which assesses overall emotional wellbeing and social functioning*
- *Behavioural Inhibition Questionnaire (BIQ) which measures child temperament*
- *Child Autism Quotient (CAQ)*
- *Social Motivation Questionnaire (SMQ) which assess social problems associated with autism*

HiLo Task

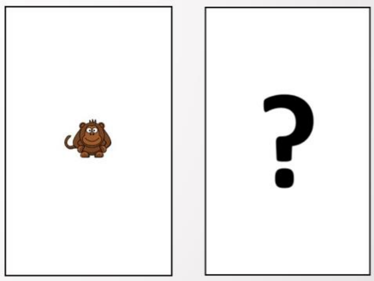
- Examining how:
  - the children deal with predicting and decision making under uncertainty
  - their body reacts to uncertainty using pupil dilation and Galvanic Skin Response (GSR)



HiLo Task Continued

- Child can ask to see array
- Task has differing levels of uncertainty
- Middle card (in array on previous page) most uncertain
- 32 trials
- Each card paired 4 times apart from middle card (paired 8 times)
- Child self-reported ratings of certainty of whether the mystery card is higher or lower than the card on screen (using 5 point Self Assessment Manikin)
- Child self-reported how worried they felt about whether the mystery card was higher or lower than each card they saw on the screen (using a feelings thermometer)

"A card will appear on the screen – it has a monkey on it. The card beside it will be a mystery card. The mystery card could be any of the other cards. I want you to guess if the monkey on the mystery card will be higher or lower than the card you can see. So, if you think it will be higher you say 'higher' and if you think it will be lower you say 'lower'."



"In this game, there are 48 Buttons on the screen. Each button has either an exclamation mark, a question mark or a circle on it. If you click on a button with an exclamation mark, you will hear a drill. If you click the button with the circle, you will hear the sound of water pouring into a jar and if you click a questionmark, you could hear either sound. This game will last a few minutes, you don't have to click any buttons but if you want to you can, there are no rules! While you are not clicking buttons, you can relax and listen to some music that is playing in the background of the game."

48 Buttons

- Adapted from Hsee & Ruan, 2016 Study 3
- Behaviour such as information seeking or avoidance can be due to uncertainty, but it also could be the result of the child's level of curiosity.
- We used this task to examine information seeking/avoidance/decision making behaviour under uncertainty, and its relationship with curiosity and IU
- Certain buttons were labelled and played neutral or aversive sounds when clicked
- Uncertain buttons were labelled with a ? And would play either neutral or aversive sounds when clicked
- Children were told they could press as many or as few buttons as they liked over the trial lasting three minutes

Behavioural Tasks in the "Uncertainty Room"

- Children taken to an observation lab
- The next tasks were filmed for future coding of behaviour such as reassurance seeking, avoidance, fidgeting, reaction times, decision making, information seeking, threshold
- Work from our group has shown that questionnaires for IU in children have limited validity as these often rely on parent report and because reactions to uncertainty are not always visible to others.
- Aim to capture individual differences in IU, and could potentially be used as the basis for an assessment battery for IU in time

Pandora's Box Returns

- In lab:
  - Make theoretical decision when viewing box and being given options on the computer
  - GSR & Pupil Dilation
- In Observation Room
  - Physically make a decision

"So when we were in the other room, you said you would choose the hole in the box that has something inside that is bad/definitely okay/might be bad, might be okay. I actually have a box with three holes in it here. This one has something inside that is <u>bad</u> (point to Certain Threat). This one has something in it that is <u>definitely okay</u> (point to Certain No Threat). And this one has something in it that <u>might be bad, but might be okay</u> (point to Uncertain). Which hole would you most like to put your hand in?"

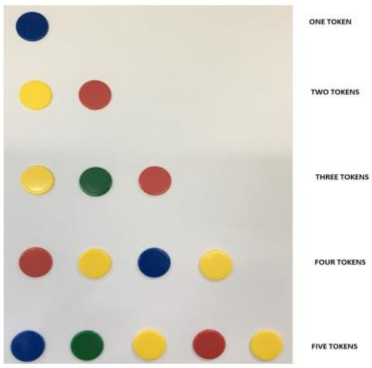
Tokens/Covered objects

Upon entering the observation room:

- There are five unusually shaped objects around the observation room covered with sheets.
- "I am giving you 5 tokens. Hang on to them– you can use them to get a prize at the end."
- If child mentions covered objects throughout session, they are told "we will come to them later". Try to keep them from peeking.

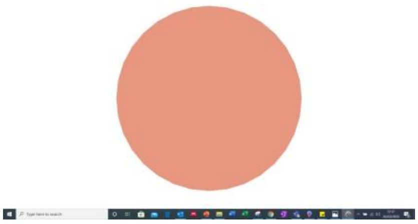
Towards the end of the testing session:

- "You may have noticed that there are some objects underneath some sheets over there. Would you be interested in seeing what is under the sheets?"
- "Do you remember the tokens you were given when we first came to the room. The ones I said would go towards a prize at the end? If you want to see what is under the sheets, youhave togive me at least one of your tokens. You could give me one, two three, four or five tokens (show picture to the right). How much do you want to see under the sheet? How many tokens would you be willing to give me?
- Allow child to hand over tokens and explore the objects if they would like



Green Light Go

- Children high in IU might differ from those lower in IU via an altered threshold for feeling certain
- Traffic light changing from red to green on computer screen
- Child presses mouse when the light is “green enough to go”
- Child completes this three times



Hybrid Animals

“I have some pictures of animals here that have been pixelated. I am going to name two animals and I want you to tell me which animal it is in the picture.”

- “Is this a rabbit of an ostrich?”
- Recording and coding avoidance, information seeking, decision making (latency to decide)

Other behavioural tasks

Snack Task

- Three cylindrical cannisters are placed on the table
- "You have been working very hard so I thought I would let you have a snack. Which would you like? You can only choose one tin."
- Child allowed to explore tins, shake them gently, lift them (but not take off lids).

Gift

- If the child gave the researcher tokens: "I know you gave me your prize tokens to see the objects, but as you did such a good job, you get to choose a prize anyway."
- If the child didn't give any tokens: "Can I ask for your tokens back now in exchange for a choice of gift?"
- "Here are five gifts. Which would you like to choose for taking part?"
- Child is allowed to explore boxes (lift, shake, etc). If they ask what is in them, researcher to say "I don't know".
- Once they have chosen, the researcher allows the child to choose from the other bags and books that have been brought to the room.

6.20 Appendix 15 R Markdown output from analysis for Study 1

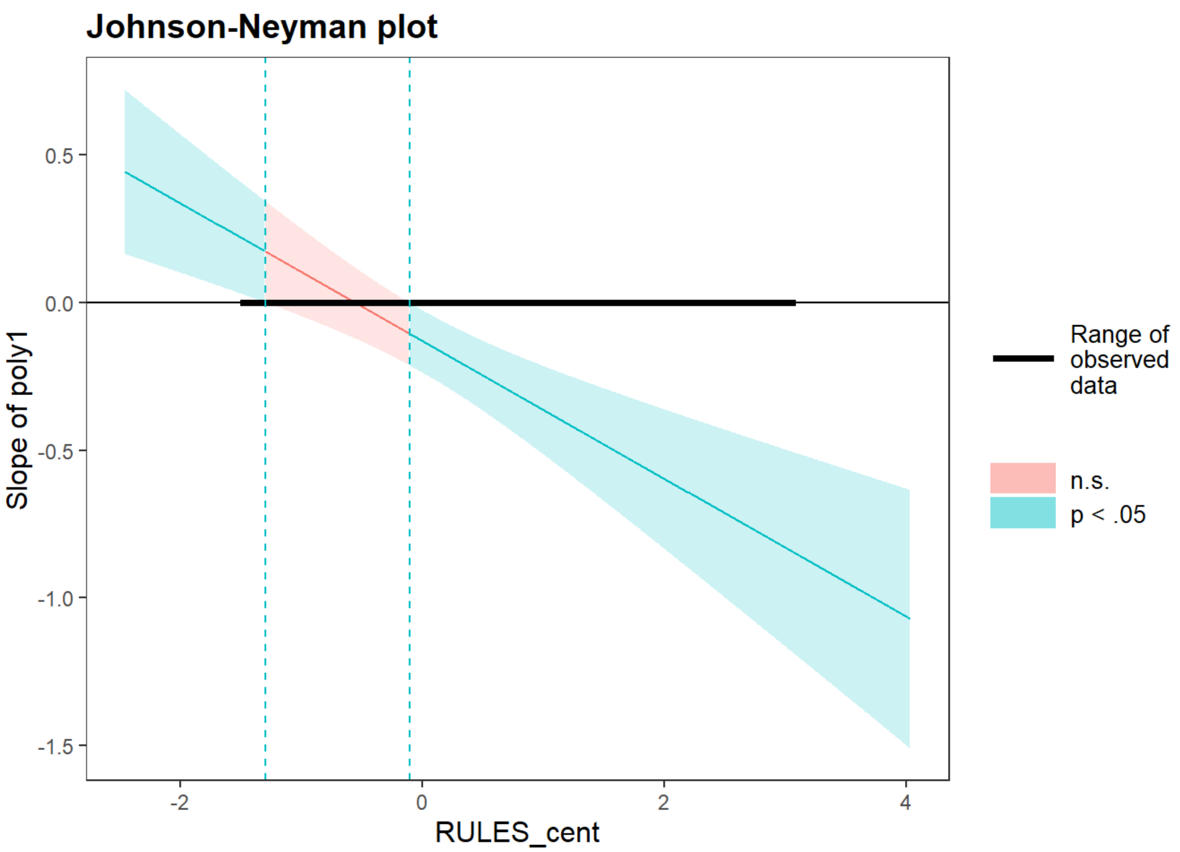
Note: Only outputs for models in the main manuscript are shown below. Full html of output available upon request. Outputs for Studies 2 and 3 can be found in OSF (links in individual papers)

```
#MAIN MANUSCRIPT - Model 1 outliers removed - controlling only for STA
I and marital status

#Due to residuals not being normal, detect outliers based on Cook's di
stance and remove outliers

cooksD1 <-cooks.distance(lmer_model1)

influential1 <-cooksD1[(cooksD1 > (4 * mean(cooksD1, na.rm=TRUE)))]

influential1

##        30        35        59       204       215       227        2
37       247

## 0.1614788 0.1353209 0.1284811 0.2343138 0.1975992 0.1384076 0.64852
49 0.1363324

##       262       314       385       390       391       419        4
33       461

## 0.1486818 0.2528478 0.1573372 0.8508373 0.3631939 0.4021539 0.32120
81 0.2016370

##       477       500       511

## 0.1280638 0.4045459 0.5628869

id_of_influential1 <- names(influential1)

outliers1 <- data.gca[id_of_influential1,]

id_without_outliers1 <- data.gca %>% anti_join(outliers1)

## Joining, by = c("child_ID", "Time_Point", "Child_Anx", "HBQ_Int",

## "HBQ_ExtADHD", "Parent_Anx", "Marital_Status", "RULES", "RULES_cent
",

## "Parent_Anx_cent", "Time_Point.Index", "poly1", "poly2")

#Run model again with controls, without outliers (model 1b in supp mat
)

lmer_model1_out <- lmer(Child_Anx ~ (RULES_cent)*(poly1+poly2) + Paren
t_Anx_cent + Marital_Status + (1|child_ID), data = id_without_outliers
1 )

full_lm_results1_out<-Anova(lmer_model1_out, type = 3, test='F')

print(full_lm_results1_out)

## Analysis of Deviance Table (Type III Wald F tests with Kenward-Roge
r df)

##

## Response: Child_Anx
```

```
##                            F Df Df.res    Pr(>F)
## (Intercept)         9.6453  1 168.76  0.002227 **
## RULES_cent        114.8520  1 181.76 < 2.2e-16 ***
## poly1               5.9316  1 311.92  0.015432 *
## poly2               6.7336  1 303.43  0.009921 **
## Parent_Anx_cent     4.2827  1 418.01  0.039115 *
## Marital_Status      2.1403  2 173.43  0.120722
## RULES_cent:poly1   19.0292  1 308.41 1.758e-05 ***
## RULES_cent:poly2    5.0498  1 308.35  0.025336 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
     ##Controlling for parent anxiety & marital status
      #dev.new()
        #print(
interactions::sim_slopes(
          lmer_model1_out,
          pred = poly1,
          modx = RULES_cent,
          jnplot = TRUE
        )#)
```

```
## JOHNSON-NEYMAN INTERVAL
##
## When RULES_cent is OUTSIDE the interval [-1.30, -0.11], the slope o
f poly1
## is p < .05.
##
## Note: The range of observed values of RULES_cent is [-1.48, 3.06]
```

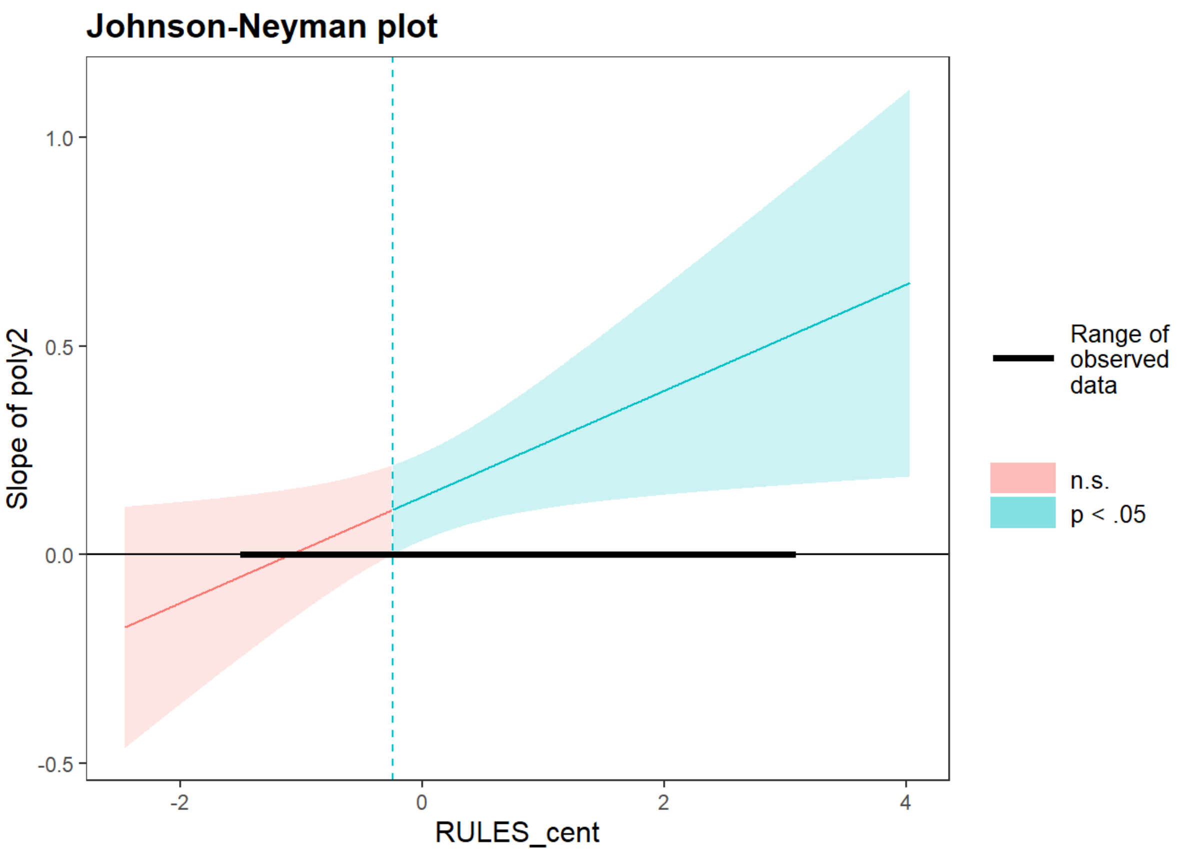



```
## SIMPLE SLOPES ANALYSIS
##
## Slope of poly1 when RULES_cent = -0.99849404 (- 1 SD):
##
##   Est.   S.E.   t val.      p
## ------ ------ -------- ------
##   0.10   0.08     1.35   0.18
##
## Slope of poly1 when RULES_cent = -0.02255742 (Mean):
##
##    Est.   S.E.   t val.      p
## ------- ------ -------- ------
##   -0.13   0.05    -2.34   0.02
##
## Slope of poly1 when RULES_cent =  0.95337920 (+ 1 SD):
##
##    Est.   S.E.   t val.      p
## ------- ------ -------- ------
```

```
##    -0.35    0.07     -4.76    0.00
```

```
 #dev.new()
        #print(
interactions::sim_slopes(
          lmer_model1_out,
          pred = poly2,
          modx = RULES_cent,
          jnplot = TRUE
        )#)
```

```
## JOHNSON-NEYMAN INTERVAL
##
## When RULES_cent is OUTSIDE the interval [-8.73, -0.24], the slope o
f poly2
## is p < .05.
##
## Note: The range of observed values of RULES_cent is [-1.48, 3.06]
```

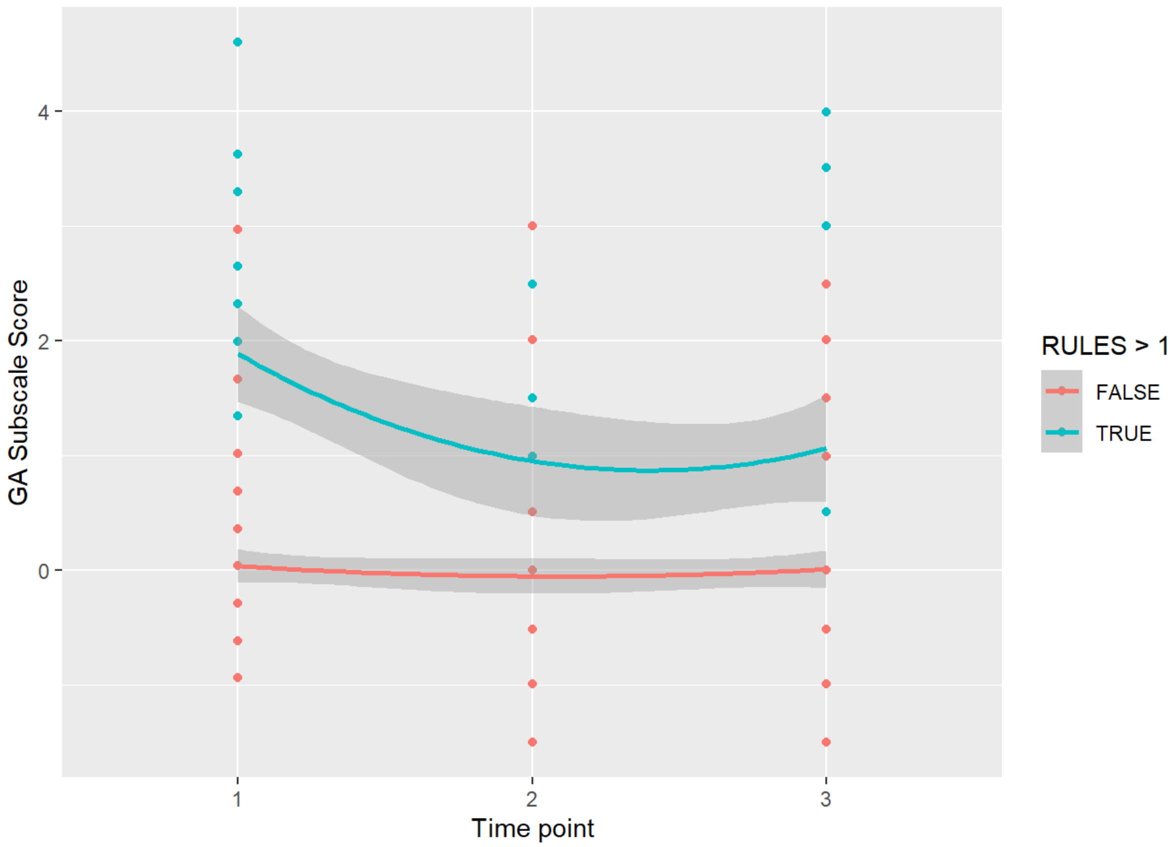



```
## SIMPLE SLOPES ANALYSIS
##
```

```
## Slope of poly2 when RULES_cent = -0.99849404 (- 1 SD):
##
##   Est.   S.E.   t val.      p
## ------ ------ -------- ------
##   0.01   0.08     0.15   0.88
##
## Slope of poly2 when RULES_cent = -0.02255742 (Mean):
##
##   Est.   S.E.   t val.      p
## ------ ------ -------- ------
##   0.14   0.05     2.54   0.01
##
## Slope of poly2 when RULES_cent =  0.95337920 (+ 1 SD):
##
##   Est.   S.E.   t val.      p
## ------ ------ -------- ------
##   0.26   0.08     3.36   0.00
```

```
#Plot of three timepoints
ggplot(data = id_without_outliers1[-c(52, 228, 401), ], aes(x = Time_Point, y = Child_Anx, colour = RULES_cent>1)) + geom_point() + labs(x = "Time point", y = "GA Subscale Score", colour = "RULES > 1") + scale_x_discrete(limit = c('1', '2', '3')) + stat_smooth(method = lm, formula = y ~ poly(x, 2, raw = TRUE))
```

```
## Warning: Removed 50 rows containing non-finite values (`stat_smooth()`).
## Removed 50 rows containing missing values (`geom_point()`).
```




```
#Model 2 MAIN MANUSCRIPT - outliers removed - with HBQ Int in place of
Child Anx

#Due to residuals not being normal, detect outliers based on Cook's di
stance and remove outliers

cooksD2 <-cooks.distance(lmer_model2)

influential2 <-cooksD2[(cooksD2 > (4 * mean(cooksD2, na.rm=TRUE)))]

influential2
```

```
##        17        51       166       167       215       237         2
47       262

## 0.1610836 0.2557415 0.1837966 0.1576138 0.1755245 0.2654912 0.37601
34 0.4052661

##       305       345       364       376       379       385         3
90       394

## 0.1733737 0.3109907 0.2917509 0.2962278 0.2886139 0.1527625 0.49492
89 0.1600125

##       400       411       419       461       490       511         5
14       520

## 0.3101631 0.2303650 0.3233391 0.2193015 0.2185246 0.3040219 0.39694
44 0.3205103
```

```
id_of_influential2 <- names(influential2)

outliers2 <- data.gca[id_of_influential2,]

id_without_outliers2 <- data.gca %>% anti_join(outliers2)
```

```
## Joining, by = c("child_ID", "Time_Point", "Child_Anx", "HBQ_Int",
## "HBQ_ExtADHD", "Parent_Anx", "Marital_Status", "RULES", "RULES_cent
",
## "Parent_Anx_cent", "Time_Point.Index", "poly1", "poly2")
```

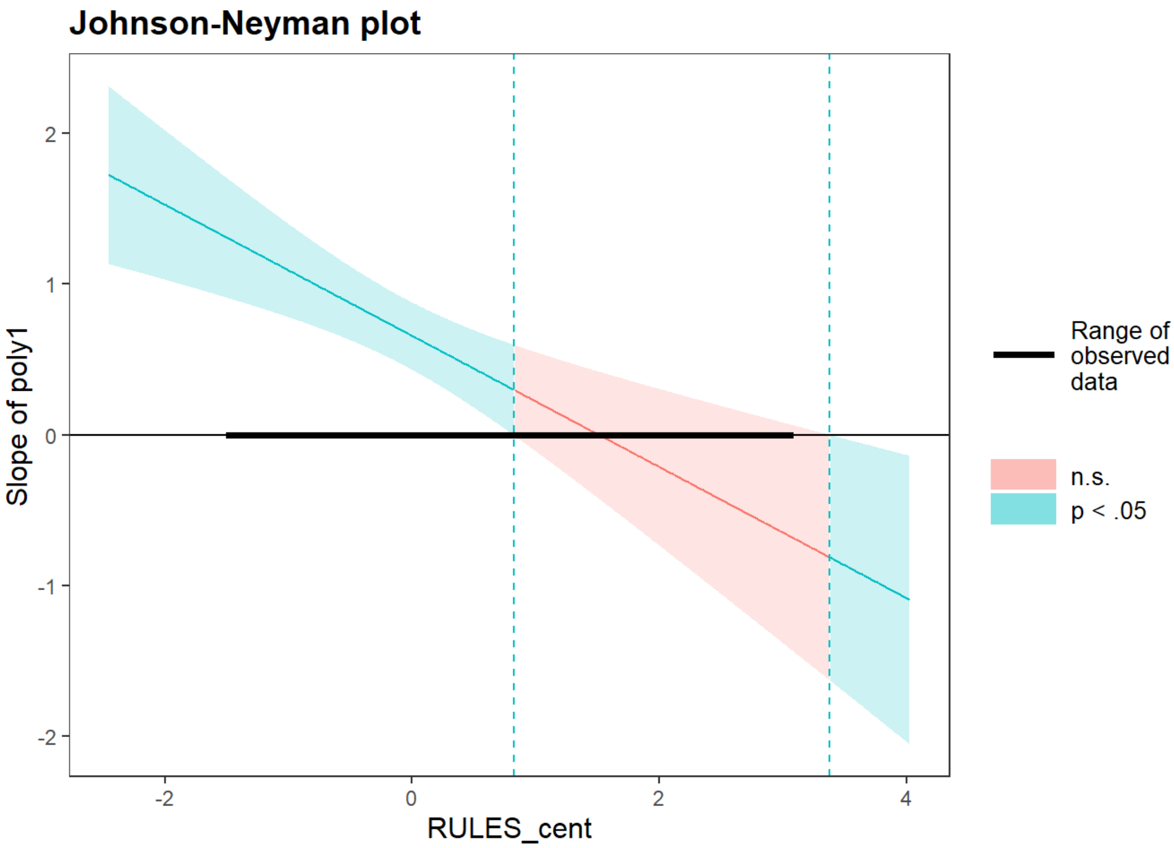
```
#Run model again with controls but without outliers

lmer_model2_out <- lmer(HBQ_Int ~ (RULES_cent)*(poly1+poly2) + Parent_
Anx_cent + Marital_Status + (1|child_ID), data = id_without_outliers2)

full_lm_results2_out<-Anova(lmer_model2_out, type = 3, test='F')

print(full_lm_results2_out)
```

```
## Analysis of Deviance Table (Type III Wald F tests with Kenward-Roge
r df)
##
## Response: HBQ_Int
##                           F Df Df.res    Pr(>F)
## (Intercept)        111.3800  1 174.12 < 2.2e-16 ***
## RULES_cent         119.1175  1 182.32 < 2.2e-16 ***
## poly1               33.4873  1 306.35 1.773e-08 ***
## poly2                3.1824  1 296.98 0.0754571 .
## Parent_Anx_cent     29.3070  1 430.50 1.028e-07 ***
## Marital_Status       2.2901  2 171.79 0.1043367
## RULES_cent:poly1    14.0601  1 306.92 0.0002116 ***
## RULES_cent:poly2     2.7513  1 301.45 0.0982157 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##Follow-up interaction Model 2b (johnson neyman) - where interaction
is significant between RULES and Poly1/2

      #dev.new()

        #print(

interactions::sim_slopes(

          lmer_model2_out,

          pred = poly1,

          modx = RULES_cent,

          jnplot = TRUE

        )#)
```

```
## JOHNSON-NEYMAN INTERVAL
```

```
##
## When RULES_cent is OUTSIDE the interval [0.82, 3.38], the slope of
poly1 is
## p < .05.
##
## Note: The range of observed values of RULES_cent is [-1.48, 3.06]
```

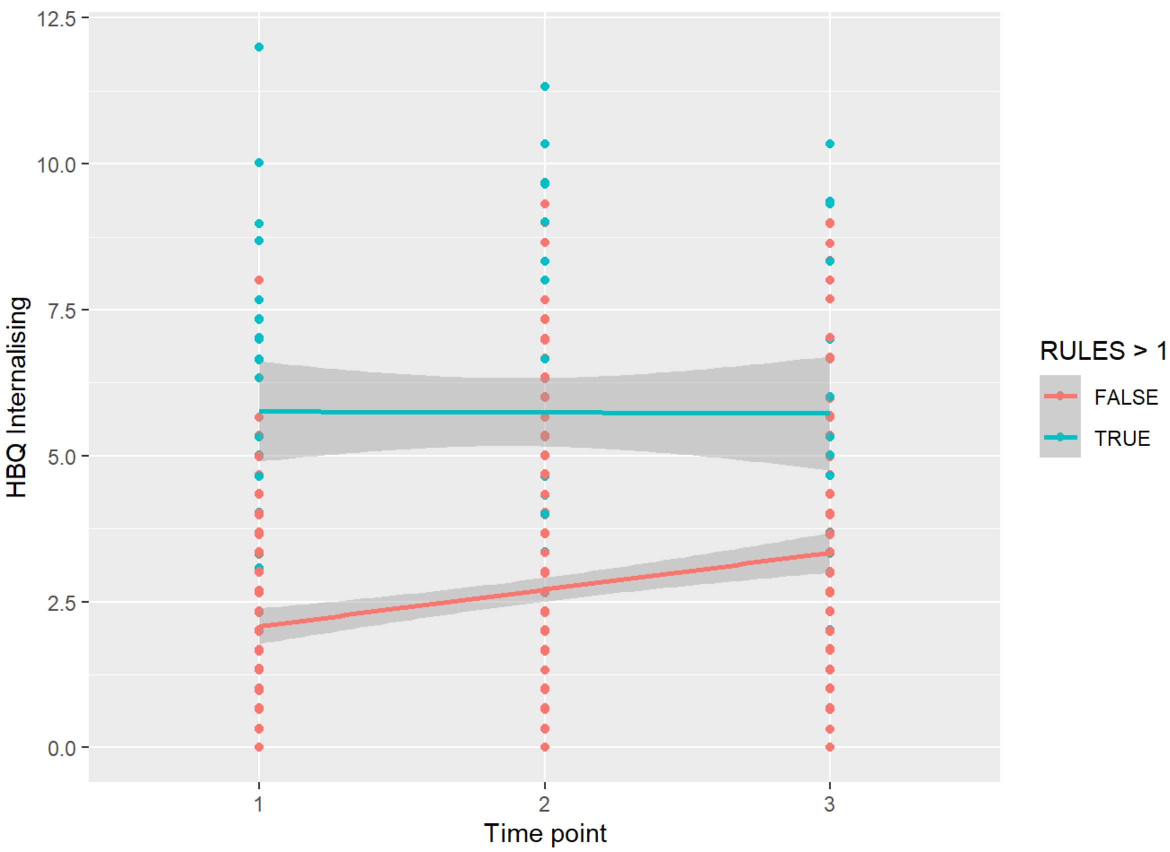



```
## SIMPLE SLOPES ANALYSIS
##
## Slope of poly1 when RULES_cent = -1.01170264 (- 1 SD):
##
##   Est.   S.E.   t val.      p
## ------ ------ -------- ------
##   1.10   0.16     6.91   0.00
##
## Slope of poly1 when RULES_cent = -0.04104162 (Mean):
##
##   Est.   S.E.   t val.      p
## ------ ------ -------- ------
```

```
##    0.67    0.11      5.96    0.00
##
## Slope of poly1 when RULES_cent =  0.92961939 (+ 1 SD):
##
##    Est.    S.E.    t val.       p
## ------ ------ -------- ------
##    0.25    0.16      1.57    0.12
```

```
#Plotting data to help with interpretation
#plot splitting high and low IU - used value of 1 for RULES to split & only plotting poly 1 (as not quadratic interaction)
ggplot(data = id_without_outliers2[-c(52, 229, 396), ], aes(x = Time_Point, y = HBQ_Int, colour = RULES_cent>1)) + geom_point() + labs(x = "Time point", y = "HBQ Internalising", colour = "RULES > 1") + scale_x_discrete(limit = c('1', '2', '3')) +  stat_smooth(method = lm, formula = y ~ poly(x, 1, raw = TRUE))
```

```
## Warning: Removed 50 rows containing non-finite values (`stat_smooth()`).
## Removed 50 rows containing missing values (`geom_point()`).
```

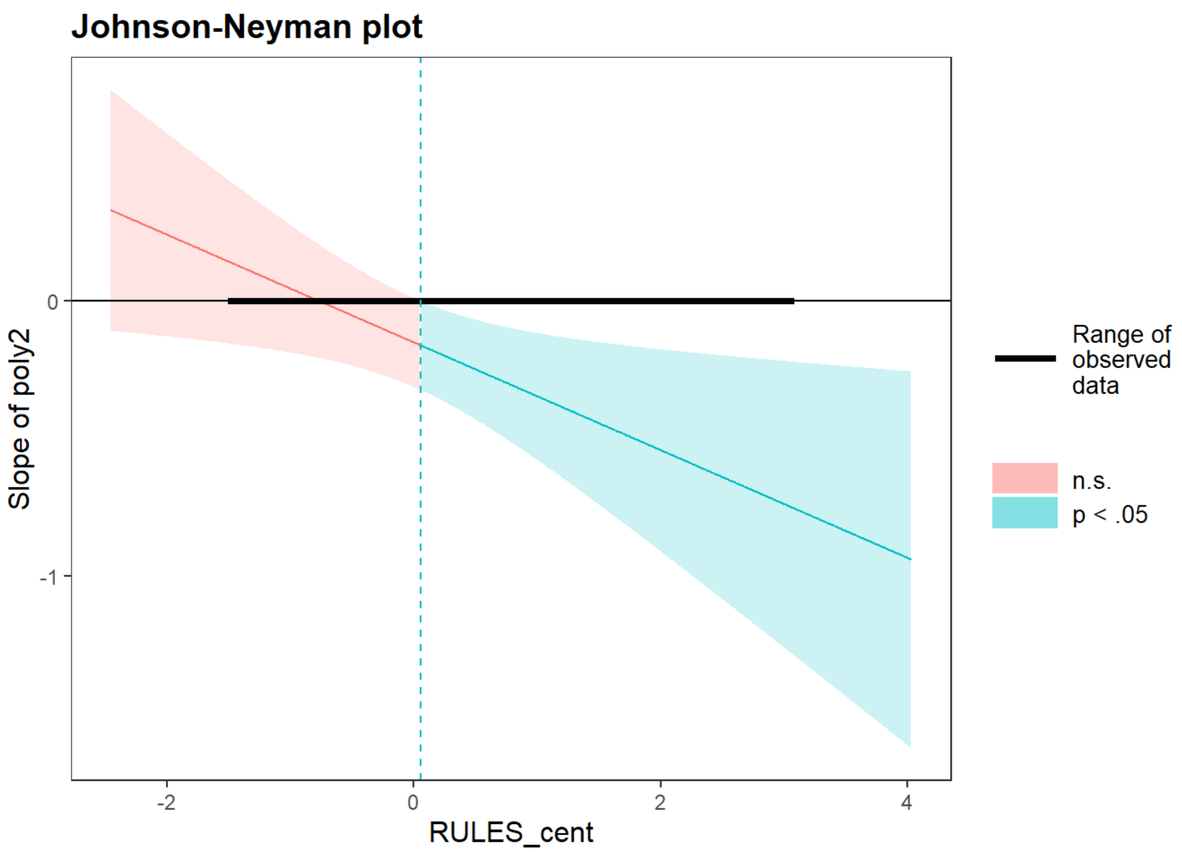


```
#Model 3 (MAIN MANUSCRIPT- outliers removed - with HBQ ExtADHD in plac
e of Child Anx

#Due to residuals not being normal, detect outliers based on Cook's di
stance and remove outliers

cooksD3 <-cooks.distance(lmer_model3)

influential3 <-cooksD3[(cooksD3 > (4 * mean(cooksD3, na.rm=TRUE)))]

influential3

##         4         49         60         65         67         94
97       100

## 0.2287412 0.2554784 0.3857645 0.2997083 0.3266786 0.4082986 0.26798
62 0.2205170

##       133       137       199       247       259       309         3
60       373

## 0.1931476 0.6863412 0.2333791 0.2204816 0.2166356 0.2923795 0.56506
53 0.3766674

##       389       425       448       464       488       497         5
20

## 0.2717049 0.6314201 0.5441143 0.3479958 0.2186923 0.5845653 0.24267
96

id_of_influential3 <- names(influential3)

outliers3 <- data.gca[id_of_influential3,]

id_without_outliers3 <- data.gca %>% anti_join(outliers3)

## Joining, by = c("child_ID", "Time_Point", "Child_Anx", "HBQ_Int",

## "HBQ_ExtADHD", "Parent_Anx", "Marital_Status", "RULES", "RULES_cent
",

## "Parent_Anx_cent", "Time_Point.Index", "poly1", "poly2")

#Run model again with controls but without outliers

lmer_model3_out <- lmer(HBQ_ExtADHD ~ (RULES_cent)*(poly1+poly2) + Par
ent_Anx_cent + Marital_Status + (1|child_ID), data = id_without_outlie
rs3)

full_lm_results3_out<-Anova(lmer_model3_out, type = 3, test='F')

print(full_lm_results3_out)

## Analysis of Deviance Table (Type III Wald F tests with Kenward-Roge
r df)

##

## Response: HBQ_ExtADHD

##                         F Df Df.res    Pr(>F)

## (Intercept)       98.4869  1 172.38 < 2.2e-16 ***

## RULES_cent        22.3344  1 175.29 4.683e-06 ***

## poly1              2.6931  1 300.06   0.10183

## poly2              3.3694  1 291.78   0.06744 .
```

```
## Parent_Anx_cent  23.3318  1 450.69 1.871e-06 ***
## Marital_Status    3.4804  2 171.98   0.03298 *
## RULES_cent:poly1  2.1533  1 295.33   0.14333
## RULES_cent:poly2  5.4127  1 290.53   0.02068 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
#HBQExtADHD RULES:poly 2 sig

 #dev.new()
        #print(
interactions::sim_slopes(
          lmer_model3_out,
          pred = poly2,
          modx = RULES_cent,
          jnplot = TRUE
        )#)
```

```
## JOHNSON-NEYMAN INTERVAL
##
## When RULES_cent is OUTSIDE the interval [-5.47, 0.06], the slope of
poly2
## is p < .05.
##
## Note: The range of observed values of RULES_cent is [-1.48, 3.06]
```




```
## SIMPLE SLOPES ANALYSIS
##
## Slope of poly2 when RULES_cent = -0.98635757 (- 1 SD):
##
##   Est.   S.E.   t val.      p
## ------ ------ -------- ------
##   0.04   0.12     0.36   0.72
##
## Slope of poly2 when RULES_cent = -0.01397314 (Mean):
##
##    Est.   S.E.   t val.      p
## ------- ------ -------- ------
##   -0.15   0.08    -1.80   0.07
##
## Slope of poly2 when RULES_cent =  0.95841129 (+ 1 SD):
##
##    Est.   S.E.   t val.      p
## ------- ------ -------- ------
```

```
##    -0.34    0.11     -2.95    0.00
#Also had a look at HBQExtADHD


ggplot(data = id_without_outliers3[-c(52, 223, 397), ], aes(x = Time_P
oint, y = HBQ_ExtADHD, colour = RULES_cent>1)) + geom_point() + labs(x
= "Time point", y = "HBQ Externalising", colour = "RULES > 1") + scale
_x_discrete(limit = c('1', '2', '3')) +  stat_smooth(method = lm, form
ula = y ~ poly(x, 2, raw = TRUE))
## Warning: Removed 51 rows containing non-finite values (`stat_smooth
()`).
## Removed 51 rows containing missing values (`geom_point()`).
```