University of Reading

Anxiety in Young Children: Cognitive biases, development and assessment

Doctorate of Philosophy

School of Psychology and Clinical Language Sciences

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Declaration of original authorship

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

Suzannah Ravenscroft

January 2018

Please note that I use my married name in my published work. Therefore, authorship of the published papers and manuscripts that make up the chapters of this thesis refer to Suzannah Stuijfzand not Suzannah Ravenscroft, but refer to the same person.

Statements of Contribution to Papers

Statements of Contribution by Suzannah Ravenscroft to the Published Papers included in this Thesis

Paper 1: Research Review: Is anxiety associated with negative interpretations of ambiguity in children and adolescents? A systematic review and meta-analysis

Suzannah Ravenscroft's contribution to this paper included: initial design of study including generation of search terms and eligibility criteria, generation of coding protocol, assistance in coding of abstracts and full papers, coding of effect sizes and completion of final coding of papers for the meta-analysis. Suzannah Ravenscroft prepared all the figures and detail necessary for adherence to PRISMA guidelines, wrote scripts for and conducted the meta-analysis with some assistance from co-authors. Suzannah Ravenscroft took the lead on writing the manuscript for publication and subsequent revisions. Her contribution amount to 70% of the work for this paper.

Approved: Dr. Helen Dodd. January 2018

Paper 4: Young children have social worries too: Validation of a brief parent report measure of social worries in children aged 4–8 years

Suzannah Ravenscroft's contribution to this paper included: contributing to the adaption of items, design and implementation of the testing protocol, the recruitment of the sample and conducted the collection of the data, wrote and set up the coding protocol, wrote and ran analysis scripts and took the lead on writing up of the manuscript for publication and subsequent revisions. Her contribution amounted to 75% of the work on this paper.

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Statement of contribution by (non-supervising) co-authors on papers in preparation

Paper 2: Look out Captain, I hear an ambiguous alien! A study of interpretation bias and anxiety in young children

Dr. Bhisma Chakrabhati contributed to this paper in assisting in the design and development of the task, providing training and superivision in the use of psycho-physiological methodology and the techniques necessary for the preparation of psycho-physiological data ready for analysis. Dr.

Bhisma Chakrabhati also oversaw data collection of psycho-physiological data to ensure the data was of good quality.

Paper 3: Anxiety differences in visual attention to emotional faces in four to eight year olds

Dr. Bobby Stuijfzand contributed to this paper through providing technical and statistical support in the preparation of the eye-tracking data for analysis and use of the eyetrackingR package for growth curve analysis. This included production of and assistance in writing of codes in matlab and R. He also contributed to the paper through providing statistical support in the writing up of results and interpretation of the growth curve analysis for the manuscript.

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Abstract

Anxiety is one of the most prevalent disorders to affect children. To understand how anxiety develops and what factors cause and/or maintain anxiety it is important to study anxiety in young children. Currently, there is a relative lack of studies focusing on anxiety and cognitive biases in children below 8 years old, in part due to a lack of methods for assessing anxiety subtypes and cognitive biases at this age. The primary aim of this thesis is to examine the associations between anxiety and cognitive biases in children aged between 4 and 8 years. A secondary aim is to develop a brief measure of early signs of social anxiety in young children. These aims are realised across four papers.

In Paper 1 a meta-analysis of the current literature on anxiety-related interpretation bias in children and adolescents is presented. A robust relationship was found, that was moderated by age. The study highlighted the need for more studies with younger children. Following this, a novel measure of interpretation bias using ambiguous tones was used in Paper 2 to assess the presence of an anxiety related interpretation bias in children aged 4 to 8. Anxiety differences in interpretation bias were only seen once developmental confounds were accounted for. Paper 3 used eye-tracking to assess the presence of an anxiety related attention bias in 4 to 8 year olds. Evidence of nuanced patterns of attention bias between anxiety groups were found. In Paper 4 a measure of social worries was adapted and validated for children ages 4 to 8.

Together, the studies provide new methods for the study of cognitive biases and anxiety in young children and new insights into their association. The work leads directly to several suggestions for future research including longitudinal work that tracks biases, anxiety and developmental factors over time.

1. General Introduction

Anxiety is one of the most prevalent disorders amongst children and young people and it is increasingly recognized that even young children can experience clinically significant anxiety (Cartwright-Hatton, McNicol, & Doubleday, 2006). Extensive research has examined the association between biases in attention and interpretation, and anxiety in older children and adults. However, relatively little is known about the role of cognitive biases in anxiety in young children. Furthermore, few parent-report measures of anxiety symptoms in young children are available. The primary aim of this thesis is therefore to examine the association between anxiety and cognitive biases in children, with a particular focus on children aged between 4 and 8 years. A secondary aim is to develop a brief measure of early signs of social anxiety in young children to facilitate future research examining the early development of social anxiety as well as the content specificity of cognitive biases. Three papers are presented in the thesis in relation to the first aim. In Paper 1, a meta-analysis of the association between interpretation bias and anxiety in children and adolescents is presented. In Papers 2 and 3, two new child friendly tasks to assess attention bias, and interpretation bias in children aged 4 to 8 years are presented. Finally, Paper 4, reports the development and evaluation of a new brief measure of social anxiety symptoms in young children. The final chapter brings the findings from the four papers together and provides directions for future research.

The following introduction outlines first why it is important to study anxiety in young children. Next, theory linking cognitive biases and anxiety is described. The existing gap in the literature surrounding the association between anxiety and cognitive biases in young children is then discussed. The introduction ends with an outline of the four stand-alone papers included in this thesis and a description of how they contribute to the overall aims of the thesis.

1.1 Definition of Anxiety

Anxiety is ‘an aversive emotional and motivational state occurring in threatening circumstances’ (Eysenck, Derakshan, Santos, & Calvo, 2007, p.336), while trait anxiety refers to the ‘disposition to experience anxiety across multiple time points’ (Bishop, 2007). Feelings of anxiety are considered clinical when the individual experiences ‘excessive feelings of anxiety and fear, where anxiety is worry about future events and fear is a reaction to current events. These feelings may cause physical symptoms such as a racing heart and shakiness.' (American Psychiatric Association, 2013).

This thesis will focus on anxiety referring to children with high symptoms of anxiety. There are several reasons for this. The first is that anxiety is recognised as a dimensional construct where an individual can have varying levels of different symptoms that collectively reflect the degree to which a certain disorder manifests itself (Bystritsky, Khalsa, Cameron, & Schiffman, 2013; Hudziak, Achenbach, Althoff, & Pine, 2007). Reflecting its dimensional nature anxiety is described and treated based on its symptomology rather than the presence or absence of a diagnosis. The second is that there are few clinical methods of assessment for use with younger children and these are only valid for children aged 6 and above, for example the anxiety disorders interview schedule for children (ADIS; Silverman & Nelles, 1988). However, there are validated methods for use with younger children that reflect their anxiety symptoms i.e. the Preschool Anxiety Scale (Spence, Rapee, McDonald, & Ingram, 2001). Indeed, even the measures of clinical assessment that are validated for children have been shown to provide an accurate reflection of the level of symptomatology being experienced (Hudziak et al., 2007; Schniering, Hudson, & Rapee, 2000), but lack good psychometrics when applied with children at the younger end of their age range (Beesdo, Knappe, & Pine, 2011; Schniering et al., 2000). Thus, it seems that describing anxiety in terms of the levels of symptoms experienced reflects better the nature of the construct and its valid assessment in younger children.

1.2 The prevalence and development of anxiety in Children

Fear and anxieties are part of typical development (Muris, Merckelbach, Mayer, & Meesters, 1998). This means that social anxiety, fear of animals or fear of being left alone are developmentally appropriate at specific points during childhood. Typically, these fears are relatively mild and transient in nature. However, when they persist beyond the age appropriate boundary or cause significant distress, concerns regarding psychopathology may arise (Beesdo et al., 2011).

There is strong evidence that anxiety is one of the most prevalent mental health problems affecting children and young people. There is also evidence that these problems with anxiety can persist over time. At any given time clinical anxiety affects around 3% of children in the UK aged 5 to 16 years (Office of National Statistics et al., 2004) and 6.5% of children and adolescents worldwide (Polanczyk, Salum, Sugaya, Caye, & Rohde, 2015). This apparent discrepancy in prevalence rates could indicate a slightly lower prevalence of anxiety in the UK but it may also be explained by differences in the source of the data; UK prevalence rates are taken from census data whereas worldwide rates are taken from a systematic review of the academic literature (Polanczyk et al., 2015). Before the age of 16, it is estimated that around 10% of all youths will have suffered from a clinically significant anxiety problem (Costello, Mustillo, Erkanli, Keeler, & Angold, 2003). As many as 40 to 60% of anxious children meet criteria for multiple anxiety disorders (Benjamin, Harrison, Settipani, Brodman, & Kendall, 2013; Kashani & Orvaschel, 1990; Last, Perrin, Hersen, & Kazdin, 1996). All anxiety disorders, except specific phobias, have shown homotypic continuity from ages 9 and 10 years to 16 years. That is, the same anxiety disorder diagnosis was given at different assessment points. Also, there is evidence of heterotypic development with depression. This is where a disorder is seen at different assessment points but a different diagnosis is given. Here, anxiety both preceded and proceeded depression (Costello et al., 2003). Given the prevalence of anxiety amongst children and adolescents, its persistence over time, and links to further anxiety disorders and depression over time, anxiety shows itself to be noteworthy of attention in children and young people.

Under the current Diagnostic and Statistical Manual of mental disorders (DSM 5; American Psychiatric Association, 2013) a variety of specific disorders fall under the umbrella of anxiety disorders, including but not limited to: generalised anxiety disorder (GAD), social anxiety disorder, specific phobia, separation anxiety, panic disorder, agoraphobia and selective mutism (American Psychiatric Association, 2013). These different diagnostic disorders reflect different subtypes of anxiety. These subtypes also manifest at subclinical levels (Spence, 1997); within a normative sample, discrete factors representing separation anxiety, social anxiety disorder, obsessive-compulsive disorder, panic-agoraphobia, generalized anxiety and fears of physical injury have been observed in children aged 2 to 12 years (Spence, 1998; Spence et al., 2001).

While the onset of some anxiety disorders may be later, a wide range of anxiety subtypes and disorders are seen in preadolescent children (Ford et al., 2003). In a community sample, Salum et al. (2013) found evidence of separation anxiety, specific phobias, social anxiety, and generalised anxiety disorders in a pre-adolescent sample of children aged 6 to 12 years. The prevalence of specific anxiety disorders varies across children's ages, with some diagnoses being very rare in young children. Beesdo, Knappe, and Pine (2011) describe that separation anxiety and some specific phobias (animal, blood injection injury, environmental type) often begin before age 12, with social anxiety disorder typically being diagnosed first in late childhood and early adolescence. Panic disorder, agoraphobia and GAD, which have a criterion that symptoms must last at least 6 months, are often not diagnosed until later adolescence. However, shortening this strict criterion increases the prevalence of GAD in younger children (Beesdo et al., 2011). Note that other authors argue that social anxiety disorder occurs a little later, at early to mid-adolescence, and suggest that panic disorders do not tend to onset until early adulthood (Rapee, Schniering, & Hudson, 2009). Nevertheless, it is clear that preadolescent children experience a range of anxiety disorders and that these subtypes of anxiety also exist at a subclinical level in community samples.

Evidence suggests that anxiety and its subtypes are also present in young children. Children start showing symptoms of anxiety from age 3 (Egger & Angold, 2006). Clinical anxiety symptoms are increasingly being recognised in preschool-aged children (c.f. von Klitzing et al., 2014). Prevalence estimates of anxiety disorders in preschool-aged children range from 1 or 2% (Wichstrøm et al., 2012) up to 19% and are stable between 3 and 6 years of age (Bufferd, Dougherty, Carlson, Rose, & Klein, 2012). There is also some evidence to suggest that anxiety disorders are as prevalent in young children as they are in later childhood. In a UK based population study 3.19% of children ages 5 to 7 years old were diagnosed with an anxiety disorder. This prevalence percentage was similar to children ages 8 to 10 years old (3.05%) and only started to increase slightly in 11 to 12 year olds (3.95%) and 13 to 15 year olds (5.04%; Ford et al., 2003). In a review of the evidence on prevalence rates of anxiety disorder in children Cartwright-Hatton et al. (2006) concluded that anxiety disorders are common amongst children in early and middle childhood. Anxiety symptoms have also been found to cluster to reflect subtypes of anxiety in pre-schoolers (Spence et al., 2001). Indeed, in the population study, while percentage prevalence rates increased with age, social phobia, separation anxiety, generalised anxiety disorder, and specific phobia were all found to be present in the 5 to 7 year old group (Ford et al., 2003). The comparable prevalence rates of anxiety disorders found in young children compared to older children and the presence of anxiety subtypes in this age groups indicates that, just as for older children, anxiety is prevalent for this age group.

Despite the growing acknowledgement of the prevalence and importance of anxiety in young children there is relatively little work concerning anxiety and its subtypes in this age group. Beyond the study assessing continuity of anxiety from 3 to 6 year olds (Bufferd et al., 2012), there is little work on the continuity of anxiety that is present in pre-schoolers. This leaves questions regarding whether the same persistence in anxiety disorders seen in older children and adolescents is also seen earlier in young children (Cartwright-Hatton et al., 2006; Spence et al., 2001). What the longer term consequences of such early demonstrations of anxiety symptoms are, are also unknown (Cartwright-Hatton et al., 2006; Spence et al., 2001). Likewise, there are questions surrounding the stability of anxiety subtypes in young children and/or their contribution to later anxiety disorders. Thus, more work studying anxiety and its subtypes in young children would contribute to filling this significant gap in the literature.

1.3 Outcomes associated with Anxiety

Anxiety in children negatively impacts on school attendance and social competence (Settipani & Kendall, 2013; Velting & Albano, 2001). Left untreated anxiety disorders are associated with depression and suicidal ideation in later life (c.f. Kendall, Safford, Flannery-Schroeder, & Webb, 2004). When adults with anxiety disorders are asked about age of onset, the average age given is 11 years old (25^{th} to 75^{th} interquartile range: 6 to 21 years; Kessler et al., 2005). Similarly, of adults diagnosed with major depressive disorder, 36% had an anxiety disorder diagnosis earlier in life (Moffitt et al., 2007). Such data indicates that childhood anxiety disorders are a significant risk factor for long term problems with both anxiety and depression. Anxiety does not just affect outcomes for the individual but also affects family processes (Ezpeleta, Keeler, Erkanli, Costello, & Angold, 2001). There is also an economic burden on society made up of the indirect costs (lost production due to work absence or early retirement), non-medical services (social services, informal care) and direct healthcare costs of anxiety disorders. The total cost of treating anxiety (inclusive of the cost of direct and indirect costs) in adults is comparable to the cost of treating addiction (Fineberg et al., 2013). Given that the onset of anxiety symptoms and clinical anxiety often occurs during childhood, significant costs are incurred when anxiety disorders in children are not recognized or effectively treated and persist into adulthood. To intervene effectively we need to understand the factors that cause and/or maintain anxiety in children.

1.4 Models of the Cause and Maintenance of Anxiety: Role of Cognitive Biases

Several theoretical models have been proposed that describe potential causal and maintenance pathways for anxiety. For example, in Vasey and Dadds' (2001) model there are two pathways to an anxiety disorder, one through precipitating influences made up of environmental events, and the second through the increasing intensity of anxiety symptoms resulting from the interplay of predisposing factors. These predisposing factors include inherited factors such as genetics and temperament, environmental factors such as parental responses, learning experiences and exposure to feared stimuli, and individual factors such emotion regulation abilities and cognitive biases. Cognitive biases being one of the main focuses in this thesis. None of these factors are deemed necessary, but the combination of predisposing factors is hypothesized to affect a child’s risk for anxiety psychopathology. Vasey and Dadds (2001) suggest these factors have an enduring influence on the child, though they may not have the same effect on each child. This is because the factors operate within the developmental and temperamental context of the child. It is further argued that these predisposing factors may play a role in maintaining anxiety disorders, though the factors that maintain may not be same as those that predisposed. In their model, cognitive biases can be seen to play a predisposing role and are also identified as one of the five main maintaining factors.

Likewise Hudson and Rapee (2004) suggest an etiological model of the development of anxiety disorders which again places cognitive biases amongst the vulnerability factors contributing to the child’s avoidance patterns. Again, this model sees vulnerability factors as bi-directional in nature, such that the presence of one factor may increase the likelihood of another factor occurring. Each factor may not increase the child’s vulnerability to anxiety in isolation, but vulnerability may come from the interaction of several factors.

The focus of the work in this thesis is primarily on cognitive biases and the association between cognitive biases and anxiety in children. Both theoretical models described above recognise cognitive biases as playing a causal and maintaining role in anxiety disorders and they place these within the context of broader risk. Cognitive biases also represent factors within the model that are potentially malleable. This is opposed to genetic and temperamental factors which may be more difficult to change. Treatments for anxiety take advantage of the idea that cognitive biases are changeable by making the biases part of the focus of their treatments, for example, cognitive behavioural therapy and cognitive bias modification procedures (see section 1.8). In the following section, models of anxiety focused specifically on cognition in anxiety are reviewed.

1.5 Information Processing models of Anxiety

Information processing models of anxiety describe how biases may be formed and function within an individual to cause or maintain anxiety. First an overview of will be given of general information processing models of anxiety, which were primarily developed with adult anxiety as the context. Then a review of information processing models of anxiety in children is provided.

1.5.1 General models.

In general, information processing models of anxiety describe several processing stages. The first, generally seen as a threat detection system, assesses incoming stimuli for threat relevance. At the second stage, attention is allocated to relevant stimuli and, at the third stage, further processing occurs, such as reappraisal as in Beck and Clark's (1997) model. Interpretation of stimuli therefore comes at a later stage of processing than allocation of attention. Information processing models suggest that for individuals who are anxious, the system is hypersensitive to detecting threat and/or allocating attention to threat. This results in cognitive biases towards threat at this and every proceeding level of processing. For example, according to Kendall (1985) individuals have threat-related schemata which guide information processing and behavioural responses and these schemata are overactive in anxious individuals. According to different models of anxiety these cognitive biases can play a predisposing (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Eysenck, 1997; Eysenck, 1992; Williams, Watts, MacLeod, & Mathews, 1988; Williams, Watts, MacLeod, & Mathews, 1997), causal (Beck & Clark, 1997), and/or maintaining (Bar-Haim et al., 2007; Eysenck, 1997; Eysenck, 1992; Mogg & Bradley, 1998; Williams et al., 1988; Williams et al., 1997) role. Two such biases that have been extensively examined in adults are: an attention bias where attention is disproportionately allocated to threat, and an interpretation bias where ambiguity is interpreted in a threatening way.

Support for information processing models comes from a body of research providing evidence of a relationship between anxiety and cognitive biases in adults. A meta-analysis indicated there is a robust relationship between attention bias and anxiety, such that individuals who were anxious were more likely to attend to a threat-related over a neutral stimulus. Such a within-subjects bias was not found amongst non-anxious controls and there was a robust, albeit relatively small, between group difference in bias (Bar-Haim et al., 2007). Bar-Haim et al.'s (2007) meta-analysis included 172 studies with 323 effect sizes: 112 for its within group effect analysis with anxious participants, 87 for its within group effect analysis with non-anxious control participants and 124 for its between group analysis. These studies were identified through strict inclusion criteria and systematic searches. Thus, while a little out dated now, this meta-analysis can be viewed as reflecting the evidence at the time. The meta-analysis included studies with clinical and community samples and considered potential moderators related to the design of the study (e.g. experimental paradigm) and related to participants in the study (e.g. anxiety disorder). No significant moderators were found.

No comparable meta-analysis of the association between anxiety and interpretation bias exists. However, a review by Blanchette and Richards (2009) concluded that there is a relationship between interpretation bias and anxiety in adults. This review did not aim to be systematic or exhaustive and while potential moderating factors were discussed, these were not quantitatively investigated.

1.5.2 Information processing models specific to childhood anxiety.

Models of childhood anxiety also include a role for cognitive biases, but the fact that children are in the midst of development adds a complicating factor for the direct downward application of adult models to children. For example, the threat detection systems mentioned in most adult models rely on schemata based on memory and previous learning, which may be limited in young children. Also, to evaluate threat and take context into account a certain amount of effortful control may be required. Effortful control is the ability to inhibit a dominant response to perform a subdominant response, to detect errors, and to engage in planning (Rothbart & Rueda, 2005). Effortful control may also be needed to regulate oneself in response to threat stimuli. Sufficient abilities to control attention and use inhibition may also be required to process the threat level of stimuli. Such abilities are still developing in children so they may not be sufficiently mature to function as the adult models suggest. Therefore, when attempting to explain child anxiety using an information processing model the child's developmental level and associated cognitive abilities need to be taken into account.

There are information processing models of anxiety that are specific to children, for example, Daleiden and Vasey (1997). In this model, anxious children selectively attend to, are distracted by, and narrow their focus of attention on threat. Consequently, anxious children interpret ambiguous information in a negative way, adapt a negative attributional style, expect negative outcomes and have a low expectation in their ability to handle or cope with both threatening situations and symptoms of anxiety. This model does not clearly argue that cognitive biases are causing or maintaining anxiety. Given the population it refers to, what this model lacks is a consideration for how the association between bias and anxiety may or may not be affected by social, emotional or cognitive development.

Other models of anxiety do introduce a possible role for development to provide a specific model of anxiety in children. These models often do this by extending adult models to include moderation by developmental factors (Hadwin, Garner, & Perez-Olivas, 2006). Kindt and Van Den Hout's (2001) model indicates that the presence of anxiety-linked information-processing biases depends on the development of the ability to inhibit attention to threat. According to this model, children who are highly anxious do not develop the ability to inhibit attention to threat and thus are at a higher risk of developing an anxiety disorder than those who have developed the ability to inhibit their attention to threat. Lonigan, Vasey, Phillips, and Hazen (2004) explained the relationship between information processing and anxiety in children as requiring a mediated moderation model whereby the link between personality and anxiety is mediated by information processing biases for threat. The presence of such biases are then moderated by effortful control. Within these 2 models (Kindt & Van Den Hout, 2001; Lonigan et al., 2004) information processing biases are central and are suggested to function as a vulnerability factor for child anxiety. Understanding the relationship between cognitive biases and anxiety, and the role of development in this relationship, would inform our models of child anxiety and provide insight for anxiety treatments, particularly those aiming to intervene by targeting cognitive biases.

Field and Lester (2010) outline three ways in which development may be included within information processing models of anxiety. The first model is the integral bias model where cognitive biases are innate and influenced solely by individual factors, e.g. anxiety. According to this model cognitive biases will be present early in development, with differences in biases remaining stable over time uninfluenced by age or developmental stage. The second is the moderation model, which proposes that cognitive biases are present in all young children, but remain over time for those children only with relevant individual factors such as anxiety, which then interact with developmental factors, e.g. social, emotional and cognitive development, i.e., emotional regulation. Finally, the acquisition model suggests that cognitive biases develop over time by interacting with social, emotional, and cognitive development. According to this model, biases are not present in all young children and it is the child's social, emotional and cognitive development that influences whether or not a cognitive bias emerges. Anxiety may be caused by the acquisition of such biases or drive the development of such biases.

Field and Lester (2010) reviewed the literature concerning the relationship between cognitive biases and anxiety, focusing specifically on interpretation bias and attention bias. Their suggestion was that for interpretation bias an acquisition model whereby as social, emotional, and cognitive ability develop so do anxiety-linked interpretation biases, is supported by the evidence. On the other hand, evidence regarding attentional bias seems to point to a moderation model where attentional biases are present in all young children and change as a function of development. While different models may be appropriate for different biases, it seems that development is important when considering the relationship between anxiety and cognitive biases. In order to distinguish between the models we need to know if the biases are present early in development and whether they are present for all children or just a sub-set, i.e., those who are anxious (Field & Lester, 2010). The studies reviewed by Field and Lester (2010) included very few studies that focused on children younger than 8 years old leaving the questions regarding the anxiety-bias associations in early development unanswered and conclusions regarding the models incomplete. If we are to increase our understanding of anxiety in children by distinguishing between the models and clarifying the role of cognitive biases in underpinning childhood anxiety, more research with younger children is required.

1.6 Relationships between Cognitive Biases and Anxiety in Children

1.6.1 Interpretation bias.

1.6.1.1 Methods.

To assess interpretation biases in children two main types of task are used. One is an ambiguous scenarios task (Barrett, Rapee, Dadds, & Ryan, 1996) where children hear or read an ambiguous story and have to choose or produce an interpretation of what they think may be happening. The other type of tasks are based on lexical knowledge, for example a homophone task (e.g. Gifford et al., 2008). Here children hear a word that could be interpreted as having a threatening or none threatening connotation and children must select a picture to match the word they heard. These tasks are then used to assess whether children's interpretation bias is related to their anxiety.

1.6.1.2 Associations with anxiety.

A relationship between interpretation bias and anxiety in adults has been found but evidence of a relationship in children and adolescents is much more inconsistent. Some studies have found a relationship between interpretation bias and anxiety symptoms in children and adolescents (Alkozei, Cooper, & Creswell, 2014; Bögels & Zigterman, 2000; Carthy, Horesh, Apter, & Gross, 2010; Cederlund & Ost, 2011; Creswell, Shildrick, & Field, 2011; Gifford, Reynolds, Bell, & Wilson, 2008; Muris, Jacques, & Mayer, 2004; Muris, Merckelbach, Schepers, & Meesters, 2003), though sometimes this relationship is small (Blossom et al., 2013; Creswell & O'Connor, 2011; Lu, Daleiden, & Lu, 2007; Mogoase, Podina, Sucala, & Dobrean, 2013; Waters, Zimmer-Gembeck, & Farrell, 2012). However, others have found no relationship between interpretation bias and anxiety (Bell-Dolan, 1995; Dalrymple-Alford & Salmon, 2013; Field & Field, 2013; Ooi, 2012; Perez-Olivas, Stevenson, & Hadwin, 2010). This equivocal evidence makes the relevance of an interpretation bias to anxiety in children and adolescents unclear. Bringing clarity to whether this relationship exists and its magnitude would inform the appropriateness of anxiety treatments that focus on altering cognitions to reduce anxiety, i.e. cognitive behavioural therapy (CBT) for different age groups (see section 1.8).

Part of the inconsistency in the literature may be due to methodological variability between the studies. For example, some studies are based on comparisons of interpretation bias between clinical and control groups, while others assess a correlation between interpretation bias and anxiety in a community sample. This may influence whether a relationship is found as Dodd, Hudson, Morris, and Wise (2012) found a cross-sectional relationship between clinical anxiety and interpretation bias, but only found a relationship between trait anxiety and interpretation bias when this was investigated longitudinally. Studies also vary in the tasks they use to assess interpretation bias. Even within the same study a relationship has been found between interpretation bias and anxiety with the ambiguous scenarios task, but not the homophone task (Eley et al., 2008). However, the extent to which such sources of variation influence the lack of clarity in the current evidence is unknown.

Using samples of different ages, and developmental abilities, may influence whether an anxiety related interpretation bias is found. If an association is stronger at one age than another, then this will affect the strength of the relationship between interpretation bias and anxiety in two ways. Firstly, in studies with large age ranges the resultant association seen will be an aggregation of the strong association found in one age group and the weak association found in the other, thus reflecting neither. Secondly, the picture of the association across studies will be clouded unless we know how age is impacting the magnitude or presence of the association. Indeed, there is some evidence that age influences the relationship between interpretation bias and anxiety, (for example; Blossom et al., 2013; Cannon & Weems, 2011; Creswell, Murray, & Cooper, 2014; In-Albon, Klein, Rinck, Becker, & Schneider, 2008); however, other studies have not found any influence of age (Muris et al., 2004; Rozenman, Amir, & Weersing, 2014; Weems et al., 2003; Weems, Zakem, Costa, Cannon, & Watts, 2005). There is also evidence that developmental abilities such as regulatory control may moderate the relationship between interpretation bias and anxiety (Salemink & Wiers, 2012). Therefore, there is some suggestion that development might influence the relationship between interpretation bias and anxiety, but exactly how this links with the inconsistencies across the literature is unknown.

Three narrative reviews have examined the association between anxiety and interpretation bias in children and young people. Two reviews concluded that there is an association (Muris & Field, 2008), even in young children (Blanchette & Richards, 2009), and the third could not conclude whether interpretation bias was specific to anxiety or general to all children due to lack of studies to include (Castillo & Leandro, 2010). These reviews highlight several unanswered questions regarding the relationship between anxiety and interpretation bias such as the specificity of cognitive distortions, both to anxiety disorders in general and to specific anxiety disorders, the role of development, and the influence of task parameters. The existing reviews cover the literature up to 2008. No systematic review or meta-analysis has been published. To comprehensively evaluate the evidence for an association between anxiety and interpretation bias in children and adolescents there is therefore a need for a systematic, quantitative review of the literature that takes potential moderating factors into account (see Chapter 2: Paper 1).

1.6.2 Attention bias.

1.6.2.1 Methods.

While there are a variety of tasks used to assess attention biases, most current research uses either the dot probe or the emotional stroop task. In the dot probe task participants classically see pairs of emotional stimuli (e.g. an angry and a neutral face) to the right and the left of the screen. A dot then replaces one of these faces and participants are asked to respond to the dot the as fast as possible by pressing a key corresponding to the placement of the dot on the screen (right or left). A faster response to the dot when replacing an angry face is taken to be indicative of a bias towards threat, while a faster response to the dot when replacing a neutral face is taken to be indicative of a bias away from threat (Shechner et al., 2010). In the emotional stroop task participants are asked to report the colour of stimuli as fast as possible. The stimuli tend to be words of varying degrees of threat, or often in child versions, emotional faces are used. The idea is that high anxiety participants will take longer to name the colour of words/faces reflecting threat than neutral or other emotional words/faces than those with lower anxiety. Both these tasks rely on reaction times to stimuli to assess attention bias. Metrics derived from the reaction times are then used to assess the association between attention bias and anxiety.

1.6.2.2 Association with Anxiety.

As previously mentioned there is a meta-analysis suggesting that there is a robust association between attention bias and anxiety which is not different between adults and children (Bar-Haim et al., 2007). However, this meta-analysis only included 11 studies that focused on children. When studies specifically focus on children and the association between attention bias and anxiety the evidence is inconsistent. Some studies report an anxiety related attention bias (Hunt, Keogh, & French, 2007; In-Albon, Kossowsky, & Schneider, 2010; Roy et al., 2008; Salum et al., 2013; Telzer et al., 2008), others find that all children show an attention bias (Kindt, Brosschot, & Everaerd, 1997; Kindt, Van Den Hout, De Jong, & Hoekzema, 2000; Price et al., 2013; Waters, Lipp, & Spence, 2004). Furthermore, some studies find that while all children have an attention bias it is stronger in children with anxiety than in those who are not anxious (Brown et al., 2013; Richards, French, Nash, Hadwin, & Donnelly, 2007; Richards, Richards, & McGeeney, 2000; Stirling, Eley, & Clark, 2006; Waters, Wharton, Zimmer-Gembeck, & Craske, 2008). When an anxiety related attention bias is found in children the nature of this bias is also inconsistent between studies; some have found a bias *towards* threat (Fulcher, Mathews, & Hammerl, 2008; Mueller et al., 2013; Susa, Pitica, Benga, & Miclea, 2012; Waters, Kokkoris, Mogg, Bradley, & Pine, 2010) while others have found a bias *away from* threat (avoidance; Brown et al., 2013; Stirling et al., 2006).

Studies vary greatly in their methods and this may contribute to the inconsistent results. One such source of variation is the task used to assess attention bias. Emotional stroop tasks (Benoit, McNally, Rapee, Gamble, & Wiseman, 2007; Kindt et al., 2000), visual search tasks (Broeren & Lester, 2013; Hadwin et al., 2003), emotional go-no-go tasks (Waters & Valvoi, 2009), an attentional deployment task (Dalgleish, Moradi, Taghavi, Neshat-Doost, & Yule, 2001), dot probe tasks (Brown et al., 2013; Salum et al., 2013) and eye-tracking tasks (Mueller et al., 2013; Shechner et al., 2013) have all been used to assess attention bias in children and adolescents. Most studies use a dot probe task; however, even amongst these studies there is little consistency: some studies report an anxiety related attention bias (Hunt et al., 2007; Taghavi, Neshat-Doost, Moradi, Yule, & Dalgleish, 1999), while others do not (Waters et al., 2004; Waters & Valvoi, 2009). There is also variation within use of the dot probe task in whether the stimuli used are pictures (Marin, Solanilla, & Barreto, 2015; Roy et al., 2008) or words (Hunt et al., 2007; Taghavi et al., 1999), but this does not appear to explain the inconsistencies fully.

Studies also vary in more than methodological parameters of tasks. The type of anxiety, fear related or distress related, being examined in the association to the attention bias may be influencing the presence and nature of an association between attention bias and anxiety. Indeed, Salum et al. (2013) found that children showed an attention bias towards threat when they had a distress related disorder i.e. generalised anxiety disorder. While those with a fear-related anxiety disorder i.e. social anxiety showed an attention bias away from threat (Salum et al., 2013). Studies also vary in whether they assess clinical or community samples and some studies have found that severity of anxiety determined whether or not the bias was anxiety related (Waters, Henry, Mogg, Bradley, & Pine, 2010; Waters, Pittaway, Mogg, Bradley, & Pine, 2013) suggesting this source of variation could be contributing to inconsistencies.

The meta-analyses of Dudeney, Sharpe, and Hunt (2015) specifically investigated the relationship between attention bias and anxiety in children and adolescents. Data from 38 studies was included and Dudeney et al. (2015), concluded that a small, but robust association exists between attention bias and anxiety in children and adolescents. A bias towards threat compared to neutral stimuli was observed and was present in both anxious and control children, though the bias was greater in anxious groups. Moderators were also assessed to see if factors related to the population or the design of the studies were influencing the presence or magnitude of the relationship between attention bias and anxiety. Despite assessing type of paradigm, type of stimuli, length of stimuli presentation (for visual dot probe only), sample size, gender, age, clinical or community sample and primary diagnosis, only two factors were shown as significantly influencing the relationship. Type of paradigm was found to significantly moderate the relationship where differences between anxiety groups was more reliably found when the stroop task was used than when the dot probe task was used. This suggests that some of the inconsistencies across studies outlined above could indeed be accounted for by the task used.

Additionally, Dudeney et al. (2015) found that age moderated the relationship between attention bias and anxiety in children and adolescents whereby the effect size of the association increased as age increased. Dudeney et al. (2015) suggested that the results of the meta-analysis fit a moderation model of anxiety: all young children show an attention bias towards threat and as children mature the differences in bias develop as a function of anxiety. However, the mean age of children in the included studies was 11 years of age with a range from 4 to 18 year olds. The lack of younger children included in the studies and lack of studies focusing on younger children makes the conclusions about the relationship between attention bias and anxiety in young children weak. This lack of clarity about attentional biases in young children is also reflected in studies that have explored age differences in the relationship between attention bias and anxiety. Some studies have found differences in the relationship between attention bias and anxiety between young children and older children/adolescents, but the nature of the difference differs across studies. Benoit, McNally, Rapee, Gamble, and Wiseman (2007) found that anxiety was only related to an attention bias to threat in adolescents, but not in children. Gamble and Rapee (2009) found anxious children showed an attention bias away (avoided) from happy faces, while anxious adolescents showed an attention bias away (avoided) from angry faces. Broeren and Lester (2013) found that all young children showed a positive attention bias to positive stimuli irrespective of anxiety but this relationship was not observed in older children. Other studies have found no effect of age on the relationship between attentional bias and anxiety (e.g. Morren, Kindt, van den Hout, & van Kasteren, 2003; Waters, Kokkoris, Mogg, Bradley, & Pine, 2010). Only a couple of studies have investigated the relationship between attention bias and anxiety specifically in young children and both found a relationship between bias and anxiety. Susa, Pitică, Benga, and Miclea (2012) found attentional bias to angry faces predicted anxiety symptoms in children with a mean age of 6 years. In an even younger sample, Dodd et al. (2015) found that anxious 3 and 4 year olds avoided face stimuli more than non-anxious children. However, one large multi-site study with an age-range of 6 to 18 years did find an anxiety related attention bias, but this was not moderated by age (Abend et al., 2017). It should however be pointed out that children at the lower part of the age range (6 and 7 years) represented only around 1% of a sample of over 1,000. Thus, whether the moderation results present a fair reflection of the attention bias anxiety relationship in the younger ages is not known. To better understand the age moderation results in Dudeney et al. (2015) and (Abend et al., 2017) as well as bring more clarity to current evidence regarding the impact of age, more studies investigating attention bias and anxiety in a younger sample are required.

While age was the only developmental proxy Dudeney et al. (2015) investigated in their meta-analysis, other developmental factors may influence the relationship between attentional bias and anxiety in children. For example, Susa, Pitică, Benga, and Miclea (2012) found that attentional control, one aspect of effortful control, fully moderated the relationship between attentional bias towards threat and anxiety in 9 to 14 year olds: attention bias towards threat was only related to anxiety symptoms when children showed poor attention control. Dudeney et al. (2015) suggested that effortful control and attention bias should be measured at the same time. If we are to understand whether age moderates the relationship between attentional bias and anxiety, and why this moderation might occur, we need more research with young children that includes measures of developmental factors.

1.7 Assessing Cognitive Biases and Anxiety in Young Children.

For both interpretation bias and attention bias, there are few studies with young children, in particular those younger than 8 years. One of the main reasons for this is the lack of developmentally appropriate measures of cognitive biases and anxiety for young children. Novel approaches to assessment of cognitive biases are required if we are to address this gap in the literature and develop a more complete understanding of how cognitive biases and anxiety interact across development.

1.7.1 Assessing interpretation bias in young children.

Tasks used to assess interpretation bias in children rely on linguistic and cognitive skills which many young children have yet to acquire. For example, self-report measures of interpretation bias, e.g. Child Ambiguous Scenario Questionnaire (Barrett et al., 1996), require children to imagine situations, generate and hold multiple outcomes in mind, relate cues to emotions to generate interpretations, or select a preferred interpretation from self – generations or forced choice. Others, e.g. homophone task, directly rely on children's language knowledge (Gifford et al., 2008). To obtain reliable responses to these tasks such abilities need to be sufficiently developed (Blanchette & Richards, 2013). Those that have attempted to investigate interpretation biases in young children have altered tasks to make them more appropriate and accessible to a younger age group i.e. the story stem task (Dodd, Hudson, Morris, & Wise, 2012). However, there remains a reliance on children's comprehension skills of both the instructions and scenarios to complete the task. Indeed, this may have been a factor in why a third of children were unable to complete the story stem task in the study of Dodd, Hudson, Morris, and Wise (2012).

Use of subjective measures that are not heavily reliant on children's comprehension skills would assist in making interpretation bias tasks more appropriate for young children. One approach might be to ask children to categorise ambiguous stimuli by valence, as positive or negative. The ability to categorise by valence is in place in infancy (feels good, feels bad; Widen, 2013) and children can label on the basis of valence by age 3.5 years (happy to label positive valence, and sad, and angry to label negative valence; Widen & Russell, 2003). By age 4, children can label the discrete categories happy, angry and sad, but accuracy in labelling fear, disgust and surprise is still developing (Widen, 2013). This suggests that angry may be a better negative emotion for use in tasks with young children rather than fear. A simple categorisation by valence task would reduce the complexity and amount of instructions necessary to explain the task to the child as well as the complexity of the required response. The instruction could simply be: "is the 'stimulus' happy or angry?" The number of responses to ambiguous stimuli as 'angry' could then be used as a measure of interpretation bias. Subjective measures of interpretation bias in young children should ideally make use of skills already in place in development and require only simple instructions.

Objective measures to assess interpretation bias may also help to reduce the confounds created by investigating developing children (Brown et al., 2013). Physiological responses such as facial responses to ambiguous stimuli may be one potential objective measure. Facial responses to stimuli are measured via facial electromyography (fEMG). Physiological responses are deemed involuntary and considered to be triggered unconsciously (Kim & Andre, 2008). Evidence is starting to suggest that facial emotional expressions have a biological basis (Eisenbarth, Gerdes, & Alpers, 2011): beyond facial reactions proving to be spontaneous and rapid (Dimberg, 1990; Dimberg & Thunberg, 1997), both visual and auditory stimuli evoke reactions in the facial muscles presented unconsciously (Dimberg, Thunberg, & Elmehed, 2000; Wexler, Warrenburg, Schwartz, & Janer, 1992). This unconscious evocation of a facial response shows it to be more than an attention arousal response (Dimberg et al., 2000).

The correspondence between environmental stimuli and facial responses begins early in development. This is demonstrated by newborns showing '*corrugator activity'*, this is associated with frowning and involves the muscle behind the eye-brow (Trapanotto et al., 2004). fEMG responses have reasonable validity, they correspond to autonomic responses of heart rate and skin conductance (Dimberg, 1990), and reflect behavioural responses to stimuli (Tottenham, Phuong, Flannery, Gabard-Durnam, & Goff, 2013). fEMG responses are not limited to reflecting facial mimicry (motor reflexes), as recordings correspond to valenced facial stimuli as well as valenced scenes and biologically/evolutionary relevant stimuli (Dimberg & Thunberg, 1997; Eisenbarth et al., 2011). In their investigation Tottenham et al. (2013) suggested that corrugator activity acted as an indicator of children's valence appraisal of ambiguous stimuli, being surprise and neutral faces. However, whether *anxiety differences* exist when such an objective measure is used to investigate valence appraisal of ambiguous stimuli has not yet been investigated.

1.7.2 Assessing attention bias in young children.

Assessing attentional bias in young children is also challenging. The extent to which the tasks used to assess attention bias, i.e., the dot probe and the emotional stroop (for descriptions of these tasks see section 1.6.2.1) can reliably capture attention bias in young children has been questioned. These tasks rely on verbal instructions and require sufficient cognitive and motor development for the children to complete the task appropriately and reliably (Brown et al., 2013). Both tasks suffer from insufficient psychometrics: bias scores derived from both tasks suffer from poor internal and test-rest reliability (Brown et al., 2013). Also, the interpretation of the emotional stroop task as involving attentional processes (Van Bockstaele, 2013) has been disputed in its use with adults (de Ruiter & Brosschot, 1994; Clarke et al., 2013) never mind children. On the other hand, the dot probe task can only provide a snapshot of attention (Gamble & Rapee, 2009) and thus is insensitive to individual differences between children. Given these limitations and the developmental issues of the emotional stroop and dot probe tasks, current tasks used to assess attention bias are not appropriate for use with young children.

To overcome the poor psychometrics and developmental issues of use of the dot probe and emotional stroop task several studies have investigated attention bias using an eye-tracking procedure. Eye-tracking provides a reliable, unobtrusive, and continuous measure of visual attention (Holmqvist et al., 2011; Liechty, Pieters & Wedel, 2010). Eye-tracking can be employed in a free-view procedure, limiting linguistic instruction and removing the need for a behavioural response dependent on motor development (Karatekin, 2007; Price et al., 2013). These characteristics give eye-tracking an advantage over reaction time measures and make the method ideal for assessing attention biases in young children. Several studies have used eye-tracking to investigate the relationship between attention bias and anxiety in children while viewing face pairs. All found patterns of viewing behaviour specific to anxious groups though these patterns varied between studies. Evidence of both an anxiety-related bias towards an angry face (Mueller et al., 2013;Shechner et al., 2013) and patterns of vigilance avoidance in an anxious group (In-Albon et al., 2010) have been found. In addition patterns of avoidance have been found. Dodd et al. (2015) found children avoided faces in general while Gamble and Rapee (2009) found anxious 7 to 11 year olds looked away more from happy faces and anxious 12 to 17 year olds avoided angry faces. Only one study that investigated attention bias and anxiety using eye-tracking did not find differences between an anxious and non-anxious group (Price et al., 2013). This study recorded children's eye movements while they completed the dot probe task. The inconsistent results with the other eye-tracking studies may be related to other problems related to use of the dot probe task (e.g., use of mean bias scores may be obscuring individual differences within groups, a lack of 'standard' dot probe task; Roy, Dennis, & Warner, 2015), as well as differences within the eye-tracking methodology. However, these studies were completed with children older than 7 years old. Only one study has investigated attention biases in anxious children in a preschool sample (Dodd et al., 2015). Eye-tracking may provide a methodology to assess attention biases in young children, but this potential has yet to be fully explored.

1.7.3 Assessing social anxiety as a subtype of anxiety in young children

While there are validated and appropriate measures of subclinical anxiety for young children, for example, the preschool anxiety scale (Spence et al., 2001), there are few dedicated measures of specific anxiety subtypes in young children. As outlined in section 1.2 a range of anxiety subtypes exist in preadolescent children including social anxiety. It may be particularly important to measure social anxiety in young children as it shows the strongest homotypic continuity between the ages of 3 and 6 of all anxiety subtypes; children who are socially anxious at age 3 years are 60 times more likely to be socially anxious at age 6 than children who are not socially anxious at age 3. This contrasts with separation anxiety and specific phobia, which are more developmentally appropriate in young children and show odds ratios of 7.88 and 2.87 respectively (Bufferd et al., 2012). Social anxiety is related to a range of negative outcomes for children, such as functioning in school (Mychailyszyn, Mendez, & Kendall, 2010) and relationships with peers (Larkins, 2014; Slee, 1994). Furthermore, social anxiety is associated with an increased likelihood of having another anxiety disorder (namely, agoraphobia, generalised anxiety disorder and phobia) as well as depression in the long term (Copeland, Angold, Shanahan, & Costello, 2014). The prevalence of social anxiety in young children is estimated as being between 2.1 to 4.6% (e.g. Egger & Angold, 2006). The incidence of social anxiety appears to increases with age (Hitchcock, Chavira, & Stein, 2009). However, with the exception of Bufferd and colleagues' work described above, little is known about the stability of social anxiety over time in young children or how social anxiety at an early age may relate to the development of other anxiety subtypes over time (Spence et al., 2001).

Social anxiety has particular relevance in the context of cognitive biases because a number of studies have focused specifically on cognitive biases linked to social anxiety (e.g. Miers, Blöte, Bögels, & Westenberg, 2008; Seefeldt, Krämer, Tuschen-caf, & Heinrichs, 2014). This focus on social anxiety has arisen in part because models of social anxiety describe a central role for biases in cognition (Clark & Wells, 1995). Also, the use of faces in attention bias tasks (dot probe, visual search, emotional stroop and free view eye-tracking paradigms) make the tasks inherently social and therefore examining the links with social anxiety is intuitive.

The content specificity hypothesis (Beck, 1976) states that cognitive biases are specific to the content of emotional disorders. Consistent with this hypothesis, there is some evidence for content specificity in cognitive biases, in relation to social anxiety (Becker, Rinck, Margraf, & Roth, 2001; Hertel, Brozovich, Joormann, & Gotlib, 2008). For example, a recent meta-analysis indicated that there was a greater attention bias towards threat stimuli when the stimuli was disorder congruent than not (Pergamin-Hight, Naim, Bakermans-Kranenburg, van IJzendoorn, & Bar-Haim, 2015). Similarly, in their review Blanchette and Richards (2009) concluded there was evidence for content specificity in interpretation bias, though they cautioned that this may be a response bias rather than an interpretation bias per se. Such evidence has yet to be found amongst young children.

One reason for the scarcity of investigations of content specificity of social anxiety in young children is the lack of a measure by which to assess social anxiety in this age group. Ideally, assessments of social anxiety in young children for use in research are brief questionnaire measures that do not require training of assessors as would be required by clinical interviews or observation measures. Currently, the five-item social anxiety subscale of the parent measure, the Preschool Anxiety Scale (PAS; Spence, Rapee, McDonald & Ingram, 2001) validated for children ages 4.5 to 6.5 could be used. However, there are a couple of issues associated with use of the PAS. First, the brief subscale is contained within a questionnaire of 22 items, it is not a stand-alone measure. Also, the items of the PAS ask parents about unobservable cognitions the child may be having, making it difficult for parents to respond (Comer & Kendall, 2004). There is a stand-alone 10 item parent report measure of social worries called the social worries questionnaire (Spence, 1995) whose items ask about more observable behaviours and which shows initial good psychometrics. However, this measure is validated for 8 to 17 year olds and has yet to be adapted for a younger age range. If we are to increase our understanding of social anxiety as an important anxiety subtype in young children and the role of content-specific cognitions associated with these subtypes, assessment tools of social anxiety validated for young children are required.

1.8 Cognitive Biases in Young Children: Potential Implications for Treatment

1.8.1 Cognitive behavioural therapy.

Cognitive behavioural therapy (CBT) is recommended for anxiety disorders by the National Institute for Health and Care Excellence (NICE). CBT is based on a psychological model that aims to assist the individual to identify and recognise their own anxious feelings and physiological reactions to anxiety, clarify cognitions experienced in anxiety-provoking situations, develop coping strategies, and evaluate outcomes. CBT has been adapted for use with children and adolescents and can be delivered in a variety of formats including individual sessions, group sessions and allowing parents to be involved in the child’s treatment. CBT has been found to lead to remission for 56% of children above the age of 6 years old (James, Soler, & Weatherall, 2007) showing it to be an effective treatment for anxiety. However, this evidence also suggests that CBT is not working for 44% of children. The fact that so many children are re-attaining their diagnosis indicates that there is room for improvement in CBT as a treatment of anxiety in children.

CBT requires a level of cognitive and emotional maturity that may not be available until middle to late childhood, which has made its appropriateness to younger children questionable. Thus, despite recognition that anxiety disorders are present and common in preadolescent children, the treatment options currently available to young children are limited (Cartwright-Hatton et al., 2006). However, recently CBT protocols have been adapted (Hirshfeld-Becker et al., 2008) and used in a randomised control trial for use with children aged between 4 and 7 years (Hirshfeld-Becker et al., 2010). As well as working directly with the child, this protocol includes heavy parental involvement. The rationale is that the children are a developmental stage where parents are their most important models, particularly with regards to emotional regulation skills (Hirshfeld-Becker et al., 2008). In addition, parents may be engaging in ineffective strategies to manage their child's anxiety. By involving parents in the treatment parents can be taught helpful coping strategies, which will in turn assist in reducing the child's anxiety and reinforce the strategies they are themselves learning in the treatment. Initial evidence suggests that those in the treatment showed reductions in anxiety disorders over wait-list controls and that these improvements were maintained at one year follow up, indicating the treatment has promise in this younger age group (Hirshfeld-Becker et al., 2010).

If we are to consider CBT as an appropriate anxiety treatment for young children, we should first consider whether the underlying assumptions of CBT hold for young children, as they do for older children and adults. CBT assumes that cognitive biases are related to anxiety in individuals. This assumption forms the basis for the idea that if you help the individual to consider and alter the cognitions present in anxiety-provoking situations the individual's anxiety can be reduced. Such examples of cognitions are attention and interpretation biases. However, as outlined above it is currently unclear whether these cognitions are linked to anxiety in young children. As such, if they are not linked in young children then working to alter their cognitions may do little or nothing for their anxiety, again questioning the appropriateness of the treatment or at least the mechanisms by which improvements are seen. Research that examines whether anxiety related cognitive biases are present in younger children will have implications for whether CBT is a sensible treatment approach for this age group.

1.8.2 Cognitive bias modification procedures.

Cognitive bias modification (CBM) procedures have recently been explored as potential treatments for anxiety in children (Eldar et al., 2012; Shechner et al., 2014; Vassilopoulos & Moberly, 2012) and adolescents (Reuland & Teachman, 2014; Rozenman, Weersing, & Amir, 2011). Within CBM procedures children are trained to alter the direction of their attention (attention bias modification; ABM) or choice of interpretation (interpretation bias modification; IBM) through repetition of trials that reinforce the preferred behaviour. For example, in the ABM procedure of Shechner et al. (2014) children took part in the dot probe task consisting of neutral –neutral trials and disgust-neutral trials, but the dot always replaced the neutral face in the disgust-neutral trials. The idea is to train attention away from the disgust face and encourage attention to the neutral face. In the IBM procedure of Vassilopoulos and Moberly (2012) children were given an ambiguous scenario with a benign interpretation or a threat interpretation of the scenario. Children were asked to choose one interpretation and given feedback as to the correct response, with the correct response being the benign interpretation. Training may make use of a benign alternative to threat, as in the two examples above, or may train attention towards a positive stimuli (Waters et al., 2013) or reinforce positive interpretations (as in Lothmann, Holmes, Chan, & Lau, 2011). Some studies have found CBM procedures result in reductions in anxiety (Eldar et al., 2012; Rozenman et al., 2011; Waters et al., 2013), while other have not (Orchard, Apetroaia, Clarke, & Creswell, 2017; Salemink & Wiers, 2011). Such inconsistencies have raised questions regarding the effectiveness of CBM as a treatment (for example Hallion & Ruscio, 2011; Heeren, Mogoa, Philippot, & Mcnally, 2015; Linetzky, Pergamin-Hight, Pine, & Bar-Haim, 2015; Menne-Lothmann et al., 2014). The advantage of these procedures over CBT for young children is that they are easily administered and make use of associative learning (Lau, 2013) rather than being reliant on the level of cognitive and emotional maturity CBT requires.

Like CBT, CBM procedures assume there is a relationship between cognitive biases and anxiety and that by altering the biases one may be able to alter the level of anxiety. CBM procedures have yet to be applied to young children, but could be adapted (Lau, 2013). However, it is unclear whether there is a relationship between cognitive biases and anxiety in young children. If the relationship is not there then the treatment will not be effective and the procedures may attempt to alter potentially normative biases for this age group. Further investigation of the presence and nature of the relationship between cognitive bias and anxiety in young children will assist in deciding whether such procedures have potential for young children.

1.9 Identifying an Appropriate Age Range.

The relative lack of research focusing on the relationship between cognitive biases and anxiety in young children has been highlighted in the previous sections. Few studies involving children below age 8 were included in a recent meta-analysis of the association between attention bias and anxiety in children and adolescents (Dudeney et al., 2015). Very few studies focusing on young children have been conducted when investigating the association between interpretation bias and anxiety (see section 1.6.1.2.). This highlights that most studies assessing the respective associations between anxiety and interpretation bias and attention bias focus on children aged 8 and above. Similarly, the existing social worries questionnaire is only validated for children aged 8 years and older. Thus, the primary focus of the work in this thesis is on children aged younger than 8 years. Age 4 years was selected as the youngest age of interest for two reasons. Firstly, it is feasible to assess anxiety symptoms in children aged 4. Children show anxiety symptoms from the age of 3 (Egger & Angold, 2006) and assessments are available for this age group in the form of parent reports (Spence et al., 2001) and clinical interviews (Egger & Angold, 2004). If there is relationship between cognitive bias and anxiety or anxiety subtypes to be found in young children they may be only become salient once children are exhibiting anxiety symptoms, i.e., beyond age 3. Secondly, the fundamental developmental skills needed to demonstrate a bias are in place around age 4 and thirdly, age 4 is a reasonable age at which to expect a child to be able to follow instructions, sit and complete a computer based cognitive task.

The second reason for selecting 4 as the younger age limit will now be elaborated upon. The age range of 4 to 8 years will provide a range of ability on developmental factors that may have relevance for cognitive biases. This will make investigation of moderation of the anxiety-bias relationship by developmental factors both possible and theoretically interesting. Various developmental abilities may be required before an attention bias can be demonstrated (Field & Lester, 2010). For example, in line with the inhibition hypothesis (Kindt & Van Den Hout, 2001), sufficient effortful control abilities may need to be in place before an attention bias is evident. Attention control in particular has been implicated as a moderator between attention bias and anxiety (Cowart & Ollendick, 2011). This is because attention control is necessary to inhibit and direct attention, and to selectively attend and disengage from environmental stimuli. Effortful control, which includes attention control, emerges in infancy (Rothbart & Rueda, 2005). Between the ages of 3 and 4 the ability to inhibit behaviour on command remains variable, but at 4 years of age, 90% showed this ability (Jones, Rothbart, & Posner, 2003). From age 7 through to adulthood, performance on the children's flanker task, which captures components of effortful control, is relatively stable (Rueda et al., 2004). Based on this evidence, it seems the fundamentals of effortful control are in place by age 4 and inclusion of children up to 8 years old would allow for variations in development of effortful control across the age group to be taken into account.

Other developmental abilities may need to be sufficiently developed before an interpretation bias can be demonstrated (Field & Lester, 2010b). For example, the ability to disambiguate information. Evidence suggests considerable development in this skill occurs between 4 and 7 years old. If theory of mind is a necessary, but not sufficient condition for understanding ambiguity then it could be suggested that by the age of 5 to 7 children could be showing interpretation bias (Field & Lester, 2010). However, only after 8 are children able to explain their reasoning (Carpendale & Chandler, 1996). Piaget (1950) would suggest that children do not have the cognitive abilities to show interpretation bias until 11 years of age when they have formal operational thinking. However, these propositions are heavily reliant on children being able to verbally explain their rationale. If we look at children's abilities to respond to ambiguity then children at 5 have been able to disambiguate faces and 3 to 4 year olds have been shown to perform tasks with ambiguous material. However, at this age (4 to 7) children may lack good strategies to disambiguate situations for themselves (Beck & Robinson, 2001), while older children may be better able to hold and decide between different possibilities and gather clarifying information (Field & Lester, 2010b). This means that children aged between 4 and 7 years, are starting to deal with ambiguous material making it a potentially sensitive time for the development of interpretation bias. This also indicates that inclusion of children at age 8 years, once their linguistic and cognitive abilities are reasonably well developed, may give us the opportunity to investigate whether these abilities are indeed necessary for the relationship between interpretation bias and anxiety to be evidenced.

As has been outlined above, key cognitive skills that are likely to be associated with attention bias and interpretation bias tasks develop between the ages of 4 and 8 years. Thus, investigating the relationship between cognitive biases and anxiety in this age range would help to fill a neglected gap in the literature. It would also provide insights into how developmental factors such as effortful control may affect anxiety-linked cognitive biases. To fully address this aim, it is imperative that such an investigation considers developmental factors in 2 ways: 1) in the design of the tasks keeping in mind the developmental level of the target age group. By identifying which developmental factors may be influencing *task performance* and measuring these alongside the task their influence can be checked, and 2) by considering which developmental factors may be influencing the cognitive bias-anxiety *relationship* and measuring these alongside the bias and anxiety.

1.10 Aim of the Thesis

It is well-established that two cognitive biases are present in anxious adults and may be present in children: an attention bias where attention is disproportionately allocated to threat, and an interpretation bias, which increases the likelihood of ambiguous stimuli being interpreted as threatening (Field and Lester, 2010a). However, very little research has examined these biases in young children and, as such, the association between anxiety and interpretation/attention bias in young children is unclear. Furthermore, it is not clear how age and development might affect these relationships (Field & Lester, 2010a). There is also evidence of the presence of anxiety subtypes in young children, specifically social anxiety, yet few reliable and valid assessments exist of these subtypes to allow investigation of their stability and development or contribution to the development of anxiety. These are important gaps in the literature because anxiety is prevalent in young children and related to significant negative outcomes in the short and long term. Currently despite anxiety being acknowledged as being common in young children, their treatment options are limited (Cartwright-Hatton et al., 2006). There being a relationship between cognitive biases and anxiety underpins treatments for anxiety such as CBT and CBM procedures. These procedures have the potential for adaption to a younger age range. Yet before they can be considered appropriate for young children the presence of anxiety related cognitive biases in this age range should be clarified. Filling these gaps in the literature will provide more understanding of anxiety in young children and inform development of appropriate treatments.

1.11 Overall Aim and Outline of Papers

The primary aim of this thesis is therefore to examine the association between anxiety and cognitive biases in children, with a particular focus on children aged between 4 and 8 years. A secondary aim is to develop a brief measure of early signs of social anxiety in young children to facilitate future research examining the early development of social anxiety as well as the content specificity of cognitive biases. These aims are realised across four stand-alone papers. The following section outlines the specific questions explored by each paper.

1.11.1 Paper 1: Is anxiety associated with negative interpretations of ambiguity in children and adolescents? A systematic review and meta-analysis.

Information processing models suggest that cognitive biases have a predisposing, causal, and/or maintaining role in anxiety. There is evidence for a relationship between interpretation bias and anxiety in adults but the evidence for a relationship between interpretation bias and anxiety in children and adolescents is equivocal. Given the prevalence of anxiety disorders and associated negative outcomes in children, understanding whether this relationship exists and the nature of this relationship is important. There are methodological sources of variation in studies investigating interpretation bias and anxiety in children and adolescents that may contribute to the inconsistency in findings. Several narrative reviews have examined interpretation bias and anxiety but there has been no systematic, quantitative review of the relationship between interpretation bias and anxiety in children and adolescents and no review has included the influence of potential moderators.

Paper 1 therefore presents a systematic review of research examining the association between interpretation bias and anxiety in children and adolescents. Three hundred and forty-five effect sizes from seventy-seven studies were identified and included in a meta-analysis. Additionally, the paper investigates whether potential population and procedural factors moderate this relationship.

1.11.2 Paper 2: 'Look out Captain, I hear an ambiguous alien!' A study of interpretation bias and anxiety in young children.

As outlined above, there is a lack of research examining interpretation bias in children aged under 8 years. One reason for this is methodological. Current measures of interpretation bias rely heavily on language skills that may not be sufficiently developed in young children. To investigate the relationship between interpretation bias and young children we need tasks that are developmentally appropriate for this age group. Subjective measures should involve simple instructions and involve cognitive abilities already developed within the sample; for example, categorisation of stimuli by valence. One objective measure that may indicate a child's appraisal of valence-ambiguous stimuli is corrugator activity, as measured by facial electromyography (Tottenham et al., 2013). To add to our understanding of child models of anxiety, developmental variables will also be considered as moderators.

Paper 2 investigates if there are differences between children with high and low levels of anxiety in their appraisal of ambiguous tones. A new child friendly task was developed specifically for this study and was completed by a sample of children aged 4 to 8, recruited from the community. The new task also investigated the potential of fEMG, through corrugator activity in response to the tones, as an objective measure of interpretations. To assess the potential influence of development on differences between children with high and low anxiety, age differences in the relationship were assessed and moderation by effortful control. The influence of non-verbal cognitive abilities and linguistic abilities on task performance was also investigated.

1.11.3 Paper 3: Anxiety differences in visual attention to emotional faces in four to 8 year olds.

In the review above, the lack of studies assessing attention bias and anxiety in young children, as well as the potential for using eye-tracking in the assessment of attention bias in young children was demonstrated. A few studies have made use of this method to assess whether visual attention can be used to assess attentional bias in anxious children. However, not many have used this technique in young children. Investigating anxiety related differences in attention bias through this technique would be especially useful in this population as the skills needed to take part in other methods of assessing attentional bias, for example the dot probe task, may not be sufficiently developed in young children.

Paper 3 uses a new child-friendly task to assess anxiety related differences in attention bias with children recruited from the community. Eye-tracking was used to record gaze during a free-viewing paradigm to assess whether children who were high or low in anxiety were different in the time they spent looking at angry vs neutral and happy vs neutral faces. The continuous nature of the data available from eye-tracking was captured in by using growth curve analysis. Anxiety differences in visual attention to initial looks to emotional faces were examined. The influence of non-verbal and verbal cognitive abilities on the time course of visual attention to the faces was investigated and age and effortful control were investigated as moderators.

1.11.4 Paper 4: Young children have social worries too: Validation of a brief parent report measure of social worries in children aged 4–8 years.

As highlighted above, social anxiety has been shown to be a distinct (Shamir-Essakow, Ungerer, & Rapee, 2005; Spence et al., 2001) and present subtype of anxiety in young children, with an estimated prevalence rate of 10.7% in 4 to 8 year olds (Paulus, Backes, Sander, Weber, & von Gontard, 2015). However, little is known about the stability and development of social anxiety from early childhood. Investigation of social anxiety in young children may assist in understanding the development of anxiety disorders more broadly. There is currently no stand alone, brief parent report measure of social anxiety that asks about observable behaviours to make such investigations possible.

Paper 4 addresses the lack of brief parent report measure of social anxiety for young children by adapting the Social Worries Questionnaire (Spence, 2003) into the Social Worries Anxiety Index in Young Children (SWAIY) for use with children aged 4 to 8 years and assessing its reliability and validity. To achieve this the content validity, test-retest reliability, convergent validity, internal reliability and factor structure of the SWAIY was assessed on responses from a community sample of 169 parents of children aged 3.92 to 8.92 years of age completed at 2 time points (time 1 n = 169) and time 2 (n= 106) 2 weeks. The factor structure at Time 1 was examined using confirmatory factor analysis on the data from Time 2. The psychometrics of the SWAIY are discussed with relation to its potential use within research to enhance our understanding of social anxiety within young children.

1.12 Summary

Information processing models of anxiety implicate cognitive biases as having a role in the cause and or maintenance of anxiety. When considering anxiety in children such models also need to consider if and how development influences the relationship between cognitive biases and anxiety. To better understand the development of anxiety in children it is important to establish if, and when, a relationship between these biases and anxiety is present. There is evidence of a small, but robust relationship between attention bias and anxiety in children and adolescents. However, the literature is equivocal regarding whether a relationship between interpretation bias and anxiety is present in children and adolescents. Moreover, few studies have investigated the relationship between these biases and anxiety in young children aged below 8 years; this makes it difficult to understand whether children's development plays a role in both the acquisition of anxiety and of cognitive biases. Evidence indicates that anxiety is prevalent in children and has both short term and long term consequences. Social anxiety has also been identified as an anxiety subtype that is present and may place children at risk of further emotional health problems. However, little is known about the stability and development of social anxiety in young children, or how it contributes to the development of other anxiety disorders in young children.

Collectively the four papers in this thesis aim to examine the association between anxiety and cognitive biases in children, with a particular focus on children aged between 4 and 8 years and to develop a brief measure of early signs of social anxiety in young children. Specifically, the following papers respectively aim to 1) bring clarity to the current literature regarding the relationship between interpretation bias and anxiety in children and adolescents, 2) investigate whether novel child friendly tasks making use of objective measures to assess interpretation bias and attention bias respectively can demonstrate differences in high and low anxiety groups in 4 to 8 year olds, 3) investigate whether development influences the relationships found by these novel tasks through examination of moderation by developmental proxies and 4) provide a valid and reliable means by which social anxiety can be assessed in 4 to 8 year olds. The extent to which the four papers collectively achieve the aims of the thesis will be discussed in the final chapter.

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Chapter 2. Paper 1: Research Review: Is anxiety associated with negative interpretations of ambiguity in children and adolescents? A systematic review and meta-analysis

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Please note Tables and Figures, and Appendices referred to in the Paper can be found at the end of the manuscript after the references as per the published article.

Abstract

Background

The tendency to interpret ambiguity as threat ('negative interpretation') has been implicated in cognitive models of anxiety. A significant body of research has examined the association between anxiety and negative interpretation, and reviews suggest there is a robust positive association in adults. However, evidence with children and adolescents has been inconsistent. This study aimed to provide a systematic quantitative assessment of the association between anxiety and negative interpretation in children and adolescents.

Methods

Following systematic searches and screening for eligibility, 345 effects sizes from 77 studies were meta-analysed.

Results

Overall a medium positive association was found between anxiety and negative interpretation in children and adolescents ($\hat{d}$ = 0.62). Two variables significantly moderated this effect. Specifically, the association increased in strength with increasing age and when the content of ambiguous scenarios matched the anxiety subtype under investigation.

Conclusions

Results extend findings from adult literature by demonstrating an association in children and adolescents with evidence for content specificity in the association. Age effects imply a role for development. Results raise considerations for when and for whom clinical treatments for anxiety focusing on interpretation bias are appropriate.

Keywords

Interpretation bias, Anxiety, Children, Adolescents, Development, Content Specificity

Anxiety disorders are amongst the most prevalent mental disorders, affecting around 6.5% of children and adolescents worldwide (Polanczyk, Salum, Sugaya, Caye, & Rohde, 2015). Anxiety in children has a negative impact on family, educational and social functioning (Settipani & Kendall, 2013; Velting & Albano, 2001) and is associated with future suicidal ideation and depression (c.f. Benjamin, Harrison, Settipani, Brodman, & Kendall, 2013).

In cognitive models (e.g. Kendall, 1985), anxiety is viewed as an emotional, behavioural and cognitive state that is underpinned by threat-related schemas. These schemas are activated and guide cognitive processing in response to threat or the potential for threat. When an individual has an overactive threat schema, negative cognitive biases result. Cognitive biases can occur at various stages of information processing including attention and interpretation (Muris & Field, 2008a). This review focuses specifically on negative interpretation bias, i.e. a tendency to interpret ambiguity in a threatening or negative way. This bias has been implicated in cognitive-behavioural models of anxiety as having a predisposing (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Eysenck, 1992; Eysenck, 1997; Williams, Watts, MacLeod, & Mathews, 1988; Williams, Watts, MacLeod, & Mathews, 1997), causal (Beck & Clark, 1997), and/or maintaining (Mogg & Bradley, 1998; Bar-Haim et al., 2007; Eysenck, 1992; Eysenck, 1997; Williams et al., 1988; Williams et al., 1997) role.

To date, three narrative reviews have been conducted that examine the association between anxiety and interpretation bias in children and young people, covering literature up to 2008 (Blanchette & Richards, 2009; Castillo & Leandro, 2010; Muris & Field, 2008). Taken together these reviews tentatively conclude that anxious children and adolescents are likely to show a negative interpretation bias. They also highlight the inconsistency in findings across studies and several unanswered questions. No previous reviews have included a meta-analysis or claimed to be systematic and none directly tackle the issue of moderators. Thus, the aim of the present paper is to conduct a systematic review and meta-analysis of the association between anxiety and negative interpretation bias in children and adolescents, taking into account a range of potential moderators.

Studies vary on a range of factors that may moderate the association between negative interpretation and anxiety in children and adolescents. These factors can be grouped together as “Population” factors, those that relate to the participants in the study (for example, age, whether the focus of the study was a clinical or non-clinical sample); and “Procedural” factors, those that relate to the way in which the study was designed and conducted (for example which task was used to assess interpretation bias and who the informant for the anxiety measure was). Careful consideration of moderators is important as it may explain some of the inconsistencies apparent in the literature and provide important insights for treatment. The following sections briefly outline the relevant population and procedural variables that will be assessed as moderators in this review.

Population Variables

Population Focus. Studies vary in whether they focus on community or clinical populations. Here we include all studies examining the association between anxiety and interpretation bias, including those that focus on clinical samples and those that focus on community samples. Larger effect sizes may be expected in studies using a clinical vs. control design than a high vs. low community sample design given that the difference in anxiety levels between groups will typically be greater in the former. For the same reason, a larger effect size would be expected when a clinical group are compared to a screened ‘non-anxious’ control group as opposed to an unscreened community sample or a different clinical population (Bar-Haim et al., 2007).

Anxiety Subtype. Studies with both community and clinical samples vary in terms of whether they look at general anxiety or a specific subtype of anxiety (e.g. social anxiety or total anxiety score). If negative interpretation bias is a feature of a specific type of anxiety then effect sizes will be stronger in some studies than others, dependent on the anxiety subtype considered.

There are also inconsistent results depending on whether the focus is on trait/state anxiety. Although only a few studies have examined state anxiety, there is evidence that both trait and state anxiety may be associated with a negative interpretation bias. However findings are inconsistent (e.g. Muris, Rapee, Meesters, Schouten, & Geers, 2003; Salemink & Wiers, 2012).

Demographics. Participant age and sex also vary widely across studies, but the effect of these sample characteristics is unclear. Age is sometimes considered as a covariate or moderator in studies examining interpretation bias and anxiety with mixed results (e.g.

Blossom et al., 2013; Waite, Codd, & Creswell, 2015; Waters, Zimmer-Gembeck, & Farrell, 2012). To our knowledge, no study has assessed sex within the context of this association.

Comorbidity. Clinical studies vary in whether and how they deal with comorbid disorders; participants with comorbid diagnoses may be included, excluded or comorbidity may not be assessed. As negative interpretation bias has also been found in other common comorbid psychiatric disorders such as depression and externalising disorders (Mathews & MacLeod, 2005; Reid et al., 2006) (although see e.g. Epkins, 1996; Leung & Wong, 1998), inclusion of those with co-morbid disorders may result in the association between negative interpretation bias and anxiety appearing stronger than it would in a 'pure' anxious group.

Procedural Variables

Type of Task. Research assessing interpretation bias in children and young people typically uses one of two task formats. Ambiguous scenario tasks (Barrett, Rapee, Dadds, & Ryan, 1996) are the most commonly used. Here participants are presented with ambiguous social and non-social vignettes (via written, auditory, pictorial, or a combination, stimuli) and asked to either choose an ending for each vignette from a list or to generate their own. An alternative task is based on lexical knowledge. For example, homophones and/or homographs that have a threat and non-threat interpretations such as berry/bury and sink (kitchen)/sink (boat) (i.e. Gifford et al., 2008) might be used. Typically in this type of task, interpretation is evaluated by asking participants to select an image that matches the word they heard or to use the word in a sentence. Even within the same study inconsistent results have been found between these different tasks (e.g. Waters, Wharton, Zimmer-Gembeck, & Craske, 2008). The extent to which the nature of the task influences the association between anxiety and interpretation bias in children and young people remains unclear.

Response formats. Both ambiguous scenario tasks and lexical tasks designed to measure interpretation bias may use open or forced choice response formats, or create a composite of the two. These response formats require active and passive information generation respectively, which may influence responses and subsequent conclusions regarding bias (Ozuru, Best, Bell, Witherspoon, & McNamara, 2007; Ozuru, Briner, Kurby, & McNamara, 2013).

Dependent Variable. Studies also vary in the dependent variable used to capture interpretation bias. For example, in an ambiguous scenarios task: threat interpretation, threat frequency, threat threshold or a composite of all three may be used (e.g. Muris et al., 2000). It is possible that some measures better capture anxiety-related interpretation biases than others, which could explain some variance in effect sizes reported across the literature.

Type of Scenario. The ambiguous scenarios task also varies by the type of scenario assessed (e.g. social, non-social, physical or a response to a range of scenarios to create 'general scenarios'). This is not typically true of lexical tasks as they are limited by the words available in the English language that possess the required properties (homograph/homophone).

Content Specificity. According to the content specificity hypothesis, (Beck,1976), the relationship between interpretation bias and anxiety is expected to be stronger when the interpretation content matches the anxiety subtype. The majority of studies examining interpretation bias and anxiety in young people do not examine content specificity. However, as outlined above, some ambiguous scenario tasks use specific types of scenario that align with specific subtypes of anxiety (e.g. social scenarios/social anxiety). To date there has been no systematic review of whether the bias-anxiety association is stronger when there is a content match than when there is not.

Anxiety Measure Informant. The individual providing information about the young person's anxiety also varies across studies: it may be a teacher, parent, or the child/adolescent participant. This may affect the strength of the association between bias and anxiety, particularly given that studies differ on whether the same or different informants report on bias and anxiety.

Aims and scope

The overall aim of the present study is to provide a systematic quantitative assessment of the relationship between negative interpretation and anxiety in children and adolescents, and to evaluate potential moderators of this relationship. The review takes a broad scope with regards to anxiety and includes research that focuses on clinical anxiety as well as research focused on normal individual variation in anxiety levels, both trait and state. Data were drawn from studies with a range of methods including, but not limited to experimental, cross-sectional, and longitudinal designs that adhered to our eligibility criteria.

Methods

Eligibility Criteria

Hierarchical eligibility criteria to screen abstracts and full texts for inclusion were:

1. *The paper must be available in English.*
2. *The paper must be an original study, not a review.*
3. *The paper must investigate a human child, adolescent or youth population.* Papers were accepted that reported a maximum age = 21 years and mean age < 18 years.
4. *Primary focus must be on typically developing children*. Children with atypical development were excluded as these children may have particular propensities to anxiety and/or may have particular patterns of information processing that could influence their interpretation of ambiguity.
5. *A sound and standardised measure of anxiety or fear should be used for all participants, including clinical and subclinical samples.* The review includes studies focused on clinical and subclinical anxiety and fear, as well as specific subtypes of anxiety (e.g. social anxiety, separation anxiety, generalised anxiety). To be included papers must have utilised a sound and standardised measure of the type of anxiety in question i.e. interviews must be semi-structured or structured, and completed by child/adolescent, parent or both. Anxiety questionnaires could have been completed by either child, parent or teacher, but had to show internal consistency of at least 0.7 and evidence of construct validity. Finally, the age range of participants must be appropriate (+ or – 1 year of the suggested age range) for the measure used.
6. Papers were included where a correlational or between-groups design was used. Where participants were pre-screened into high and low anxiety groups: *Papers should determine high anxiety by either: i) a clinical diagnosis via a standardised diagnostic interview; ii) All participants in high anxiety group must score more than 1SD above a normative mean on a standardised measure of anxiety or fear; iii) All participants in the high anxiety group must score above a cut-off recommended by the authors of the measure used (sensitivity analysis must have been conducted to validate this cut-off). No differences in age and sex should have*

been found between the high anxiety group and the corresponding comparison group. Where these criteria were not met, papers were included only if a continuous measure of anxiety could be obtained to produce a correlation.

7. *The sample should not represent a restricted range of anxiety.* Those including only clinical/high anxious or at risk samples were excluded.
8. *Papers using cognitive bias modification are eligible only if a pre-modification measure of the relationship between interpretation bias and anxiety was reported*, and, if so, this effect size was extracted for this the meta-analysis.
9. *The measure of interpretation bias captured the extent to which participants interpreted ambiguity as threatening or negative and/or the child/adolescents readiness to perceive threat i.e. Reduced Evidence for Danger (RED).*[1]
10. *Where open-ended interpretations of ambiguous scenarios were coded, inter-rater reliability must be at least .7 for inclusion,* unless open-ended responses were significantly associated with forced choice answers.
11. *Full text access must be available to be able to code and extract all the information necessary for the meta-analysis*.
12. *Appropriate statistics regarding the relationship between interpretation bias and anxiety should be available*. If these were not immediately accessible from the paper authors were contacted.

Information Sources

Studies were identified through searches on the databases: PubMed, Psych Info/Psych Articles, Web of Science, Google Scholar, NHS Evidence database. The searches were conducted on all papers from 1990, when the first studies examining interpretation bias and child anxiety were published, to the present day. A check for papers prior to 1990 was conducted and no papers conforming to the age limit were identified. Searches were conducted on 6th August 2015. Additionally, the references of previous reviews (i.e. Blanchette & Richards, 2009; Castillo & Leandro, 2010; Muris & Field, 2008) and all accepted papers were checked for relevant papers. Finally, first authors and

[1] After discussion between authors, any paper utilising the Children's Negative Cognitive Errors Questionnaire (Leitenberg, Yost, & Carroll-Wilson, 1986) were excluded from the analysis given the interpretation of ambiguity could not be directly extracted from the measure.

corresponding authors of accepted papers were contacted to request any relevant unpublished work.

Search

Two sets of search terms were used. One set of terms focused on interpretation bias and anxiety, including anxiety subtypes, while the second set specifically identified papers using cognitive bias modification (CBM) that may have been missed by the first search terms. The exact search terms used can be found in Appendix B.

Study Selection

Study selection procedures adhered to PRISMA guidelines (Liberati et al., 2009). To select studies, abstracts from all sources were first screened against the eligibility criteria, followed by full texts. A paper could be excluded at any stage of the screening process on the basis of a 'no' response to any of the eligibility criteria; the first criterion that was not met was recorded as the reason for rejection. Where criteria were coded as unclear (in the absence of any 'no' codes) at the abstract stage, papers went through to full text screening. Where particular criteria were not applicable they were not coded. Those papers that were accepted via the full paper screening were then coded according to the coding criteria (see below and Table A1, Appendix A), and appropriate data were extracted.

Data Collection Process

A post-graduate student piloted the eligibility criteria and search terms and eligibility criteria were altered accordingly (specifically the word "human" was added to criteria 3 regarding age of participants to ensure only papers on human populations were accepted). After completion of the piloting two coders (both post-graduate students) checked the first 208 abstracts against the eligibility criteria. On the basis of these 208 abstracts a high level of inter-rater reliability between coders was found for reject/accept decisions ($\kappa = .91$, $p < .001$). The remaining abstracts were coded by the first coder.

To ensure reliability of the criteria for full paper screening, the same two coders both assessed 20 full texts against the eligibility criteria. Agreement between the two coders was found on 90% of the papers[2]. Any disagreements between coders at either stage

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[2] There were no papers where coder 1 accepted and coder 2 rejected resulting in an empty cell so it was not possible to calculate a kappa value.

of the screening were discussed with the first author to reach a consensus. The first coder then coded the remaining full texts. Once all the full texts had been screened, the first author then extracted the relevant statistics (effect sizes; sample sizes; means and standard deviations where effect sizes were not available; and demographic information including, mean age, and percentage of males in the sample) from the accepted full texts.

Data Items

Papers were coded for a range of sample characteristics and moderator variables. A detailed description of coding criteria for each characteristic and level of all moderators is provided in Table A1, Appendix A. Where papers had investigated potential mediators or moderators of the association between negative interpretation and anxiety, the moderator/mediator of interest was coded along with the resultant associations with anxiety and negative interpretation separately.

Risk of Bias Within Individual Studies

Attempts were made to reduce risk of bias within the studies included in the meta-analysis in two ways. Firstly, studies were only included if they adhered to our strict eligibility criteria regarding methods. Secondly, characteristics related to quality such as control group, measures used, and whether the study was published or unpublished were included as moderators within the analysis to investigate whether these affected results.

Summary Measures

Cohen's *d* was extracted for all papers included in the meta-analysis. Where Cohen's *d* was not available for the association of interest, means and standard deviations were used to compute *d*. If these were also not available, *t*-statistics and degrees of freedom were used. Where studies reported a correlation *r*, this was converted to Cohen's *d* using the formula described by Rosenthal (1994) on p.239. Effect sizes were coded in the same direction so that a positive *d* always indicated that those with higher anxiety showed greater negative interpretation. Where correlations were included, positive correlation coefficients always indicated that as anxiety/fear scores increased so did negative interpretation scores prior to transformation to *d*.

Planned Method of Analysis

Most studies yielded more than one effect size due to multiple outcome measures being used or the same outcome being taken at multiple time points. To account for the dependency this created amongst effect sizes within studies a multi-level approach was used, in which effect sizes (level 1) were nested within studies (level 2). Effect sizes were allowed to vary across studies as a random effect, and moderators were treated as fixed effects. The model fitted is described by:

$$d_j = \gamma_0 + \gamma_1 Z_{1j} + \gamma_2 Z_{2j} + \cdots \gamma_p Z_{pj} + \mu_j + e_j$$

Which states that effect size, *d*, in study *j* are predicted from the mean effect size across studies, γ_0, study characteristics, $Z_1 \ldots Z_p$, and their associated parameter estimates, $\gamma_1 \ldots \gamma_p$. The deviation of the effect in study *j* from the overall mean is reflected in the residual, μ_j, which is assumed to have a normal distribution with variance σ_μ. The sampling error for study *j* is reflected in e_j, which is have a normal distribution with variance σ_j. When no moderators are included, this model reduces to:

$$d_j = \gamma_0 + \mu_j + e_j$$

Which states that the effect, *d*, in study *j*, is equal to the mean effect across studies γ_0, its deviation from that mean, μ_j, and the sampling error for that study, e_j.

The models were fitted using R 3.2.4 (R Core Team, 2015) using the rma.mv() function in the metafor package (Viechtbauer, 2010), data processing was conducting using the reshape (Wickham & Hadley, 2007) and car packages (Fox & Weisberg, 2011), and sensitivity analysis was conducted with the weightr package (Coburn & Vevea, 2016). To be included as a level within a moderator analysis at least two effect sizes had to be available.

Funnel and forest plots of effect sizes aggregated within studies (so that each study was represented by one effect size) were used to assess outliers, as well as Cooks distance where influence was assessed by checking whether dfbetas were greater than one (Wolfgang & Cheung, 2010).

Risk of Bias Across Studies

In addition to reducing publication bias by requesting and including unpublished work, publication bias was also assessed using a funnel plot with statistical tests of asymmetry.

Additional Analysis

Sensitivity analyses were conducted using the trim and fill method (Duval &

Tweedie, 2000a, 2000b) and a priori weight functions (Vevea & Woods, 2005).

Results

Study Selection

Six authors were contacted as the information required to calculate an effect size was not available in the paper. Three authors were able to provide the necessary information and the studies were therefore included. After the complete selection process, a total of 77 studies representing 75 samples were included in the meta-analysis, resulting in the inclusion of 345 effect sizes (see Figure 1 for flow chart of numbers screened and accepted at each stage of the selection procedure).

Study Characteristics and Results from Individual Studies

Following assessments, no studies yielded an effect size that was an outlier. Therefore, the total sample included 11,507 children and adolescents with an average age across studies of 11.19 years old (*SD* = 1.28, min = 2, max = 22). Eighteen studies (16 samples) focused on anxiety and interpretation bias within clinical samples and 57 studies focused on anxiety and interpretation bias within community samples. Table 1 lists all studies included within the meta-analysis and their characteristics. Aggregated effect sizes within each study, along with their confidence intervals, can be seen in Figure 2. Note that the statistics in the following sections are from a multi-level model that factors in the dependency between effect sizes from the same study, whereas the overall effect size in Figure 2 is based on a model in which effect sizes within studies are aggregated so that each study contributes only 1 effect size.

Synthesis of Results

The overall meta-analysis yielded a population estimate of the association between anxiety and negative interpretation in children and adolescents of $\hat{d} = 0.62$ of a standard deviation (Table 2). There was significant variation between effect sizes, $Q = 1452.28$, $p < .001$.

Table 2 shows all moderation analyses, and separate meta-analyses for each level of the moderator, as well as their respective confidence intervals (see Appendix A for a list of all moderators and their definitions). The first level listed under the title of each moderator indicates the reference group used in the moderation analyses.

Moderation by population variables. As shown in Table 2, variation amongst effect sizes was not accounted for by population focus. Therefore, the effect sizes from clinical and community samples were combined for all remaining moderation analyses.

There were not enough effect sizes (k ≤ 1 for all levels except social anxiety and separation anxiety) available to conduct an analysis across clinical anxiety disorders. As there were enough effect sizes comparing social anxiety (k = 21) and separation anxiety (k = 2) and other anxiety disorders we included two additional levels in the planned overall control group analysis: 'Not social anxiety' and 'Not separation anxiety' respectively (see Table 2; for descriptions of these levels see Table A1, Appendix A). Variation was not found to be accounted for by control group. Given these results, the associations with "Not social anxiety", the "Not separation anxiety" or the "Clinical Externalising" control groups were excluded from the remaining analyses to allow a clear picture of the association between negative interpretation and anxiety in children and adolescents (for descriptions of these levels see Table A1, Appendix A).

Variation amongst effect sizes was not significantly accounted for by the inclusion/exclusion of comorbidity with another anxiety disorder or comorbidity with another psychiatric disorder (Table 2). Further, variation amongst effect sizes was not accounted for by anxiety subtype, (descriptors of all moderators and their respective levels can be found in Table A1, Appendix A). Nor was variance in effect sizes accounted for by sex, b = -.0003 [-.009, .009], p = .940. In contrast, age significantly predicted effect size magnitude, b = .06 [03, .10], p < .001; with increasing age, the association between negative interpretation and anxiety in children and adolescents also increases. To provide greater insight into the significant moderation by age, mean age per study was plotted against the study's corresponding aggregated effect size (see Figure 3).

Moderation by Procedural Variables. As Table 2 indicates, variation amongst effect sizes was not significantly accounted for by task used to assess interpretation of ambiguity, open vs. forced choice responses, scenario type, the dependent variable assessed or anxiety measure informant. However, content specificity was a significant moderator (see Table 2); when the scenario content matched the anxiety subtype, the association between negative interpretation and anxiety was larger than when they did not match.

Risk of Bias Within Studies

Whether the study was unpublished (15 samples, 64 effect sizes) or published (61 samples, 254 effect sizes) did not significantly account for variation amongst effect sizes *Q* = 2.99, $p = .0838$. Individual meta-analyses indicate that a robust effect size was present amongst both published ($\widehat{d} = 0.63$ [.55, .72], $p < .001$) and unpublished ($\widehat{d} = 0.54$ [.27, .80], $p < .001$) work.

Risk of Bias Across Studies

To reduce publication bias through the inclusion of unpublished works, 58 researchers were contacted (4 could not be contacted) and 70% responded to our email request. Of these, 21 authors provided additional unpublished manuscripts or data resulting in 29 further studies assessed for eligibility, 24 were accepted (since this request ten of these papers have been either published or are under review at the time of writing, as reflected in the references in Appendix C).

The funnel plot to assess publication bias was found to be asymmetrical ($\tau = .21$, $p = .0072$; $z = 3.30$, $p < .001$), this appears to be mainly driven by three studies with large effect sizes but small sample sizes. Studies with small samples and negative effects were absent, hence the asymmetry.

Additional Analysis

The sensitivity method, trim and fill, indicated that 15 more studies would be required to satisfy symmetry. If these extra studies were entered with a *d* of 0, the association between negative interpretation and anxiety would be only slightly smaller ($\hat{d} = .51$, p < .001). Following Vevea & Woods (2005) a pre-specified sensitivity analysis was conducted using a priori weight functions. The estimate from the overall meta-analysis proved to be quite robust, suggesting publication bias is unlikely to be an important influence on the results (adjusted model estimates ranged from $\widehat{d} = .51$ - .61).

Discussion

Summary of Evidence

Our meta-analysis indicated that there is a medium sized overall association between negative interpretation and anxiety in children and adolescents, and that this effect is robust across clinical and community samples as well as across comparison groups for clinical samples. There was significant heterogeneity across studies, which was partially accounted for by child/adolescent age and whether the content of the interpretation-task matched the specific subtype being assessed.

The overall findings are consistent with adult reviews on the association between interpretation bias and anxiety (Blanchette & Richards, 2009; Mobini, Reynolds, & MacKintosh, 2013) and the previous narrative reviews of the child and adolescent literature (Muris & Field, 2008). There is no equivalent meta-analysis assessing the association between negative interpretation and anxiety in adults, therefore as yet the effect sizes cannot be compared. However, to give some context, the population effect size estimate of $\hat{d}$ = 0.62 is larger than that found between anxiety and attention bias in children and adolescents ($\hat{d}$ = 0.21; Dudeney, Sharpe, & Hunt, 2015).

Evidence for an Age effect. The results indicated that as age increases the association between negative interpretation and anxiety increases in strength. Dudeney et al. (2015) also found age effects in their meta-analysis of attention bias and anxiety in children and adolescents. Taken together, these findings indicate that age/development may moderate the association between anxiety and cognitive biases more broadly.

The analysis presented in Figure 3 indicates a positive linear relationship between the magnitude of the effect size and age, however it is important to note that the vast majority of studies included had a participant mean age above eight years. There are very few effect sizes available for children below eight years old (*Nstudies* = 4, k = 9), with none available for children between six and eight years old. This limits the conclusions that can be drawn about interpretation bias and anxiety in young children which is a noteworthy omission as anxiety symptoms causes significant impairments in children as young as three and anxiety disorders are as common in younger as older children (Egger & Angold, 2006).

Developmental factors, such as the ability to inhibit attention to threat (inhibition hypothesis; Kindt & Van Den Hout, 2001) and regulatory control (Salemink & Wiers, 2012) may moderate the association between negative interpretation and anxiety in adolescents and underpin age effects (see Field & Lester, 2010a, b for a more detailed discussion of potential moderating developmental factors). We were only able to investigate age as a proxy for development as, to date, there is a paucity of studies investigating the influence of specific developmental factors on the association between negative interpretation and anxiety. Another consideration is that findings may reflect age-related differences in task *performance* rather than information processing per se (Field & Lester, 2010a). If younger children have difficulty understanding and completing the task as intended, this will likely lead to underestimated associations between negative interpretation and anxiety. In order for results from tasks to be reliable, the skills necessary for task completion must be sufficiently developed (Brown et al., 2013). Moving forward, it will be important for interpretation bias tasks to be designed in a developmentally sensitive way with studies ideally including assessments of relevant developmental factors alongside interpretation bias and anxiety.

Evidence for Content Specificity. The finding that there was a larger association between bias and anxiety when anxiety subtype and scenario content matched than when they did not match provides evidence for content specificity in children and adolescents. Such evidence is in line with the cognitive specificity hypothesis (Beck, 1976) and adult reviews that have concluded that there is an association between emotions and mood-congruent interpretation biases (Blanchette & Richards, 2009). Our results extend this finding to children and adolescents.

It is important to consider whether this finding relates to all anxiety disorders. Where studies had examined content specificity it was almost always for social anxiety with interpretation of social versus non-social scenarios. Therefore, it would be premature to suggest that this evidence for content specificity applies across anxiety disorders. Furthermore, this analysis is based upon primary anxiety diagnoses or anxiety symptoms and it is therefore unclear how the presence of comorbid anxiety disorders affect biases.

Clinical Implications. The moderate overall association between anxiety and negative interpretation confirms that it may be appropriate for anxiety treatments to include some focus on negative interpretation, at least in older children and adolescents. The finding that age significantly moderated the association between anxiety and negative interpretation suggests that, with age, the processing of ambiguity may become increasingly important as a focus within anxiety treatments and may be an important treatment target for adolescents with elevated anxiety. On the other hand, targeting negative interpretation may not be so central to the treatment of anxiety in younger children: for example, Thirlwall, Cooper, and Creswell (2015) found that for seven to 12 year olds undergoing parent guided cognitive behavioural therapy, child threat interpretation decreased from pre to post-treatment in both treated and wait list groups, and this change was not associated with recovery from primary anxiety diagnosis. It is possible that there are interactions between age and other moderating variables that would assist in elaborating on the clinical implications of the age effect. For example, age may interact with a match between scenario and anxiety type whereby focusing on scenarios matching the child's anxiety in treatment may only be/be more appropriate for a particular age group. However, a lack of power in this study meant investigations of such interactions was not possible and would be an important consideration for future research.

The moderation by a match between scenario and anxiety subtype suggests targeting interpretations related to the child/adolescent's specific anxiety diagnosis may prove most efficacious. However, three things should be noted when considering the clinical implications of results. First, while the meta-analysis did find a larger association between interpretation bias and anxiety when there was a match between scenario content and anxiety subtype, an association was still present when there was no match. This suggests that the targeting of interpretations, regardless of whether they do or do not reflect the anxiety subtype, may still be appropriate in treatment. Second, it is unclear whether age/development influences content specificity; it may be that targeting interpretations related to anxiety subtype may be more appropriate for some ages than others. Finally, the present findings are entirely based on cross sectional data and it is important to keep in mind that the *causal* relationship between negative interpretation and anxiety has not been confirmed by the present results. While experimental studies were included, effects sizes were only taken from associations at a single time point, as per the focus of this review. They are therefore, subject to the same issues, that unobserved confounding variables might account for the associations, that apply to correlational designs. Whether interpretation bias and anxiety are causally related and whether associations are unidirectional or reciprocal remains unclear. Hallion & Ruscio (2011) and Van Bockstaele, Verschuere, Tibboel, De Houwer, Crombez, & Koster's (2013) both found evidence to suggest a modest causal relationship between cognitive biases and anxiety, going from the bias to anxiety, among adults. Some studies with children and adolescents have also shown that successful manipulation of interpretation (using Cognitive Bias Modification of Interpretation; CBM-I) is associated with changes in anxiety and fear (Lau, Belli, &

Chopra, 2013; Lau, Pettit, & Creswell, 2013; Vassilopoulos, Banerjee, & Prantzalou, 2009), consistent with a causal pathway. However, a recent meta-analysis concluded that changes in interpretation bias caused by CBM paradigms did not significantly affect symptoms of anxiety in children (Cristea, Mogoase, David & Cuijpers, 2015). Thus, there is scope for further work to examine the exact interplay between biases and anxiety and the conditions under which a causal association is found. The association between interpretation and attention biases is also unclear, with the majority of cognitive bias research focusing on one or other of these biases. It is possible that both biases share the same processing mechanism (Williams et al., 1997) or that one may directly influence the other (Hirsch, Clark, & Mathews, 2006), for example, attention bias may have a cascading influence on interpretation bias (Daleiden & Vasey, 1997; Muris & Field, 2008b; White, Suway, Pine, Bar-Haim, & Fox, 2011). Future research capturing the interaction between attention and interpretation bias in child anxiety over time would be beneficial. Furthermore, extending cognitive bias research to consider other biases such as confirmation bias may be a useful avenue for future research with a recent study suggesting a possible reciprocal relationship between bias and anxiety in children (Remmerswaal, Huijding, Bouwmeester, Brouwer, & Muris, 2014).

Strengths and Limitations

This meta-analysis is the first to provide a systematic quantitative investigation of the size of the association between negative interpretation and anxiety in children and adolescents as well as the first to investigate whether particular variables influence this association. Quantitative investigations of publication bias suggest that results are unlikely to indicate a positive association where there is none. Also 24 unpublished manuscripts/datasets were accepted from our request for unpublished work. The lack of significant moderation by publication status indicated that the effect size was robust, and not significantly different, across published and unpublished studies

It should be noted that some planned moderation analyses for population variables could not be conducted. It was also not possible to assess moderation by inclusion or exclusion of those with comorbid depression because there were not enough effect sizes present within the excluded level ($k = 1$). In addition, we chose not to conduct an analysis comparing state vs. trait anxiety specifically because of the large discrepancy in numbers of effect sizes available for each level (state anxiety level (k = 6), trait anxiety level (k = 203)). However, the moderation analysis by anxiety subtype included state anxiety and no significant difference in effect sizes was found across subtype. It is also important to note that the moderation by comorbid anxiety disorders may have been underpowered to detect a difference between the levels due to the small number of effect sizes within the "excluded" level (k = 5) ("included" level, k = 77). However, inspection of the effect sizes shown in Table 2 support the lack of significant difference found by this moderation analysis.

The meta-analysis was powered to investigate its main aims, but it is important to note that few studies and effect sizes were included in some analyses affecting the generalizability of findings and some moderation analyses may have been underpowered to find an effect. This is particularly relevant to the analysis of whether effect sizes vary across clinical disorders and across different control groups. Therefore, conclusions from these analyses may not be generalisable beyond this meta-analysis and may warrant further investigation. The issue of power is also relevant to levels of certain moderators that contained a small number of studies. Specifically, the moderator levels of concern are identified by a superscript 'c' in Table 2. Should more effect sizes become available from new studies these moderation questions may be revisited.

To ensure a focused review, we did not examine the potential association between anxiety and positive interpretation or distress ratings. There is some evidence from adults, particularly within social anxiety, that the difference in interpretation bias between anxious and non-anxious individuals may be a *lack* of a positive bias (Gutiérrez-García & Calvo, 2014; Moser, Huppert, Foa, & Simons, 2012). Amongst the studies accepted for this meta-analysis seven suggested that there was no association between anxiety and positive interpretations (Bögels et al, 2009; Dodd, 2012; Klein et al., 2014; Levin 2008; Miers et al, 2008; Schnieder, 2009). However, in line with adult studies, three found non-anxious children rated positive outcomes as more likely than anxious children (De Hullu, 2012; Haller, Raeder, Scerif, Cohen Kodash, & Lau, 2016; Pile & Lau, 2015). Distress ratings, from ambiguous scenarios tasks, were not included amongst the dependent variables in this meta-analysis because it did not conform to our operationalisation of negative interpretation. However, anticipated distress has been found to be associated with anxiety in children (Creswell & O'Connor, 2006; Marques, Pereira, Barros, & Muris, 2013; Vassilopoulos & Banerjee, 2012; Waters et al., 2008). Although beyond the scope of the present meta-analysis, a thorough investigation of whether anxious children and adolescents show a lack of positive interpretation bias, and/or experience elevated anticipated distress when faced with ambiguous situations, may provide further insight into how anxious children and adolescents process ambiguity.

Conclusion

This meta-analysis provides the first quantitative systematic investigation of the association between negative interpretation and anxiety in children and adolescents. Results indicate a robust association between negative interpretation and anxiety in children and adolescents. Two moderators of this association were found: age and whether the scenario content matches the anxiety. The results expand age effects found in investigations of attention bias and anxiety in children and adolescents to another cognitive bias and broaden evidence of content specificity within this association from adults to children and adolescents. Future research and treatments should consider the impact of development on the relationship between interpretation bias and anxiety and whether evidence for content specificity holds across disorders.

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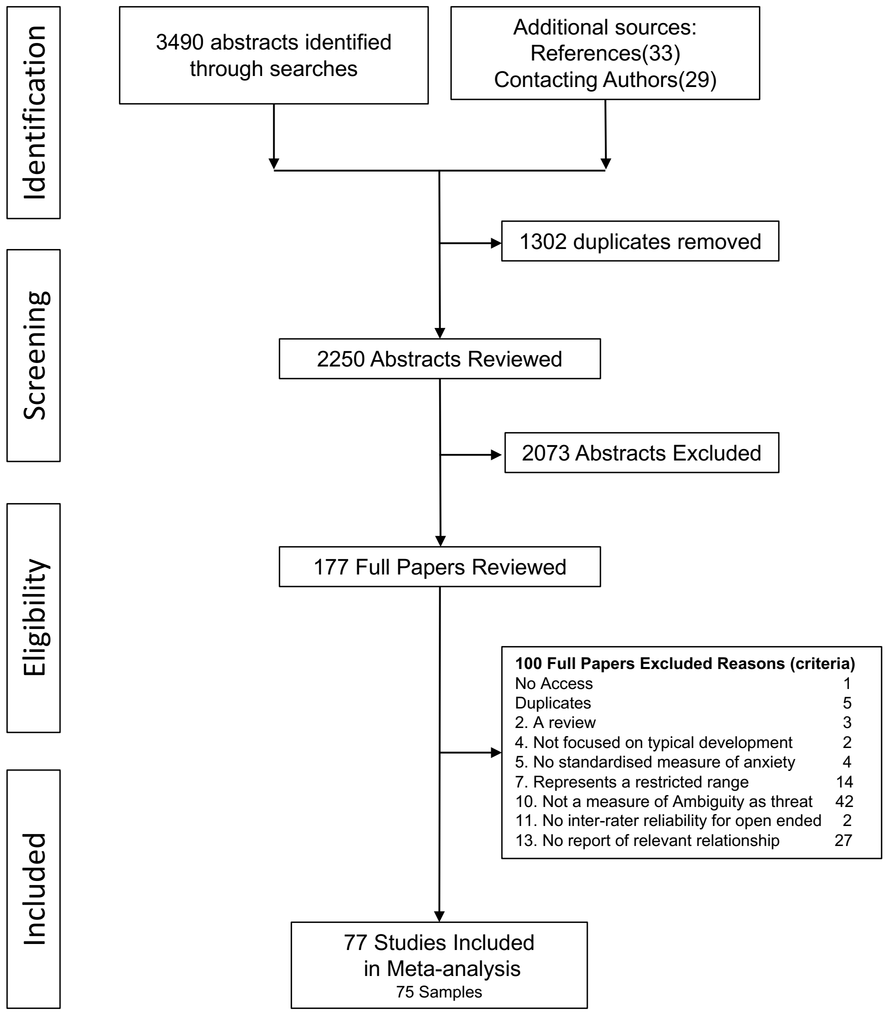

Figure 1. Flow Chart of Abstracts and Papers Accepted through the Eligibility Screening Process.

Table 1.

Study Characteristics Related to Each Sample Included in the Between Groups Analysis

Sample no.	Study Label	*N*	Mean Age	(*SD*)	*n* (Clinical)	*n* (Community)	*d*	no. ES
1	Alkozei et al (2014)	50	10.07	(1.91)	50	25	0.96	18
2	Cederlund & Ost (2011)	75	11.50	(1.80)	38	38	1.25	4
3	Creswell et al. (2011a)	94	-	-	-	92	0.67	1
4	Bögels et al. (2003)	25	12.20	(2.90)	6	25	2.08	1
5	Bögels & Zigterman (2000)	30	12.45	(3.00)	30	16	1.36	6
6	Carthy et al. (2010)	88	-	-	46	42	0.99	2
7	Creswell et al. (2011b)	56	-	-	-	65	0.59	1
8	Creswell & O'Connor (2006)	65	-	-	-	65	0.54	1
9	Creswell et al. (2005)	60	10.61	(2.36)	27	33	0.69	1
10	Creswell et al. (2014)	52	9.66	(1.02)	80	40	0.25	2
11	Hudson & Dodd (2010, 2012, 2015)	117	8.73	(0.37)	36	81	0.26	3
12	Eley et al. (2008)	300	-	-	-	300	0.17	3
13	Field & Field (2013)	187	10.07	(0.88)	-	187	0.21	27

14	Gifford et al. (2008)	43	9.98	(1.19)	32	23	0.68	2
15	In-Albon et al. (2009)	96	8.94	(2.20)	102	42	0.08	6
16	In-Albon et al. (2008)	252	9.69	(1.80)	-	265	0.26	6
17	Klein et al. (2014)	108	10.10	(1.40)	-	108	0.12	24
18	Lau et al. (2013)	36	9.33	(1.33)	-	36	1.19	7
19	Lu et al. (2013)	459	10.98	(0.90)	-	459	0.41	4
20	Mogoase et al. (2013)	571	13.01	(1.19)	-	571	0.65	2
21	Muris et al. (2009)	120	10.86	(1.07)	-	120	1.15	3
22	Podina et al. (2013)	423	11.69	(3.63)	-	423	0.65	1
23	Salemink & Wiers (2012)	64	14.50	(0.60)	-	65	0.84	2
24	Smith-Janik et al. (2013)	59	9.59	(0.83)	-	59	0.36	12
25	Waters et al. (2012)	85	10.43	(1.41)	-	85	0.43	6
26	Lester et al. (2010)	92	9.13	(1.41)	-	92	0.5	3
27	Micco & Ehrenreich (2008)	80	10.96	(2.12)	40	40	0.53	2
28	Micco et al. (2013)	80	-	-	40	40	0.24	9
29	Miers et al. (2008)	209	13.68	(0.98)	-	73	1.09	1
30	Muris et al. (2007)	216	10.88	(0.95)	-	216	0.41	3
31	Vassilopoulos	94	10.50	(0.50)	-	94	0.28	1

	et al. (2012)							
32	Levin (2008)	111	14.70	-	-	111	0.11	2
33	Muris et al. (2004)	113	10.10	(1.00)	-	113	0.76	1
34	Muris et al. (2000a)	76	10.40	(1.20)	-	76	0.7	1
35	Muris et al. (2003a)	299	9.80	(1.20)	-	299	0.72	4
36	Muris et al. (2003b)	156	10.70	(0.90)	-	156	0.60	10
37	Muris et al. (2000b)	252	10.10	(1.30)	28	224	0.78	2
38	Muris et al. (2000c)	105	10.20	(1.20)	-	105	0.73	4
39	Ooi (2012)	40	4.71	(0.86)	-	44	-0.24	1
40	Pereira et al. (2014)	80	8.84	(1.23)	-	80	1.5	1
41	Reid (2006)	192	-	-	-	192	0.3	4
42	Salemink & Wiers (2011)	158	14.50	(0.50)	-	158	0.59	6
43	Schneider et al. (2006)	143	11.57	(1.68)	-	143	0.98	3
44	Smari et al. (2001)	184	-	-	-	184	0.78	60
45	Shortt et al. (2001)	124	8.93	(2.12)	113	-	0.47	9
46	Suarez-Morales & Bell (2006)	292	10.46	(0.55)	-	292	0.47	9
47	Taghavi (2000)	57	13.39	(2.33)	17	40	0.92	3
48	Waters et al. (2008)	39	9.95	(1.25)	19	19	0.75	6
49	Vassilopoulos & Banerjee (2012)	110	11.50	(0.50)	-	210	0.57	1
50	Muris & Van	138	10.50	(1.20)	-	138	0.47	1

	Doorn (2003)							
51	Chorpita et al. (1996)	12	11.30	(1.78)	4	8	1.96	1
52	Muris et al. (2005)	157	10.80	(0.95)	-	157	0.72	1
53	Varela et al. (2004)	154	11.46	(1.10)	-	154	0.16	1
54	Vassilopoulos et al. (2015a)	38	10.40	(0.30)	-	38	1.15	3
55	Vassilopoulos et al. (2015b)	89	11.20	(0.60)	-	89	1.06	1
56	In-Albon et al. (2016)	70	10.21	(1.55)	35	28	0.02	11
57	Cox et al. (2015)	29	11.43	(0.28)	-	29	1.07	1
58	Fu et al. (2015)	73	14.15	(1.60)	-	73	0.89	1
59	Haller et al. (2016)	95	16.67	(1.05)	-	95	1.01	2
60	Pile & Lau (2015)	17	16.53	(0.62)	-	17	2.4	2
61	Pereira et al. (2016)	131	9.70	(1.50)	131	-	0.57	4
62	Păsăreu et al. (2015)	480	13.19	(1.67)	-	480	0.63	2
63	Dodd (2012)	50	16.68	(1.02)	-	50	0.87	2
64	Dobrean et al. (2015)	366	12.90	(1.86)	-	366	0.66	3
65	Waite et al. (2015)	80	12.24	(0.99)	40	40	0.59	1
66	Micco et al. (2012)	27	5.26	(1.14)	-	27	0.325	1
67	Miers et al. (2014)	559	13.90	(1.63)	-	559	1.53	3
68	Ooi et al. (2015)	50	4.00	(0.50)	-	50	0.8	2
69	Chan et al.	75	16.64	(0.67)	-	74	0.825	1

	(2015)							
70	Hullu (2012)	389	13.56	(0.69)	-	284	0.68	1
71	Pearcey (2014)	72	8.62	(1.05)	42	31	0.003	1
72	Loscalzo et al. (2015)	329	15.36	(1.12)	25	204	1.12	3
73	Klein et al. (2014a)	333	9.95	(1.25)	-	381	0.07	2
74	Klein et al. (2014b)	125	9.24	(1.65)	103	21	0.70	1
75	Klein et al. (2017)	678	14.37	(1.16)	-	678	0.174	2

Note. Dashes indicate the data were not available for extraction. Multiple effect sizes were taken from each study therefore values in the table represent aggregated sample size per association, aggregated mean age, aggregated standard deviation of age, aggregated sample size from a clinical population and aggregated sample size from a community population, number of effect sizes taken per study and aggregated effect size. Because numbers are aggregated within studies, the total aggregated sample size may appear different to the sum of the aggregated clinical and community samples respectively. no. ES = number of effect sizes drawn from each sample.

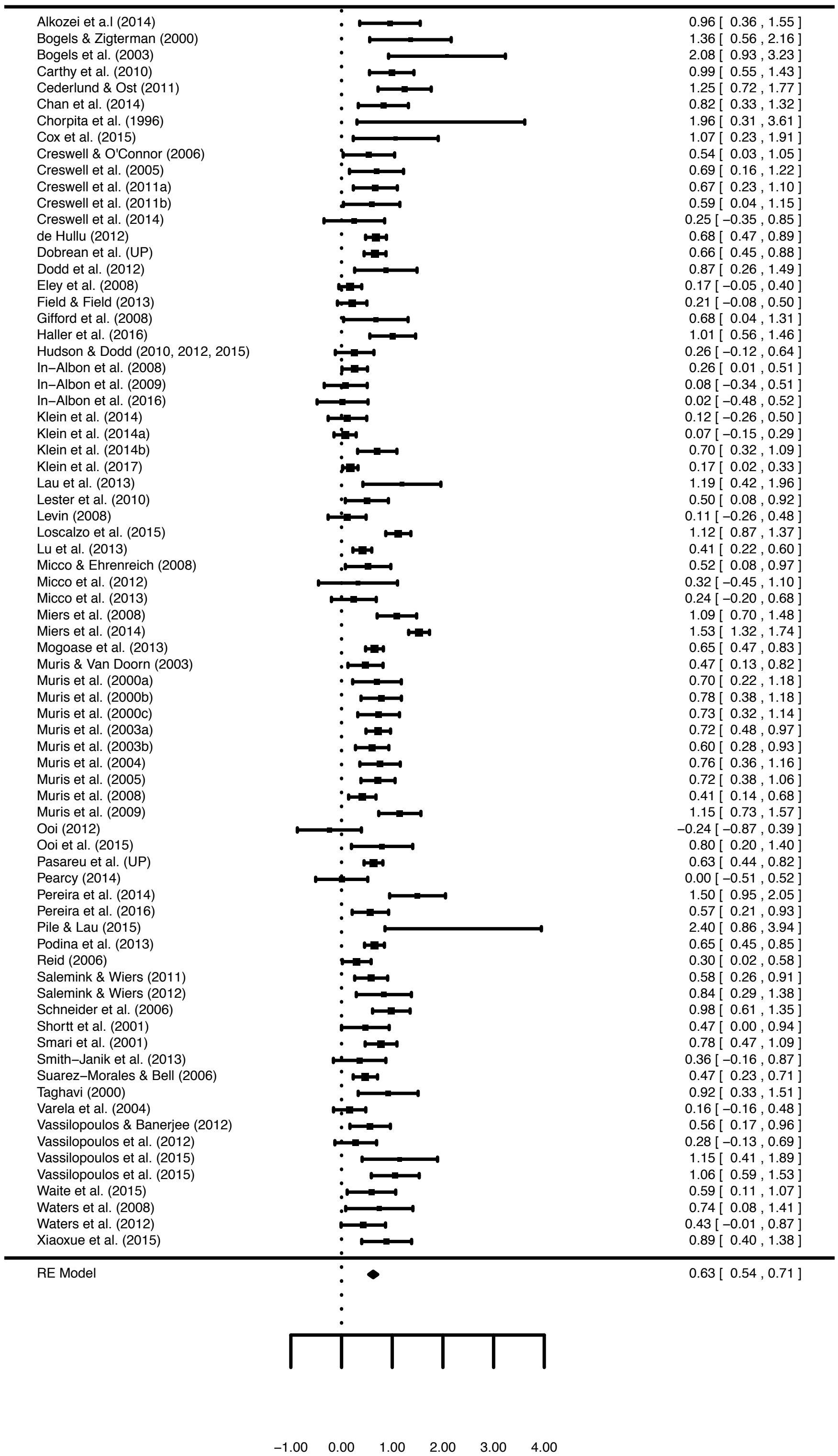

Figure 2. Forest Plot of all Studies included in the Meta-analysis and Moderation Analyses. Values represent the mean effect sizes within a study.

Table 2.

Meta-analytic Results

	Nstudies	*k*	$\hat{d}$	*95% CI*	Q^a	*p*
Overall						
Anxious vs. Non-Anxious	75	345	0.62**	0.53, 0.70		
Moderators						
		Population-Related Moderators				
Population Focus	75	317			0.35	.555
Clinical	18	110	0.58***	0.41, 0.76		
Community	57	207	0.64***	0.54, 0.73		
Control group	17	134			2.77	.734
Screened Non-Anxious	9	52	0.51***	0.28, 0.73		
Diagnosed Non-Anxious	9	43	0.70***	0.46, 0.95		
Not Social Anxiety	4	21	0.58	-0.06, 1.24		
Not Separation Anxiety[c]	1	2	-0.22	-0.56, 0.11		
Clinical Externalising[c]	3	4	0.57	-0.77, 1.91		
Correlation[c]	3	12	0.46*	0.05, 0.86		
High Trait Anxiety[d]	1	1	-	-	-	-
Low Trait Anxiety[d]	1	1	-	-	-	-
Comorbidity with Other Anxiety Disorder	18	82			0.59	.441
Included	16	77	0.61***	0.43, 0.79		

Excluded[c]	3	5	0.69***	0.03, 1.35		
Comorbidity with Depression	-	-			-	-
Included	12	62	0.66***	0.45, 0.86		
Exclude	1	1	-	-		
Comorbidity with Another Disorder[b]	15	63			.01	.939
Included	8	41	0.65***	0.31, 0.98		
Excluded	7	22	0.60***	0.37, 0.83		
Anxiety Subtype	75	317			9.92	.193
General Anxiety	55	201	0.61***	0.53, 0.69		
OCD[c]	3	3	0.55**	0.21, 0.89		
Phobias	5	10	0.43**	0.18, 0.69		
Separation Anxiety	9	15	0.36***	0.17, 0.55		
Social Anxiety	27	57	0.72***	0.51, 0.92		
State Anxiety[c]	4	6	0.62***	0.50, 0.74		
Other Anxiety	4	19	0.41	-0.03, 0.84		
PTSD	1	1	-	-	-	-
Procedural Moderators						
Task Type	75	318			1.18	.277
Ambiguous Scenarios	72	310	0.63***	0.54, 0.71		
Lexical tasks[c]	5	8	0.54**	0.11, 0.96		
Response Format	75	318			5.78	.056
Forced Choice	57	209	0.66***	0.56, 0.76		
Open	31	84	0.51***	0.39, 0.63		
Open and Forced Choice	5	25	0.36***	0.23, 0.48		
Dependent Variable	75	317			2.87	.237
Threat	75	241	0.68***	0.58, 0.78		

Interpretation						
Threat Frequency	10	39	0.78***	0.66, 0.90		
Threat Threshold	9	37	0.68***	0.58, 0.78		
Scenario Type	72	268			1.42	.841
Social	18	46	0.60***	0.44, 0.78		
General	60	173	0.62***	0.52, 0.72		
Separation	7	29	0.49***	0.26, 0.72		
Phobias[c]	3	5	0.29	-0.06, 0.65		
Physical Information	6	15	0.51**	0.19, 0.82		
Match: Scenario and Anxiety Subtype	75	318			4.24	.039
No Match	70	289	0.59***	0.50, 0.68		
Match	13	29	0.79***	0.53, 1.05		
Informant Measure Anxiety	74	317			2.77	.250
Child	56	215	0.65***	0.56, 0.75		
Parent	7	21	0.50***	0.19, 0.80		
Child and Parent	17	81	0.54***	0.36, 0.72		
Teacher[d]	0	0	-	-		

Note. The first level under each moderator is the reference category.

[a] *Q* for comparisons of the subtypes of the moderator. [b] Other disorder refers to an externalising or other psychiatric disorder rather than an internalising disorder. [c] Moderator levels identified with small numbers of studies and effect sizes that may influence the generalisability of the findings. [d] One or no effect sizes were available for these moderator levels therefore the level was not included in the moderation analysis.

*p = .05, **p = .01, ***p < .001

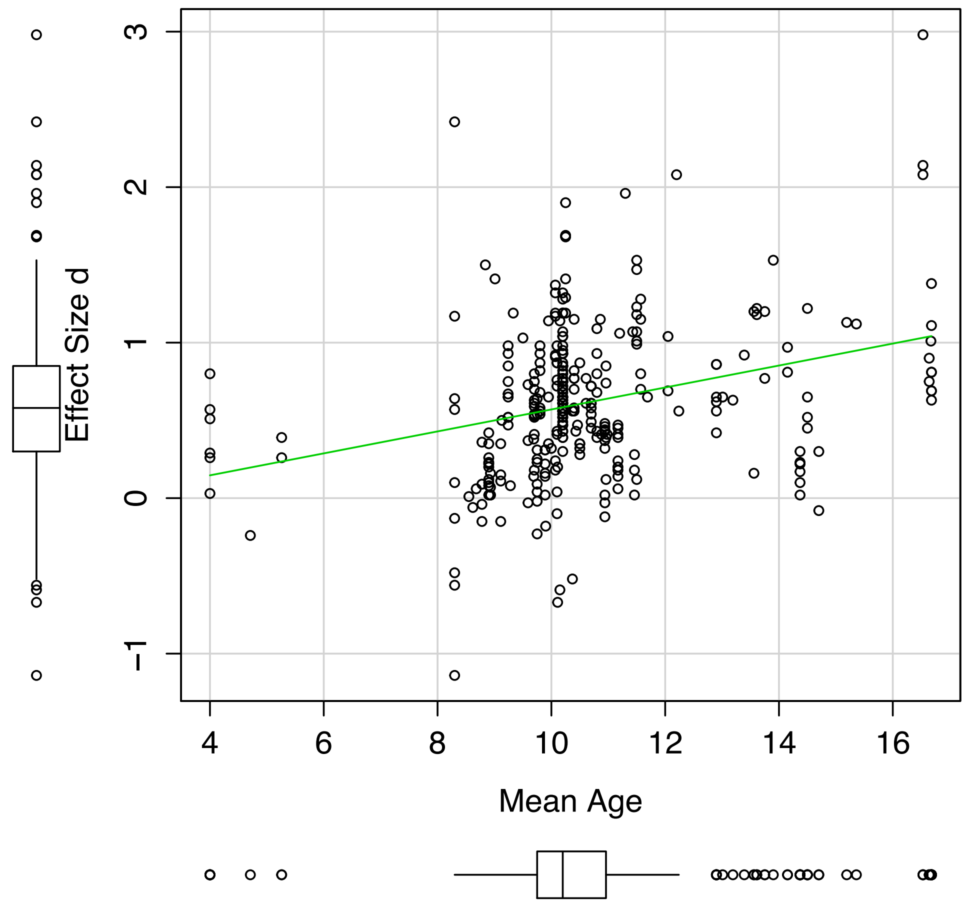

Figure 3. Scatterplot with box plots to show the relationship between the mean age (in years) and corresponding effect size (d) from each study included in the meta-analysis. The green line represents a parametric regression line.

Appendix A

Table of Coding Criteria and Descriptions of each Criterion

Table A1.

Descriptions of Coding Criteria Applied to Obtain Appropriate Sample Characteristics and Information Regarding Moderator Variables.

Sample Characteristic	Description of coding
Age	age range, mean age, standard deviation of age were all coded to represent the sample's age
Gender	% of males in the sample
Ethnicity	% of each identified ethnic group within the sample
Socio-economic status (SES)	% within categories of SES
Moderators and Level Names	**Description of coding within the level**
Population Focus	
Clinical	The focus of the study was to assess interpretation bias in a clinically anxious population.
Community	The focus of the study was to assess interpretation bias within a normative sample.
Control Group	
Screened Non-Anxious control	Studies with a clinical group, where the comparison group consisted of children and adolescents screened to be non-anxious using a standardised measure of anxiety/fear.
Diagnosed Non-Anxious	Studies with a clinical group, where the comparison group consisted of children and adolescents with no clinical anxiety diagnosis as deemed by a clinical diagnostic measure.
Not *target anxiety disorder* .i.e. Not	Studies that compared participants with a specific anxiety disorder (X) to those with another anxiety disorder (not

Social Anxiety, Not Separation Anxiety	X). The comparison group was then coded 'Not X anxiety'.
Clinical Externalising	Studies where the comparison group, for a group of clinically anxious children and adolescents consisted of children and adolescents with a diagnosed externalising disorder.
High Trait Anxiety	Studies with a clinical group, where the comparison group consisted of children and adolescents from the community screened as having high anxiety.
Low Trait Anxiety	Studies with a clinical group, where the comparison group consisted of children and adolescents from the community screened as having low anxiety.
Correlation	If an effect size was drawn from correlation analyses.
Comorbidity with Other Anxiety Disorder	
Included	Those with more than one diagnosed anxiety disorder were included in the clinically anxious group.
Excluded	Those with an anxiety disorder other than the disorder of interest or had more than one diagnosis where excluded from the clinically anxious group.
Comorbidity with Depression	
Included	Those with comorbid diagnosed clinical depression were included in the clinically anxious group.
Excluded	Those with comorbid diagnosed clinical depression were excluded from the clinically anxious group.
Comorbidity with Another Disorder	
Included	Those with a comorbid diagnosed psychiatric disorder (other than depression) were included from the clinically anxious group.

Excluded	Those with a comorbid diagnosed psychiatric disorder (other than depression) were excluded from the clinically anxious group.
Anxiety Subtype	
General Anxiety	Studies where no specific subtype was assessed, including those that assessed general trait anxiety as the concept of interest.
OCD	Studies where the target group had high symptoms or a diagnosis of obsessive compulsive disorder.
Phobias	Studies where the target group had high symptoms or a diagnosis of a specific phobia.
Separation Anxiety	Studies where the target group had high symptoms or a diagnosis of separation anxiety.
Social Anxiety	Studies where the target group had high symptoms or a diagnosis of social anxiety.
State Anxiety	Studies where the target group was assessed for levels of state of anxiety.
Other Anxiety	Studies where the anxious group was defined by the absence of a specific anxiety disorder (e.g. Social Anxiety Disorder), but had (symptoms of) another anxiety disorder.
PTSD	Studies where the target group had high symptoms or a diagnosis of post traumatic stress disorder.
Task Type	
Ambiguous Scenarios	The task used to assess interpretation bias involved responding to a set of ambiguous scenarios e.g. the ASQ.
Lexical Tasks	The task used to assess interpretation bias involved responding to language based stimuli e.g. homophone/graph task, lexical decision task.
Response Type[b]	
Forced Choice	Participants responded to the interpretation bias task by

	selecting a response from a provided set of responses that included a threat/negative interpretation.
Open	Participants responded to the interpretation bias task by providing an open response (usually their interpretation in their own words), which was then coded, for example, as a threat/negative interpretation.
Open and Forced Choice	Scores calculated from open and forced choice responses were combined to create a composite score of threat/negative interpretation.
Dependent Variable[a]	
Threat Interpretation	Responses to ambiguous scenarios are coded as reflecting a negative or threat interpretation via forced choice or open question.
Threat Threshold	The number of sentences taken to describe an ambiguous scenario before the child or adolescent stated the story was scary/threatening/negative.
Threat Frequency	Out of all the sentences of the story read to the child/adolescent: the total number of sentences after which the child/adolescent identified the scenario as threatening.
Scenario Type[a]	
Social	The scenarios were described as have a social element or as being relevant to social anxiety and a given example scenario confirmed this description.
General	The scenarios were described as non-social, without physical information (see below), reflect generalised anxiety, or total scenario scores from studies that have not reported separate effects from scenario subtypes.
Separation	The scenarios were described as involving some form of separation from another person or being relevant to separation anxiety and a given example scenario

	confirmed this description.
Phobias	The scenarios were described as providing information that could be resolved by assuming the presence of a feared object or as being relevant to panic disorder and a given example scenario confirmed this description.
Physical Information	The scenarios were described as involving reference to physical sensations of the participant i.e. heart beating, poorly stomach and a given example scenario confirmed this description.
Match: Scenario and Anxiety Subtype[a]	
No Match	Given the description and examples of scenarios used in the study the content of the ambiguous scenario did not directly reflect the anxiety subtype under investigation.
Match	Given the description and examples of scenarios used in the study the content of the ambiguous scenario directly reflected the anxiety subtype under investigation.
Anxiety Measure Informant	
Child	The child or adolescent responded to the anxiety/fear questionnaire measure or was interviewed to assess clinical anxiety.
Parent	The child or adolescent's parent responded to the anxiety/fear questionnaire measure or was interviewed to assess clinical anxiety.
Child and Parent	The results from both child/adolescent and parent clinical anxiety interviews or anxiety/fear questionnaires were combined to create a composite.
Teacher	The child or adolescent's teacher responded to anxiety/fear questionnaire measure or was interviewed to assess clinical anxiety.

Note. [a] This criteria only applied to studies utilising an ambiguous scenarios tasks to assess interpretation bias. [b] Responses were only included regarding a negative or threat interpretation. While it is acknowledged the positive interpretations and distress ratings are possible responses to ambiguous scenarios and lexical tasks they are beyond the scope of this review.

Appendix B

Search Terms

1. Search terms to identify those related to interpretation bias and anxiety:

(Interpret* bias OR Interpretation of ambig* OR bias* interpret* OR interpret ADJ bias* OR "Reduced evidence for danger" OR "Threat perception bias") AND (anxi* OR worry OR fear OR obses* OR compul* OR OCD OR panic OR anxi* disorder OR GAD OR generali* anxiety disorder OR phobi*). The other set was: (cognitive bias modification AND interpret*) AND (anxi* OR worry OR fear OR obses* OR compul* OR OCD OR panic OR anxi* disorder OR GAD OR generali* anxiety disorder OR phobi*)

2. Search terms to identify those specifically related to cognitive bias modification:

(cognitive bias modification AND interpret*) AND (anxi* OR worry OR fear OR obses* OR compul* OR OCD OR panic OR anxi* disorder OR GAD OR generali* anxiety disorder OR phobi*)

Appendix C

References included within the Meta-analysis

*Indicates that the data or paper was provided by the authors under the requested for unpublished data and was unpublished at the time the meta-analysis was conducted.

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Key Points

- An association between interpretation bias and anxiety is consistently found in adults; however evidence for this association in children and adolescents is inconsistent.
- This is the first systematic, quantitative investigation of the magnitude of the association between interpretation bias and anxiety in children and adolescents including investigation of moderators.
- Overall a robust medium positive association was found in children and adolescents. Only two potential moderators were found to influence the association. Moderation by age suggested that the association strengthens with increasing age. Match between scenario content and anxiety subtype supported content specificity.
- Moderation results encourage consideration of the influence of development in treatments for clinical anxiety and how content specificity may influence treatment effectiveness in this population.

Chapter 3. Paper 2: Look out Captain, I hear an ambiguous alien! A study of interpretation bias and anxiety in young children.

Manuscript in Preparation for submission to Behaviour Research and Therapy

Stuijfzand. S., Chakrabhati. B., Reynolds, S. & Dodd. H. F. *Look out Captain, I hear an ambiguous alien! A study of interpretation bias and anxiety in young children.* Manuscript in Preparation

Appendices Associated with this Chapter:

Appendix 1: Investigation of Tone Rating Task

Appendix 2: Examples of Alien stimuli used in the Ambiguous Tones Task

Appendix 3: Examples of Information Sheets and Informed Consent Sheets provided to the Parents

Appendix 4: Information and Assent Sheets for Children

Appendix 5: Example of Reward Chart

Appendix 6: Investigation of Technical Issues regarding the Demonstration of the Tones

Appendix 7: Example of Debrief Sheets for Parents (7-8 year olds)

Appendix 8: Certificate given to Children at completion of the Space Quest

Appendix 9: Examples of Stickers given as a Reward for Completion of the Space Quest

Appendix 10: Protocol of the Ambiguous Sound Task

Appendix 11: Further Examination of Whether the Ambiguous Tones Task Worked

Appendix 12: Use of Galvanic Skin Response (GSR) in the Ambiguous Tones task

Abstract

Cognitive models postulate a relationship between anxiety and interpretation bias, a tendency to interpret ambiguity as threatening. A recent meta-analysis suggested that age moderates this relationship in children and adolescents, with a stronger association found with increasing age. There is, however, a paucity of studies with children younger than 8 years old. One reason for this is that the methods for assessing interpretation bias typical rely on language and cognitive abilities that aren't well developed until middle childhood.

Here we develop a novel child friendly task that aims to assess children's appraisal of ambiguous tones to capture their interpretation of ambiguity. Children were taught to categorise high tones as belonging to a happy alien and low tones to an angry alien. Then children were asked to categorise middle (ambiguous) tones as 'happy' or 'angry'. In addition to behavioural data, corrugator muscle activity in response to tones was recorded as a potential objective measure of children's valence appraisal. A community sample of 110 children aged 4 to 8 years, split into high and low anxious groups completed the task. Group differences were examined and the influence of developmental proxies was investigated.

Results indicated that participants were able to complete the task and that children in the high anxious group were more likely to interpret the ambiguous tones as negative once developmental proxies were taken into account. While increased activity of the corrugator was seen during the practice trials to tones reported as 'angry', this was not the case in response to the ambiguous tones and no differences were seen between anxiety groups.

This study is the first to make use of a novel children friendly task to assess interpretation bias with an objective measure. Results highlight the importance of accounting for development in of investigations into the relationship between interpretation bias and anxiety. Results also suggest that corrugator activity does not reflect the valence appraisal of ambiguous tones in young children.

Introduction

Cognitive models of anxiety suggest that individuals possess threat-related schemas (Kendall, 1985), which when activated guide information processing and behavioural responses. For anxious individuals, it is theorised that threat-related schemas are overactive which results in cognitive biases such that information is processed and responded to as if it was threatening. One such bias is interpretation bias whereby there is an increased likelihood of interpreting ambiguity as negative/threatening. Cognitive biases are implicated as having a predisposing (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Eysenck, 1997; Eysenck, 1992; Williams, Watts, MacLeod, & Mathews, 1988; Williams, Watts, MacLeod, & Mathews, 1997), causal (Beck & Clark, 1997) and or maintaining or role in anxiety (Bar-Haim et al., 2007; Eysenck, 1997; Eysenck, 1992; Mogg & Bradley, 1998; Williams et al., 1988; Williams et al., 1997).

Reviews suggest that there is an association between interpretation bias and anxiety in children (Blanchette & Richards, 2009; Castillo & Leandro, 2010; Muris & Field, 2008) and a recent meta-analysis found a robust association between interpretation bias and anxiety in children and adolescents (Stuijfzand, Creswell, Field, Pearcey, & Dodd, 2017). This meta-analysis also found that age moderated the association between interpretation bias and anxiety in children and adolescents; whereby the size of the association increased with age. However, most studies included in the meta-analysis had a mean age of between 8 and 12 years old, some with a mean age greater than 12, but very few with a mean age below age 8. The moderation by age suggests that development affects the association between interpretation bias and anxiety, but the nature of this change across time is unclear given the lack of studies with a mean age below 8. Whilst some studies have considered age as a moderator of the relationship between interpretation bias and anxiety (Cannon & Weems, 2011; Waite, Codd, & Creswell, 2015), age is only one proxy for development. The lack of studies available focusing on childern younger than 8 means that it is unclear whether there is an anxiety related interpretation bias present in young children and whether it increases with age as the moderation found by Stuijfzand et al. (2017) suggests.

Field and Lester (2010) describe how development could be involved in the relationship between cognitive biases and anxiety through three models. In the first, biases are innate and influenced by individual factors such as anxiety (integral model). In the second, all children have biases early on but only those will certain individual factors (influenced by social, emotional and cognitive development) retain the biases as they age (moderation model). In the final model, children do not all show the biases early on, but the biases emerge as a function of their emotional, social and cognitive development. Anxiety may be a cause or a consequence of the emergence of these biases (acquisition model). On reviewing the evidence available at the time, Field and Lester (2010) suggested that an acquisition model is appropriate for the relationship between interpretation bias and anxiety in children. The recent meta-analysis suggested a role for development (Stuijfzand et al., 2017). However, it was not clear whether a relationship between interpretation bias and anxiety existed in young children. It was not therefore possible to determine which of Field and Lester's (2010) models is most appropriate for interpretation bias. More research with young children that considers the role of development would assist in achieving this aim.

The inhibition hypothesis (Kindt & Van den Hout, 2001) suggests that the ability to inhibit attention to threat may influence a child's vulnerability to anxiety. If attention is focused on threat, other non-threat related elements of the situation might not be encoded; thus, an interpretation bias to threat might be seen in children who have poor inhibition. Inhibition is one skill that falls under the construct of effortful control, which forms part of self-regulation. Effortful control has been defined as the ability to inhibit a dominant response to perform a subdominant response, to detect errors, and to engage in planning (Rothbart & Rueda, 2005). Effortful control develops considerably before age 8 (Rothbart & Rueda, 2005) with some components (focusing and inhibition) showing relative stability from around age 7 with little difference to adult proficiency (Eisenberg, Smith, Sadovsky, & Spinard, 2004; Mezzacappa, 2004). Kindt and Van den Hout's (2001) framework proposes that anxious children do not develop these skills. If we consider the development of effortful control, of which inhibition is part, then the inhibition hypothesis may suggest that early in development when inhibition is not sufficient to move attention away from threat, all children may show an interpretation bias. However, as effortful control develops only anxious children who are low in these skills may retain the bias while non-anxious children will no longer show the bias. Kindt and Van den Hout (2001) suggest this difference between anxious and non-anxious children may be apparent by age 10 to 12 years, though this based on only a few studies. Thus, effortful control may influence the association between interpretation bias and anxiety in children. Indeed, there is evidence that effortful control may moderate the association between interpretation bias and anxiety in children (Salemink & Wiers, 2011). Given the potential influence of effortful control on the relationship between interpretation bias and anxiety in children it seems pertinent to consider effortful control as a potential moderator.

The paucity of studies investigating interpretation bias and anxiety in young children may in part be due to methodological limitations. Current measures heavily rely on verbal and non-verbal cognitive skills. Self-report measures, e.g. Child Ambiguous Scenario Questionnaire (Barrett, Rapee, Dadds, & Ryan, 1996), require children to imagine situations, generate and hold multiple outcomes in mind, and to select a preferred interpretation from various alternatives. Others explicitly make use of lexical knowledge, e.g. the homophone task (Gifford, Reynolds, Bell, & Wilson, 2008). Some tasks to assess interpretation bias have been developed with younger children in mind, for example the Story Stem task (Dodd, Hudson, Morris, & Wise, 2012) and the Nature Reserve Task (Field & Storksen-Coulson, 2007); however, these tasks still heavily rely on language. The cognitive and linguistic skills necessary for task completion must be sufficient for the results to be reliable. If they are not sufficiently developed then cognitive and linguistic skills may be confounding results such that a response bias is seen rather than an interpretation bias (Blanchette & Richards, 2009; Brown et al., 2014; Field & Lester, 2010).

What is currently lacking is a developmentally appropriate, child friendly task to assess interpretation bias in young children who are in the midst of cognitive and linguistic development. Ideally, to measure biases in young children, objective measures of interpretation of ambiguity that complement subjective measures are required (Brown et al., 2014). Ideally, task performance should not be dependent upon verbal or non-verbal ability.

Psycho-physiological responses may be useful as an objective measure of interpretation of ambiguity. One candidate is the measurement of corrugator activity using fEMG. Corrugator activity of an individual can differentiate between stimuli with different valences while they view images (adults; Tan et al., 2011, 2012) (children; Deschamps, Schutte, Kenemans, Matthys, & Schutter, 2012; Tottenham, Phuong, Flannery, Gabard-

Durnam, & Goff, 2013), or listen to auditory stimuli (Dimberg, 1990; Hawk, Fischer, & Van Kleef, 2012), with different valences. More importantly here corrugator activity also reflects the subjective experience of the stimuli (Dimberg, 1990; Tan et al., 2012). Specifically, the corrugator will reflexively react to stimuli perceived in a negative way. This reflex reaction has been suggested as a physiological index of an individual's appraisal of a valence-ambiguous stimulus (Tottenham et al., 2013). Therefore, recording fEMG corrugator activity may provide a unique opportunity to objectively measure children's interpretation of ambiguous material.

This study aims to assess interpretation bias in 4 to 8 year olds via a novel, developmentally appropriate, child friendly task. Children are first taught to associate different tones with the emotion of an alien (happy- positive or angry – negative) and then children are asked to verbally categorise the valence of an ambiguous tone. It is hoped this will provide a behavioural/subjective measure of interpretation of ambiguity that avoids the heavy reliance on linguistic and cognitive skills thought to be necessary for other tasks. Activity of the corrugator will be measured via fEMG during the task to investigate whether it could serve as an objective physiological index of valence appraisal of ambiguity.

We first aim to establish that children between 4 and 8 years old can complete the ambiguous tones task and that the task is appropriate for measuring interpretation bias. After this we will investigate the association between interpretation of ambiguity and anxiety. We will conclude that the task is suitable for assessing interpretation bias in young children if the following criteria are met: 1) children maintain the >60% learning criteria on the practice blocks throughout the task; 2) responses to the tones in the practice trials are not dependent of anxiety grouping, and non-verbal and verbal cognitive abilities. As a check for whether corrugator activity can differentiate between the valenced tones, it is expected that there will be greater corrugator activity when children hear tones associated with an alien when it is angry than tones associated with when it is happy. Next, we will investigate whether anxiety is associated with responses to the ambiguous tones. It is expected that high anxious children will be more likely to report the ambiguous tones as 'angry' than low anxious children. Additionally, it is expected that children in the high anxious group will show more corrugator activity when presented with the ambiguous tones, possibly indicating a negativity bias. If the corrugator can serve as an objective measure of interpretation bias we may expect to find a difference in activity for the ambiguous tones reported as ‘angry’ between the high and low anxious groups.

Following previous research and theory, age and effortful control and their interactions with anxiety will also be added as predictors to the model to investigate moderation of the relationship between attention bias and anxiety. Based on previous research regarding the influence of development, it could be expected that a relationship between anxiety and responses to the ambiguous tones may only be evident in the high anxious group for those with poor effortful control. Based on the meta-analysis of Stuijfzand et al. (2017) we tentatively hypothesise that the association between responses to the ambiguous tones in the task and anxiety may increase with age. Autism and anxiety disorders are often comorbid (van Steensel, Bögels, & Perrin, 2011). To ensure that differences in anxiety groups reflect differences due to anxiety, autistics traits were assessed. Should differences in autistics traits be found between the anxiety groups then scores on the autistic quotient will be added as a covariate within analyses. Finally, if the task has been successfully in being developmentally appropriate non-verbal and verbal abilities should not show as significant predictors in children’s responses to the ambiguous tones.

Methods

Participants

One-hundred and ten children took part in the task (44 females, M_{age} = 5.69, *SD* = 1.34). Of these, 97 learnt the associations necessary to complete the task (38 females, M_{age} = 5.08, *SD* = 1.19, age range 4 to 8 years). Participants were recruited for a study investigating anxiety and thinking styles in children via: advertisements placed in local magazines and newsletters targeted at families, local newspapers; posters placed in public places likely to be visited by families, for example local libraries, museums, and children’s toy shops; leaflets handed out by local schools and at children’s groups, for example, rainbow and guide groups. Parents answered online screening questionnaires regarding their child’s anxiety using the Preschool Anxiety Scale (PAS; Spence, Rapee, McDonald, & Ingram, 2001) or the Spence Children’s Anxiety Scale (SCAS; Nauta et al., 2004) depending on age. Children identified as having high anxiety (one standard deviation above the normed mean) or low anxiety (below the normed mean) were invited with their parents to come to the University to take part in the tasks. The final sample included 62 high anxious and 35 low anxious participants. The majority of parents were female (95%) and reported they were the primary caregiver (97%). Ethnicity data was available for 32 children, with 94% reported to be White British (remainder were White British with Arabic 3%; Australian 3%).

There were no differences between those that learnt the associations necessary to complete the task and those that did not in age ($t(108) = -1.791$, $p = .076$), distributions across anxiety groupings ($X^2(1) = .50$, $p = .481$), or gender ($X^2(1) = .23$, $p = .630$). Children identified by parents as having a diagnosis of an Autism Spectrum disorder, Attention Deficit Hyperactivity Disorder, Learning Disability or a combination of the above were excluded from taking part. This was because these conditions have a propensity for anxiety and/or particular cognitive processing difficulties that would influence the findings regarding the association between anxiety and interpretation bias.

Measures: Parents

Spence Child Anxiety Scale (Preschool version; PAS and child version; SCAS).

Parents completed these measures of anxiety for screening purposes. Both measures yield a total score and include six subscales that assess symptoms of specific anxiety disorders. On both measures, higher scores indicate higher anxiety.

Parents of the 4 to 6-year-olds completed the PAS, a 28 item questionnaire answered on a five point likert scale from 0 (Not true at all) to 4 (Very often true) (minimum = 0, maximum = 112). The measure has strong psychometric properties being consistent with DSM-IV classification and with the internalising scale of the Child Behaviour Checklist (CBCL; Achenbach, 1991; Spence, Rapee, McDonald, & Ingram, 2001). The total score of the PAS showed excellent internal consistency ($\alpha = .91$).

Parents of the 7 and 8-year-old group answered the parallel measure SCAS, a 38 item measure answered on a four point likert scale of 0 (never) – 3 (always) (minimum = 0, maximum = 114). The SCAS has shown good psychometric properties (Nauta et al., 2004; Spence, 1998). The SCAS showed excellent internal consistency ($\alpha = .90$).

Child Behaviour Questionnaire – Effortful Control Scale (CBQ-EFC; Rothbart, Ahadi, Hershey, & Fisher, 2001).

The Effortful Control Scale is a parent report measure consisting of 47 items from the Children's Behaviour Questionnaire (CBQ; Rothbart et al., 2001). The CBQ assesses individual differences in attentional self-regulation as a basic dimension of temperament. The effortful control scale shows good psychometric properties (Rothbart et al., 2001) and consists of the subscales low intensity pleasure, inhibitory control, perceptual sensitivity and attentional control. We also added the five-item subscale of attention shifting to the original 47 items of the effortful control scale. The attention shifting subscale has showed good internal consistency when combined with attention focusing and inhibition to assess effortful control (Eisenberg et al., 2007). Therefore, parents answered 52 items on a likert scale of 1-7 (1 = extremely untrue, 7 = extremely true, or 8 = not applicable; minimum = 52, maximum = 364). Higher scores indicate more effortful control. Internal reliability was excellent for the total effortful control scale (α = .89).

The Autism Spectrum Quotient: Children's Version (AQ: Child; Auyeung, Baron-Cohen, Wheelwright, & Allison, 2008).

The AQ: Child is a 50 item parent report measure of autistic traits with good psychometric properties (Auyeung et al., 2008). Parents were asked to rate each item indicating to what extent they agree or disagree with the statements about their child on a four point likert scale (0 = definitely agree to 3 = definitely disagree). The higher the score the more autistic-like traits the child shows (minimum = 0, maximum = 150). The full scale showed good internal consistency (α = .83).

Measures: Children

The Wechsler Preschool and Primary Scale of Intelligence (WPPSI-IV).

The Wechsler Preschool and Primary Scale of Intelligence (WPPSI-IV) is an individually administered standardised test of cognitive development for children 2;6 to 7;7. The WPPSI is administered through standardised protocols and is found to be a highly reliable and valid measure of child general intelligence (Weiss, Keith, Zhu, & Chen, 2013). The individual scales, rather than the full test, of the WPPSI have been previously used for research purposes (for example, Bernier, Beauchamp, Bouvette-Turcot, Carlson, & Carrier, 2013). The ancillary index scales of vocabulary acquisition and non-verbal abilities were used to assess child verbal and non-verbal cognitive abilities, specifically: verbal comprehension and block design respectively. Age equivalence on these tasks were used as metrics of verbal and non-verbal cognitive abilities within analyses. The measure includes current and developmentally appropriate norms against which individual child's scores were measured and these norms have shown good reliability and validity (DeThorne & Schaefer, 2004).

Interpretation bias task: Ambiguous Tones Task.

Stimuli. For this task three sets of five tones were produced. First, three tones were selected: one high pitch tone, one low pitch tone, and one from the mid-point of the two other tones (an ambiguous tone). Five computer generated instruments were then used to play each of the three tones using Logic Studio 9 (2007). Five instruments were selected: a guitar, a piano, a saxophone, strings and a Wurlitzer. The selected instruments were judged to have a similar frequency and valence to enable associations to be formed on the basis of pitch without interference from the instrument itself. An independent group of 40 children aged 4 to 8 ($M_{age} = 6.78$, $SD = .77$) rated the three sets of tones using a 5 point SAM rating scale from very happy to very angry. The high tones ($M = 3.81$, $SD = .40$) were judged to be more positive (happy) than the low ($M = 2.41$, $SD = .95$; $t(39) = 6.76$, $p < .001$, $d = 1.75$) and ambiguous tones ($M = 2.89$, $SD = .65$; $t(39) = 6.32$, $p < .001$, $d = 1.45$). The low tones were judged to be more negative (angry) than the ambiguous tones ($t(39) = -2.96$, $p = .005$, $d = .59$). A rating of 3 would indicate a neutral rating and no difference was found between the mean rating of the ambiguous tones and three ($t(39) = -1.08$, $p = .288$). Which instrument was playing the tone did not influence children's ratings, children did not differ in their reaction time in responding to the tones, and trait anxiety score was not associated to the proportion of positive, neutral or negative ratings children made to the tones over the task.

An image of a space captain with his thumb up, an alien expressing a happy face, and an alien expressing an angry face were produced. The alien expressing happiness and anger were identical except for facial expression: the happy alien had no eyebrows and a smile, the angry alien had v-shaped eyebrows and a frown. All images were created using Adobe Photoshop and Illustrator.

Design. The task was created in Eprime 2.0 (Psychology Software Tools Inc., 2012) and had a learning and experimental phase. The learning phase included only trained tone (TT) blocks, which had 10 trials followed by a break. Each trial began with a wait of 6400ms-6500ms (jittered) during which the child was asked to count to five then a tone was played for 250ms while the child saw a space scene. The child was asked to verbally respond to the tone with ‘angry’ or ‘happy’. There was no timeout and the experimenter recorded the child’s response. Feedback consisted of the words ‘you’re right’ and a green tick, or ‘Ooops’ and a red cross and was onscreen for 1000ms. This was followed by the image of the alien associated to the tone they had just heard. The five-high pitched and five-low pitched tones were played in each TT block and order was randomised. The child completed as many TT blocks as necessary to achieve >60% correct over one block, after which they could move to the experimental phase.

Once the learning phase was completed, the experimental phase began. This consisted of alternating one experimental block (EX) with one TT block. An EX block consisted of seven or eight trials. Trials were identical to TT trials above but no feedback was given, instead a blank screen was shown. In EX blocks, five ambiguous tones were presented with two or three trained tones. The order of trials in blocks was randomised. TT blocks in the experimental phase were identical to those in the learning phase. Children could complete up to four EX blocks and four TT blocks in the experimental phase. The TT blocks were included in the experimental phase to maintain the learnt associations between the tones and emotion of the aliens.

Procedure

The study had ethical approval from the University of Reading Ethics Committee. The parent completed the parent-report questionnaire measures while the child completed the tasks. Before the child completed any tasks, verbal assent from the child was obtained. Then the fEMG electrodes were placed on the child. Where the electrodes would be placed and what they would feel like on the child’s face were first demonstrated through putting small stickers on the face of the child and the experimenter. Children were then introduced to the task as a special job for the captain of a space ship. They were told that aliens in this part of the galaxy are sometimes happy and sometimes angry. The captain wants to know whether the alien coming towards the spaceship is angry or happy; one can tell this by the sound they make. Children were told that the captain has asked them to learn which sounds the alien makes when it is happy and when it is angry.

Before the task started the child saw the image of the ‘happy’ alien and was played the high pitch tones. Subsequently the angry alien was displayed and the low-pitched tones were played. After hearing the tones, the children were asked if they could tell that the tones made when the alien was happy or angry were different and they were asked how they were different. Children were then asked if they would like to hear the tones again or if they would like to practise. The learning phase of the task was started when the children said they would like to practice.

If the child had >60% of trials correct in one TT block the experimenter would ask the child if they would like to move on or do another TT block. If the child had < 60% correct over one TT block the experimenter would encourage the child to do another TT block until they got >60% correct or had completed four TT blocks without getting >60% after which the task was terminated. Before starting the experimental phase and the EX blocks children were told that this time the computer would not tell them if they were getting the answers right or not, but if they were doing a good job at the break they would see the captain with his thumb up. During breaks children always saw the captain with his thumb up for motivation. After completing all four possible EX blocks or if the child asked to stop the task, the task ended and all sensors were removed.

On completion of all the tasks the parent was provided with a debrief sheet explaining further the purpose of the tasks and they were given £5 towards travel expenses. All child participants received a certificate, stickers and a token prize for their co-operation and time.

Recording Physiological data

All physiological data was recorded using ADI Power Lab 8T, with an Octal Bioamp (AD Instruments, Australia) and acquired using Lab Chart 7.0 (AD Instruments, Australia).

Facial Electromyography (fEMG).

The areas above the child’s left eyebrow and the middle of the forehead were first cleaned with 70% alcohol prep pads (Professional Disposables, Inc., USA TD-230) and left to dry for five minutes to reduce impedance. Bipolar sensors were placed above the eyebrow to measure corrugator activity, with the reference ground placed on the forehead using four-millimetre Ag/AgCl EMG surface sensors (Discount Disposables, USA) on 5 mm collars filled with isotonic electrode gel. Children were asked to make facial expressions (angry, happy, and surprised) as a check to ensure signal from the sensors was adequate and placement was accurate before the task was introduced. Children were encouraged not to touch the sensors during the task.

Offline the fEMG signal was filtered using a 50Hz notch filter to remove electrical noise, and a band pass filter (500 – 10 Hz) was applied. The signal was rectified and a logarithmic transformation applied to reduce the influence of extreme values. The signal was then visually checked for good signal and movement. This was done by assessing whether the facial expression checks were visible and whether a thick invariable signal, signifying the sensors had come off or lost contact with the skin, could be seen at any point during the recording. If the checks for facial expression movement were not visible in the signal the data was excluded and trials where the sensor lost contact with the skin, or trials where the signal proved to be three standard deviations above or below the mean signal, were excluded. Plots were created to determine the window in which the peak response to the tone would be best captured. Following this the response window was taken as the 300ms after onset of the tone.

Statistical Analysis Plan

Prior to analysis, differences between anxious and non-anxious children on demographics, autistic quotient scores, total effortful control scale, as well as age equivalence on block design and age equivalence on receptive language were assessed. If differences between groups were detected then these variables were included as covariates in all proceeding analyses to avoid potential confounds. To allow this assessment assumptions of normality were checked via assessment of skewness and kurtosis for all continuous variables. If non-normality was found then non-parametric tests were used to assess for differences between anxiety groups.

To investigate whether participants were able to complete the novel task, descriptive statistics on children's average accuracy on the TT blocks were derived and checked to see children maintained the >60% learning criteria throughout the EX blocks. The same was checked on the trained tones heard during the EX blocks. To check the consistency in responses to the ambiguous tones over the experimental trials, responses to ambiguous tones were totalled and then divided by the number of trials completed to create a proportion. As children may have treated the tones from each instrument differently, this was conducted per instrument. Histograms were created to check consistency or responses, where 0 or 1 would indicate consistency or stability in responses while .5 would indicate children reported the ambiguous tones as happy half the time and angry half the time.

For the remainder of the analyses, multilevel modelling was used. This was done to address three aspects of the dataset. Firstly, children varied in the number of trials they completed on the interpretation bias task (10-20). Secondly, the data was nested. Not all children could be considered independent of each other, as in some cases their siblings took part in the study as well. Additionally, the responses on the dependent variable are nested within individuals and as such are dependent (Field & Wright, 2011). Multilevel models allow for inclusion of incomplete cases, and allow for the modelling and investigation of dependency structures in the data (Hox, 2010; Hox, Moerbeek, & van de Schoot, 2010). Thirdly, multi-level analysis has less restrictive assumptions of variance and a balanced design (Field & Wright, 2011; Hox, 2010a). The unequal numbers in the anxiety groups in this study may have caused issues for conventional analyses, but can be handled by multi-level models. For the multilevel models in this study we treated a trial as the unit of analysis, which is referred to as level 1 (e.g., a response to a tone). This data is influenced by the participant that completed the trial, and so we consider trials to be nested within participants (level 2). We also include family on the third level as, due to the presence of siblings, participants are in turn nested within families. The study was adequately powered for this analysis, with more than 50 participants having valid responses to 10 or more trials involving ambiguous tones on the interpretation bias task (Bell, Morgan, Kromrey, & Ferron, 2010; Maas & Hox, 2005; Snijders, 2005).

The first step in each multilevel analysis involved creating two random intercept models: 1) where the intercept was allowed to vary between participants (i.e., a two level random intercept model), 2) where the intercept was allowed to vary between both participants and families (i.e., a three level random intercept model). Using a likelihood ratio test, these models were compared against each other, as well as to a single level linear regression model. This, in combination with examining how much variance was accounted for at each level, was used to establish the appropriate model for the subsequent analyses.

Once the appropriate model was selected we added the predictors of interest: first any appropriate trial variables (level 1 variables; e.g. valence), second by adding predictors concerning the individual (level 2 predictors). Inclusion of age^2 as a predictor allows for assessment of a quadratic influence with age. The developmental proxies of effortful control and age were added as well as their interactions to assess moderation. Non-verbal cognitive abilities and verbal cognitive abilities were finally added as predictors it is unlikely we have been able to completely remove any confounds of non-verbal and verbal cognitive abilities from the task. By adding non-verbal and verbal cognitive abilities as predictors on responses to the tasks they were effectively acting as covariates. Dummy variables were created for any binary variables Anxiety grouping, Valence, Response, and Accuracy where the low anxious group, positive (happy), 'happy' and 'not accurate' were the respective reference categories. All continuous predictors were included grand-mean centred (see Hox, 2010; Hox et al., 2010).

At each step, the significance of predictors were checked and the model compared to the random intercept model to assess whether adding predictors improved model fit using the likelihood ratio test. Should the model not show improvement the simplest model was retained i.e. the random intercept model. If a model was found to improve model fit subsequent models were then compared to this improved model and so on until no further models show improvements indicating the final model has been established. If the model including interactions with developmental variables did not show model improvement, but the interactions were not significant, then interactions were excluded from further models to maximise power.

Four multilevel models were investigated. Two were created to investigate the behavioural data: one to investigate the influence of anxiety grouping and developmental proxies on children's accuracy in the practice trials, the second to investigate whether high anxious children showed different responses to the ambiguous tones in the experimental trials and whether these responses were moderated by development proxies. As the dependent variables were binary, logistic regressions were used and therefore model change in variance explained by each level was not meaningful and are not commented on.

The remaining two models investigated the potential of the corrugator to reflect children's responses to the tones. One model investigated whether the children showed greater corrugator activity when they heard or reported an 'angry' tone and whether this was influenced by anxiety grouping and developmental proxies during the practice trials. The second model investigated whether high anxious children showed greater corrugator activity in response to ambiguous tones than low anxious children. Psycho-physiological data resulted in continuous dependent variables therefore standard multi-level models were used.

Data was processed and analysed using R studio version 1.0.153 (R Core Team, 2015). R packages lme4 (Bates, Maechler, Bolker, & Walker, 2015), Pastecs (Grosjean & Ibanez, 2014) and VGAM (Yee, 2014) were used to conduct the analysis.

Results

Behavioural data

Of the 97 participants who learnt the associations, 73 participants had 10 or more valid trials involving the ambiguous tones. Reasons for not having enough valid trials included a technical difficulty with Eprime for 16 participants that led to data loss, the remainder did not complete enough experimental blocks due to refusal to continue or did not provide responses to enough trials. There were no differences between those with 10 or more valid trials and those who had fewer than 10 valid trials in age ($t(95) = -.993$, $p = .323$), distributions across anxiety groupings ($\chi^2(1) = .105$, $p = .746$), or gender ($\chi^2 1) = .083$, $p = .773$). There was also no difference in the percentage correct children achieved in their final practice block ($t(95) = -4.70$, $p = .600$). Within the sample there were nine sibling pairs meaning 64 families were represented by the sample. Forty-two children showed age equivalence or above on the block design task of the WIPPSI, 30 were below age equivalence and one participant did not complete this task (Table 1). On the receptive language task of the WIPPSI 52 children showed age equivalence or above, 20 were below age equivalence and again one did not complete the test.

Differences between high anxious and low anxious groups.

Descriptive statistics of participants on variables of interests by anxiety grouping can be found in Table 1. Table 1 also shows the mean proportion of ambiguous tones the children reported as 'angry' (negative). The total proportion of ambiguous tones reported as negative was found to be significantly different from 50% in a one sample t-test (*t*(72) = 3.02 *p* = .002, *d* = .71) with a medium effect. This indicates that in general children are showing a bias towards reporting the ambiguous sounds as negative. Mean proportion of tones reported as negative by anxiety group is reported for purely for descriptive purposes. Examination of these differences will be investigated in the multi-level analyses. There were no differences in age (*t*(71) = -0.155 *p* = .877), the distribution of genders ($\chi^2$1) = 0.002 *p* = .962) between the high anxious and low anxious group. High anxious and low anxious groups were found to differ on autistic quotient score where, on average, the high anxious group showed more autistic traits than the low anxious group (see Table 1) with a large effect size (t(68) = 3.55, p = .0007, *d* = .86). Groups also differed on total effortful control score (Mann Whitney U = 870, *p* = .0045), where the high anxious group, on average, showed lower scores than the low anxious group (see Table 1) with large effects. No other differences were found. Therefore, autistic quotient scores were included in further analysis to ensure this was not acting as a confound. Other variables where the groups differed were already included in the planned analysis.

Table 1.

Descriptive statistics for Variables of interest by anxiety grouping

	Total (N = 73)		High Anxious group (N = 46)		Low Anxious Group (N = 27)	
Variables	Mean	SD	Mean	SD	Mean	SD
Age	5.86	1.42	5.84	1.35	5.89	1.55
AQ total	65.33	18.54	71.09*	14.80	56.15*	20.39
ECS total	4.58	1.02	4.38*	1.14	4.91*	.68
Non-Verbal	5.65	1.28	5.61	1.31	5.71	1.25
Verbal	5.89	1.27	5.73	1.25	6.15	1.30
Prop. Ambiguous Sounds Negative	56.01	19.58	58.04	20.67	52.36	17.21

* difference between groups p>.05. Prop. Ambiguous Sounds Negative = The proportion of Ambiguous Sounds reported as Angry 'Negative'. Non-Verbal = Non-verbal cognitive ability. Verbal = Verbal cognitive ability.

Trained Tones Blocks in the Experimental Phase.

Table 2 shows that, on average, children maintained the >60% learning level throughout the TT blocks in the experimental phase of the task.

Table 2.

Means and Standard Deviations of percentage accuracy on Trained Tone blocks within the Experimental Phase of the task split by Anxiety Grouping.

	Total Sample		High Anxious		Low Anxious	
	N	M (SD)	N	M (SD)	N	M (SD)
TT block 1	72	75.15 (18.93)	45	74.07 (19.42)	27	76.95 (18.30)
TT block 2	47	81.74 (17.73)	32	80.42 (14.87)	15	84.55 (23.04)
TT block 3	33	75.18 (16.75)	20	74.65 (17.28)	13	75.98 (16.57)
TT block 4	6	76.48 (22.38)	4	79.72 (26.95)	2	70 (14.14)

*TT = Trained tone.

The first model assessed the influence of anxiety and developmental proxies on accuracy in the practice blocks. Here the dependent variable was accuracy (accurate or not accurate). As can be seen in Table 3 a multilevel model with three levels (trials within participants, within families) and a multilevel model with two levels (trials within participants), both provided a significant improvement on a single level linear regression model. There was no difference in model fit between the three and two level model ($\chi^2 3$) = .00001 $p > .995$). Given this a two-level model was accepted as the appropriate analysis for the data on the practice trials as it is the most parsimonious.

As can be seen in Table 4, level 1 predictors were then systematically added to the model. Model 2 was the first model to show improvement to the random intercept model ($\chi^2(2) = 85.34$, $p < .005$). Model 6 was the first model to show improvement to Model 2 ($\chi^2 7$) 21.06, $p < .005$) therefore, Model 6 was selected as the final model.

All coefficients, variance and model fit statistics can be found in Table 4. As can be seen in Table 4, the final model (Model 6) indicates that the only predictors influencing accuracy on the practice trials are the linear and quadratic age terms, with a small effect size ($OR_{age} = 1.60$; $ORage^2 = .85$; Chen, Cohen, & Chen, 2010). The positive coefficient indicates that, at the average of all other variables, as age increases the likelihood of the child being accurate increases (Table 4).

Table 4.
Coefficients and Model Fit Statistics for Models predicting Accuracy of Children in the Practise Trials.

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	B	*OR(CI)*	*B*	*OR(CI)*	*B*	*OR(CI)*	*B*	*OR(CI)*	*B*	*OR(CI)*	*B*	*OR(CI)*
Predictors												
Valence	.14	1.15 (.91, 1.45)	.14	1.15(.91, 1.45	.14	1.15(.91, 1.45)	.14	1.15(.91., 1.45)	.15	1.15(.91, 1.45)	.13	1.14(.91, 1.44)
Anxiety grouping	-.47	.62 (.36, 1.07)	-.43	.65 (.40, 1.03)	-.65	.52(.25, 1.07)	-.41	.66(.41, 1.06)	-.39	.68(.41, 1.11)	-39	.68(.41, 1.08)
AQ	0.01	1.01(1.00, 1.03)	.007	1.01 (.99, 1.02)	.005	1.01(.99, 1.02)	.008	1.01(.99, 1.02)	.008	1.01(.99, 1.02)	.01	1.01(1.00, 1.92)
Age	-	-	.47***	1.6 (1.33, 1.94)	.63**	1.87(1.22, 2.90)	.47*	1.60(1.33, 1.94)	.47*	1.60(1.33, 1.94)	.36*	1.43(1.08, 1,92)
Age^2	-	-	-.20**	.82(.71, .93)	-.31*	.73(.55, .98)	-.20*	.82(72, .94)	-.19*	.83(.71, .95)	-.17*	.85(.73, .98)
Age*Anx	-	-	-	-	-.18	.83(.52, 1.34)	-	-	-	-	-	-
Age^2*Anx	-	-	-	-	.14	1.15(.82, 1.61)	-	-	-	-	-	-
Effortful Control	-	-	-	-	-	-	.08	1.08(.78, 1.51)	.16	1.18(.68, 2.05)	.11	1.12(.80, 1.57)
Effortful Control* Anx	-	-	-	-	-	-	-	-	-.13	.88(.45, 1.71)	-	-
Non-Verbal Cognitive Abilities	-	-	-	-	-	-	-	-	-	-	.11	1.12(.87, 1.44)
Verbal Cognitive Abilities	-	-	-	-	-	-	-	-	-	-	.03	1.03(.83, 1.29)
Model Fit Statistics												
Variance		.79		.73		.46		.46		. 46		.46
AIC		1998.3		1919.0		1901.1		1902.9		1904.7		1886.0
BIC		2009.7		1947.2		1940.6		1948.1		1955.6		1942.4
Loglik		-997.2		-954.5		-943.6		-943.4		-943.4		-933

Note. Anx = Anxiety Grouping.
* p <.05, ** p <.01, *** p <.001.

Table 3.

Logliklihood ratio tests between random intercept models and 2 and 3 level models, and variance components associated with each model.

	Practise Trials		Ambiguous Trials	
	2 Level Model	3 Level Model	2 Level Model	3 Level Model
-2Logliklihood compared to single level	-58.77*	-58.77*	28.35*	28.35*
df	1	1	1	1
Variance level 1 (Trials)	81	81	90	90
Variance level 2 (Participants)	19	19	10	10
Variance level 3 (Families)	-	0	-	0

Note. * p <.005

Trained Tones in the Experimental Blocks.

This refers to the high and low tones that were played amongst the ambiguous tones in the EX blocks. The minimum number of trials available per participant on trained tones is two and the maximum is 10. Descriptive statistics are presented in Table 5 as there is too little data to assess accuracy to the trained tones within an ANOVA model or a multilevel model. As Table 5 shows, on average children maintained above 60% accuracy on trained tones across all the experimental blocks they completed and in both anxiety groups.

Table 5.

Descriptive Statistics of Percentage Accuracy on Trained Tones within the EX Blocks

	Total Sample		High Anxious		Low Anxious	
	N	M (SD)	N	M (SD)	N	M (SD)
EX block 1	73	74.20 (31.43)	46	72.46 (33.19)	27	77.16 (28.55)
EX block 2	71	79.11 (31.71)	45	81.11 (32.10)	26	75.64 (31.35)
EX block 3	46	77.17 (32.65)	31	74.73 (34.12)	15	82.22 (29.86)
EX block 4	32	79.17 (29.33)	19	74.56 (33.04)	13	85.90 (22.41)
Total across all blocks	73	76.85 (24.26)	46	76.71 (24.93)	27	77.11 (23.55)

*EX = experimental blocks in the Experimental phase of the task.

Ambiguous Tones in the Experimental Blocks.

Figure 4 shows that most children were consistent in their categorisation of the ambiguous tones across instruments across the experimental trials. Though more children were consistent than not consistent, a fair number were reporting the ambiguous tones as happy half the time and angry half the time.

The dependent variable was the response recorded to the tone per trial. As can be seen in Table 3, both the three level (trials within participants, within families) and two-level models showed a significant improvement on a single level linear regression model. There was no difference between the two and three level models ($\chi^2(1)$ = .00000007, p > .005). However, given the lack of variance at the third level (see Table 3) a two-level model was compared to a single level linear regression model and the two level model was accepted as the appropriate model for analysis here.

As can be seen in Table 6, level 1 predictors were then systematically added to the model. Model 1 showed improvement to the random intercept model ($\chi^2(1)$ = 64.70, p < .005). Model 6 was the first model to show an improvement in the model fit beyond Model 1 ($\chi^2(4)$ = 19.6, p < .05) and was accepted as the final model.

The final model (as seen in Table 6) indicates that Anxiety grouping is a significant predictor of response to the ambiguous tone as negative when Autistic quotient, Age, Age^2, Effortful Control Total score, Non-verbal Cognitive abilities and Verbal Cognitive Abilities were included in the model. The positive coefficient of the anxiety grouping predictor indicates that at the average of the other predictors, those with high anxiety are more likely to interpret the ambiguous tone as negative. The odds ratio of anxiety grouping indicates this is a small effect (Chen et al., 2010).

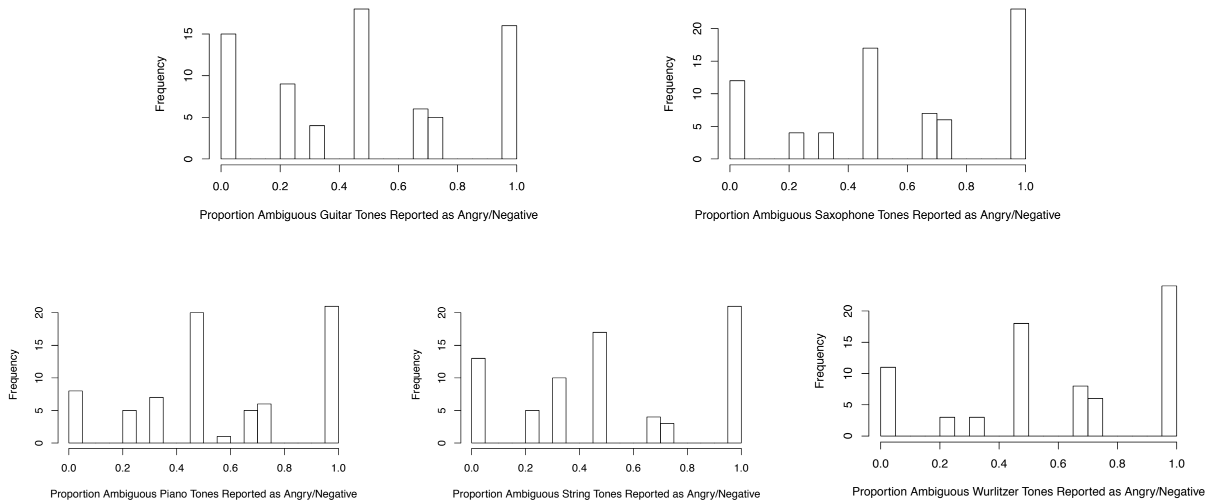

Figure 3. *Histograms to show the Frequency of Times the Ambiguous Tones were Reported as Negative by Instrument*

Table 6.

Coefficients, Standardised Coefficients and Model Fit statistics associated to Model adding Level 2 predictors on Trials on Ambiguous Tones

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	B	*OR(CI)*	*B*	*OR(CI)*	*B*	*OR(CI)*	*B*	*OR(CI)*	*B*	*OR(CI)*	*B*	*OR(CI)*
Predictors												
Anxiety grouping	.36	1.43(.94, 1.49)	.39	1.47(97, 2.58)	.41	1.51(.82, 2.83)	.39	1.45(.97, 2.28)	**.**27	1.32(.86, .2.03)	**.42***	1.53(1.00, 2.35)
AQ	.002	1.00(.99, 1.01)	.004	1.00(.99, 1.02)	.003	1.00(.99, 1.02)	.004	1.00(.99, 1.02)	.003	1.00(.99, 1.02)	.005	1.01(.99, 1.02)
Age	-	-	.04	1.04(.87, 1.35)	-.10	.90(.61, 1.34)	.04	1.04(.87, 1.25)	.04	1.04(.88, .1.24)	.01	1.01(.78, 1.32)
Age^2	-	-	.07	1.07(.94, 1.22)	.12	1.12(.87, 1.46)	.07	1.07(.94, 1.22)	.05	1.05(.93, 1.20)	.08	1.09(.95, 1.25)
Age*Anx	-	-	-	-	.21	1.23(.80, 1.91)	-	-	-	-	-	-
Age^2*Anx	-	-	-	-	-.03	.97(.72, 1.33)	-	-	-	-	-	-
Effortful Control	-	-	-	-	-	-	.02	1.02(.76, 1.38)	-.32	.73(.45, .1.15)	-.01	.99(.73, 1.36)
Effortful Control*Anx	-	-	-	-	-	-	-	-	.54	1.72 (.98, 3.07)	-	-
Non-Verbal Cognitive Abilities	-	-	-	-	-	-	-	-	-	-	.05	.95(.76, 1.20)
Verbal Cognitive Abilities	-	-	-	-	-	-	-	-	-	-	.11	1.11(.91, 1.36)
Model Fit statistics												
Variance	.33		.31		.30		.31		.30		.27	
AIC	1386.7		1387.7		1390.4		1389.7		1388.1		1376.7	
BIC	1406.5		1417.4		1429.9		1424.3		1427.6		1426.0	
Loglik	-689.4		-687.9		-687.2		-687.9		-686.1		-678.3	

Psycho-Physiological Data: fEMG

The metric area under the curve was calculated from stimulus onset to 300ms post stimulus onset. Using area under the curve per trial as the dependent variable, when single, two and three level models were investigated to assess the appropriateness of multi-level modelling of the fEMG data no differences were found between the models. To take into account the different number of trials per child (missing data) and prevent the inflation of standard errors it was decided that multi-level analysis would be the appropriate method over a standard regression. Single level regression models were checked and results did not substantially differ though, as would be expected, the multi-level model was more conservative in its *p*-value estimation. After data pre-processing and cleaning described above 62 children had valid data on the fEMG measure for analysis. Descriptive statistics of the fEMG data for both the practice and ambiguous tones can be seen in Table 7.

Table 7

Descriptive Statistics of the fEMG data from the Experimental Phase for each Dependent Variable by Total Sample and by Anxiety Group

	Total Sample			High Anxious			Low Anxious		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Trained tones									
Area Under the Curve	62	.0004	.002	39	.0002	.0008	23	.0008	.004
Ambiguous Tones									
Area Under the Curve	62	.001	.003	38	.003	.002	24	.001	.004

Trained Tone Blocks in the Experimental Phase.

As expected, level 1 variables response (whether the tone was reported as ‘angry’ or ‘happy’) and valence (whether the tone was trained to be classified as ‘angry’ or ‘happy’) were correlated with a large effect ($r = .63$, $p < .001$). Given this, two sets of models were created where valence and response were entered as level 1 predictors respectively. This also allowed clear investigation of whether corrugator activity could be predicted by the valence of the tone in the trial or by the perceived valence of the tone (response).

In the model including “valence” as a predictor (See Table 8) Model 1 showed an improvement on the random intercept model ($\chi^2(4) = 14.63$, $p < .05$). The next model to show an improvement over Model 1 was Model 6 (χ^2 (6) = 38.92, $p < .05$) and so Model 6 was accepted as the final model (see Table 8). As can be seen in Table 8 none of the predictors proved significant in this final model.

In the model including "response" as a predictor (See Table 9: Model 1) showed an improvement on the random intercept model ($\chi^2(6) = 629.71$, $p < .001$). The next model to show an improvement over Model 1 was Model 6; ($\chi^2(6) = 17.89$, $p < .05$). Therefore, Model 6 was accepted as the final model (see Table 9). Only level 1 predictor "response" was a significant predictor of corrugator activity in the practise trials, though with a small effect, such that when the child reported the tone as coming from an alien who was 'angry' there was greater corrugator activity. Anxiety group and developmental proxies appeared to have no significant influence on corrugator activity in the practise trials when response was the level 1 predictor.

Ambiguous Tones in the Experimental Blocks.

Model 1 showed an improvement on the random intercept model ($\chi^2(4) = 130.26$, $p < .001$. The next model to show an improvement over Model 1 was Model 4 ($\chi^2(9) = 5514.44$, $p < .001$). Model 5 showed an improvement over Model 4 ($\chi^2(10) = 5514.44$, $p < .001$) and as Model 6 did not show any further improvement ($\chi^2(11) = 1.70$, $p = .995$) Model 5 was accepted as the final model (see Table 10). However, none of the predictors reached significance (see Table 1). This indicates that corrugator activity in response to the ambiguous tones was not influenced by the subjective valence categorisation of the child, their anxiety grouping or components of their development.

Table 8

Coefficients, Standardised Coefficients and Model Fit statistics associated to Models investigating Corrugator Activity adding Valence and Level 2 predictors on TT blocks in the Assessment Phase

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	β	*B*	*β*	*B*	*β*	*B*	*β*	*B*	*β*	*B*	*β*	*B*
Predictors												
Valence	.00009	.003	.00004	.003	.00004	.003	.00004	.003	.00004	.003	.0001	.009
Anxiety grouping	-.0004	-.056	-.0007	-.054	-.0003	-.026	-.0007	-.059	-.001	-.085	-.0006	-.048
AQ	.000002	.007	.000006	.014	.000005	.017	.000001	.004	.000002	.004	.000006	.020
Age	-	-	-.0002	-.035	-.0008	-.176	-.0002	-.038	-.0002	-.032	-.0004	-.095
Age^2	-	-	.0001	.037	.0004	.136	.0008	.029	.00002	.005	.0002	.067
Age*Anx	-	-	-	-	.0009	.136	-	-	-	-	-	-
Age^2*Anx	-	-	-	-	-.0003	-.071	-	-	-	-	-	-
Effortful Control	-	-	-	-	-	-	.0003	-.037	-.002	-.148	-.0003	-.030
Effortful Control*Anx	-	-	-	-	-	-	-	-	.002	.138	-	-
Non-Verbal Cognitive Abilities	-	-	-	-	-	-	-	-	-	-	-.0002	-.039
Verbal Cognitive Abilities	-	-	-	-	-	-	-	-	-	-	.0006	.119
Model Fit statistics												
Variance	.000005		.000005		.000005		.000005		.000005		.000005	
AIC	-13413.6		-13409.9		-13407.5		-13408.3		-13409.0		-134442.5	
BIC	-13380.6		-13365.9		-13352.5		-13358.8		-13354.0		-13382.1	
Loglik	6712.8		6713.0		6713.3		6713.2		6714.5		6732.3	

Note. Anx = Anxiety Grouping. * $p < .05$

Table 9.

Coefficients, Standardised Coefficients and Model Fit statistics associated to Models investigating Corrugator Activity adding Response and Level 2 predictors on TT blocks in the Assessment Phase

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	β	*B*	*β*	*B*	*β*	*B*	*β*	*B*	*β*	*B*	*β*	*B*
Predictors												
Response	.0005	.043	.0005	.043	.0005	.043	.0005	.043	.0005	.043	**.0006***	**.048**
Anxiety grouping	-.0007	-.052	-.0006	-.050	-.00006	-.005	-.0007	-.056	-.001	-.082	-.0006	-.046
AQ	.000006	.020	.000009	.030	.00005	.040	.000005	.016	.000002	.008	.000007	.024
Age	-	-	-.0001	-.032	-.0009	-.202	-.0002	-.036	-.0001	-.030	-.0004	-.093
Age^2	-	-	.0001	.042	.0005	.176	.00009	.031	.00003	.009	.0002	.072
Age*Anx	-	-	-	-	.001	.160	-	-	-	-	-	-
Age^2*Anx	-	-	-	-	-.004	-.104	-	-	-	-	-	-
Effortful Control	-	-	-	-	-	-	-.0004	-.050	-.001	-.153	-.0003	-.036
Effortful Control*Anx	-	-	-	-	-	-	-	-	.001	.128	-	-
Non-Verbal Cognitive Abilities	-	-	-	-	-	-	-	-	-	-	-.0002	-.049
Verbal Cognitive Abilities	-	-	-	-	-	-	-	-	-	-	.0006	.121
Model Fit statistics												
Variance	.000005		.000005		.000005		.000005		.000005		.000005	
AIC	-13212.0		-13208.3		-13206.2		-13207.0		-13207.3		-13219.9	
BIC	-13179.1		-13164.4		-13151.4		-13157.6		-13152.4		-13159.6	
Loglik	6612.0		6612.1		6613.1		6612.5		6613.6		6620.9	

Note. Anx = Anxiety Grouping. * p <.05

Table 10.

Coefficients, Standardised Coefficients and Model Fit statistics associated to Models investigating Corrugator Activity adding Response and Level 2 predictors on Ambiguous Trials in the Assessment Phase

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	β	*B*	*β*	*B*	*β*	*B*	*β*	*B*	*β*	*B*	*β*	*B*
Predictors												
Response	.0007	.042	.0007	.043	.0006	.040	.0007	.042	.0007	.042	.0007	.041
Anxiety grouping	-.001	-.071	-.001	-.070	-.006	-.063	-.001	-.074	-.001	-.076	-.001	-.065
AQ	.000005	.001	.00001	.023	.000008	.018	.00005	.012	.000005	.011	.00001	.024
Age	-	-	-.0005	-.078	-.001	-.222	-.0005	-.080	-.0005	-.080	-.0008	-.127
Age^2	-	-	.0003	.072	.0006	.142	.0003	.061	.0002	.060	.0004	.088
Age*Anx	-	-	-	-	.001	.140	-	-	-	-	-	-
Age^2*Anx	-	-	-	-	-.0002	-.036	-	-	-	-	-	-
Effortful Control	-	-	-	-	-	-	-.0005	-.042	-.0006	-.051	-.0004	-.038
Effortful Control*Anx	-	-	-	-	-	-	-	-	.0002	.112	-	-
Non-Verbal Cognitive Abilities	-	-	-	-	-	-	-	-	-	-	-.0002	-.022
Verbal Cognitive Abilities	-	-	-	-	-	-	-	-	-	-	.0006	.090
Model Fit statistics												
Variance	.000007		.000006		.000006		.000001		.000006		.000006	
AIC	-5890.6		-5888.0		-5886.2		-5886.6		-5884.6		-5884.3	
BIC	-5862.1		-5849.9		-5838.5		-5843.7		-5836.9		-5831.8	
Loglik	2951.3		2952.0		2953.1		2952.3		2952.3		2953.1	

Note. Anx = Anxiety Grouping. * p <.05

Discussion

Evidence from the behavioural data indicates that this task was appropriate for children aged 4 to 8 years. Most participants learnt the associations between tone and valence. Likelihood of learning the association was not influenced by age, gender or anxiety group. Most children were shown to be consistent in their categorisation of the ambiguous tones by instrument, though some children categorised the tones as happy half the time and angry half the time. Multi-level analysis indicated that as children increased in age they were more likely to be accurate on the practice trials. However, children on average did maintain their accuracy over the learning threshold (> 60%) throughout the practice trials and on the trained tones within the experimental trials regardless of anxiety group. Even the 4-year olds were, on average, maintaining their accuracy over the threshold, though again older children showed a higher accuracy. Therefore, while overall, participants could maintain their learning at the set threshold, the older the child the more likely they were to be accurate. This evidence suggests that children could categorise the tones accurately throughout the task and therefore it is reasonable to assume that the children were also categorising the ambiguous tones rather than guessing.

Further evidence that the task was appropriate for the age group comes from investigations of the influence of verbal and non-verbal cognitive abilities on task performance. Multi-level analysis also showed that while verbal and non-verbal cognitive abilities contributed to the final model in the behavioural data and the final models for the fEMG data in the practise trials, they were not significant predictors of task performance. In the final model for fEMG data in the experimental trials the addition of verbal and non-verbal cognitive abilities did not improve model fit, indicating they did not contribute to the model. Such evidence suggests that performance of the task in the subjective or objective measures was not unduly influenced by verbal and non-verbal cognitive abilities.

Initial viewing of the mean proportion of ambiguous tones reported as angry indicated that all participants showed a tendency to interpret ambiguous tones as negative. Multi-level analyses of the behavioural data on the responses to ambiguous tones indicated that in the initial model where only anxiety grouping and autistic quotient were added, group differences did not reach significance. However, once all developmental proxies were added to the model group differences did reach significance, with the high anxious group more likely to interpret an ambiguous tone as negative than the low anxious group. This suggests that developmental factors may confound the association between anxiety and behavioural responses to the ambiguous tones. However, it should be noted that the difference between anxious groups remains small and given this effect is not very different from the initial model it may be that the developmental proxies accounted for enough variance to push the effect over the significance threshold of $p = .05$.

The investigation of the fEMG data in response to the tones revealed that in the practice trials there was greater corrugator activity to tones the children reported as negative, rather than tones they had been trained to categorise as negative. Increased corrugator activity in response to negative stimuli would be expected, but our results indicate that corrugator activity was reflecting their subjective perception of the tone. This is in line with Dimberg (1990) and Tan et al. (2012) who also found that corrugator activity reflected the participants subjective experience of the stimuli. However, this was not the case in the experimental trials where neither the child's subjective valence categorisation of the ambiguous tones nor their anxiety group predicted corrugator activity in response to ambiguous tones. Unlike the behavioural data, differences between anxiety groups in corrugator activity were still not evident once development had been accounted for. Therefore, unlike Tottenham, Phuong, Flannery, Gabard-Durnam, and Goff (2013) we did not find the corrugator to be a physiological index of an individual's appraisal of valence-ambiguous stimuli.

There may be several explanations for our results. First, our results may indicate that interpretation bias is present on a behavioural, conscious level, but does not reflect emotional reactions. Yet, Tottenham et al. (2013) did find a correspondence between subjective and physiological responses. However, Tottenham et al. (2013) used images in their study with a much greater age range (6 to 17yrs). While no differences were found in corrugator activity to standardised visual and auditory stimuli in adults (Zhou, Qu, Jiao, & Helander, 2014), we do not know if this is the case in children. It may be that children respond differently in terms of corrugator activity to stimuli of different modalities, showing a greater response to visually valenced stimuli than auditory. This may explain why Tottenham et al (2013) found correspondence between responses to ambiguous stimuli and corrugator activity, when we did not. Our participants did show a greater corrugator response to the trained tones they reported as negative, but they had also been given a visual representation of the alien when it was happy, and angry in the practise. There was no such visual representation associated with the ambiguous tones. Thus, when they perceived a tone to be negative they may have also conjured up the visual of the alien when it was angry resulting in the corrugator response. Without the visual bolster for the ambiguous tones the same strength of corrugator response may not have been seen.

Compared to corrugator responses to the trained tones any response to the ambiguous tones would be expected to be quite subtle. This is because when ambiguous tones are classified as ‘happy’ or ‘angry’ one would not expect the same level of emotional reaction as when they were experiencing the happy or angry tone. As such, the level of felt emotion may be too subtle for it to be reflected in the children’s corrugator activity. Viewing a face however, is a social stimulus and much more familiar than a tone, which again may have resulted in differences between the tasks. Finally, our sample included children ages 4 to 8 and with this comes inherently noisy data when trying to capture such reflexive activity from a tiny surface area. So, while every effort was used to reduce movement and noise in the data it may have been the case that these efforts were not enough to produce clean enough data to reveal any differences in or influences on subtle corrugator activity.

The finding that development is acting as a confound on the behavioural responses to ambiguous tones highlights the importance of taking development into account and is suggestive of a role for development in the relationship between interpretation bias and anxiety. However, what our study is unable to indicate is the exact nature of this role and which developmental proxy may be most important. These were not specific research questions addressed here. Field and Lester (2010) concluded that from the evidence reviewed the nature of the role of development best fitted an acquisition model. In this model biases only emerge as social, emotional and cognitive abilities develop. Anxiety may be part of the cause or consequence of the biases. The recent meta-analysis of Stuijfzand et al. (2017) also found evidence of a moderation by age suggesting that development may be important for the relationship between interpretation bias and anxiety. However, this study stressed the importance of more studies with younger children to verify this effect (Stuijfzand et al., 2017). In the first step of our analysis investigating responses to ambiguous tones, anxiety grouping (and AQ) were added to investigate whether anxiety differences were present. While this model did improve model fit from a random intercept model, no differences in anxiety groups were found. This initial finding is in line with other studies that did not find relations between anxiety and interpretation bias (e.g. Bell-Dolan, 1995; Dalrymple-Alford & Salmon, 2013; Field & Field, 2013). However, these other studies did not control for development. As in our study, anxiety group differences may be present in other studies, but are masked by confounds created by developmental factors in the sample.

While determining the final model for the behavioural data in response to the ambiguous tones, interaction terms between anxiety and the developmental proxies were added. This model did not show an improvement to the model with no interactions present. However, it is noteworthy that the interaction between effortful control and anxiety group showed the largest odds ratio in the model and may hint towards a potential avenue to further research. Salemink and Wiers (2012) found a moderating role for regulatory control in the relationship between interpretation bias and anxiety, again indicating a potential developmental candidate and potential relationship for future research. However, as yet, very few studies investigating interpretation bias and anxiety in children consider development in their design or analysis (Stuijfzand et al., 2017). Our results show that developmental models of anxiety need to play a larger role in our investigation of interpretation bias and anxiety in children if we are to increase our understanding and inform treatments.

Inevitably this study has its limitations. Two limitations revolve around the sample. Firstly, it would have been preferable for the high and low anxious groups to have been defined by one standard deviation above and below the mean. However, there was difficulty in recruiting children who qualified for the low anxious group. This was despite changes in advertising and recruitment strategy when this difficulty became apparent. It is possible that, had the difference in anxiety been greater between the groups, larger group differences in behavioural and psycho-physiological data would have been evident. Future research could replicate this task with a clinical sample compared to a healthy control where the difference in anxiety could not be called into question. Secondly, this was a self-selecting sample. Parents may have entered the study due to an interest in anxiety in general or because they were concerned about anxiety in their child, as evidenced by the difficulties recruiting low anxious children. Finally, while many children took part in the task the numbers included in the final analysis may have meant that the study was not powered enough to fully investigate moderation by the age and effortful control. Therefore, it is not clear whether the lack of moderation found on the different dependent variables was due to lack of power or because adding the interactions terms did not improve the model and were not significant predictors. A larger sample would enable a better powered investigation of the interaction terms with developmental proxies and could aim specifically to investigate the relative importance of the proxies to the model.

Anxiety in children is often treated via cognitive behavioural therapy which targets interpretation biases to change anxiety. Our results suggest that should young children be involved in such therapy their development, for example, cognitive and linguistic abilities, should be taken into account when assessing whether and for whom treatments are appropriate for. Should future studies find moderation of the relationship between interpretation bias and anxiety by a developmental proxy such as effortful control this proxy may provide an avenue for treatment for such children. If the relationship between interpretation bias and anxiety is only present in those with low effortful control, for example, then high effortful control is acting as a protective factor. By training effortful control in those with low effortful control it may be possible to prevent or alter the association between interpretation bias and anxiety. It is stressed however, that such an intervention requires a lot more powered research with younger children using developmentally appropriate paradigms before this is considered.

To conclude, this is the first study to attempt to assess interpretation bias using a developmentally sensitive paradigm in young children and to explore the potential of fEMG alongside behavioural measures using this paradigm. Results indicate that young children can complete the task and there is evidence they are making genuine categorisations of ambiguous stimuli. Behavioural results indicate that high anxious children are more likely to interpret ambiguous tones as negative once developmental proxies have been statistically accounted for. While this study found that corrugator activity reflected children's subjective experience of the tones in the practise trials, this was not the case with ambiguous tones in the experimental trials. Therefore, we did not find evidence for the corrugator as a physiological marker of children's appraisal of valence-ambiguous stimuli. Results highlight the importance of considering development in both design and analysis of investigations of interpretation bias and anxiety in children as well as encouraging more consideration of theories of anxiety that consider a role for development.

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Chapter 4. Paper 3: Anxiety differences in visual attention to emotional faces in four to eight year olds

Manuscript in preparation for submission to Clinical Psychological Science

Stuijfzand, S., Stuijfzand, B.G., Reynolds, S. & Dodd., H. F. *Anxiety differences in visual attention to emotional faces in four to eight year olds.* Manuscript in Preparation

Appendices Associated with this Chapter:

Appendix: 3 Examples of Information Sheets and Informed Consent Sheets provided to the Parents

Appendix 4: Information and Assent Sheets for Children

Appendix 5: Example of Reward Chart

Appendix 7: Example of Debrief Sheets for Parents (7-8 year olds)

Appendix 8: Certificate given to Children at completion of the Space Quest

Appendix 9: Examples of Stickers given as a Reward for Completion of the Space Quest

Appendix 13: Protocol of Attention Bias task

Appendix 14: Examples of Faces Used in the Attention Bias Task

Appendix 15: Example of IAPS Images used in the Attention Bias Task

Appendix 16: Examples of Aliens used in the Attention Bias Task

Appendix 17: Full Mixed ANCOVA Table from Paper 3

Abstract

Cognitive models of anxiety postulate there is a relationship between an attention bias, (the disproportionate allocation of attention to threat-related stimuli) and anxiety. Two meta-analyses have found evidence of a robust attention bias-anxiety relationship in children. However, a lack appropriate measures of attention bias for young children has resulted in a sparsity of research investigating the attention bias-anxiety relationship with children below 8-years-old.

This study uses a new child friendly eye-tracking task to investigate whether anxiety related attention biases exist in children aged 4 to 8 years. Participants were 104 children split into high and low anxious groups based on parent report. Children viewed happy-neutral and angry-neutral face pairs whilst eye-gaze was recorded. Summary statistics were assessed using mixed ANCOVA's and growth curve analysis was used to assess the time course of the children's visual attention to the faces based on the face looked at first.

Initial analyses indicated that all children were vigilant to the emotional faces over the neutral faces and young children looked at the angry face for less time than happy faces. Growth curve analysis revealed anxiety differences and more nuanced patterns of visual attention. In addition, moderation by age indicated younger and older children show differences in the nature of anxiety related biases. While moderation by effortful control was not found, effortful control influenced visual attention to the faces. Such results highlight the importance of considering developmental factors in the anxiety-attention bias relationship in young children. Results have implications for the appropriateness of anxiety treatments targeting attention bias for different ages.

Introduction

Clinical anxiety has been estimated to affect 6.5% of children and adolescents worldwide at any one time (Polanczyk, Salum, Sugaya, Caye, & Rohde, 2015). Additionally, before the age of sixteen, 9.9% of all youths will have suffered from a clinically significant anxiety problem (Costello, Mustillo, Erkanli, Keeler, & Angold, 2003). Such evidence suggests that anxiety is one of the most prevalent mental health disorders in children and adolescents. Given this, understanding the mechanisms by which anxiety is caused and maintained in this population is crucial to understanding how best to treat anxiety and assist children onto a healthy trajectory into adulthood.

Cognitive models of anxiety suggest that there are particular cognitive biases that predispose (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Eysenck, 1997; Eysenck, 1992; Williams, Watts, MacLeod, & Mathews, 1988; Williams, Watts, MacLeod, & Mathews, 1997) cause (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Eysenck, 1997; Eysenck, 1992; Williams, Watts, MacLeod, & Mathews, 1988; Williams, Watts, MacLeod, & Mathews, 1997) and/or maintain anxiety (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Eysenck, 1997; Eysenck, 1992; Williams, Watts, MacLeod, & Mathews, 1988; Williams, Watts, MacLeod, & Mathews, 1997). These biases result from over-active threat-related schemas that guide the processing and responding to incoming stimuli (Kendall, 1985). Cognitive models suggest that after an initial assessment for threat, anxious individuals have an attention bias whereby attention is disproportionately allocated to threat (Van Bockstaele et al., 2013). Two meta-analyses have found evidence of an anxiety related attention bias to threat in adults (Bar-Haim et al., 2007) and children (Bar-Haim et al., 2007; Dudeney, Sharpe, & Hunt, 2015), though the size of the relationship appears to be smaller in children (Dudeney et al., 2015).

While there appears to be evidence for an anxiety-related attention bias in children the nature of the bias is not clear. According to cognitive theories by disproportionately allocating attention to threat it would follow that anxious individuals will be more vigilant to threat than non-anxious individuals. There is indeed evidence to this effect, with anxious children showing a greater attention bias *towards* threat than non-anxious children (Fulcher, Mathews, & Hammerl, 2008; Mueller et al., 2013; Susa, Pitică, Benga, & Miclea, 2012; Waters, Kokkoris, Mogg, Bradley, & Pine, 2010). However, there is also evidence that anxious children display an attention bias *away* from threat (Brown et al., 2013; Stirling, Eley, & Clark, 2006). There is evidence that demonstrating the nature of the attention bias seen may be related to specific types of anxiety disorders. An attention bias towards threat may be related to distress related anxiety disorders (i.e. generalised anxiety disorder) while demonstrating an attention bias away from threat may be related to fear related anxiety disorders (i.e. separation anxiety, phobias and social anxiety; Salum et al., 2013; Waters, Bradley, & Mogg, 2014). The vigilance avoidance hypothesis suggests that attention bias is characterised by both a bias towards and away from threat (e.g. Mogg & Bradley, 1998). Anxious individuals initially may show an initial vigilance towards threat, followed by avoidance of threat as they divert attention away from the threat (Mogg & Bradley, 2006). Which component of the bias is seen depends on when the measure was taken following stimulus onset (Williams et al., 1997). Evidence for such a vigilance avoidance pattern has been seen when the time course of attention was investigated in adults (Garner, Mogg, & Bradley, 2006; Rinck & Becker, 2006) and in children with separation anxiety disorder (In-Albon, Kossowsky, & Schneider, 2010).

Understanding the nature of an attention bias related to anxiety in children is important for informing procedures being explored as treatments for anxiety in children such as attention bias modification (Eldar et al., 2012; Shechner et al., 2014). In these procedures attention is trained away from threat stimuli towards a neutral stimuli. This is achieved by the children completing trials of the dot probe task using threat-neutral visual pairs, but the probe consistently replaces a neutral stimuli. These procedures assume the nature of the attention bias in anxious children is towards threat. If an attention bias is characterised by an avoidance of threat or is characterised by a vigilance-avoidance pattern, then such procedures may not be as effective as hoped.

A complicating factor in understanding the relationship between attention bias and anxiety in children is that the role of development should be considered. The changing nature of children's abilities over time may influence the presence or magnitude of the relationship between an attention bias and anxiety. Indeed, the meta-analysis of Dudeney et al. (2015) found that age moderated the relationship such that the effect size increased with age. Field and Lester (2010b) suggested three models to describe how development may affect the relationship between attention bias and anxiety. The integral model sees biases as innate and only influenced by individual factors i.e. anxiety. In this model development has no influence. In the moderation model while biases may be present early in all children they will only remain for those with particular individual factors (such as anxiety) which may be influenced by social, emotional, or cognitive development. Finally, the acquisition model proposes that the appearance of biases in children is dependent on the interaction of biases with social, emotional and cognitive development. In this final model anxiety may drive or be the result of the appearance of biases. The results of both Field and Lester's (2010) review and the moderation by age in Dudeney et al.'s (2015) meta-analysis on the relationship between attention bias and anxiety in children are suggestive of a moderation model for attentional bias.

While some studies have found an influence of age on the presence or nature of the relationship between attention bias and anxiety (Benoit, McNally, Rapee, Gamble, & Wiseman, 2007; Gamble & Rapee, 2009), there are very few studies that assess the relationship between attention bias and anxiety in children younger than 8 years. The average age in Dudeney et al.'s (2015) meta-analysis was around 11 years old and the authors comment that more studies involving young children are required. This means that while moderation by age was found, it is unclear whether this was driven by a lack of studies at the younger age range. It also remains unclear whether there is a relationship between attention bias and anxiety present in young children. If we are to distinguish between the models described by Field and Lester (2010) it is important to know whether an attention bias is present early and if it is anxiety related, currently such evidence is lacking. Treatments for anxiety for children such as cognitive behavioural therapy (James, James, Cowdrey, Soler, & Choke, 2015) and, more recently, attention modification procedures (e.g. Eldar et al., 2012; Shechner et al., 2014), target attention biases to reduce anxiety. Understanding when an anxiety related attention bias is present and the role of development in that relationship would assist in making treatments for anxiety more targeted. More understanding could provide information about when and for whom such treatments are appropriate.

Other evidence for the role of development comes from studies that have looked at the moderation of the attention bias-anxiety relationship by certain cognitive abilities;

namely inhibition and attention control. It has been suggested that it is the inability of children to inhibit their selective attention to threat that gives rise to the relationship between an attention bias and anxiety (Kindt & Van Den Hout, 2001). Such a theory would suggest that early in development all children would show a bias, but over time it would only remain for anxious children. Evidence to this effect has been found (Kindt, Van Den Hout, De Jong, & Hoekzema, 2000); however, there is also evidence that this is not the case (Morren, Kindt, van den Hout, & van Kasteren, 2003). Susa, Pitică, Benga, and Miclea (2012) found that attention control, the ability to focus and shift attention, moderated that relationship between attention bias and anxiety in 9 to 14 year olds. Only children with low attention control showed an anxiety related attention bias: those with greater anxiety showed an attention bias. Attention control and inhibition are both components of effortful control, which has been defined as the ability to inhibit a dominant response to perform a subdominant response, to detect errors, and to engage in planning (Rothbart & Rueda, 2005). It has also been suggested that while vigilance to threat may be driven by bottom up reflex responses, withdrawal or avoidance of threat may be under more voluntary top down control, namely from attention control. Given attention control is an ability that develops across childhood, it follows that the avoidance of threat may be particularly sensitive to developmental stage (Shechner et al., 2017). Effortful control emerges in infancy (Rothbart & Rueda, 2005) and shows considerable development between the ages of 4 and 8 (Jones, Rothbart, & Posner, 2003; Mezzacappa, 2004). Thus, when considering the relationship between attention bias and anxiety in a young age group developing skills such as effortful control should be taken into account.

One reason for the paucity of studies examining the relationship between attention bias and anxiety in younger children is methodological. The most commonly used tasks for assessing attention bias are the dot probe task or the emotional stroop task. The cognitive demand of these tasks and their reliance on verbal instructions and reaction time responses calls into question the appropriateness of such tasks for use with children (Brown et al., 2014). The reaction time responses in the dot probe task are motor-dependent (Price et al., 2013), yet such skills are still developing in children. Demonstration of attention bias within reaction time paradigms has been shown to dependent on general response speed (Van Damme & Crombez, 2009). The variation of response time in children and the tendency to find slower reaction times in children (Van Damme & Crombez, 2009) may contribute to the unreliability of this task within a developing population. Beyond the tasks appropriateness for children, the interpretation of the emotional stroop task as involving attentional processes (Van Bockstaele et al., 2013) has been disputed (Clarke, MacLeod, & Guastella, 2013; de Ruiter & Brosschot, 1994). Also, the dot probe task also only provides a snapshot of attention (Gamble & Rapee, 2009); it is possible that attention shifts multiple times within a stimulus presentation prior to a reaction. However, where participants were looking before the reaction times were recorded is unknown (Yiend, 2010). Given this, snapshot reaction times maybe insensitive to individual differences, which could be elucidated through assessment of time course (Garner, 2010). Also, both tasks suffer from insufficient psychometrics questioning the reliability of such measures (Brown et al., 2014). Ideally, a measure of attention bias for use with children is required that makes use of objective measures without the heavy reliance on linguistic and motor abilities, and avoids some of the inherent problems of reaction time tasks (Brown et al., 2014).

There have been attempts to overcome the limitations of conventional assessments of attention bias, particularly with regards to the dot probe task, by using eye-tracking. Eye-tracking provides a continuous measure of overt visual attention, following the assumption that the direction of gaze closely reflects the object of attention (Just & Capenter, 1976). With particular relevance for use with young children, eye-tracking can be employed during a free viewing paradigm where all the children have to do is look at the screen. This removes the need for advanced linguistic and cognitive abilities or the reliance on reaction times (Price et al., 2013). Lagattuta and Kramer (2017) used a free viewing task where children and adults viewed emotional faces and found that amongst a normative sample all showed a bias (looked longer) for negative faces, but this effect was stronger in children (4 to 10 year olds). Not only does this study demonstrate the ability of this technique to be used with a young sample, but also its ability to elucidate developmental differences in attention bias.

Eye-tracking has also been used to assess anxiety related attention biases. Price et al. (2013) recorded eye-tracking while children completed a dot probe task with the intention of overcoming the limitations of the dot probe and to quantify attention across time. However, the behavioural reaction time data and eye-tracking data were analysed separately in this study. Recording both may provide complementary measures. However, to really overcome the intrinsic limitations of the dot probe task, eye-tracking could have been used to assess where the child was looking prior to the recording of reactions times and used this to decide which reaction times were valid. Mueller et al. (2013) made use of eye-tracking during an anti-saccade task with 9 to 15 year olds where children were instructed to either look towards or away from a face stimuli. They found that children in the anxious group were faster to look towards an angry face than a neutral face; showing a bias in orienting to threat not found in the non-anxious group. While this is a simple task which can be modified, the requirement to switch between looking towards or away makes this task difficult for younger children. A block design would be easier for young children, but would rather measure attention control, than an attention bias per se. Other studies have made use of free viewing paradigms. In-Albon, Kossowsky, and Schneider (2010) found evidence of a vigilance, avoidance pattern in 8 to 13 year olds, Gamble and Rapee (2009) found anxiety related differences in initial fixations in 7 to 17 year olds and Dodd et al. (2015) found, relative to non-anxious children, anxious 3 and 4 year olds avoided face stimuli across attentional processing. However, only one of these studies included young children (Dodd et al., 2015) and none took developmental factors, such as effortful control, into account.

One advantage of eye-tracking data over reaction times is that it produces continuous data allowing investigation of the time course of visual attention over a task. Some eye-tracking studies have attempted to make use of the time course by splitting the task into time bins and using repeated measures analyses to assess whether there are changes in looking behavior over time (Gamble & Rapee, 2009; In-Albon et al., 2010; Shechner et al., 2013). One showed that while differences in anxious groups were only found when investigating the time course and not when comparing initial looks (In-Albon et al., 2010). A further study, while assessing normative change, did not find differences between age groups in initial looks, but did in last looks: 4 to 10 year olds were more likely to end trials looking at angry faces than happy faces, this was not found in adults (Lagattuta & Kramer, 2017). Such studies suggest that investigating the time course may reveal nuances in results not seen in conventional analyses. However, these attempts still selected an arbitrary time bin by which to split the time course and averaged data to compare means across time bins. The focus of repeated measures analysis remains on difference rather than trajectory, which is what the continuous nature of the eye-tracking data can provide (Mirman, Dixon, & Magnuson, 2008). One way to make use of the continuous nature of the data and investigate the time course is through use of growth curve analysis (GCA). This approach assumes that observed fixation proportions reflect underlying probability distributions (Mirman et al., 2008). GCA allows the investigation of the form of these distributions and whether predictor variables are influencing the time course. GCA has been used to assess the time course of attention in social anxiety adults (Byrow, Chen, & Peters, 2016) and eye-tracking data in young children (Mahr, McMillan, Saffran, Ellis Weismer, & Edwards, 2015). If we are to make full use of the advantages eye-tracking methodology over reaction times it seems pertinent to use GCA to assess whether there are anxiety related differences in the time course of visual attention to emotional stimuli during a free-viewing task.

This paper aims to assess whether an anxiety related attention bias to emotional stimuli, specifically threat, is present in children aged 4 to 8 years using a child friendly novel eye-tracking task. This will be done by investigating the time course of visual attention to an angry and happy face. While there were neutral face vs neutral face and non-emotional image vs non-emotional image trials in the task, for the purpose of this paper the focus remains on the emotion trials. To assist in the collection of evidence regarding the role of development in the relationship between attention bias and anxiety, age and effortful control will be assessed as moderators. Verbal and non-verbal cognitive abilities of the children will be assessed and examined as predictors to check that task performance is not reliant on these abilities. Autism and anxiety disorders are often comorbid (van Steensel, Bögels, & Perrin, 2011). To ensure that differences in anxiety groups reflect differences due to anxiety, not autistic traits, autistics trait were assessed. Should differences in autistics traits be found between the anxiety groups then scores on the autistic quotient will be added as a covariate with analyses. To take advantage of the continuous nature of the eye-tracking data, growth curve analysis will be used. To provide a comparison and check whether such fine-grained analysis does reveal further information about children's visual attention to the faces, conventional repeated measure ANOVA analyses utilising summary statistics of initial looks will also be conducted.

Following the meta-analysis of Dudeney et al. (2015) and evidence from recent eye-tracking studies it is expected that there will differences between anxious groups in looking behaviour to the angry faces over the trial. In line with previous eye-tracking data, we tentatively suggest that anxious children will show an initial vigilance to angry faces, followed by avoidance. It is also tentatively suggested that age will moderate this relationship, with a stronger association between anxiety and attention to threat found in the older children, than the younger children. Following evidence and the inhibition hypothesis it is expected that children in the high anxious group with low effortful control will show an attention bias, whereas other groups will not. However, what this may look like in the time course is not yet clear as it has not been previously investigated. If a vigilance avoidance pattern is indeed present it could be expected that the avoidance component may be stronger in those with greater effortful control. Should we have achieved in developing a task which is not dependent on verbal and non-verbal abilities these variables should not predict patterns of gaze across the time course.

Methods

Participants

One hundred and thirteen children took part in the attention bias task (65 males, *Mage* = 6.06, *SD* = 1.16, age range 4.08 to 8.83 year olds). Following data cleaning procedures (see below), the data of 104 children (62 males, *Mage* = 6.02, *SD* = 1.15, age range 4.08 to 8.83 year olds) were included in the final analysis. Of those excluded, four were from the high anxious group (3 males, *Mage* = 6.45, *SD* = 1.24, age range 4.75 to 8.83 year olds). Participants were recruited for a study investigating anxiety and thinking styles in children via: advertisements placed in local magazines and newsletters targeted at families, local newspapers; posters placed in public places likely to be visited by families, for example local libraries, museums, and children's toy shops; leaflets handed out by local schools and at children's groups, for example, rainbow and guide groups. Parents (two males) answered online screening questionnaires regarding their child's anxiety using the Preschool Anxiety Scale (PAS; Spence, Rapee, McDonald, & Ingram, 2001) or the Spence Children's Anxiety Scale (SCAS; Nauta et al., 2004) depending on age. Children identified as having high anxiety (one standard deviation above the normed mean) or low anxiety (below the normed mean) were invited with their parents to come to the University. The final sample included 65 high anxious, 39 low anxious children. The majority of the parents identified their children's ethnicity as being British (90%; 3 % European; 3% Mixed (Arabic and white British; 3% Australia). Ethnicity information was only available for 39 children, but we can assume the sample of ethnicity taken to be representative of the entire sample as the study took place in Berkshire, where around 80% of the population is white with the remaining 20% representing a range of ethnicities (Office of National Statistics, 2012). 91% parents identified themselves as the primary caregiver.

Measures: Parents

Spence Child Anxiety Scale (Preschool version; PAS and child version; SCAS).

Parents completed these measures of anxiety for screening purposes. Both measures yield a total score of general anxiety symptoms. On both measures, higher scores indicate higher anxiety.

Parents of the 4 to 6-year-olds completed the PAS, a 28 item questionnaire answered on a five point likert scale from 0 (Not true at all) to 4 (Very often true) (minimum = 0, maximum = 112). The measure has strong psychometric properties being consistent with DSM-IV classification and with the internalising scale of the Child Behaviour Checklist (CBCL; Achenbach, 1991; Spence, Rapee, McDonald, & Ingram, 2001). The total score of the PAS showed excellent internal consistency (α = .93).

Parents of the 7 and 8-year-old group answered the parallel measure SCAS, a 38 item measure answered on a 4 point likert scale of 0 (never) – 3 (always) (minimum = 0, maximum = 114). The SCAS has shown good psychometric properties (Nauta et al., 2004; Spence, 1998). The SCAS showed excellent internal consistency (α = .94).

Child Behaviour Questionnaire – Effortful Control Scale (CBQ-EFC; Rothbart, Ahadi, Hershey, & Fisher, 2001).

The Effortful Control Scale is a parent report measure consisting of 47 items from the Children's Behaviour Questionnaire (Rothbart et al., 2001) that assesses individual differences in attentional self-regulation as a basic dimension of temperament. The scale shows good psychometric properties (Rothbart et al., 2001) and consists of the subscales low intensity pleasure, inhibitory control, perceptual sensitivity and attentional control. We also added the five-item subscale of attention shifting to the original 47 items of the effortful control scale. The attention shifting subscale has showed good internal consistency when combined with attention focusing and inhibition to assess effortful control (Eisenberg et al., 2007). Therefore, parents answered 52 items on a likert scale of 1 to 7 (1 = extremely untrue, 7 = extremely true, or 8 = not applicable; minimum = 52, maximum = 364). Higher scores indicate more of effortful control. Internal reliability was excellent for the total scale (α = .88).

The Autism Spectrum Quotient: Children's Version (AQ: Child; Auyeung, Baron-Cohen, Wheelwright, & Allison, 2008).

The AQ: Child is a 50 item parent report measure of autistic traits with good psychometric properties (Auyeung et al., 2008). Parents were asked to rate each item indicating to what extent they agree or disagree with the statements about their child on a four point likert scale (0 = definitely agree to 3 = definitely disagree). The higher the score the more autistic-like traits the child shows (minimum = 0, maximum = 150). The full scale showed good internal consistency (α = .83).

Measures: Children

The Wechsler Preschool and Primary Scale of Intelligence (WPPSI-IV).

Wechsler Preschool and Primary Scale of Intelligence (WPPSI-IV) is an individually administered standardised test of cognitive development for children 2;6 to 7;7. The WPPSI is administered through standardised protocols and is found to be a highly reliable and valid measure of child general intelligence (Weiss, Keith, Zhu, & Chen, 2013). The individual scales, rather than the full test, of the WPPSI have been previously used for research purposes (for example, Bernier, Beauchamp, Bouvette-Turcot, Carlson, & Carrier, 2013). The ancillary index scales of vocabulary acquisition and non-verbal abilities were used to assess child verbal and non-verbal abilities, specifically: verbal comprehension and block design respectively. The measure includes current and developmentally appropriate norms against which individual child's scores were measured and these norms have shown good reliability and validity (DeThorne & Schaefer, 2004).

Attention bias task.

Stimuli. Children were presented with a series of pictures of faces and objects. Faces of children displaying anger, happiness and neutral mood were selected from the Radboud standardised set (Langner et al., 2010). Six models, three males, were selected presenting each emotion resulting in a set of 24 faces being used in the task. The faces were grey-scaled and all features extraneous to the face were removed using photoshop. Six neutral non-emotional pictures of objects from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1999), matched on arousal, were also grey-scaled for use. Average luminosity across faces and non-emotional images was checked and found to be equal.

Cartoon pictures of aliens were designed for presentation after the faces or images. Three pairs of aliens were produced that differed in one characteristic per pair, for example, within a pair, one alien had one eye, one five eyes. Average luminosity across the alien images was found to be equal. The body and look of the alien remained consistent across the aliens and only the eyes were shown so that no facial expression, and therefore emotion, could be interpreted from the alien's facial features.

Design. The task was made up of one practice block and one experimental block broken up into six presentation blocks. The practice block consisted of six trials. The experimental blocks included 12 trials divided by a self-timed break. As eye gaze was recorded throughout the task, a six-point calibration procedure was conducted, where a red ball moved around the screen. Calibration was conducted before the practice block and at the beginning of each presentation block after each break to ensure calibration was maintained throughout the task.

Each practice trial started with the presentation of a fixation cross in the centre of the screen. The duration the fixation cross appeared on screen was jittered between 50 and 100ms, the duration for which it stayed on screen was then contingent on gaze. Once the eye-tracker had registered the children were looking at the fixation or within two visual degrees of the centre of the fixation cross for 100ms two faces, or non-emotional images appeared on screen. One image appeared to the left and one to the right of the centre of the screen. These images were presented for between 1500ms to 2000ms, timing was randomised across trials and blocks. Next, with the faces/non-emotional images still on screen, an alien appeared above or below the centre of the screen. Once the aliens had been displayed for 1000ms a blank screen appeared until the child's verbal response to the alien was recorded by the experimenter, who did this by pressing the appropriate mouse button. Once the children had given their verbal response and the experimenter recorded the response with a mouse click, feedback appeared on screen for 1000ms. Feedback informed the children either “You’re right” and a green tick or “Ooops” with a red cross.

The response requested from the child about the alien and the presentation of the face/non-emotional images were not linked, thus there was no motivational interference from this irrelevant task concerning the alien. The children saw each of the aliens from the three pairs once in turn during the practice trials, by the end of the practice trials they had been introduced to each alien and each respective appropriate response.

The experimental block consisted of 72 trials involving presentation of pairs of either non-emotional pictures (12 trials) or emotional faces (24 angry-neutral, 24 happy-neutral, 12 neutral-neutral). The experimental trials were identical to the practice trials but no feedback was given. The six presentation blocks were created where the face pairs or non-emotional images were presented in a random order. One alien pair was randomly assigned to each presentation block and which one of the alien pair was presented in each trial was randomised within each presentation block per participant.

Procedure

The study had ethical approval from the University of Reading Ethics Committee. Parents were provided with an information sheet about the task and the eye-tracking methodology used within the procedure via email on being invited to take part. Information sheets were also provided on arrival at the University and parents were asked to read these before giving informed consent for their child. The parents completed the parent-report questionnaire measures while the child completed the tasks. Before the child completed any tasks, the protocol was explained to them using child appropriate information sheets and verbal assent from the child was obtained. To help children stay motivated during the tasks, a sticker was given after each task to contribute towards a take home reward chart. The order in which tasks were completed depended on the child’s choice and how settled they were. Children tended to first take part in the attention bias task, then the developmental tasks of the WPPSI and finally an ambiguous tones task (reported in Stuijfzand, Chakrabhati, Reynolds & Dodd., in preparation).

Participants were first introduced to the eye-tracking computer. They were told it was a space computer that liked to see where they were looking and what they liked to look at. The calibration was introduced by asking the children to help the computer learn a bit more about them by following the red ball around the screen moving only their eyes. Calibration was conducted and the practice block introduced. The children were told that as soon as they saw a cross in the middle of the screen they should look at it and the quicker they looked at it the more points 'Tobii' the computer would give them. Participants were then told they would see some faces or pictures of objects appear on the screen, then an alien will appear at the top or bottom of the screen. Children were told that once the alien appeared they should say if the alien was upside down/had its eye open/had a planet or if the alien was the right way up/had its eye closed/didn't have a plant. They were told they were going to practice first before going for 'real'. Once the practice block was completed the first presentation block of the experimental block was introduced and the child was informed that the computer was going to show them one set of aliens, then there would be a break and then they would see some more. When the child had confirmed they were ready, the first presentation block of the experimental block was started with the calibration. Children were informed when they were half way through the presentation blocks and their compliance to continue was checked. During breaks children were encouraged to move and rest their eyes. Once the child had completed all six presentation blocks or had refused to continue, the child was able to put a sticker on their reward chart and moved on to another task. On completion of all the tasks the parent was provided with a debrief sheet explaining the purpose of the tasks in more detail and £5 towards travel expenses was given. All children received a certificate, a sticker and a token gift for their co-operation and time.

Recording and Pre-processing of Eye-tracking data

Eye-tracking data was recorded using a Tobii T60, stimuli were presented through E-prime version 2.0 (Psychology Software Tools Inc., 2012a), and data was recorded through Eprime Tobii extension (Psychology Software Tools Inc., 2012b). Children, on average, sat 55cm from a 17-inch monitor. The centre of the IAPS and Radbound face images were placed to the right and left (4.487^o) from the centre of the screen, with the inner edge of the image being 2^o from the centre of the screen and the image subtended a visual angle of 4.897^o. The cartoon images of the aliens were 6.996^o above and below the centre of the screen, with the inner edge being 3.47^o from the centre of the screen and the alien images subtended a visual angle of 7.697^o. Images were therefore placed within parafoveal vision of the children.

Eye-tracking data was processed using Matlab version R2014b and R studio version .98.1103 (R Core Team, 2015) using gdata (Warnes et al., 2015) to assess whether data recorded from each child was valid. A trial was deemed valid if the calibration on that trial was successful and the child's final fixation prior to the faces/objects appearing on screen was in the centre of the screen. This ensured that: firstly, the eye-tracker was accurately recording where participants were looking during the trial and secondly, that all participants were looking in the same place at the onset of the face/object stimuli and this location was equi-distance between the two competing face stimuli. This validation procedure consisted of two phases both of which were carried out using matlab.

To determine whether the calibration was successful, observation plots were produced for each participant and for each screen within the task: fixation screen, faces screen, face plus aliens screen. These plots showed where observations measured during the task fell within the screen area and in relation to areas of interest, being the fixation cross, the two faces/objects and the aliens. Observations whose co-ordinates fell on the edge of the screen area or beyond it, denoted by (-1,-1) in E-prime output, and all observations that were not successfully recorded denoted as matlab as not a number (NaN) were first removed. Observations across the entire task were first visually checked for each participant for systematic shifts in observations recorded for each part of the trial (i.e. fixation cross, faces/objects, faces/object plus aliens). If calibration was not successful a pattern of observations would be seen surrounding the centre of the screen and areas of interest with the same pattern visible shifted systematically in a given direction. If a systematic shift was found for a participant across the whole task, the data was then split into blocks and the calibration of each block was checked following the same procedure. When the block containing the systematic shift was identified, the calibration of each trial in this block was checked using the same procedure. Any trial or complete block that did not pass the calibration check was removed from the dataset prior to analysis.

The next phase was to determine whether the participant was looking in the centre prior to the onset of faces in each trial. To carry out this phase, the 10 observations prior to the onset of the faces/images on screen were selected and coded according to whether these observations were within 2° of the centre. This area included the region denoted as the area of interest for the gaze contingency and 1° further degree beyond this frame. Adding this extra 1° allowed for any error generated by the eye-tracker in measuring location of observation to be accounted for. Also, foveal vision is anticipated to by 2° therefore any location with 2° of the recorded location by the eye-tracking could still be considered within the focus of visual attention. Taking these 10 observations allowed the 160ms prior to the onset of the face/image stimuli to be examined. If more than five consecutive samples were within this region they were deemed to be a fixation (<100ms) in this region and the trial valid. The output from this phase indicated whether each trial carried out by each participant was valid. Any trials deemed "not valid" by this phase were excluded from the data-set for further analysis. To get the data ready for GCA, data deemed valid by the previous checks was passed through the pre-processing functions of R package EyetrackingR (Dink & Ferguson, 2015). This package assessed whether the eye-tracker had registered the participant's gaze per sample, if it had not the sample was deemed invalid. If a trial contained 40% of more invalid observations it was excluded from the analyses.

Statistical Analysis

Growth curve analysis was conducted on the eye-tracking data recorded while the faces were on screen (2000ms) following the procedures of Mirman et al. (2008), as well as examples from Byrow, Chen and Peters. (2016) and Schofield, Inhoff, and Coles (2013). Analyses were conducted using R studio (R Core Team, 2015) using packages eyetrackingR (Dink & Ferguson, 2015) and lme4 (Bates, Maechler, Bolker, & Walker, 2015), as well as ggplot (Wickham, 2009), matrix (Bates & Maechler, 2017) and tidyverse (Wickham, 2017). Time was split into 50ms time bins and the dependent variable, proportion of samples observed within a given AOI, was calculated per time bin. To ensure the same behavioural event for each participant was assessed, initial looks to each AOI were computed in the following way. The proportion was calculated whereby each sample showing a valid observation within a time bin was allocated 1 if its location was within a face AOI and 0 if it was not. The allocations were summed and then divided by the number of samples within that time bin. Proportions were then averaged over trial type (happy vs neutral, angry vs neutral), then participants. Raw proportions were transformed using a logit adjustment and used as the dependent variable to account for issues with impossible confidence intervals as well as issues with the link between means and variance inherent with the bounded nature of proportions to zero and one. To avoid inclusion of anticipatory eye movements and ensure that only fixations in response to the onset of the faces on screen were included in the analysis the first 100ms post face onset on screen were excluded from investigation of the time course.

The time course of the proportions of fixations to an emotional face was modelled using fourth-order (linear, quadratic, cubic, and quartic) orthogonal polynomials (time codes; following Mirman et al. (2008) and Schofield et al. (2013)) and the fixed effects of trial/emotion type (happy vs neutral, angry vs neutral; within subjects) and face type (emotional expression vs neutral expressions; within subjects) to investigate whether the time course of initial looks to a face differed by emotion. Then the fixed effect of group (high and low anxious groups; between subjects variable), and the interactions between emotion type, face type and anxiety group were entered to investigate whether there were anxiety related differences in the time course of initial looks to the faces. Two further models investigating moderation were constructed. Age and the interactions with emotion type, face type, anxiety and time polymonials were added in one model to investigate whether age influenced visual attention over the time course and moderated any anxiety related differences in visual attention to happy and angry faces. In the second, effortful control was entered in the same way. In a fourth model, cognitive and linguistic abilities were entered as main effects alongside emotion and anxiety grouping to assess whether they influenced visual attention to the emotional faces over the task. Models were constructed in this way to prevent over fitting from adding too many variables into the model based on the number of participants and observations available. For brevity, only significant predictors will be fully reported. Continuous predictors were centred and dummy codes were produced for binary variables. Anxiety grouping, emotion type and face type were dummy coded such that the low anxious group, the happy trials and emotional faces were the respective reference categories.

For comparison, conventional repeated ANOVA’s were also conducted on summary statistics derived from the eye-tracking data following the pre-processing described above. To allow investigation of initial vigilance, the average proportion of trials in which the initial look was to the emotional face per participant was computed. To investigate anxiety differences this was entered into a repeated measures ANOVA with a within subjects factor of emotion (angry and happy) and a between subjects factor of anxiety group (high and low). To further investigate moderation by age and effortful control these were added as between factors to the repeated measures ANOVA models respectively in two separate models. To investigate whether children showed differences in initial looking to the faces and to see if there was evidence of avoidance, the average proportion of time spent looking at the initial face was also computed per participant. This average proportion was calculated as the average length of the first look to a face as a proportion of looking time to faces across the trial. This was then entered into a repeated measures ANOVA with 2 within factors, emotion (angry and happy) and face type (emotional and neutral), and one between factor of anxiety grouping (high and low). To allow investigation of moderation by age and effortful control these were added as between factors to the repeated measures ANOVA models respectively in two separate models. For brevity, results only pertaining to the research questions will be interpreted, although full results will be reported in tables.

Results

Differences between High and Low Anxious Groups

Descriptive statistics of participants on variables of interest by anxiety grouping can be found in Table 1. There were no differences in age ($t(80) = 0.172$ $p = .863$) or the distribution of genders between the high anxious and low anxious group ($X^2(1) = 0.096$ $p = .76$). High and low anxiety groups were found to differ on autistic quotient score where, on average, the high anxious group showed more autistic traits than the low anxious group (see Table 1) with a large effect size ($t(99) = 4.43$, $p < .0001$, $d = .89$). Groups also differed on total effortful control score (*Mann Whitney U* = 1603.5, $p = .02$), where the high anxious group, on average, showed lower scores than the low anxious group (see Table 1). No other differences were found. Therefore, autistic quotient scores were in further analysis to ensure this was not acting as a confound. Thus, conventional analyses made use of a mixed ANCOVA to include autistic quotient as a covariate and in the GCA autistic quotient was added as a main effect to all models to prevent over fitting. Other variables on which the groups differed were already included in the planned analysis.

Table 1.

Descriptive statistics for Variables of interest by Anxiety Group

	Total (N = 104)		High Anxious group (N = 65)		Low Anxious Group (N = 30)	
Variables	Mean	SD	Mean	SD	Mean	SD
Age	6.02	1.15	6.04	1.12	5.99	1.22
AQ total	63.27	16.97	68.71*	15.70	54.62*	15.38
ECS total	4.69	.89	4.38*	1.14	4.91*	.68
Non-verbal Cog	5.58	1.31	5.56	1.30	5.65	1.35
Verbal Cog	5.75	1.16	5.73	1.25	5.93	1.32

* difference between groups p>.05. Non-verbal Cog = Non-verbal Cognitive Abilities; Verbal Cog = Verbal Cognitive Abilities.

Repeated Measures Analysis

Proportion of Trials where the Initial Look to faces was to the Emotional face.

Table 2 shows the average proportion of trials where the initial look was to the emotional face in the angry and happy trials by each of the anxiety groups. The means seen in Table 2 suggest that children were initially looking to the emotional face in around 60% of trials. When these means were compared to 50% (chance) using one-sample t-tests, results indicated a significant difference for likelihood of first look to the emotional face on the angry trials ($t(101)=3.92$, $p < .001$, $d = .78$) with a medium effect and the happy trials ($t(99)= 6.32$, $p < .001$, $d = 1.27$) with a large effect suggesting children were vigilant to the emotional faces. The mixed ANCOVA analysis including anxiety grouping as the between factor and autistic quotient as the covariate revealed there was no differences between happy or angry trials in proportions of trials where the initial look was to the emotional face and, importantly, no differences in anxiety groups or two-way interaction between emotion type and anxiety group. Nor did the mixed ANCOVA analyses investigating moderation by age or effortful control reveal any differences in anxiety group nor any interactions between anxiety group or either of the moderators (See Table 3). Results from the ANCOVAs indicate that there was no difference in vigilance to the emotional faces by emotion or by anxiety grouping, nor was any influence by age or effortful control on the proportion of trials the children initially looked to the emotional face.

Table 2.

Summary Statistic of Initial Looks to the Faces by Anxiety Group

	Mean Proportions (*SD*)		
	Total	High Anxious Group	Low Anxious Group
Mean Proportions of Trials where the Initial look was to the Emotional Face			
Angry Trials	.59 (.22)	.60 (.23)	.57 (.20)
Happy Trials	.63 (.21)	.64 (.22)	.63 (.20)
Mean Proportions of Time Spent Looking at Faces during Initial Looks			
Angry Trials			
Emotional Face	.35 (.17)	.35 (.16)	.36 (.18)
Neutral Face	.16 (.16)	.15 (.15)	.17 (.16)
Happy Trials			
Emotional Face	.40 (.19)	.41 (.20)	.39 (.20)
Neutral Face	.13 (.12)	.13 (.13)	.13 (.11)

Proportion of Time Spent Looking at the Faces during Initial Looks.

Table 2 also shows the average proportion of time spent looking at each face when initially viewed in the happy and angry trials by each of the anxiety groups. Mixed ANCOVA analysis where anxiety was the between factor and autistic quotient was the covariate showed no main effects of emotion type, face type or anxiety grouping or interaction between emotion type and anxiety grouping (See Table 4). The lack of main effects indicates that the proportion of time spent initially looking at the face was not significantly affected by: whether the initial look was to the emotional or neutral face; whether the trial type was angry and happy trials; anxiety group of the child. Neither of the four-way interactions investigating moderation by age or effortful control were significant. However, in the moderation by age analysis there was a significant interaction: the interaction between age, face type and emotion type was significant with a large effect (see Table 4). To further investigate this interaction, the data were split into younger (below mean age) and older (above mean age) children and the analysis was re-run. The interaction between emotion type and face type only remained in the younger children ($F(1) = 4.45$, $p = .04$, $\eta_p^2 = .09$) with a medium effect. The interaction indicated that, in terms of the initial face viewed in the trial, in the angry trials young children, on average, looked for a smaller proportion of time at the emotional face (*M* = .36, *SD* = .18) and for greater proportion of time at the neutral face (*M* = .16, *SD* = .16) than in the happy trials ($M_{emotional}$ = .44, $SD_{emotional}$ = .20; $M_{neutral}$ = .13, $SD_{neutral}$ = .14). These results may suggest that in terms of initial looks, young children are displaying some avoidance of the emotional face in the angry trials by looking for less time at the emotional face before moving attention away. It is important to note that this did not differ by anxiety group.

Table 3.

Results of the Mixed ANCOVA's for Mean Proportions of Trials where the Initial look was to the Emotional Face

	df	*F*	η_p^2	*p*
Anxiety Differences				
Anxiety Group	1	.002	0	.968
Emotion type	1	.002	0	.966
Anxiety x Emotion type	1	.001	0	.999
Moderation by Age				
Anxiety Group	1	1.01	.05	.325
Emotion type	1	.032	.002	.859
Age	40	1.72	.77	.091
Anxiety Group x Age	10	.35	.14	.956
Anxiety Group x Age x Emotion type	10	.20	.09	.993
Moderation by Effortful Control				
Anxiety Group	1	.57	.05	.467
Emotion type	1	2.04	.17	.183
Effortful Control	76	1.66	.93	.194
Anxiety Group x Effortful Control	7	.40	.22	.885
Anxiety Group x Effortful Control x Emotion type	7	1.62	.53	.236

Note. Full results can be seen in Appendix 17

Table 4.

Results of the Mixed ANCOVA's for Mean Proportions of Time Spent Looking at Faces during Initial Looks

	df	F	η_p^2	p
Anxiety Differences				
Anxiety Group	1	.09	.001	.768
Emotion type	1	1.85	0	.966
Face Type	1	2.03	.03	.158
Anxiety Group x Emotion type	1	.19	.003	.668
Anxiety Group x Face type	1	.03	0	.873
Moderation by Age				
Anxiety Group	1	1.32	.06	.262
Emotion type	1	13.45	.39	.001***
Face type	1	.95	.04	.341
Age	40	2.77	.84	.007**
Anxiety Group x Age	10	.66	.24	.746
Anxiety Group x Age x Emotion type	10	2.06	.50	.078
Anxiety Group x Age x Face type	10	.40	.16	.933
Anxiety Group x Age x Emotion type x Face type	10	.57	.21	.822
Moderation by Effortful Control				
Anxiety Group	1	.39	.06	.558
Emotion type	1	.89	.13	.382
Face type	1	6.22	.51	.047*
Effortful control	59	2.27	.96	.151
Anxiety Group x Effortful control	6	1.18	.54	.151
Anxiety Group x Effortful control x Emotion type	6	4.10	.80	.055
Anxiety Group x Effortful control x Face type	6	.60	.37	.728
Anxiety Group x Effortful control x Emotion type x Face type	6	1.99	.67	.211

Note. Full results can be seen in Appendix 17

Growth Curve Analyses: Initial Looks to Faces

These analyses focus on data concerning the first faces looked at only. After pre-processing and preparation for analysis, 27177 observations were included in the analysis from 104 participants. On average participants contributed 23 trials (SD = 13.56, min = 1, max = 48) to the analysis. There was no correlation between age and number of trials contributed (r (80) = .11, p = .315) indicating that age was not influencing whether or not children's eye-tracking data was included in the analysis. To describe significant interactions, data was visualised using figures; for brevity, only figures visualising the highest order interactions are presented here. Given the number of parameters per model and number of significant parameters found, focus is given to results that pertain to the research question related to each analysis.

Influence of Anxiety Group.

There were significant main effects of face type (b = -.79, SE = .01, t = -69.71, p < .001) indicating that on average children were more likely to look initially to an emotional face than a neutral face. There were also main effects of all time codes: linear (b = -1.28, SE = .05, t = -28.22, p < .001), quadratic (b = -2.17, SE = .05, t = -43.00, p < .001), cubic (b = 2.40, SE = .04, t = 57.44, p < .001) and quartic (b = -1.44, SE = .04, t = -34.18, p < .001) indicating that looking behaviour to faces changed over time.

Suggestive of differences between anxiety groups, there was a significant two-way interaction between anxiety grouping and quadratic time (b = -.14, SE = .08, t = -1.71, p = .002) indicating that there was a difference in rise to peak fixations to initial looks to the faces between anxiety groups. Figure 1 suggests that low anxious children are faster to look at the faces and look for a greater proportion of time within the first 800ms than the high anxious children, regardless of whether the face is an emotional or neutral face. There were no significant three or four-way interactions with anxiety grouping.

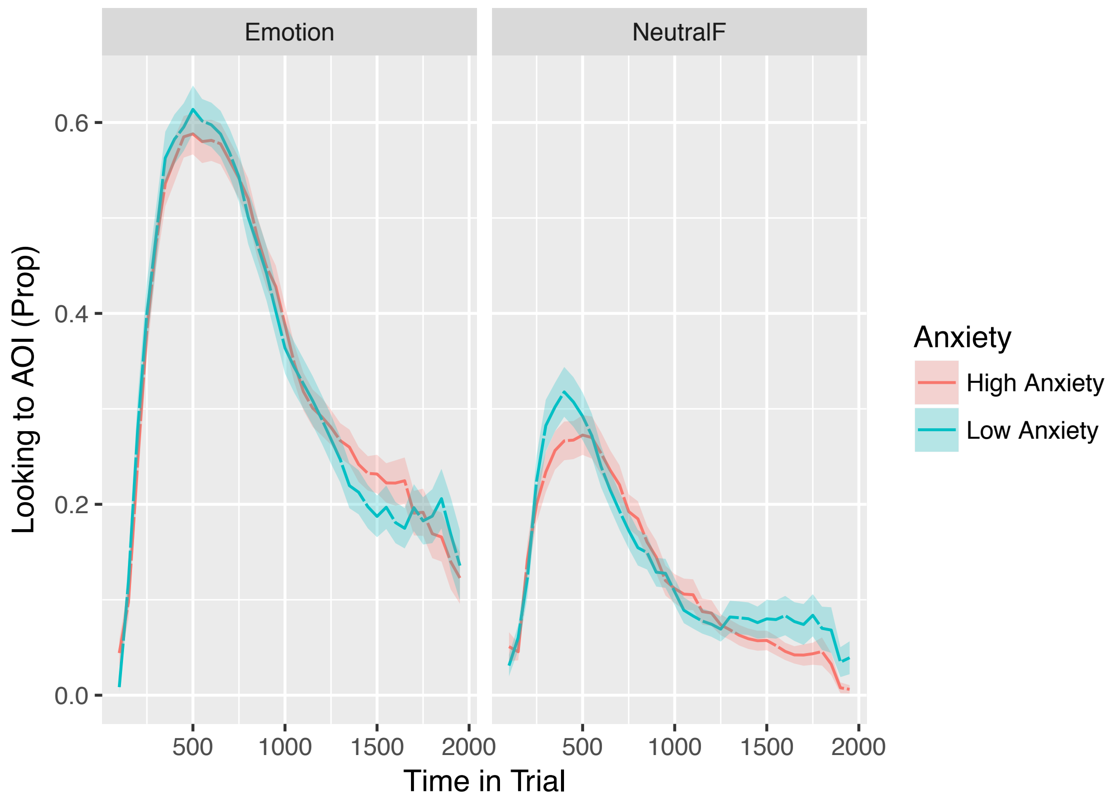

Figure 1. Time Course of proportion of time looking at the first face viewed averaged over trials, split by face type and anxiety grouping. Standard errors in proportion of looking to AOI's can be seen as shaded areas surrounding the lines denoting anxiety groups.

Moderation by Age.

When compared to the model assessing anxiety differences, adding age improved the model fit (χ^2 (83) = 5117.82, $p < .05$) and explained a small amount of variance on the level of the subject (5.15%).

There was no significant two-way interaction between anxiety grouping and age. There were two significant three-way interactions. One between face type, anxiety grouping and age (b = .13, SE = .02, t = 5.55, p < .001) and one between anxiety grouping, age and linear time (b = .30, SE = .10, t = 3.16, p = .02).

There were two significant four-way interactions involving age and anxiety grouping: face type, anxiety grouping, age and linear time (b = -.40, SE = .19, t = -2.11, p = .03) and emotion type, anxiety grouping, age and quartic time (b = -.41, SE = .18, t = -2.32, p = .02).

Finally, there was one significant five-way interaction between face type, emotion type, anxiety grouping, age and quartic time (b = .83, SE = .36, t = 2.33, p = .02). Figure 3 shows this interaction. For purposes of visualisation, age was split into two groups, with the first group one standard deviation below mean age and the second group one standard deviation above the mean.

The interaction between face type, anxiety grouping and age indicates that, anxiety differences were characterised by, on average, children in the high anxiety group initially looked more to emotional faces when they were in the older group. Low anxious younger children, on the other hand, initially looked more to the neutral face suggesting patterns of initial vigilance. The three- and four-way interactions with linear time suggested that high anxious older children showed the steepest decrease in fixation proportions when the emotional faces were initially viewed. This suggests a stronger withdrawal of attention/avoidance component from faces for high anxious, older children. As can be seen in Figure 2, the five-way interaction suggests that these patterns for the younger and older children were particularly the case in the angry trials.

Overall, it seems that when an angry face is the initially viewed face, older children show a vigilance avoidance pattern, with a stronger avoidance component seen in the high anxious group. Younger children with high anxiety show a similar pattern, but with a slightly later peak in their attention to the angry face, suggesting attentional capture is slightly slower. In contrast, young children who are low in anxiety are more likely to attend to the neutral faces first than the angry faces.

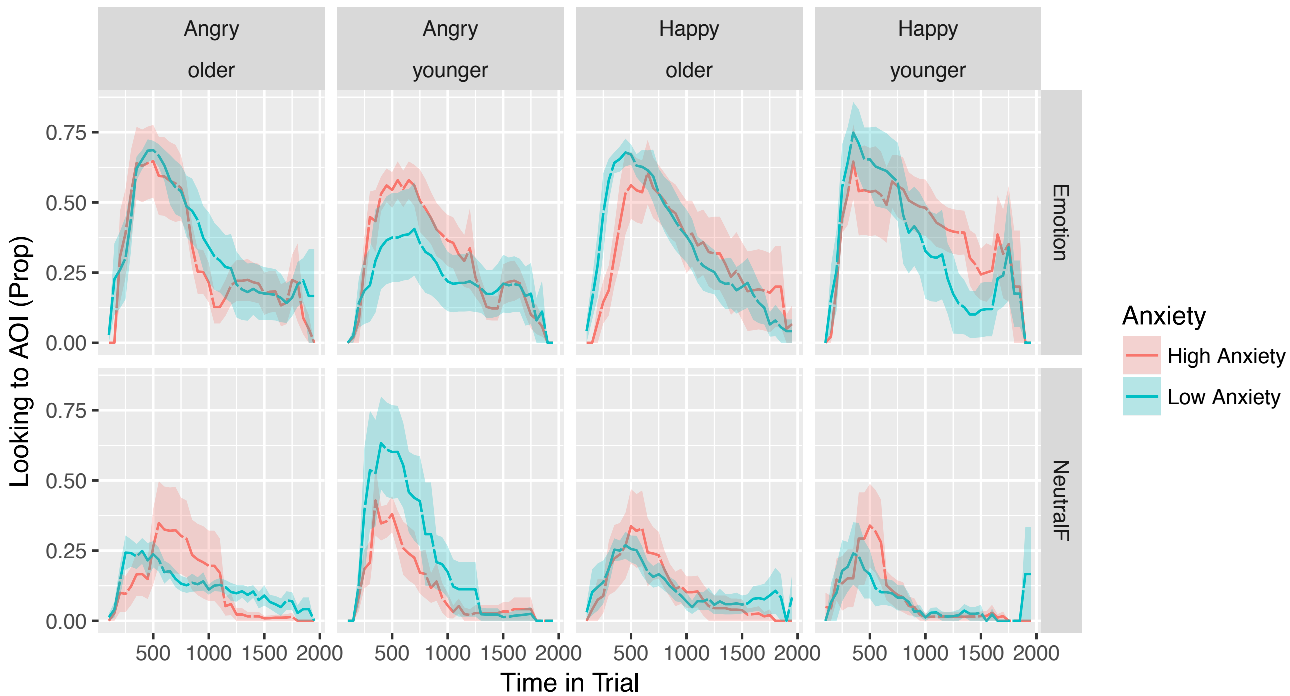

Figure 2. Time Course of proportion of time looking at the first face viewed averaged over trials, split by face type, emotion type, age and anxiety grouping. Standard errors in proportion of looking to AOI's can be seen as shaded areas surrounding the lines denoting anxiety groups.

Moderation by Effortful Control.

When compared to the model assessing anxiety differences, adding effortful control increased the model fit (χ^2 (83) = 173.1907, $p < .05$) and explained a small amount of variance on the level of the subject (1.30%) and some residual variance (.30%).

There was no two-way interaction between anxiety grouping and effortful control. There was a three-way interaction between face type, anxiety grouping and effortful control (b = .13, SE = .04, t = 3.03, p = .002). The three-way interactions between anxiety grouping, effortful control and all time codes were significant: linear (b = .38, SE = .17, t = 2.19, p = .03), quadratic (b = -.95, SE = .19, t = -4.98, $p < .001$), cubic (b = .36, SE = .16, t = 2.29, p = .02) and quartic (b = .42, SE = .16, t = 2.61, p = .009).

There was one significant four-way interaction involving effortful control and anxiety grouping: face type, anxiety grouping, effortful control and quartic time (b = -.65, SE = .32, t = -2.04, p = .04). None of the five-way interactions were significant. Figure 2 shows the significant four-way interaction. For the purposes of visualisation, two effortful control groups were created, one representing those with the lowest 25% scores on effortful control and the other representing those with the highest 25% scores on effortful control[3].

Interactions with quartic time are more difficult to interpret, but suggest differences lies in the withdrawal of attention to faces and what happens at the end of the trial (Mirman et al., 2008). This is further supported by the 3-way interactions between anxiety grouping, effortful control, linear, cubic and quartic time. Figure 3 suggests that those with low anxiety and low effortful control were quicker to withdraw their attention from the emotional faces than all other groups. The low anxiety group was also relatively fast to withdraw attention from the neutral faces when they were viewed first, regardless of effortful control ability. However, the high anxiety group showed fast withdrawal of attention from neutral faces when effortful control was low but slow withdraw of attention from neutral faces when effortful control was high.

Finally, there is evidence that those with low anxiety and high effortful control look to the faces faster than all other groups (as supported by the interaction between anxiety, effortful control and quadratic time). The steeper rise to peak, and higher peak for those with low anxiety and high effortful control relative to those with high anxiety and high effortful control indicates that, when low anxious children had better control over their attention, they showed vigilance for the faces.

Influence of Verbal and Non-Verbal Cognitive abilities.

The results were similar to those found when examining anxiety differences (see Anxiety Group Differences). Model fit was improved over the model assessing anxiety differences ($\chi^2(46) = 527.94$, $p < .05$) and explained a small amount of variance on the level of the subject (3.86%) and some residual variance (.38%). There were no main effects of verbal or non-verbal IQ suggesting they were not, on average, influencing initial looking behaviour to the faces.

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[3] 1 SD above and below the mean was used to form groups, as in the age moderation, however this resulted in too small a group in the low anxiety, low effortful control group (n=6) to allow confidence in interpretation.

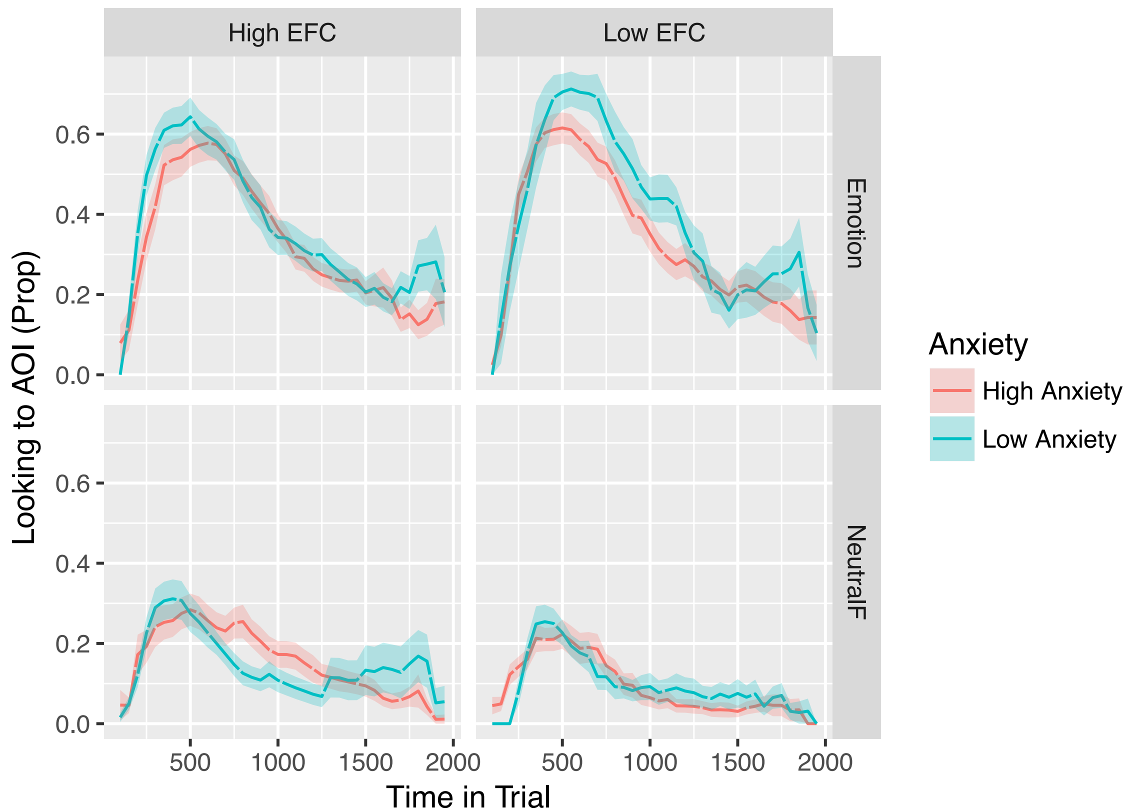

Figure 3. Time Course of proportion of time looking at the first face viewed averaged over trials, split by face type, EFC group and anxiety grouping. Standard errors in proportion of looking to AOI's can be seen as shaded areas surrounding the lines denoting anxiety groups. High EFC and Low EFC refers to those with the highest and lowest 25% of scores on EFC respectively.

Discussion

The aim of this study was to assess whether an anxiety related attention bias to emotional stimuli is present in children aged 4 to 8 years. It was hypothesised that there would be differences in visual attention to angry faces over the trial, with a tentative suggestion that high anxious children may show a pattern of vigilance followed by avoidance of the angry faces. However, there was little support for this. Initial analyses using standard statistics extracted from eye-gaze data indicated that all children were initially vigilant for the emotional faces and this was not particular to threat-related faces or the high anxious group. In addition, while there were no anxiety differences found in the proportion of time spent looking at faces during initial looks, young children looked for a shorter time at angry faces than the happy faces. Growth curve analysis examining anxiety differences suggested that while all children were more likely to initially look to the emotional faces than the neutral faces, this was particularly pronounced in the low anxious group, perhaps suggesting that the high anxious group were slightly avoidant of the emotional faces. There was however support for the hypothesis that anxiety differences in visual attention to the faces would be moderated by age. Moderation by age analyses revealed that in the angry trials all high anxious children and older low anxious children showed a vigilance avoidance pattern to the emotional face. Furthermore, for the high anxious older children there was a stronger avoidance component than for the other groups. Younger children in the low anxious group, on the other hand, looked more initially to the neutral face in the angry trials.

It was also hypothesised that an attention bias to emotional faces would be moderated by effortful control. Evidence was not found in support of a moderation by effortful control as there was no interaction found between effortful control, face type, emotional type, anxiety and time. However, in line with our hypotheses, analyses suggested that effortful control was moderating the looking behaviour of anxiety groups to emotional faces over time in different ways, it was just not specific to emotion. Focusing only on participants with high effortful control highlighted differences between the anxiety groups in terms of vigilance to the faces: with those with low anxiety appearing more vigilant. In contrast, focusing on participants with low effortful control highlighted differences in the withdrawal of attention where those with low anxiety showed a quicker withdrawal of attention to the emotional face. While children still looked more to the emotional faces than the neutral faces, for those with high anxiety, effortful control made a difference to looking behaviour in that having high effortful control allowed children to slowly withdraw attention from the neutral face, potentially assisting avoidance of the emotional faces. It was hypothesised that an attention bias would be particularly pronounced in participants with high anxiety and low effortful control, but as demonstrated by the results above there was no evidence to this effect. The final hypothesis was that the task would not be dependent on verbal and non-verbal cognitive abilities. To examine this, we evaluated whether these abilities were associated with visual attention to the faces. No associations were found, supporting the hypothesis.

Anxiety Group Differences

Based on previous research, it was hypothesised that a pattern of vigilance for angry faces, followed by avoidance, would be found for the high anxiety group but not for the low anxiety group. Based on initial analyses without any developmental moderators, there was little evidence to support this hypothesis. Our initial look analyses suggested that children were vigilant to emotional faces over neutral faces, but this was not specific to angry faces or to anxiety group. However, there was some indication that the children with low anxiety looked at the faces, both emotional and neutral, more during the first 500-600ms than those with high anxiety. This subtle avoidance of face stimuli is in line with one previous study of attention bias and anxiety in young children (Dodd et al., 2015) but caution should be taken as the differences appear small and subsequent analyses indicate that anxiety differences across the time course may be influenced by developmental factors.

Moderation by Age

It was expected that anxiety related attention biases would be stronger with age. Both young and older children in the high anxious group showed a similar pattern of looking to the emotional face in the angry trials, however, the older high anxious children appeared to be looking away from the angry face faster than the high anxious younger children. In this way, the avoidance component following initial vigilance could be said to be stronger in the older high anxious children. Age also made a difference to the low anxious group where the younger children in the low anxious group showed a bias towards initially looking at the neutral face in the angry trials, not seen in any other group. Thus, in the angry trials, younger children with high anxiety attended first to emotional faces, while those with low anxiety attended first to neutral faces. Given this, it seems that the nature of the differences in attention to the angry faces between the high and low anxiety groups is greater for the younger children than for the older children.

Evidence of moderation by age is in line with other studies that have also found differences in anxiety related attention bias by age (Benoit et al., 2007; Gamble & Rapee, 2009). Both studies found that their older age groups avoided angry faces, while in one study the young group did not show an attention bias, in the other young children avoided happy faces. Our results suggest that after initially looking to the angry faces, indeed the difference for the older children between anxiety groups is in the avoidance of angry faces. While this is in line with the previous studies cited, it should be remembered that our sample is younger than the young age groups in both these studies. Our oldest children are close in age to the younger samples of these studies. The differences in results may be created by our more fine-grained analysis of the time course of visual attention versus more conventional analyses, or use of different methodologies (eye-tracking versus dot probe tasks), or the combination of both. Alternatively, these differences may potentially reflect the changing nature of the attention bias-anxiety relationship over development.

Our results regarding initial vigilance to the emotional faces for all children, and initial vigilance to the neutral face for the low anxious younger children is in contrast with Gamble and Rapee (2009) and Mueller et al. (2013) who both found biases in orienting or an initial vigilance to threat only in the anxious group. However, differences in results may be due to the age group of samples used in these studies. Neither of these studies included children younger than 7 years old. When younger children have been included all children have also been shown to be vigilant to emotional faces (Dodd et al., 2015). It may be that particular anxiety related patterns of attention bias to threat are not present in children until middle childhood. Indeed, our results concerning age differences in the time course of gaze may indicate a vigilance avoidance like pattern, particularly to threat, only in the high anxious older children in this sample of 4 to 8 year olds.

The moderation by age effect appeared in the interaction with cubic time suggesting that the anxiety differences, though different in nature by age, were in the later stages of processing, which are thought to be under top-down control. Consideration of top-down, bottom-up processing may assist in examining which processes are driving the anxiety differences seen in the younger and older age groups. Top-down processing can be driven by stimulus driven bottom-up processing whereby, for example, attention allocation (top-down) is given to a stimuli of specific emotion deemed relevant to the individual (bottom-up) (Corbetta & Shulman (2002). This may be relevant for the younger children where anxious groups differ in which stimuli they allocate attention to. However, for the older children the differences were seen in the avoidance component, when attention was being withdrawn. The avoidance component may be under top-down processing, though more reliant on skills developing in childhood, such as attentional control (Shechner et al., 2017), rather than driven by bottom-up processes. Interestingly, if this was due to our older children have greater attentional control we would expect this to be reflected in the moderation by effortful control analysis too. However, contrary to our expectations it was not. Whether this was due to issues of power or our children not showing sufficiently developed effortful control (see section below) for this to be seen is unclear. The results for the older children in our sample are more in line with In-Albon et al. (2010), who found an anxiety related vigilance avoidance pattern in 8 to 13 year olds, who are close in age to our older children. Our results may be suggesting that we are seeing anxiety differences in visual attention to the faces being different in nature due to changes and developments in top-down processing of the children.

Theories concerning the influence of arousal/interest may offer some explanation for the anxiety related differences in the younger children. Lang, Greenwald, Bradley and Hamm (1993) found that dwell time, interest and arousal judgments, and skin conductance response represented one factor when assessing affective responses to images. They suggested that these measures could represent estimates of the degree to which an image engages attention (Lang et al., 1993). Arousal has also been found to index the motivational significant of a stimuli to individuals (Bradley & Lang, 2007) and so may have relevance for when differences appear in the allocation of attention to a stimuli, as in the younger children of this sample. Here the difference was driven by more attention being allocated to the neutral faces, in the angry trials, by the low anxious group and the high anxious group allocating more attention to the angry faces. For the younger high anxious children, who have a system sensitive to threat, the angry faces dominate in salience in the angry trials, where the threat is clear. They find the angry faces more arousing and so attention is allocated here by top-down processing. For the younger children in the low anxious group given the threat in the angry face is clear and not as arousing as for high anxious children, it may be that the neutral face, where emotion is ambiguous, becomes more interesting/arousing. This may result in the neutral face being initially selected for further processing and attention is allocated within the younger low anxious children. Indeed, other studies have also found that when the threat level of a stimuli is ambiguous further processing of the stimuli is engaged for gathering further information (Champion, 2006). The same effect may not be seen in older children who have more experience with neutral faces and thus the interest and arousal created by the neutral face is no longer different between groups.

Moderation by Effortful Control

The theory of Kindt and Van Den Hout (2001) would suggest that all children attend to threat and that this attention bias for threat would only remain over developmental time for anxious children with low effortful control. Following this theory and evidence (e.g. Susa, Pitică, Benga, & Miclea, 2012) it was expected that children in the high anxious group with low effortful control would show an attention bias, whereas other groups would not. Indeed, we did find evidence of vigilance for all faces, but this was for those with low anxiety and high effortful control and this was not particular to threat. However, children in the task of Susa et al. (2012) were older than the children in this sample and assessed moderation by attention control rather than effortful control. While attention control is a component of effortful control, they are not the same construct, which may have influenced the difference in results. The moderation may be particular to a component of effortful control rather than the complete construct. Alternatively, the differences in results may be a reflection that effortful control or its components may not be sufficiently developed in our sample to show the moderation found by previous studies and suggested by theory.

The presence of the four-way interaction, but no five-way interaction may also be indicative of a lack of power in the sample to fully explore the potential moderation. Therefore, rather than generalise results of the moderation by effortful control, it should be taken that our results suggest there is some potential in the influence of effortful control on anxiety related attention bias in this age group, but better powered studies are required to fully investigate the nature of the moderation relationship.

Influence by Verbal and Non-Verbal Cognitive Abilities

It was expected that if we had successfully developed a task not dependent on verbal and non-verbal cognitive abilities this would be reflected in these predictors not showing an influence on the time course of visual attention. In line with this, verbal and non-verbal cognitive abilities did not show as significant predictors in our analysis. Therefore, we can conclude that the task was not dependent on verbal or non-verbal cognitive abilities. It should however be acknowledged that it is unlikely that the task is entirely independent of these abilities. Indeed, the model including verbal and non-verbal cognitive abilities did show an improvement over the model examining anxiety differences suggesting some influence or the relevance of such factors to the data. Previous tasks used to assess attention biases in children, such as the dot probe, have previously been criticised for their complex instructions and reliance on developing abilities. By avoiding use of reaction time and utilising a free viewing paradigm within an eye-tracking task we have shown it is possible to create a task that is not unduly influenced by verbal and non-verbal cognitive abilities.

Implications for Developmental Models of Anxiety in Children

Consistent with cognitive theories and moderation models of the development of anxiety, our data indicates there is evidence of moderation by age and influence of effortful control on the relationship between anxiety and attention biases in children aged 4 to 8. These results are also in line with the conclusions of Field & Lester (2010a), and Dudeney, Sharpe, and Hunt (2015) suggesting that a moderation model of anxiety in children may be appropriate for attention biases. The moderation model proposes that while biases may be present early in all children they will only remain for those with particular individual factors which may be influenced by social, emotional, or cognitive development. There are differences in the results from our moderation investigations, for example the moderation by age showed particular patterns in the age groups in the angry trials, while the moderation by effortful control was not particular to emotion. While this may suggest that different developmental factors are interacting with anxiety and attention biases in different ways it is not clear from our results whether one is more influential than the other or whether there are accumulative effects of factors.

Although there was evidence for moderation by age, the mechanism behind this moderating effect are unclear. Moderation could occur because of time/experience or be due to other developmental factor(s) that change with age. Indeed, in this study we only assessed cognitive factors yet a moderation model has room for social and emotional factors which have not been considered here. For example, previous research has considered the impact of attachment style on the relationship between social anxiety and attentional biases (Byrow et al., 2016) and there may be other emotional or social factors that might be important such as emotion regulation or facial emotion recognition (Field & Lester, 2010a, 2010b).

Implications for Treatment

The moderation by age result suggests that, following initial vigilance to emotional faces, only our older children show the anxiety related avoidance pattern away from threat that has been found in previous work with adults and children. This suggests that treatments that aim to reduce anxiety via changing assumed cognitive bias, such as cognitive behavioural therapy, may become increasingly appropriate with age. However, this study requires replicating with a clinical sample before it can be claimed this moderation by age is clinically relevant and it should be noted that a similar pattern was found in younger children though the avoidance of angry faces was stronger in the older children.

When considering attention bias modification procedures, it should be noted that all children were vigilant to the emotional faces, over neutral faces, but only the high anxious older children differed from others in their quick withdrawal from angry faces. If it is the avoidance of angry faces that is the problem in anxiety then perhaps children could be trained not to avoid the angry face children rather than train them to attend more to a happy/neutral stimuli. A different approach may be required for young children: the difference between anxiety groups amongst younger children was the attention given to neutral faces. In the angry trials, younger children in the low anxious group looked more at the neutral face than the emotional face, while the reverse was true for the high anxious group. Attention bias modification procedures for children tend to train attention towards positive or neutral stimuli. There is currently considerable discussion over the use of attention bias modification procedures as treatment (for example; Heeren, Mogoa, Philippot, & Mcnally, 2015; Linetzky, Pergamin-Hight, Pine, & Bar-Haim, 2015), but if they are found to be effective then our results would support the use of training to attend to neutral stimuli for the children younger than five and half .

Strengths and Limitations

This study made use of eye-tracking to assess whether an anxiety related attention bias is present in children aged 4 to 8, an age group largely ignored by the literature until now. This study adds to the growing body of evidence utilising eye-tracking to assess attention bias in children. One of the strengths of the study is the use of growth curve analysis. Using this technique allowed for a fine-grained analysis of overt attention to emotional stimuli than reaction time data or conventional assessment of eye-tracking data can provide. The GCA revealed particular patterns that were not apparent in the conventional analyses, such as the withdrawal of attention from faces. By averaging across looking behaviour across participants it seems that while the broad picture of distribution of attention is revealed in the ANOVA analysis, details with what children do with their attention once allocated to the faces was better revealed by the growth curve analysis.

A further strength is the consideration of developmental factors that may influence task performance and moderate the associations of interest. We demonstrate that the task was relatively unaffected by children's verbal and non-verbal cognitive abilities. In addition, the results suggest that developmental factors such as age and effortful control may be influencing the anxiety-attention bias relationship. Until now, it has been rare for the impact of such developmental factors on the relationship between anxiety and attention biases to be examined. While several studies have assessed the influence of age, very few have assessed the influence of effortful control despite it being acknowledged as being theoretically interesting for the attention bias anxiety relationship (Field & Lester, 2010a).

Regarding limitations, while eye-tracking has advantages over reaction time tasks, it remains a measure of overt attention, and does not take covert attention into account. It is possible to give cognitive attention to something you are not directly looking at. However, the images were intentionally placed with parafoveal vision where it has been suggested that semantic analysis begins (Calvo & Avero, 2005). Thus, it is reasonable to infer that first look behaviour was influenced by valence and was not an artefact of scanning behaviour. Like Calvo and Avero (2005), we found that children looked more to emotional faces than neutral faces when placed within parafoveal vision, suggesting that children in our study may have already started assessing the semantic content of the faces before moving their eyes from the fixation point.

There are other limitations concerning the sample. As participants were recruited via adverts, the sample is self-selecting and as a result parents with an interest in their child's anxiety or anxiety in general may be more likely to respond. This may well be the case as we had trouble recruiting children for the low anxious group. Additionally, the study focused on recruitment in Berkshire, an area predominantly made up of white British families (Office of National Statistics, 2012), which is again reflected in our sample. Both these factors limit the generalisability of the results. Originally the study intended for the low anxious group to be made up of children with anxiety scores 1 standard deviation below the mean. However, after issues with recruitment this was altered to include all children with anxiety scores below the mean. This resulted in a smaller difference in anxiety between groups than originally intended. It may be that future studies utilising a sample made up of clinically anxious children versus healthy controls may find stronger anxiety differences and the difference in anxiety between groups could not be called into question.

A further limitation of this study is that the influence of development was assessed within a cross-sectional design. To really understand the nature of the role of development, as well as the nature of role of cognitive biases in the development of anxiety, longitudinal work is required. Results of this study assist in preparation for longitudinal work by providing hypotheses. As previously mentioned, further analysis of the moderation by effortful control, with greater power, is needed to clarify the nature of this moderation and whether the results found here are reproducible and meaningful. Inclusion of measures of effortful control in a longitudinal study would assist this aim. It should also be acknowledged that the measures of anxiety and effortful control were reliant on parent report given the age of the children in the sample and as such, these measures are subject to the limitations of parent report. However, there are observational measures of anxiety (Glennon & Weisz, 1978) and behavioural measures of components of effortful control (i.e. Attention Network Task; Rueda et al., 2004) available for this age group that may avoid the limitations of parent report measures. To improve the current study, future research could include behavioural/observational measures of anxiety and effortful control in a longitudinal sample with the aim to assess the role of development in the relationship between attention bias and anxiety in young children.

Conclusion

This study utilised a novel child-friendly eye-tracking task to assess whether there is evidence of an anxiety related attention bias to threat in children aged 4 to 8, an age group largely ignored by previous literature due to methodological reasons. There was little initial evidence of anxiety differences in initial looks to faces; all children showed vigilance for emotional faces over neutral faces. Growth curve analysis indicated that low anxious children were vigilant to and looked more at emotional faces than high anxious children. Analysis of moderation by age revealed nuanced differences in visual attention to faces between anxiety groups. Specifically, more pronounced differences between anxious groups were found in the younger children and the pattern of vigilance-avoidance seen in adults was clearer in older children. Evidence of moderation by effortful control was found, but it's influence did not to a specific emotion. Results are suggestive of a moderation model of anxiety in children and have implications regarding for whom treatments that focus on targeting biases to reduce anxiety are appropriate. Future studies should extend this study to a clinical sample and use a longitudinal design to truly capture the nature of role of developmental factors in the anxiety-attention bias relationship in young children.

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Chapter 5. Paper 4: Young children have social worries too: Validation of a brief parent report measure of social worries in children aged 4–8 years

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Please note Appendix A referred to in the Paper can be found at the end of the manuscript after the references as per the published article.

Also see Appendix 19: Social Worries Questionnaire as used in Paper 4

Abstract

This study investigated the psychometric properties of the Social Worries Anxiety Index for Young children (SWAIY), adapted from the Social Worries Questionnaire – Parent version (SWQ-P; Spence, 1995), as a measure of social anxiety in young children. 169 parents of children aged 4 to 8 years from a community sample completed the SWAIY and a standardized measure of anxiety; the SWAIY was completed again two weeks later. Parents deemed the items appropriate and relevant to children of this age. The SWAIY demonstrated excellent (>.80) internal consistency and a one-factor model. Test-retest reliability was strong ($r = .87$) and evidence of convergent validity ($r >.50$) was found. The study provides initial evidence for the validation of SWAIY as a measure of social anxiety in children aged 4 to 8 years old. This questionnaire is ideal for investigating social anxiety over early childhood and the relationship between early social worries and later anxiety disorders.

Keywords: Children, Social Anxiety, Psychometric properties, Rating Scales, Parent Report

1. Introduction

Social anxiety disorder often begins in early adolescence (Kessler et al., 2005) yet symptoms of social anxiety have been identified much earlier in childhood. Between 2.1% to 4.6% of pre-schoolers in non-psychiatric samples meet criteria for social anxiety disorder (Egger & Angold, 2006). Although social anxiety affects the wellbeing and achievements of children in the short term and in later life (Copeland, Angold, Shanahan, & Costello, 2014; Ginsburg, Silverman, & La Greca, 1998), we currently know little about the specific manifestations of social anxiety in young children or about the stability and development of social anxiety over childhood (Spence et al., 2001). While several anxiety assessments for older children include a social anxiety subscale, to our knowledge there is currently no stand-alone measure of social anxiety for children younger than eight years. The present study therefore reports on the adaptation and validation of the Social Worries Questionnaire – Parent version (SWQ-P; Spence, 1995) into the Social Worries Anxiety Index for Young children (SWAIY), a brief parent-report measure of social anxiety that is appropriate for young children.

Social anxiety is characterised by an intense and irrational fear of embarrassment in social situations (Alkozei, Cooper, & Creswell, 2014). For a DSM-5 diagnosis of social anxiety, a child must respond to these situations with avoidance or distress that interferes significantly with day-to-day functioning (American Psychiatric Association, 2013). Social anxiety in childhood is associated with a range of negative correlates both concurrently and prospectively. For example, children with social anxiety have difficulties with social competence (Ginsburg, Silverman, & La Greca, 1998; Spence, Donovan, & Brechman-Toussaint, 1999) and poorer functioning at school (Mychailyszyn, Mendez, & Kendall, 2010). In 8 and 9 year olds, social anxiety is negatively associated with friendship and positively associated with peer victimisation (Larkins, 2014; Slee, 1994), specifically overt victimisation (verbal or physical aggression; Storch, Zelman, Sweeney, Danner, & Dove, 2002). Furthermore, social anxiety during childhood is associated with poor mental health in adulthood (Copeland et al., 2014).

Social anxiety can be diagnosed as distinct from other anxiety disorders in children as young as four to five years (e.g. Ford, Goodman & Meltzer, 2003; Shamir-Essakow, Ungerer & Rapee, 2005). Further, factor analysis of parent-report scales such as the

Preschool Anxiety Scale (PAS; Spence, Rapee, McDonald, & Ingram, 2001) shows that items related to social anxiety can be differentiated from items related to other common anxiety problems in young children such as separation anxiety disorder. A recent population-based study found a prevalence rate of 10.7% for social anxiety disorder amongst four to eight year olds (Paulus, Backes, Sander, Weber, & von Gontard, 2015). Despite the potential negative consequences and high prevalence, research investigating social anxiety in early childhood is rare (e.g. Kingery, Erdley, Marshall, Whitaker, & Reuter, 2010; Morris et al., 2004). It is known that the incidence of social anxiety increases with age (Hitchcock, Chavira, & Stein, 2009), yet we know little about the stability and development of social anxiety within individuals, from early childhood. Initial research suggests that early social anxiety may indicate risk for emotional health problems across childhood. For example, Bufferd and colleagues found that a diagnosis of social anxiety at age three years predicted social anxiety disorder and specific phobia 3 years later (Bufferd, Dougherty, Carlson, Rose, & Klein, 2012). Furthermore, Carpenter et al. (2015) found that a history of preschool social anxiety predicted less functional connectivity between the amygdala and ventral frontal cortices when children viewed angry faces (Carpenter et al., 2015), indicating a potential difficulty with emotion regulation.

These examples highlight the potential that research examining social anxiety in young children holds for furthering our understanding of the development of anxiety across childhood. However, to conduct this type of work with young children it is imperative that we have valid and reliable measures of social anxiety for this age group that can be administered quickly and easily. Whilst diagnostic assessments such as the Preschool Age Psychiatric Assessment (PAPA; Egger & Angold, 2004) used by Bufferd et al., 2012, and the Anxiety Disorders Interview Schedule (ADIS; Silverman & Nelles, 1988) are the gold standard, they are not always practical given the time and resources required to train assessors and carry out the interviews. Currently, the only available questionnaire measure of social anxiety in early childhood is a subscale of the PAS; other subscales include generalized anxiety, separation anxiety, obsessive compulsive disorder and physical injury fears. The PAS was developed as a parallel measure of the Spence Children’s Anxiety Scale (SCAS; Spence, 1998), which measures anxiety symptoms in children aged seven-18 years. The PAS is not ideal for capturing social anxiety for two reasons. First, the social anxiety scale, which consists of six items, is not designed as a stand-alone measure so many additional items (a further 22 items) must be completed unnecessarily. Second, the PAS includes many cognitive items i.e. “Worries that he/she will do something to look stupid in front of other people ”. Due to the ‘hidden’ nature of cognitions and the broad context of the questions, it may be difficult for parents to accurately respond to these items (Comer & Kendall, 2004).

In contrast, the SWQ-P is a brief (10-item) parent-report measure of social anxiety in eight to 17 year olds. All items load onto a single ‘social worries’ factor. The items focus on specific situations and observable behaviours e.g. “Avoids or gets worried about entering a room full of people”. As avoidance is more easily observed than cognitive symptoms and specific situations are given, parents should be able to provide more accurate report than on the PAS. Given this advantage of the SWQ-P as a parent-report measure, it is an attractive candidate for adaptation into a measure of social anxiety for a younger age group (children aged four to eight years) for whom no specific measure of social anxiety currently exists. Such a measure will provide a valuable new tool for gathering information about social anxiety within this age group. The original SWQ-P has been acknowledged as a useful prescreening tool for social anxiety in children (Hitchcock et al., 2009) and the adapted version may also assist researchers and clinicians in this way. Beyond this, the adapted measure would be useful, as discussed, for addressing questions regarding the stability of social worries over childhood and the role of early social worries in the development of anxiety disorders later in life. This research may then, in turn, have implications for the prevention and early treatment of social anxiety in children.

In the present study, we describe the adaptation of the SWQ-P into the Social Worries Anxiety Index for Young children (SWAIY) and assess the content validity, test-retest reliability, convergent validity and internal reliability of the new measure as well as examining the internal structure through factor analysis. These investigations contribute to assessment of the questionnaire’s construct validity.

2. Materials and Method

2.1. Participants

Data was collected via online questionnaires. To be included as a study participant at either time 1 or time 2, full data was required for the SWAIY and basic demographics. This resulted in a sample of 169 parents (166 female) at time 1 and 106 (105 female) at time 2. An additional eight parents at time 1 and six parents at time 2 only partially completed the online questionnaires and were therefore excluded.

Parents completed questions about their child. At time 1, 99% considered themselves the child's primary caregiver. Children's ages ranged from 3.92 to 8.92 years old (M = 6.25, SD = 1.29, 4 year olds = 38, 5 year olds = 35, 6 year olds = 41, 7 year olds = 36, 8 year olds = 23), 81 of the children were female. No differences in age were found between male and female children ($t(167) = .711$, $p = .75$). No children were reported as having a diagnosis of Autistic Spectrum Disorders (ASD) or learning difficulties but two were reported as having ADHD. These children did not appear as outliers on any of the variables of interest and analyses were consistent when these children were excluded thus their data is included in the analyses reported. Note that details regarding ASD and learning difficulties were collected due to the potential social difficulties that these children might experience which could affect parents' responses on the questionnaires of interest (Kreiser & White, 2014).

At Time 2, 106 of the original 169 parents completed the online questionnaire for a second time. The same parent answered the questionnaire at both time points. At this point, 98% of parents stated they were the child's primary caregiver. Children's ages ranged from 3.92 to 8.92 years old (M = 6.20, SD = 1.32, 4 year olds = 23, 5 year olds = 22, 6 year olds = 28, 7 year olds = 22, 8 year olds = 14) and 52 were female. No differences in age were found between genders of the children ($t(104) = 1.03$, $p = .305$). No children were reported as having a diagnosis of ADHD, ASD or learning difficulties.

2.2. Measures

2.2.1. Spence Child Anxiety Scale – Parent version (SCAS-P) and Preschool Anxiety Scale (PAS)

Both scales are parent report questionnaires assessing child anxiety symptoms in specific anxiety domains, for example social anxiety and separation anxiety. The PAS is a

28 item questionnaire validated for use with four and a half to six and a half year olds. Items are answered on a five point Likert scale (0 = Not true at all; 4 = Very often true). Two scores were computed: total anxiety score being a sum of responses from all 28 items (min = 0, max = 112) and the social anxiety subscale (6 items; min = 0, max = 24). Higher scores indicate more anxiety. The PAS has strong psychometrics; scores align with DSM-IV diagnoses, and the internalising scale of the Child Behaviour Check List (CBCL; Achenbach, 1991; Spence et al., 2001). The PAS has also shown good internal consistency both in terms of the full scale (α = .86) and social phobia subscale (α = .81) (Broeren & Muris, 2008). In the present sample α = .88 for total score and α = .82 for the social anxiety subscale.

The SCAS-P is a parallel measure which includes 38 items answered on a four point Likert scale (0 = Never; 3= Always) validated for use with six to 18 year olds. The SCAS-P can be split into six subscales assessing specific anxiety domains, i.e. social anxiety. Two scores were taken from this questionnaire: the total anxiety score (the sum of all 39 items (min = 0, max = 114)) and the social anxiety subscale (the sum score of 6 items (min = 0, max = 18)). Higher scores indicate greater anxiety. The SCAS-P has good psychometric properties. It has good internal consistency of the total score (α = .82) and social phobia subscales in a community sample (α = .70) (Spence, 1998). In the present sample α = .87 for total score and α = .77 for the social anxiety subscale. The total score is able to differentiate between anxiety-disordered children and normal controls and the social anxiety subscale can differentiate between children with primary social anxiety and those with another primary anxiety diagnosis. The SCAS has also shown convergent validity with the CBCL (Achenbach, 1991).

2.2.2. Social Worries Anxiety Index for Young children (SWAIY).

The SWAIY was developed based on the Social Worries Questionnaire (SWQ-P; Spence, 1995). The SWQ-P is a 10-item parent report questionnaire assessing symptoms of social anxiety, validated for eight to 17 year olds. Parents are asked how much his or her child avoids or worries about particular social situations. For example "He or she avoids or gets worried about going to parties". The original questionnaire has shown good internal consistency within the validated age group (Guttmann split half reliability = .93, α = .94; Spence, 1995). Factor analysis indicated a single factor accounting for 66% of variance.

Children with social anxiety disorder score significantly higher on the SWQ-P than control children (Spence et al., 1999) and the scale can usefully discriminate between children with and without social anxiety disorder at least as well as the other major scales of child social anxiety (Bailey, Chavira, Stein & Stein, 2006). Thus the psychometrics available show the questionnaire to be a reliable and valid measure of social anxiety in children ages eight to 17 years old.

For the present research, the SWQ-P was adapted to form the SWAIY. Seven questions of the 10 original SWQ-P items were edited to make them more applicable to children aged four to eight i.e. “Avoids or gets worried about presenting work to the class” was edited to “Avoids or gets worried about putting their hand up or speaking in front of the class (show and tell)”. Alterations to situations were made by first devising potential alternatives and then presenting these alternatives at a research meeting attended by clinical psychologists and researchers from the Child and Adolescent Mental Health Service (CAMHS) Anxiety and Depression in Young people research (ANDY) unit at University of Reading. The final items were selected based on the discussion and feedback that took place within this research meeting and were approved by Professor Sue Spence, author of the SWQ-P. In keeping with the SWQ-P, parents answered the 10 items on a three-point scale (0 = not true; 2 = mostly true). A total score is computed by summing all responses (min = 0, max = 20). Higher scores indicate more social worries. To investigate whether the adaptations successfully presented scenarios that a four to eight-year-old would encounter an additional question was added asking parents to indicate whether any of the items were not applicable to their child. See Table 3 for the full item list.

2.3. Procedure

Data for this study was collected online as part of the screening process for an experimental study investigating the relationship between cognitive biases and anxiety in a community sample of children ages four to eight-years-old. Families were recruited through advertisements in magazines and newsletters targeting families and distribution of leaflets and posters to libraries, museums, brownie and scout groups, holidays groups, sports clubs, leisure centres and schools throughout Berkshire. To answer the advert, parents followed a link to a website where they could read the study information sheet. Once they had given informed consent they completed the questionnaires online. Parents answered the SWAIY and, depending on age, the PAS (for parents of children aged 4 to 6 years) or the SCAS-P (for parents of children aged seven or eight years). Demographic and contact details were also collected at this stage. Parents had the option to enter a prize draw to win an i-pod when visiting the online questionnaire. Parents were also asked if they were willing to be contacted again. Those who consented (94%) were contacted via email and invited to complete the SWAIY online again up to two weeks later. No other questionnaires were completed at time 2.

2.4. Attrition and missing data.

Time 1 data was collected over 11 months between 2014 and 2015. All parents who completed the measure at Time 1 were invited to complete the questionnaire a second time. As stated, 106 participants completed the questionnaire for a second time. On average the two time points were 13.35 days apart (*SD* = .01), ranging from 5 – 31 days. There was a 37% drop out from Time 1 to Time 2; there were no differences between those who completed the questionnaire once or twice in parent gender ($X^2(1) = .937$, $p = .713$, $\varphi = .01$), child gender ($X^2(1) = .988$, $p = .558$, $\varphi = .01$) or child age *(t*(167) = -.151, *p* = .880, *d* = .02). However, parents who answered the SWAIY at Time 1 and Time 2 (*n* = 106, *M* = 6.12, *SD* = 4.78) reported that their child was more anxious than parents who only answered the SWAIY at Time 1(*n* = 60, *M* = 4.60, *SD* = 4.42), the difference was significant with a small effect (Mann-Whitney U independent t-test, *p* = .035, *d* = .33).

All participants included in the study (169 at time 1 and 106 at time 2) had full data on the SWAIY but data on additional questionnaires (e.g PAS/SCAS-P) was missing for twelve of the 169 participants at time 1. The convergent validity analyses requiring these measures were therefore conducted with a reduced sample of 157 (47.8% female*, Mage* = 6.27, *SD* = 1.28).

2.5 Data analysis

Distributions for each of the questionnaires were examined for normality via visual inspections of histograms and boxplots as well as assessment of skewness and kurtosis. If non-normal distributions were identified non-parametric assessments were carried out with these variables. All comments regarding effect sizes are based on Cohen (1988). Data from Time 1 and Time 2 were checked for age and gender differences. Items scored as “not applicable” at each time point were assessed to gather evidence for content validity and to establish whether items should be excluded. Internal consistency and test-retest reliability were investigated via correlation analysis using data from Time 1 and Time 2. To complement the internal consistency measures, data from Time 1 (n=169) was used to examine the factor structure of the SWAIY using exploratory factor analysis (EFA), with confirmatory factor analysis (CFA) carried out on data from Time 2 (n=106). Given the relatively small sample size available for the CFA, the results should be interpreted with some caution, as model fit indices may be liable to type two error when sample size is small (Jackson, 2001). EFA and CFA analyses and internal consistency analyses were carried out on item responses of the SWAIY using maximum likelihood estimation. Given that item responses were categorical, polychoric correlations were used to assess internal consistency as well as for factor analysis (Holgado-Tello, Chacón-Moscoso, Barbero-García, & Vila-Abad, 2009) using R (R Core Team, 2015) packages nfactors (Raiche, 2010), polycor (Fox, 2010), psych (W Revelle, 2015), gdata (Warnes et al., 2015), and lavaan (Rosseel, 2012). Polychoric correlations estimate the correlation between items had they been continuous and normally distributed (Holgado-Tello et al., 2009). These correlations can then be utilised within factor analysis with no further need to account for the categorical nature of the items.

Data from Time 1 were used to assess convergent validity with anxiety scores on the PAS or SCAS-P. As different measures were completed depending upon the age of the child, t-scores were calculated for total anxiety and social anxiety based on the published norm data (Nauta et al., 2004; Spence et al., 2001). Convergent validity was then examined by correlating these T-scores with the SWAIY total scores.

3. Results

The total score on the SWAIY at Time 1 was positively skewed (*skewness* = .84*, kurtosis* = .13, *z score skewness* = 4.56) and non-parametric tests were therefore used for analyses including this variable. The other anxiety measures and SWAIY total score at Time 2 were normally distributed, though there was a slight positive skew for total anxiety (*skewness* = .649, *kurtosis* = -.327) and the social anxiety subscale (*skewness* = .601, *kurtosis* = .371) of the SCAS.

Table 1 shows the descriptive statistics of the SWAIY at Time 1 and Time 2. At Time 1 there was no difference between boys and girls total scores on the SWAIY (*p*

= .121, *d* = .45) at Time 1. At Time 2 there was a significant difference between female and male children (*t*(104) = 2.24, *p* = .027, *d* = .44) with females scoring higher than males. There were no significant correlations between age and total SWAIY score at Time 1 (*r* = -.102, *p* = .187) or Time 2 (*r* = -.07, *p* = .486).[4]

Table 1.

Descriptive Statistics of the total scores on SWAIY at Time 1 and Time 2.

SWAIY	N	Mean	SD	Range
Total T1	169	5.44	4.66	0-20
4 yr. olds	35	5.63	5.10	0-18
5 yr. olds	35	5.91	5.15	0-20
6 yr. olds	42	6.43	4.73	0-17
7yr. olds	35	5.49	4.16	0-18
8 yr. olds	22	3.22	3.12	0-10
Total T2	106	6.58	4.60	0-17
4 yr. olds	22	5.95	4.58	0-16
5 yr. olds	22	7.32	3.98	0-16
6 yr. olds	28	7.25	5.03	0-17
7 yr. olds	22	6.95	4.99	0-17
8 yr. olds	12	4.17	3.56	0-10

Note. T1 = Time 1, T2 = Time 2.

3.1. Content Validity

Frequencies of items identified by parents as not applicable to their child can be seen in Table 2. Given the low numbers of items identified and their respective frequencies, no formal analysis on this data was carried out. As Table 2 illustrates there was no consensus or consistency in the items identified as not applicable. Therefore, all items were deemed appropriate for the age group and none were removed. Items identified

[4] No evidence of moderation by gender or age (4-6.5 yr. olds and 6.5-8 yr. olds) was found in subsequent analyses; therefore these are not reported here.

in Table 2 were considered when conducting the factor analysis in case this informed interpretation of factor loadings.

Table 2.

Frequencies of Items Identified as 'Not Applicable' at Time 1 and Time 2.

Item	T1	T2
4.Avoids or gets worried about presenting work to the class/ about putting their hand up or speaking in front of the class (show & tell)	4	1
5.Avoids or gets worried about attending groups, clubs or after school activities	--	1
7.Avoids or gets worried about talking in front of a group of adults	2	1
8.Avoids or gets worried about going into a shop alone or to buy something or telling staff in a café what they would like to eat/drink	3	4

Note. T1 = Time 1 (N = 169), T2 = Time 2 (N = 106).

3.2. Internal Consistency and Factor Analysis

Internal consistency of the SWAIY was excellent at both time points (Time 1 α = .92, Time 2 α = .92).

3.2.1. Exploratory Factor Analysis.

Exploratory factor analysis was conducted using Time 1 data. Several tests were carried out to check that the data was appropriate for factor analysis and to ascertain how many factors should be explored. Firstly the Kaiser-Meyer-Olkin measure of sample adequacy (MSA) and Bartlet's test was carried out to check factor analysis was appropriate. MSA assesses whether the sample for each variable and for the complete model is adequate for assessment by factor analysis by producing a figure between 1 and 0, values close to 1 indicate a good fit for factor analysis. Bartlett's test assesses the correlation matrix to determine whether the items cluster into factors or represent individual factors. For factor analysis to be appropriate Bartlett's test should be significant (Field, 2013). In the present case, factor analysis was deemed to be appropriate as the MSA was close to 1 and Bartlett's test was significant (MSA = .87, Bartlett's test X^2 (45) = 1123.669, $p < .001$). The number of factors that should be explored was then determined. The number of factors after which eignevalues levelled off was assessed via a scree plot.

To complement this test Minimum Average Partial criterion (MAP) was used to assess how many common components were found in the data (Ledesma & Valero-mora, 2007). Finally a very simple structure analysis (VSS) was run to assess which number of factors maximises the goodness of fit (William Revelle & Rocklin, 1979). The scree plot and MAP criterion were suggestive of a one-factor solution and the VSS analysis also indicated one factor would be optimal (*BIC* = 148, *RMSEA* = .18). However a two-factor model had lower RMSEA values and BIC values, indicating a better model fit (*BIC* = 85, *RMSEA* = .16) than the one factor model. Given these results both a one factor and two-factor model were explored using a promax rotation.

A one-factor solution accounted for 53% of the variance and factor loadings for all items were sufficient with loadings ranging from .63 to .81 (See Table 3). While the two factor solution accounted for 60% of the variance, analysis indicated that a Heywood case had occurred. This occurs when one item has a negative variance and a factor loading greater than one. The Heywood case related to item 8 “Avoids or gets worried about going into a shop alone or to buy something or telling staff in a café what they would like to eat/drink” within the first factor and item 1 “Avoids or gets worried about going to parties or play-dates” within the second factor of the two factor solution. This can indicate a number of things including that one item accounts for all the variance within a factor or that there too many factors being fitted to the data. Also, when considering the items contained within each of the two factors there appeared to be no theoretical/conceptual distinction between the two factors. Given this, a varimax rotation which assumes the factors correlated, was also checked however, this did not substantially alter the results. Therefore a one-factor model was investigated within the confirmatory factor analysis using Time 2 data.

Table 3.

Factor loading coefficients of items from exploratory and confirmatory factor analysis on 10 items of the SWAIY.

Item	EFA 1 Factor Model	EFA 2 Factor Model 1	EFA 2 Factor Model 2	CFA 1 Factor Model
1.Avoids or gets worried about going to parties or play-dates	.63		1.05	.54
2.Avoids or gets worries about using or speaking on the telephone	.67	.41		.60
3.Avoids or gets worried about meeting new people	.81		.45	.81
4.Avoids or gets worried about presenting work to the class/ about putting their hand up or speaking in front of the class (show & tell)	.70	.76		.53
5.Avoids or gets worried about attending groups, clubs or after school activities	.78		.78	.57
6.Avoids or gets worried about approaching groups of kids to ask to join in/play	.78	.57		.71
7.Avoids or gets worried about talking in front of a group of adults	.80	.89		.76
8.Avoids or gets worried about going into a shop alone or to buy something or telling staff in a café what they would like to eat/drink	.75	1.03		.76
9.Avoids or gets worried about standing up for him/herself with other kids i.e. when someone takes their toy	.63	.50		.59
10.Avoids or gets worried about entering a room full of people	.72		.40	.66

Note. (EFA) Exploratory factor analysis, (CFA) Confirmatory Factor Analysis. Exploratory factor analysis was carried out with Time 1 data (N = 169), factor loadings represent pattern loadings. Confirmatory factor analysis was carried out with Time 2 data (*N* = 106), factor loadings represent standardised factor loadings.

3.2.2. Confirmatory Factor Analysis.

To confirm the one-factor structure at Time 1, a confirmatory factor analysis using a structural equation modelling approach was conducted in R using Time 2 SWAIY data. For adequate model fit it has been suggested that CFI and TLI statistics should be close to .90 and that RMSEA values close to .06 demonstrate a good fit (Hu & Bentler, 1999), although model fit statistics should be taken together when assessing goodness of fit (Jackson, 2001). Confirmatory factor analysis indicated that model fit for a one-factor solution had a CFI and TLI approaching .90, but a RMSEA higher than .06 (*CFI* = .87, *TLI* = .83, *RMSEA* = .12). Taken together therefore, we judged that the one-factor solution showed reasonable model fit. Analyses indicated that all the items significantly contributed to one latent variable, loadings ranged from .53 to .76 (See Table 3). These results confirm the structure found at Time 1.

3.3. Test re-test reliability

Non-parametric correlations were conducted between SWAIY total scores at Time 1 and Time 2 for 106 children. The average length of time between Time 1 and Time 2 was 13.35 days (*SD* = .01). A large positive correlation (*Spearman Rho* = .87) was found between scores on the SWAIY at Time 1 and Time 2.

3.4. Convergent validity

Given non-normality of the SWAIY at Time 1 non-parametric correlations were used to assess convergent validity. Mean T-scores for total anxiety and for the social anxiety subscales suggest that, as a whole, the sample had an average level of anxiety (*Mtotal* = 55.07, *SD* = 12.71; *MSocial* = 54.72, *SD* = 13.36). Total anxiety and social anxiety both showed robust correlations with SWAIY at Time 1 (*r* = .63; *r* = .70) and Time 2 (r = .64; r = .87) respectively, with large effect sizes.

4. Discussion

The aim of this research was to develop a brief parent report measure of social anxiety in young children and to conduct an initial psychometric evaluation of this questionnaire. The psychometric evaluation provides initial evidence that the SWAIY is a reliable and valid measure of social anxiety in children aged between four and eight years old. Very few parents identified any of the items as not applicable to their child, indicating that the ten items were appropriate and relevant to this age group and providing initial evidence of content validity. The internal reliability of the questionnaire was demonstrated through excellent internal consistency at Time 1 and Time 2. The internal structure of the questionnaire was scrutinised using factor analysis and a one-factor solution explaining 53% of the variance was suggested by the exploratory factor analysis using the data collected at Time 1. This one factor solution was confirmed using the data collected at Time 2 with adequate model fit. These results are consistent with the one-factor structure which explained 66% of the variance in the original SWQ-P (Spence, 1995). Findings therefore indicate that the items of the SWAIY are collectively measuring the same construct, namely social worries and symptoms of social anxiety. The SWAIY showed excellent test-retest reliability when completed by parents two weeks apart. Convergent validity was also assessed and the SWAIY was correlated with the other standardised questionnaires of anxiety in children and their respective social anxiety subscales. As would be anticipated, correlations with the social anxiety subscales were slightly stronger than correlations with the total anxiety scales.

To our knowledge, the SWAIY is the first measure to focus on child social anxiety that has been developed for use with parents of young children. Such a measure will facilitate investigation of the development and stability of social anxiety in younger children, as well as the relationship between social anxiety symptoms and later social and mental health outcomes. Given the strong correlation between the SWAIY and existing measures of child anxiety, one could question the utility of the SWAIY over these measures. The strong correlations confirm the construct validity of the SWAIY reflecting both the SWAIY and the subscales of the standardised measures as assessing the underlying construct of social worries or symptoms of social anxiety. What is crucial is that the SWAIY is a brief, stand-alone measure, requiring parents to complete only 10 items. As a comparison, the PAS is 22 items and its social anxiety subscale was not designed to be a stand-alone measure. Also the SWAIY focuses on observable behaviours in specific social situations whereas the social anxiety subscales of the SCAS-P and the PAS include cognitive symptoms, which might be difficult for parents assess. Given this distinct focus, the SWAIY could be used to complement a standardised measure of anxiety or by itself as a brief measure of social anxiety in young children.

Gender differences in the SWAIY were not found at Time 1 replicating the findings of Spence (1995) with eight to 17 year olds using the SWQ-P. There was also little difference between the means of the SWAIY for males and females at Time 2, although this difference was statistically significant with female children reported as having higher social worries scores than male children. These gender differences are consistent with studies of older children (i.e. Spence, 1998) and adolescents (Davidson, Hughes, George, & Blazer, 1993; Garcia-Lopez, Ingles, & Garcia-Fernandez, 2008), though they are not typically found in young children (Spence et al., 2001). Further analyses indicated that reliability and validity were not moderated by gender and that the factor structure of the SWAIY was the same across genders. Having said this, alongside the difference between genders found at time 2, previous work indicates that factor structure of other anxiety measures, such as the SCAS (Holly, Little, Pina, & Caterino, 2014), may be influenced by gender. Therefore, checking measurement invariance by gender for the SWAIY using a larger sample may be warranted in future research.

Overall, there is strong support for the psychometric properties of the SWAIY as a new brief measure of social anxiety in young children but this conclusion should be considered in light of some considerations. First, the scores for eight-year-old children were notably lower than the scores for younger children. Given the items were specifically adapted to be appropriate for a younger age group than the original measure (validated for eight-17 year olds) it may be that the SWAIY is a more valid and accurate measure of social worries in children aged four to seven years than children aged eight years. Unfortunately, there were not enough eight year olds in this sample to assess factor structure for the eight year olds specifically. With this in mind, it may be prudent to use the original SWQ to assess social worries in eight-year olds until further psychometric evaluation of the SWAIY for older children has been conducted. The second consideration is that the sample was recruited from Berkshire, UK, where approximately 80% of the population are white and a range of ethnic groups are represented in the remaining 20% of the population (Office of National Statistics, 2012), thus analysis of race effects was not feasible with the present data. Given this, we should be cautious about generalising the findings to other populations without further research assessing the psychometric properties of the measure in other samples. It is also noteworthy that the sample was self-selecting; participants were recruited via adverts asking for children to take part in a study on child anxiety and confidence. The description of the study may have attracted parents who were interested in child anxiety possibly because they were concerned about their own child's anxiety. This may in part explain why those who answered twice reported higher anxiety scores for their children than those who answered once; parents with children with higher anxiety may have been motivated to continue with the study. Thirdly the small sample size available for the CFA may have influenced model fit indices, which approached the criteria for adequate fit. As model fit indices are affected by sample size (Jackson, 2001), future research may wish to reassess the one-factor structure using CFA with a larger sample. This would help to clarify whether the present findings are robust.

While this study provides initial evidence of the validity and reliability of the SWAIY, additional psychometric assessment with a clinical sample would be useful to assess divergent and discriminative validity further. In particular it would be useful to assess the divergent validity of the SWAIY in relation to clinically diagnosed anxiety disorders to see if it is able to discriminate between social anxiety and other child anxiety disorders. This would be interesting and important given the comorbidity found in childhood anxiety (Waite & Creswell, 2014) and the reliance on parent report of anxiety in the present study. Similarly, evaluating the SWAIY in relation to other measures of anxiety such as teacher-report and observation measures will give further information regarding the utility and psychometric properties of the scale.

4.1. Conclusions.

The results indicate that the SWAIY has robust reliability and validity, providing evidence of construct validity. Our findings replicate those from the validation of the original SWQ-P questionnaire and suggest that the questionnaire can be adapted to measure social worries or symptoms of social anxiety in children aged four to eight years old. Future research using a clinical sample to assess discriminative validity, for example by assessing whether scores on the SWAIY differentiate between a clinically socially anxious sample and a community/non-clinical sample, would provide a more complete investigation of the psychometric properties of the scale. The measure shows promise in providing information about the social worries that children experience in response to specific situations. Thus, the SWAIY may be useful for investigating the stability and development of social anxiety symptoms across early childhood and has the potential to be useful clinically as a screening tool for social anxiety.

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Appendix 1

Table A1.

Items and response scale of the Social Worries Anxiety Index for Young Children

	Not True	Sometimes True	Very True	Not Applicable
Avoids or gets worried about going to parties or play-dates	0	1	2	n/a
Avoids or gets worries about using or speaking on the telephone	0	1	2	n/a
Avoids or gets worried about meeting new people	0	1	2	n/a
Avoids or gets worried about presenting work to the class/ about putting their hand up or speaking in front of the class (show & tell)	0	1	2	n/a
Avoids or gets worried about attending groups, clubs or after school activities	0	1	2	n/a
Avoids or gets worried about approaching groups of kids to ask to join in/play	0	1	2	n/a
Avoids or gets worried about talking in front of a group of adults	0	1	2	n/a
Avoids or gets worried about going into a shop alone or to buy something or telling staff in a café what they would like to eat/drink	0	1	2	n/a
Avoids or gets worried about standing up for him/herself with other kids i.e. when someone takes their toy	0	1	2	n/a
Avoids or gets worried about entering a room full of people	0	1	2	n/a

6 General Discussion

The primary aim of this thesis was to examine the association between anxiety and cognitive biases in children, with a particular focus on children aged between 4 and 8 years. A secondary aim was to develop a brief measure of early signs of social anxiety in young children to facilitate future research examining the early development of social anxiety as well as the content specificity of cognitive biases. There are notable gaps in the literature surrounding anxiety in young children that hamper our overall understanding of how anxiety manifests, develops and might be treated. This is driven, at least in part, by the lack of age appropriate tasks available to assess cognitive biases in young children, and the limited measures available to assess anxiety subtypes, such as social anxiety. An increased understanding of anxiety in children should facilitate the development of targeted interventions for young children who have problems with anxiety.

This thesis had four specific objectives: 1) to systematically review and analyse the evidence of a relationship between interpretation bias and anxiety in children and adolescents; 2) to develop new child friendly tasks to assess interpretation bias and attention bias respectively and to investigate if there are anxiety-related differences on these tasks in children aged 4 to 8 years; 3) to investigate whether development influences the relationships found using these new tasks, with a specific focus on age and effortful control as moderators and 4) to provide a valid and reliable means to assess social anxiety in 4 to 8 year olds.

An overview of the findings from each paper will first be presented followed by consideration of how these results relate to the aims and objectives of the thesis. This is followed by a consideration of the common strengths and limitations that apply across the papers. The final sections of this chapter discuss the implications of the results collectively, for our understanding of anxiety in children, treatments for young children and for future work.

6.1 Overview of Findings

6.1.1 Paper 1: Is Anxiety Associated with Negative Interpretations of Ambiguity in Children and Adolescents? A Systematic Review and Meta-analysis.

Cognitive theories of anxiety stipulate that cognitive biases, such as an interpretation bias where ambiguity is more likely to be interpreted as negative, underpin anxiety in individuals. While there is consensus that an anxiety related-interpretation bias exists in adults there is inconsistency about whether this relationship exists in children and adolescents. This inconsistency may be driven by methodological differences between studies such as the population under study and the study design. Several narrative reviews have been conducted but no systematic, quantitative review of the anxiety-interpretation bias relationship in children and adolescents. In Paper 1, a systematic review and meta-analysis was therefore conducted. Moderation analyses were included to examine various potential population and procedural variables that may be contributing to the inconsistency in the literature. In addition, data was analysed for the influence of publication bias. Following a systematic search, 345 effect sizes from 77 studies were entered into the meta-analysis. A multi-level model approach was taken to analyses to account for dependency as a result of multiple effect sizes being taken from the same study. The analysis indicated that there was a relationship of $\hat{d} = 0.62$ with a medium effect between anxiety and interpretation bias in children and adolescents.

Only two factors were significant moderators of the relationship between anxiety and interpretation bias: 1) age and 2) the match between anxiety subtype and scenario content. For moderation by age, the association between interpretation bias and anxiety increased as age increased. This suggests that development influences the anxiety-interpretation bias relationship. However, the limited number of studies with very young children does limit the interpretation of these data. The moderation by the match between anxiety subtype and scenario content was that when the content of the scenario (e.g. social scenario) matched the anxiety subtype under study (i.e. social anxiety) the association between anxiety and interpretation bias was larger than when they did not match (i.e. social scenario + specific phobia subtype). This provides evidence for content specificity in the anxiety-interpretation bias relationship, which aligns with the content specificity hypothesis (Beck, 1976). It should be noted, however, that the majority of studies included in this analysis reflected the relationship with social/non-social scenarios and social anxiety, thus the result cannot be generalised across disorders.

The study concluded that there is a robust association between anxiety and interpretation bias in children and adolescents and that this is stronger in older children and when the content of the task is relevant for the anxiety subtype. The study also highlighted that lack of research of involving younger children necessary to confirm the moderation by age found in the study.

6.1.2 Paper 2: Look out Captain, I hear an ambiguous alien! A study of interpretation bias and anxiety in young children.

One reason for the lack of studies examining interpretation bias and anxiety in young children is likely that the measures used to assess interpretation bias in older children are not appropriate for younger children. For example, the ambiguous scenarios task requires verbal and non-verbal skills that are not likely to be developed in children younger than eight years old (Field & Lester, 2010).

Paper 2 described a new interpretation bias task designed to examine whether an anxiety related interpretation bias exists in children aged 4 to 8 years old. Children were trained to associate a high tone with an alien when it was happy and a low tone with an alien when it was angry. Once children had learnt this association they were played ambiguous tones from the middle of the high-low range, and asked if the alien was happy or angry. In addition to this behavioural measure of interpretation of ambiguity, activity of the corrugator muscle via facial electromyography was recorded to assess whether this may provide a physiological index of their appraisal of ambiguous stimuli (Tottenham, Phuong, Flannery, Gabard-Durnam, & Goff, 2013).

Children were recruited from the community and were split into high and low anxiety groups based on parental report of child anxiety. One hundred and ten children, aged 4 to 8 years, completed the task. The majority (97/110) learnt the associations between tones and the valence of the alien (>60% accuracy). Whether the associations were learnt or not was not dependent on age, gender or anxiety grouping. Of those that learnt the associations 73 children had enough valid trials to be included in the analysis. Anxiety groups were found to differ on autistic quotient, consequently this was added as a covariate in the analyses. Multi-level analysis of the behavioural data for the ambiguous tones suggested that in initial models with autistic quotient acting as a covariate and anxiety grouping, the difference between anxiety groups in the likelihood to report the ambiguous tones as angry (negative) did not reach significance. In the final model which also included age, effortful control, verbal and non-verbal cognitive abilities, the child's level of anxiety was a significant predictor. The final model indicated that children who were more anxious were more likely to report the ambiguous sound as negative than children who were less anxious. There was no evidence that interpretation of the ambiguous sounds was influenced by verbal and non-verbal cognitive abilities. While developmental proxies were not significant independent predictors of whether the children reported the ambiguous tones as angry, they had a confounding effect on anxiety group differences such that only when developmental proxies were taken into account were anxiety group differences clear.

Analysis of the psychophysiological data from the corrugator muscle to the trained tones (TT) in the learning phase indicated that children responded physiologically to them. Two sets of models were created, one including response (whether the tone was reported as ‘angry’ or ‘happy’) as a predictor and the other including valence (whether the tone was trained to be classified as ‘angry’ or ‘happy’) as a predictor. The final models indicated that there was greater corrugator activity when the children reported a tone was from an angry alien than when they reported the tone was from a happy alien but that trained valence did not significantly predict corrugator activity. There was no influence of anxiety or of the developmental proxies on performance in the practice trials. This result indicates that participants’ subjective evaluation of the sounds could be captured via corrugator activity. Given this, it was deemed appropriate to investigate corrugator activity in response to the ambiguous tones. In line with previous studies (Tottenham, Phuong, Flannery, Gabard-Durnam, & Goff, 2013) it was expected that greater corrugator activity would be seen when the ambiguous tones were reported as angry (negative), particularly for the high anxious group. However, regardless of anxiety, there were no differences in corrugator activity when the children reported the ambiguous sounds as angry (negative) or (happy).

In summary, behavioural results indicated that developmental proxies confounded the relationship between anxiety and interpretation bias. When developmental proxies were considered, high anxious children were more likely to report the ambiguous sound as negative (angry) than children with low anxiety. Psychophysiological data indicated that there was greater corrugator activity in response to interpreting the trained tones as negative in the learning phase for all children, regardless of anxiety. However, corrugator activity did not differ according to responses to ambiguous tones, thus it was not functioning as an index of children’s valence appraisal of ambiguous stimuli.

6.1.3 Paper 3: Anxiety differences in visual attention to emotional faces in four to eight year olds.

There is evidence of an anxiety related attention bias in adults, children and adolescents, but whether the relationship is present in young children is not yet clear due to a lack of studies focusing on this age group. Current methods of assessing attention bias, such as the dot probe, are not appropriate for young children given the motor and cognitive abilities needed for reaction time tasks (Brown et al., 2014). One promising method that does not require such abilities is eye-tracking (Karatekin, 2007). Several studies (e.g. In-Albon, Kossowsky, & Schneider, 2010; Price et al., 2013) have investigated the relationship between attention bias and anxiety using this method, although only one has included younger children (Dodd et al., 2015). Paper 3 used a new, child friendly free-viewing eye-tracking task to assess if anxious children recruited from the community exhibited an attentional bias when viewing emotional faces. Children were recruited from the community and based on parent report of anxiety were split into high and low anxiety groups. One hundred and four children aged between 4 and eight years old completed the eye-tracking task.

One of the advantages of eye-tracking over reaction time data from tasks such as the dot probe is that it provides a time course of visual attention. Growth curve modelling can be used to take full advantage of this continuous time course data. As yet, no study has analysed an eye-tracking task to assess attention bias in young children using this technique. To assess whether development influences anxiety-related attention bias in this age group, effortful control and age were assessed as moderators. In addition, given the criticisms levelled regarding the appropriateness of current tasks for assessing attention bias in young children, the influence of verbal and non-verbal cognitive abilities on looking behaviour to the face was also investigated.

To assess visual attention, the proportion of looks to specific face types was calculated based only on the first face looked at in each trial. Initial looks to faces were analysed using growth curve modelling, alongside conventional mixed ANCOVA analysis. The results indicated that all children were more likely to look first at an emotional face than a neutral face and this was not higher in anxious children. Conventional analysis concerning moderation by age suggested that younger children, on average, spent less time looking at the angry face during initial views than the older children; however, growth curve moderation analysis revealed further nuanced patterns in children's initial looks towards the faces. High anxious older children showed a stronger avoidance component in relation to angry faces than high anxious younger children and low anxious children. For young children, the high anxious group was vigilant to emotional faces, while the low anxious group looked more to the neutral face. There was no evidence that differences in an attention bias to angry faces between the anxiety groups was moderated by effortful control; however, effortful control appeared to influence visual attention to emotional faces versus neutral faces between the anxiety groups. Finally, verbal and non-verbal cognitive abilities did not influence children's visual attention towards faces. This indicates that performance on this task was not dependent on such abilities as has been the criticism of previous tasks assessing attention bias in children. The results add to the growing body of evidence utilising eye-tracking to investigate attention bias in young children and highlight the importance of considering development when investigating the anxiety-attention bias relationship in young children.

6.1.4 Paper 4: Young children have social worries too: validation of a brief parent report measure of social worries in children aged 4–8 years.

While social anxiety is present in young children little is known about its stability and development over childhood and thus, how it contributes to the development of anxiety more broadly. There is no stand-alone brief measure of social anxiety validated for young children. Paper 4 sought to address this by adapting the 10-item parent report measure Social Worries Questionnaire (SWQ; Spence, 1995) for 4 to 8 year olds to create the Social Worries Anxiety Index for Young Children (SWAIY), then assessing its reliability and validity. The SWQ was deemed a good candidate for adaption given the focus of the items in the original measure on observable behaviours. It is assumed that observable behaviours are easier for parents to report on than cognitive symptoms.

Parents of children aged 4 to 8 years old, who were recruited from the community, filled in the SWAIY twice, two weeks apart. The content validity, test-retest reliability, convergent validity and internal reliability of the new measure was scrutinised and the internal structure was investigated via factor analysis. The SWAIY showed initial evidence of having good psychometric properties. Clinicians and the original author of the SWAIY agreed with the appropriateness of the questionnaire items, suggesting evidence for the questionnaire's content validity. The internal reliability of the questionnaire was excellent at both time points. Assessment of the internal structure of questionnaire data taken at time 1 suggested a one-factor structure, which was confirmed with data from time 2. The one-factor solution suggested that all the items were assessing one construct, namely social worries and accounted for 66% of the variance within the confirmatory factor analysis. The SWAIY also showed excellent test-retest reliability ($r = .87$) over the two-week period indicating the level of agreement between the parents' responses at the two-time points was high. Finally, evidence for convergent validity of the SWAIY was found with standardised measure of anxiety, the Spence's Children's Anxiety Scale (Spence, 1998) and the Preschool Anxiety Scale (Spence, Rapee, McDonald, & Ingram, 2001). As would be expected the SWAIY showed stronger convergent validity with the social anxiety scales from these measures than the total score assessing trait anxiety, but both scales showed strong correlations with large effects. However, this study did not include a clinical sample therefore could not investigate the divergent or discriminative validity of the SWAIY.

Overall, initial evidence for good psychometric properties was found for the SWAIY. As such the SWAIY holds promise as a brief assessment of social worries of young children. This questionnaire should facilitate research that will advance our understanding of social anxiety in this age group.

6.1.5 Findings related to aims.

The primary aim to examine the association between cognitive bias and anxiety in children was in part fulfilled by the meta-analysis of Paper 1 and the focus on children aged between 4 and 8 years being fulfilled by Papers 2 and 3. The meta-analysis provided good evidence of a medium sized association between interpretation bias and anxiety in children over aged eight years old. This is in line with the consensus in the literature regarding the presence of an association between interpretation bias and anxiety in adults (Blanchette & Richards, 2009). The moderation by age suggested that this association is expected to be smaller in younger children than older children. This would be consistent with a moderation model of anxiety in children (Field & Lester, 2010) but the lack of studies focusing on children below eight years limits the conclusions that can be drawn. Paper 2 followed up this point by investigating the association between interpretation bias and anxiety in children aged 4 to 8. The small association between interpretation bias and anxiety in 4 to 8 year olds found in Paper 2, which was confounded by developmental factors, is unlike the robust associations between interpretation bias and anxiety found in older children and adolescents (Paper 1; Stuijfzand, Creswell, Field, Pearcey, & Dodd, 2017) and assumed to be in place in adults (Blanchette & Richards, 2009). The results of Paper 2 are therefore consistent with the moderation by age effect found in the meta-analysis of Paper 1. While an influence of developmental factors on the association between interpretation bias and anxiety was found in Paper 2, the exact nature of this influence remains unclear.

Paper 3 found nuanced patterns of anxiety differences in attention bias in children aged 4 to 8. The clearest evidence for anxiety differences in attention bias were found amongst the younger children in the sample. It may be that differences in the arousal /interest created by the angry/neutral faces may influencing attention allocation of the younger children. The vigilance avoidance pattern seen in the older end of our sample reflects the patterns found in other children and adolescents (In-Albon et al., 2010) and adults (Rinck & Becker, 2006). A difference in association between attention bias and anxiety by age has been suggested previously in the meta-analysis of Dudeney, Sharpe, and Hunt (2015) where the association between attention bias and anxiety was expected to be smaller in younger children than older children. However, we found the difference between anxiety groups to be characterised by a difference in the nature of the bias in the younger children, rather than a smaller association. Paper 3 is one of a few studies to assess the influence of developmental factors on the association between anxiety and attention bias. As only age and effortful control were evaluated, it is not clear whether these are the only or most influential factors on the association. What is clear from Paper 3 is that the anxiety-related attention bias present in young children may be qualitatively different to the anxiety related attention bias found in adults (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007).

To obtain evidence regarding the presence of anxiety-related cognitive biases in young children, Papers 2 and 3 made use of two new child friendly tasks. These tasks were shown not to suffer from the same reliance on linguistic and cognitive abilities that current cognitive bias tasks suffer from (Blanchette & Richards, 2009; Brown et al., 2014). The tasks made use of paradigms that required simple instructions and assessed whether objective measures may be used in investigations of cognitive biases in young children. Paper 3 adds to the growing literature investigating an anxiety related-attention bias using eye-tracking with a young sample. Paper 2 demonstrates that assessing interpretation bias in young children is possible and provides a new task for this purpose.

The secondary aim of this thesis was to develop a brief measure of early signs of social anxiety in young children to facilitate future research examining the early development of social anxiety as well as the content specificity of cognitive biases. Paper 4 fulfilled this aim by demonstrating evidence of good psychometrics of the adapted social worries anxiety index for young children for children ages 4 to 8 years old. This is the first stand-alone measure of social worries thought to be available and validated for young children. The measures items reference to observable behaviour give it an advantage over items in the subscales of social anxiety found in the Preschool Anxiety Scale which ask about unobservable cognitions which parents may find hard to comment on. Paper 4 shows the measure to be ready for use to investigate the early development of social worries and content specificity in cognitive bias in children ages 4 to 7 in a community sample.

Results from the examination of the association between cognitive biases and anxiety in children aged 4 to 8 described in this thesis (Papers 2 and 3) suggest that if there is an association presents in this younger age group it is different from the association found in adults and is subtle. This may be because the association is in fact different in younger children and emerges over time to eventually manifest in the way seen in adults. Such a rationale would be suggested by the information processing developmental models of anxiety described by (Field & Lester, 2010a).

6.2 Implications for Theoretical Models of Anxiety

6.2.1 Cognitive Models of Anxiety

One theory of attention suggests that while vigilance to threat may be a result of reflex saliency filters driven by bottom up reflex responses, the effortful withdrawal of attention or avoidance of threat may be under more voluntary top-down control (Knudsen, 2007). A review of the evidence suggests that an attention bias depends on both bottom-up and top-down processing (Cisler & Koster, 2011), at least in adults. The varied patterns that seem to distinguish anxious individuals from non-anxious individuals (i.e. vigilance to threat, faster avoidance, or vigilance followed by avoidance) has been taken to be suggestive of this view (Waters & Craske, 2016). Neurophysiological evidence suggests that top down selection is being driven by bottom-up distinctiveness/saliency of an object (Corbetta & Shulman, 2002). In the case of an anxious individual top-down selection of a stimulus for allocation of attention maybe driven by detection of the stimulus as threatening by bottom-up processes. Hereby top-down and bottom-up process are interacting in stimuli selection (Corbetta & Shulman, 2002). Top down processes such as avoidance have been seen as part of the individuals attempts to regulate distress (Waters & Craske, 2016).

Evidence from Paper 3 regarding attention bias suggests that high and low anxious groups were differentiated in later (top-down) processing, reflected in the five way interaction being with cubic time, rather than in early bottom-up processes that would be reflected in initial vigilance. The anxiety differences found in Paper 3 were dependent on age. Examination of the results suggests that these differences may be driven by different motivating processes, which is in line with potential developmental differences between the children. The younger children differed in the nature of bias between the anxious groups, whereby high anxious younger children gave more attention bias towards angry faces than the low anxious group who viewed the emotional face first. Conversely when the neutral face was first viewed in the angry trials the low anxious groups looked more to the neutral face than the high anxious group. The difference here was not in the speed in which they looked to the faces, but in the amount of attention allocated to the faces. However, for the older group the difference between the anxious groups was a subtle faster withdrawal of attention from the angry faces, relative to all other groups, when the emotional face was viewed first. Thus, for younger children the difference may be driven by attention allocation, as a top-down process driven by the emotional content (or lack of; see the discussion of Chapter 4)) of the face stimuli. Anxiety-related differences for the older children were seen in a subtle stronger avoidance component when the angry faces were viewed faster, reflecting a different top-down process. One which has been suggested to be part of regulation attempts (Waters & Craske, 2016), which may make use of skills such as attention control.

For both younger and older children within the sample the difference appears to occur within top-down processes, but these may be different between the age groups. This makes sense considering the older children in our sample (7-8 year olds) may indeed have greater attention control skills then the younger children (4-5 years old). Attention control is the ability to focus and shift attention and develops across childhood (Rothbart & Rueda, 2005) and has been suggested as a potential top down ability influencing attention biases (Eysenck, Derakshan, Santos, & Calvo, 2007). Indeed, it have been suggested that avoidance reflects the effortful use of attention control to regulate distress (Craske & Waters, 2016). Thus, developmental differences in abilities such as attention control may be influencing the differential nature of anxiety related biases seen between age groups.

6.2.2 Models of the Development of Anxiety

Vasey and Dadds' (2001) model of the development of anxiety places cognitive biases amongst a collection of inherited, individual and environmental factors that interact to predispose and/or maintain anxiety. Results from Papers 2 and 3 suggest that cognitive biases appear to present in all children ages 4 to 8 with anxiety differences in these biases being subtle and may be influenced by developmental factors. The presence of an anxiety-related interpretation bias influenced by development in children and adolescents was also suggested in the meta-analysis reported in Paper 1. The presence of anxiety symptoms, the subtlety of the anxiety differences in cognitive biases and the suggestion of the influence of developmental factors by the papers presented in this thesis are in line with the idea forwarded by models such as Vasey and Dadds (2001) and Hudson and Rapee (2004): that in the development of anxiety one factor does not act alone to maintain or predispose a child to anxiety. However, the direction of effects between the cognitive bias and anxiety cannot be determined through the research presented here. Longitudinal work would assist in clarifying whether cognitive biases act as predisposing and/or maintaining factors in the development of anxiety. Given the subtlety of anxiety differences found in Papers 2 and 3 in children aged 4 to 8 it will be imperative that future longitudinal work considers that cognitive biases may not be acting alone to influence anxiety in young children. Thus, development factors, i.e. effortful control, may also need to be considered in the longitudinal relationships in order to fully understand the anxiety-cognitive bias relationships (Hudson & Rapee, 2004; Vasey & Dadds, 2001).

6.2.3 Models of the Development of the Anxiety-Cognition Relationship

Results from Papers 1, 2 and 3 provide new evidence about the relationship between cognitive biases and anxiety in children. These results have implications for the models outlined by (Field & Lester, 2010). Field and Lester (2010) suggested there were three possible models of how development might influence associations between anxiety and cognitive biases: the integral model, the moderation model and the acquisition model (see section 1.5.2. for a detailed description of the models). Evidence can help separate these models by indicating whether the biases are present early in development and whether they are only present for a specific subgroup of children (e.g. those that are anxious). Furthermore, investigation of the influence of development on anxiety-bias relationships adds to our understanding of the nature of the role of development, providing further evidence for the models. Field and Lester (2010) concluded that the anxiety-interpretation bias relationship may align with an acquisition model of development. In contrast, the anxiety-attention bias relationship may more closely fit a moderation model of development.

Both Paper 1 and Paper 2 focused on the association between interpretation bias and anxiety in children. Paper 1 (meta-analysis) suggested that there is a relationship between interpretation bias and anxiety in children and adolescents and that this differed according to the age of the child. The review of Field and Lester (2010) and our meta-analysis was based mostly on studies including children over age 8 and therefore, could not include whether there is an anxiety-related bias early in development. Without knowing if there is a relationship in younger children, but knowing there may be an influence of development, we still cannot tell from these results alone if a moderation or acquisition model is more appropriate. To address this question, Paper 2 focused on associations between interpretation bias and anxiety in 4 to 8 year olds, providing evidence from a younger sample. Results suggested that children in general were biased towards reporting the ambiguous tones as negative indicating a bias is present at a young age. Furthermore, the results suggest that there is an association between interpretation bias and anxiety at this age but the difference between high and low anxious groups was small and was confounded by developmental factors. The moderation model would suggest that the bias is present in early development, in line with our results and the differences develop through interaction with social, emotional development. Again, our results do suggest an influence of development, again in line with the moderation model. The acquisition model suggests that biases would be seen once necessary and sufficient development abilities are in place. Given that all children showed a bias in our study, it may be there is sufficient development by ages 4 to 8 for the bias to be present. The fact that anxiety differences were only present after accounting for developmental factors may suggest that anxiety differences are only starting to emerge. Interpreted this way, our results may be in line with an acquisition model. Thus, while Paper 2 provides evidence that would rule out an integral model for the development of the relationship between interpretation bias and anxiety, further investigation is required to confirm whether a moderation or acquisition model is supported. Greater power to assess the nature of the influence of the moderation by age and effortful control would assist this and evidence of whether the bias is present at an even younger age would assist in separating the models.

Paper 3 examines the anxiety-attention bias relationship in 4 to 8 year olds and provides evidence regarding whether such a relationship exists in young children. Anxiety differences in attention bias were found in Paper 3, and were most clear when the moderating effect of age was examined. The moderation by age results suggest that there was a relationship between the pattern of visual attention to the angry faces and anxiety, but that the nature of the relationship was different in younger and older children. For older children, the relationship was characterised by differences in the avoidance component, where those in the high anxious group showing a stronger avoidance component to angry over happy faces than those in the low anxious group. Other studies involving older children (In-Albon et al., 2010) and adults (Koster, Crombez, Verschuere, Van Damme, & Wiersema, 2006) have also indicated that those with high anxiety are characterised by an attention bias towards followed by an attention bias away from or avoidance of threat suggesting that our older children may be showing an attention bias that is more like that shown by adults. There was an attention bias present in children at the younger end of our sample and anxiety differences were already present there. However, the nature of the bias differed from that found in the older children. Thus, in line with previous reviews (Dudeney et al., 2015; Field & Lester, 2010a) our results would be suggestive of a moderation model, where an attention bias is present and anxiety related in young children, but the nature of this relationship changes to become more akin to that found in adults with age.

6.3 Alternative Explanations

As outlined, the work included in this thesis provides some evidence for an association between anxiety and cognitive biases in young children but this bias is relatively subtle. This may indicate that the association changes over time, as discussed above. However, there are alternative explanations for why the biases found in Papers 2 and 3 were not strong and these will now be considered.

6.3.1 Further consideration of developmental fears and anxieties.

As outlined above, development was taken into consideration in Papers 2 and 3 regarding task design in terms of how to make the task appropriate for children aged 4 to 8 years. Development was considered in the selection of stimuli for the attention bias task (Paper 3). Child faces were used in the free viewing task rather than adult faces. Use of adults faces within assessments of attention bias in children have been recognised as a limitation of previous studies (Gamble & Rapee, 2009; Shechner et al., 2013). There is evidence that children are better able to identify the emotional expressions on child faces that adult faces (Anastasi & Rhodes, 2005; Benoit, McNally, Rapee, Gamble, & Wiseman, 2007). This may be because children find adult faces in general salient so have more difficulty identify emotions on adults than those of their peers (Benoit et al., 2007). Since we expected anxiety related differences in responses to the angry/threat faces it was important that our children were able to recognise the emotions they viewed and results were not confounded by how salient the children found all the faces to be. Therefore, using child faces seemed developmentally appropriate as stimuli in our assessment of attention bias in children ages 4 to 8 years (Paper 3). On reflection, the developmental stage of the children could have also been considered in the choice of stimuli for each task. The stimuli used contained inherently social stimuli: faces, and tones associated with an alien to communicate an emotion. As outlined in the introduction to this thesis and in Paper 4, social worries and anxieties are present in younger children. However, anxieties surrounding social evaluation grow in prominence between the ages of 6 and 12 years (Gullone, 2000; Vasey, Crnic, & Carter, 1994). Consequently, social stimuli may be more potent or relevant for adolescents who are at a stage in their development where their anxieties focus on social evaluation (Gullone, 2000; Vasey et al., 1994). It is possible that we may have seen different results if the stimuli in the task had better reflected the fears more common in this age group.

There are developmental trends in children's fears and younger children are typically more concerned by animal fears and concerns about the dark than they are about social situations. There is evidence that children aged 4 to 13 years show an attention bias to stimuli *relevant* to the children, both threatening (spiders and guns) and positive (gifts and cakes; Broeren & Lester, 2013). The fact that children gave preferential allocation of attention to both threat and positive relevant stimuli indicates that stimuli were given preference based on relevance, rather than threat. Thus, the choice of stimuli used in the tasks may have masked evidence of biases that were present, but would only have been evident if appropriate stimuli had been used.

Taking this reasoning one step further, it is plausible that, all children are biased to attend to stimuli that are associated with developmentally typical fears when those fears first emerge. Then, over time, as such anxieties resolve in a normative way, the bias may also wane, remaining only in those children who remain fearful. This is quite a speculative hypothesis but it is testable and, to date, there has been no systematic investigation of how children's attention bias for specific categories of stimuli develops and changes across time. Furthermore, such a rationale is in keeping with evidence for content specificity in interpretation bias found in the meta-analysis described in Paper 1, which was driven by social anxiety and its relation to social vs non-social scenarios and whose sample had a mean age of around eleven years of age.

Adapting the tasks to overcome this potential limitation would be possible, the emotional faces in the attention bias task (Paper 3) could be changed to spiders for example, but this would have to be carefully considered. This is because not only do children show anxieties towards different things at different ages, gender differences in normative fears and anxieties have been found (Gullone, 2000). Also, while young children may show anxieties surrounding animals at a young age, an animal that may raise anxiety in one child, may not provoke the same anxiety in another child of the same age (Gullone, 2000). Assessment of content of current anxieties in the sample may be required to ensure the content of the task is relevant to the group being studied.

6.3.2 The issue of thresholds.

The tasks designed to assess cognitive biases in Papers 2 and 3 may not capture subtle differences between groups in their thresholds for perception of threat. The stimuli used in the attention bias task included happy faces, angry faces and neutral faces each of the respective same intensity. In the ambiguous tones task one pitch was used to create the happy tones, one pitch to create the angry tones and one pitch to create the ambiguous tones. However, these stimuli represent points on a continuum: there are facial expressions/tones that lie between overtly happy and neutral/ambiguous and similarly between overtly angry and ambiguous/neutral, which weren't included. It may be that children start to identify one expression or tone as being categorised in a particular direction (angry/happy) at different points on that continuum; this would not be captured in the tasks as they are designed. For example, a high anxious participant might identify an ambiguous tone as angry at 20% angry whereas a low anxious participant might identify an ambiguous tone as angry at 45% angry but they would both respond with 'angry' at 50%, where the task required a response. Similarly, all children might attend to an overtly angry face but more anxious children might also attend toward an angry face at a lower intensity (Mogg, Garner, & Bradley, 2007; Wilson & MacLeod, 2003), whereas low anxious children might not. In both examples, biases are reflected by between-group differences in threshold that cannot be detected in the current tasks.

Ideally, the study would have included stimuli from across the full continuum to investigate whether there were indeed threshold effects between groups and this was in fact considered at the initial design stages for the thesis work. However, it was judged that investigating threshold differences was not practical for the target age group because of the number of trials that would have been necessary. Decisions regarding the number of trials within the tasks had already been adjusted from those commonly used to assess cognitive biases in adults and adolescents to ensure the task was not too long and maintained the attention of the children. The experimental protocol for the tasks described in Papers 2 and 3, as well as the tasks to assess verbal and non-verbal cognitive abilities, required two hours of assessment time. Therefore, further assessments or longer tasks were not feasible. Future work, however, could focus on just one task and include assessment of thresholds for categorising the stimuli.

6.3.3 Limitations concerning the sample.

The same children and parents took part in studies reported in Papers 2, 3 and 4. Therefore, the limitations of the sample can be applied across these papers. One issue is that the sample was self-selecting, families were recruited via advertising for a study on anxiety and confidence in children. Parents who had an interest in anxiety, due to their own anxieties or concerns regarding their child, may have been more attracted to the study than those who had no concerns or specific interests. There was some evidence to suggest this was the case; we had difficulty recruiting children with low anxiety. As a result, the criteria for the low anxious group was lowered from those 1 standard deviation below the normed mean to those who scored anywhere below the mean. Similarly, parents who completed the SWAIY at both time points reported their child's social worries to be higher than those who only completed the SWAIY at the first-time point. Given this, we cannot claim that the sample is fully representative of the general population. In addition, recruitment took place in West Berkshire, an area of the country with a majority population of white families (Office of National Statistics, 2012). Data on ethnicity of our sample indicates a dominance of white British families, confirming what would be expected by the targeted recruitment area. Together these sample limitations limit the generalisability of the results.

Given the difficulties in recruiting children with low levels of anxiety the mean scores of the high and low anxiety groups differed by only 1 standard deviation. This may have resulted in an underestimation of between group differences in Papers 2 and 3. Concerning how this may have influenced the results of the anxiety- interpretation bias relationship in Paper 2: the results of meta-analysis in Paper 1 found no differences in the effect size across control groups, suggesting that comparison group was not influencing whether an effect was found or not. Thus, our difference in anxiety groups may not have been an issue for our conclusions regarding anxiety and interpretation bias. Concerning the anxiety-attention bias relationship investigated in Paper 4, the meta-analysis on attention bias and anxiety by Dudeney, Sharpe, and Hunt (2015) did not investigate a moderation by control group. Thus, results from this meta-analysis cannot assist in discussion of whether the difference in our anxiety groups was an issue for our conclusions. To clarify whether the results from Paper 2 and 3 would be replicated, the tasks described in Papers 2 and 3 should be conducted with more stringently defined anxiety groups and/or clinical control groups (for further discussion of this point see section 6.6.4).

6.3.4 Limitations concerning power.

Despite recruitment for the lab-based tasks running for over two years and using statistical methods to maximise the number of participants included in the analysis (see section 7.5.3.) there were issues of power that may have influenced the results reported in Papers 2, 3 and 4. While moderation analyses were conducted in Paper 2 and 3 these may have been underpowered given the number of parameters included in these models. The confirmatory factor analysis of the SWAIY in Paper 4 confirmed the one-factor model found in the exploratory factor analysis. However, this analysis was underpowered and meant that further exploration of the factor structure such as measurement invariance by gender and age could not be conducted.

There may have been a lack of power to investigation moderation by effortful control and age in the relationships between cognitive biases and anxiety (Paper 2 and 3). In Paper 2, investigating the association between interpretation bias and anxiety, the models including the interactions between anxiety and the developmental proxies did not show an improvement in model fit while investigating the behavioural data. The developmental proxies being effortful control, age, verbal and non-verbal cognitive abilities. The lack of model fit improvement through the addition of these terms meant the interactions between anxiety and these developmental proxies was not further investigated. To include these types of interactions in multi-level models ideally more power is required, thus it may have been a lack of power that meant the inclusion of these interactions did not significantly improve model fit. Had there been more power, for example, the interaction between effortful control and anxiety, which showed the largest odds ratio in the model, may have reached statistical significance. Having said this, estimating the power necessary for multi-level analysis is difficult and the simulation studies and advice in the literature (e.g. Maas & Hox, 2005) indicated 110 children with data from 10 trials was a sufficient sample size to answer our questions at the outset of the study.

In Paper 3, growth curve modelling was used to assess the time course of visual attention to the faces and four time polynomials were included. To assess moderation by effortful control or age, a five-way interaction was required. To define this model the interactions between nine parameters were included resulting in the estimation of over 80 coefficients. There is no agreed upon method of estimating power for this type of analysis, but the power of the analysis is bound by the number of observations and participants. Despite having 104 children included within the analysis and 50 time bins per trial, which is similar to other studies that have assessed moderation with this analysis (Byrow, Chen, & Peters, 2016) and much greater than other studies that have assessed a difference between groups with predictors (e.g. Law, Mahr, Schneeberg, & Edwards, 2016; Schofield, Inhoff, & Coles, 2013; Waxman et al., 2016), the analysis may have been underpowered. With this limitation in mind, to increase confidence in the results and conclusions drawn from the moderations analyses of Papers 2 and 3 replication studies should be conducted with greater sample sizes.

In Papers 2 and 3 the sample consisted of children selected on the basis of membership to a high and low anxiety group created using screening scores of anxiety. In this way a continuous measure of anxiety was dichotomised. However, this may have resulted in a loss of measurement information and therefore power, which may have affected the ability of the analyses to detect differences (Cohen, 1983). Additionally, where the relationship between anxiety and the bias scores (for example) cannot be assumed to be monotonic (ever increasing/decreasing), important measurement information is lost by dichotomising one of the variables (Cohen, Cohen, Aiken & West, 2003). This may well be the case in the relationship between anxiety and cognitive biases where the relationship between the anxiety and biases may not be straight forward. As has been described, development may be influencing the nature of the relationship between anxiety and biases. Also anxiety (i.e. separation anxiety) is known to rise and fall in a normative way over development which may influence the observed relationship between anxiety and a bias over ages/time (see section 1.2). Thus it cannot be ruled out having a continuous measure of anxiety may have resulted in more power to detect differences. Adding anxiety as a continuous measure in the analyses in this thesis was considered. However, due to selection for participation being based on membership to high and low groups, the anxiety variable had a bimodal distribution violating assumptions that would allow its inclusion as a continuous predictor in the models. Having said this, the study was designed as a between groups design in order to compare extremes within the normal population. This was done to avoid having a sample that reflected mean anxiety without adequate representation of the range within the normative population. This can happen when recruiting with a continuous variable in mind. Given the design and selection criteria a bimodal distribution was to be expected and thus dichotomisation was the best course of action. Future studies should consider utilising a continuous measure of anxiety with care taken to represent the complete range of anxiety within the normal population to reduce the chance that such power issues are raised as a concern.

6.4 Strengths

6.4.1 Consideration of development.

Results from this thesis highlight the need for development to be considered in investigations of the relationship between anxiety and cognitive biases. By including developmental factors as moderators, the influence of development in the relationship between anxiety and cognitive biases was seen and subtleties in the results in Papers 2 and 3 were revealed only by including developmental factors as moderators. While this thesis focused on young children, given the evidence for an influence of development on the anxiety-cognitive bias relationship, it may also be worthwhile for research involving older children and adolescents to consider developmental factors as moderators. This approach could provide insight into different developmental factors that may influence the anxiety-cognitive bias relationship at different ages.

6.4.2 Development of age appropriate methods.

Without age appropriate measures to assess anxiety subtypes and cognitive biases in young children, research examining the development of anxiety within this age group is limited. One of the main strengths of this thesis is the development of methods for use with an age group that has been relatively neglected in previous research. The social worries measure and cognitive bias tasks presented in this thesis show initial evidence of being appropriate for children aged 4 to 8. Contrary to the social anxiety subscale of the preschool anxiety scale (PAS; Spence et al., 2001) the SWAIY ensured that the items of the measure were based on observable behaviour in specific situations rather than cognition in broad contexts. Asking about young children's cognitions may make it difficult for parents to respond to the items accurately (Comer & Kendall, 2004). Thus, development was carefully considered in the writing of the items in terms of what situations could be expected to have been experienced and what behaviours would be demonstrated by 4 to 8 year olds. The initial evidence of content validity of the Social Worries Anxiety Index for Young children (SWAIY; Paper 4) indicates that the measure is appropriate for the age range. Clinical professionals and parents deemed all the items to be appropriate for 4 to 8 year olds and the confirmatory factor analysis indicated that all the items hung together to measure one-factor.

The ambiguous sounds task described in Paper 2 was designed to overcome some of the methodological issues that have prevented assessment of interpretation bias in children younger than eight years. In this task children were asked to categorise ambiguous tones as positive (happy) or negative (angry). Key to the success of this task was the children's ability to learn to accurately categorise the trained tones and to show that they could continue to do this throughout the task. If a child was not able to accurately categorise the trained tones we could not assume they were attempting to categorise the ambiguous tones.

The majority of children (88%) who completed the task were able to accurately categorise the trained tones in the learning phase. In addition, whether the children learnt the task or not did not depend on their age, gender or level of anxiety. Children were just as accurate in categorising the happy as the angry tones and, on average, remained over 60% accurate on the trained tones throughout the task (Appendix 10). Given this evidence we can suggest that children aged between 4 and 8 years were able to complete the categorisation part of the task and the difficulty of the task was appropriate to the age range.

In the eye-tracking task (Paper 3) a free-viewing paradigm was used. Children were given an irrelevant task to maintain their attention (i.e. to identify a feature of an alien). Children aged 4 to 8 years participated and there was no correlation between child age and the number of trials included in the analysis. Thus, the eye-tracker could record valid data from children within the age range. Number of valid trials could also be interpreted as a proxy for how well the child's attention was held, indicating that children were able to maintain attention to the task regardless of age.

In Papers 2 and 3 key developmental factors that may influence *task performance* were identified, namely verbal and non-verbal cognitive abilities. These factors may be related more to the task rather than the relationship between the bias and anxiety. Previous tasks have been criticised as being inappropriate for younger children due an over-reliance on verbal and non-verbal cognitive abilities (Brown et al., 2014; Field & Lester, 2010a, 2010b). Unlike previous tasks of cognitive bias, verbal and non-verbal cognitive abilities did not predict task performance in either task, indicating that the tasks developed here did not rely on verbal or non-verbal cognitive abilities.

Despite these strengths, some age differences were observed across the papers. For example, in Paper 4 eight-year-old children had the lowest scores on the SWAIY. This may not be so surprising as the original questionnaire was valid for children aged 8 to 17 years old, and the items were altered for younger children. In Paper 4, it was suggested that until the factor structure was confirmed to be invariant by age, the original social worries questionnaire should still be used with children eight years old. Also, while it was shown in Paper 2 that learning the associations between valence (happy and angry aliens) and the tones (high and low) was not dependent on age, children aged six, seven, and eight years were more accurate than four year olds (Appendix 10). This suggests that younger children were just as able to learn the associations as the older children in the learning phase. Then, in the experimental phase, while younger children were on average maintaining the required 60% learning criteria in categorising the trained tones, older children were more accurate in categorising the trained tones. If children were categorising the trained tones accurately then we can assume they were also categorising the ambiguous tones. Following the above evidence that older children were more accurate on the trained tones in the experimental phase, it may be that the responses to the ambiguous tones by the younger children may be more prone to guessing than the responses of the older children. This may be the case as inspection of the consistency histograms in older children indicated they were more consistent in their responses to the ambiguous tones than younger children. Further research on the psychometrics of the SWAIY and the interpretation bias task will provide further insight into their age appropriateness (see section 6.6.1 Psychometrics of Tasks).

6.4.3 The moderating role of development.

Despite numerous suggestions (e.g. Field & Lester, 2010a; Kindt & Van Den Hout, 2001) that developmental factors influence the anxiety-cognitive bias relationship e.g. the inhibition hypothesis (Kindt & Van Den Hout, 2001), few studies have investigated the influence of development on these relationships. Understanding the role of development and which developmental factors influence the association between anxiety and cognitive biases is important for models of anxiety in children and for treatment (see sections 7.2. and 7.6.). The influence of development on the relationship between cognitive biases and anxiety was investigated in Papers 1, 2 and 3.

The data reported suggest that development should be considered in examining the associations between anxiety and cognitive biases in children. In the meta-analysis (Paper 1), age was included as a potential moderator, as a proxy for development that was easily extractable from studies. In Papers 2 and 3 developmental factors that theory and evidence suggest may influence the cognitive bias-anxiety relationship, namely effortful control and age, were measured alongside anxiety and assessed as moderators. Thus, the research reported in this thesis has shown that considering development within the cognitive bias-anxiety relationship is feasible and useful (expansion of this point can be found in section 1.3.2 Implications for Models of the Development of Anxiety).

6.4.4 Use of appropriate analysis techniques.

Multi-level analysis allows the nested nature of data to be taken into account and has less restrictive assumptions on variance and having a balanced design (Hox, 2010). This was a consideration in Paper 2 were anxiety group differences were of interest, but there were unequal numbers in the groups. Use of multi-level methods has been suggested for experimental studies in psychology where the dependent variable is made up of responses to trials that are not independent, they come from particular individuals (Field & Wright, 2011). Thus, there is dependency in the data. In Paper 2 multi-level analysis was used account for the nested nature of the data both within the behavioural and psychological data analysed and the further nesting from the presence of siblings in the sample.

In conventional methods means are constructed by averaging the dependent variable across participants. The difference in means is then investigated. By averaging across participants, you lose the information in the variability between participants. Multi-level analysis can test whether predictors from level 2 (i.e. anxiety grouping) can explain this variability. In addition, children varied greatly in the number of trials they completed, thus different numbers of values contributed to the means that would be then averaged across participants. This may have caused issues for conventional analyses. However, if only complete data had been used for analysis in Paper 2 (20 trials) this would have led to the inclusion of only 24 children. This sample would not have provided enough power to answer the research questions posed in Paper 2. Rather, multi-level analysis uses a long format where each row represents one trial. This meant that missing data on one row resulted in the loss of one trial, but not the loss of a participant. These analyses therefore deal better with the variation in the number of trials completed than conventional analyses. Imputed data could also resolve the problem of missing data; however, multi-level approaches have the advantage over imputed data in that actual observations can be included rather than simulated, imputed values. In addition, the imputation of data would not resolve the issues related to unequal groups and the nested nature of the data. Thus, given the issues of the data-set from unequal groups, nested data, and missing data use of multi-level analysis was deemed the more appropriate to answer the questions posed in Paper 2.

While there is a growing body of studies assessing interpretation bias and anxiety in children and adolescents, this number is much lower than studies in adults. Use of multi-level analysis in the meta-analysis allowed multiple effect sizes to be taken from one study, resulting in 345 effect sizes being included in the overall meta-analysis, from 77 studies. Multi-level analysis allows inclusion of multiple effect sizes by nesting the effect sizes within studies preventing the inflation of standard errors that would be seen in conventional analyses (Hox, 2010). With inclusion of such a large number of effect sizes the resulting overall conclusion of the meta-analysis can be viewed with confidence despite the smaller available number of studies for children and adolescents than adults.

In Paper 3, concerning the anxiety-attention bias relationship, growth curve analysis was used. Unlike conventional analysis, this analysis allows investigation of the time course of visual attention. This is done as the time course was split into 50ms time bins. Then proportion of looks towards faces were entered for each time bin (level 1), and then averaged across trials and participants. If this was entered into a conventional repeated measures design then few time bins would have been used and any missing data present in a time bin would result in the loss of a participant due to the wide format nature of the data.

However, growth curve analysis makes use of a long format where the loss of data in one row results in the loss of data for that time bin on that participant. Therefore, growth curve analysis maximised the power available for the analysis. As discussed in Paper 3 this allowed for a more fine-grained analysis of the children's visual attention than conventional analysis would provide. Indeed, as seen in Paper 3, nuanced patterns of children's visual attention were revealed by the growth curve analysis not evident in the conventional analyses. Therefore, by using growth curve analysis the power of the sample was maximised and allowed for a more fined grained analysis of the time course.

One of the strengths of this thesis, therefore, is the use of advanced analyses that maximised the potential insights that can be gained from the data available for each study.

6.5 Implications for Treatment

If development is important to the relationship between cognitive biases and anxiety, as all three studies on cognitive bias included in this thesis suggest, treatments that focus on altering such cognitive biases to reduce anxiety should also consider the development of the child. The results of Papers 1 and 2 suggest that focusing on negative interpretations may be more appropriate in older children and adolescents than for younger children. This conclusion is supported by the moderation by age found in the meta-analysis of Paper 1 and results from Paper 2, which indicate that, whilst there may be an anxiety related interpretation bias in 4 to 8 year olds, the effect is small and confounded by development. Future research should focus on examining interpretation bias in clinically anxious young children to ensure these results are clinically relevant.

The evidence for content specificity in the interpretation bias-anxiety relationship in children and adolescents found in Paper 1 may also have implications for treatment. The association between interpretation bias and anxiety was larger when there was a match between the content of interpretation and the anxiety subtype under study. Thus, while targeting interpretations in general may be appropriate for treatment, targeting interpretations related to the child or adolescent's anxiety may be *most* efficacious for treatment. This evidence for content specificity may be particularly relevant for social anxiety as most of the effect sizes included in the moderation analysis that led to this result concerned social anxiety and its relationship to social vs non-social scenarios. Such evidence is in line with CBT treatments derived from Clark and Wells' (1995) model of social anxiety. This model focuses on the thoughts, feelings and beliefs that are provoked when a socially anxious individual enters social situations. Such treatments have been shown to be more effective in reducing social phobia symptoms than exposure plus applied relaxation and a waitlist control in adults (Clark et al., 2006). However, there is currently no comparative adaptation of this treatment for children. To further investigate the relevance of this effect for treatment, future research should assess whether there is content specificity across disorders and whether this is influenced by age.

6.6 Future Work

While some suggestions have been made in previous sections as well as in individual papers regarding areas that would be fruitful for future work, there are some commonalities which will be outlined below.

6.6.1 Psychometrics of tasks.

The cognitive bias tasks described within this thesis were specifically designed for this PhD and their psychometric properties have not yet been assessed. It would be useful to establish their psychometrics properties for several reasons. First, criticisms of current measures of attention bias include the poor psychometrics of the metrics derived from the dot probe task. If we are to confirm that the attention bias task described in Paper 3 is better than the dot probe task for this age group, establishing the reliability of the task is essential. Second, showing evidence of good psychometric reliability would provide further evidence for the appropriateness of both tasks for use with young children. Third, robust psychometrics are required if these tasks are to be used within investigations that aim to link cognitive biases to other lower levels of analysis such as brain functioning or genetics.

To begin to assess the psychometrics of the tasks it would first be necessary to establish that an individual’s performance on the tasks was reliable over time. This could be tested using test-retest reliability over a relatively short period of time. Indeed, other studies have also used test-retest reliability to establish the psychometrics of similar eye-tracking tasks (Pel, Manders, & van der Steen, 2010; Waechter, Nelson, Wright, Hyatt, & Oakman, 2014). Unfortunately, assessing test-retest reliability was not practical within the time constraints of this PhD given the time taken for data collection at one time point and the time burden of the study already placed on participants.

6.6.2 Further investigation of the influence of developmental factors.

The influence of cognitive development on the relationship between anxiety and cognitive biases was investigated in Paper 2 and 3; however, social and emotional factors may also be influencing the relationship (Field & Lester, 2010b). For example, interpretative theory of mind, being the ability to understand that an object or message could have multiple meanings, could be one potential social cognitive factor (Field & Lester, 2010b). Such an ability helps children disambiguate situations and may be sufficiently developed to do so by ages 7 to 8 years (Carpendale & Chandler, 1996; Field & Lester, 2010b). Thus, interpretative theory of mind may be an influential factor on the relationship between interpretation bias and anxiety. As pointed out in Paper 3, attachment, being a social factor, has been previously investigated as having an influence on the relationship between social anxiety and attention bias (Byrow et al., 2016), but this was not included here. Emotional factors such as emotional regulation have also been suggested to play a role in the relationship between cognitive bias and anxiety (Field & Lester, 2010a, 2010b). To fully understand which developmental factors may be influencing the relationships between anxiety and cognitive biases within a moderation model or acquisition model framework, more and varied developmental factors should be considered in future work.

Particularly with regards to Paper 3, investigating development factors that may influence top-down processing may prove relevant. In Paper 3 the age dependent anxiety differences are suggested to be driven by differences in top-down processing, but which processes drove the anxiety-related bias was different between ages. Abilities facilitating top-down processing are developing over childhood, for example, attention control (Eysenck, Derakshan, Santos, & Calvo, 2007). By assessing the time course of visual attention to emotional faces, at different time points, in conjunction with assessing the influencing of attention control from a performance measure would allow investigation of changes in top-down processing and the mechanisms behind this. This investigation would seem prudent, as opposed to investigation of metrics such as engagement, or disengagement. In fact, as McNally (2018) points out the scientists who suggested such a decomposition of attention are now moving towards reformulation of these processes in terms of top-down, bottom-up processing.

6.6.3 Lack of investigation of content specificity in 4 to 8 year olds.

As outlined in the introduction (section 1.7.3) social anxiety has gained particular attention within research in terms of its relations to cognitive biases in adults and adolescents. One reason for this is the content-specificity theory (Beck, 1976), evidence surrounding attention bias and content specificity in adults and youth (Pergamin-Hight, Naim, Bakermans-Kranenburg, van IJzendoorn, & Bar-Haim, 2015) and suggested to be present in relation to interpretation bias (Blanchette & Richards, 2009). Evidence gained in this thesis showed an extension of this evidence for content specificity in interpretation bias to children and adolescents (Paper 1; Stuijfzand, Creswell, Field, Pearcey, & Dodd, 2017). In the light of this, an investigation of the relationships between cognitive biases and social anxiety seems appropriate. However, to investigate social anxiety and its relations, a valid and reliable measure of social anxiety and appropriate tasks assessing interpretation bias, ideally in a social and non-social context, in young children are required. Prior to this thesis these assessments were not available. This thesis aimed to develop these measures and use the tasks to assess whether an anxiety-related attention and interpretation bias are present in children ages 4 to 8.

The association between biases on the interpretation bias and attention bias tasks with the SWAIY was not considered within this thesis for several reasons. First, the aim of the tasks was not to investigate content specificity of cognitive biases in relation to social anxiety and this is reflected in design choices made at the outset of the study. Second, the study to validate the SWAIY ran concurrently with recruitment for and testing for the cognitive bias tasks. As a result, the SWAIY was completed at screening rather than at the same time as the cognitive bias assessment and it was not validated for use at the time of testing. Third, prior to using the new bias tasks to investigate questions of content specificity we felt it should first be established that the tasks were feasible and appropriate for use with young children. Finally, participants who completed the cognitive bias tasks were split into high and low anxious groups based on a measure of total anxiety symptoms, not social anxiety. This resulted in an atypical distribution of social worries scores towards the high and low ends, but without clear high and low groups. Despite the fact that the content specificity of cognitive biases in relation social anxiety was not examined in this thesis, the work included provides the means by which this investigation could be carried out in the future.

It has been acknowledged earlier that the tasks developed in this thesis may make use of inherently social stimuli. To assess content specificity in young children the stimuli used in the tasks described in Paper 2 and 3 could be adapted to be non-social. For example, the ambiguous tones task (described in Paper 2) could be altered to ask children to categorise tones based on safety or danger. This would maintain the categorisation by valence, but remove the inherent social aspect introduce by asking children to categorise stimuli as happy or angry and showing them an alien with a happy or angry expression during the learning phase. The back story could be altered to tell children that when passing through space the captain want to know what type of zone we are coming up to, a danger zone or a safe zone of space. Children could then be trained to associate the high tone with a danger zone and the low tone a safe zone. During the experimental phase children could be asked to categorise the ambiguous tones as indicating a danger or safe zone. To use the non-social adaptation of the task in conjunction with the original task, differed tones would need to be created, perhaps using a different set of instruments.

The stimuli used in the attention bias task (described in Paper 3) could be adapted to be non-social by replacing the emotional face expression with positive and negative images. The negative images could reflect threat objects such as spiders, needles and guns, while positive images could be, for example cakes and wrapped gifts (Broeren & Lester, 2013). Non-social Images rated by valence by children aged 7 to 9 are available from the international affective picture systems, which could be used in the adaption (Lang, Bradley, & Cuthbert, 1997). Thus, with some adaption it would be possible to use both a social and non-social version of the children friendly age appropriate cognitive biases tasks developed for this thesis to assist in the investigation of content specificity in young children.

6.6.4 Use of a clinical sample.

Samples used in Papers 2, 3 and 4 were restricted to a community sample to take a first look at the appropriateness of the novel methods developed for this thesis. The next step is to see whether the results hold when a clinical group are compared to a healthy control group. This would be useful for several reasons. The original social worries questionnaire, which was adapted to produce the SWAIY (Paper 4), has been shown to be useful as a pre-screening tool for social anxiety (Hitchcock, Chavira, & Stein, 2009). By asking parents of a clinical sample to complete the SWAIY alongside clinical diagnoses, the internal reliability and factor structure could be checked to see if the results of Paper 4 would be replicated in a clinical sample. In addition, divergent validity could be assessed by seeing if the SWAIY could discriminate between those with social anxiety from those with other anxiety disorders. Should the results of Paper 4 be reflected in a clinical sample and initial evidence be found of discriminative validity then this may also suggest its usefulness as a pre-screening tool. This would increase the utility of this tool in assessing social anxiety as an anxiety subtype of interest in younger children.

The results regarding anxiety differences and moderation by developmental factors in Papers 2 and 3 may provide hypotheses of what might be expected if these tasks were conducted within a clinical sample. Results of the two meta-analyses concerning the attention bias-anxiety (Dudeney et al., 2015), and interpretation bias-anxiety (Paper 1; Stuijfzand, Creswell, Field, Pearcey, & Dodd, 2017) relationships suggest that there is no statistical difference in the magnitude of effect between clinical and community samples. This may be because of heterogeneity in the studies using clinical samples (e.g. variation in diagnostic profiles of clinical participants, different types of control groups, differences in comorbidity inclusion/exclusion and variation in clinical severity) that may cloud the picture of the relationship between the biases and anxiety. Thus, it may be that relationships seen in our community sample will be present when a clinical sample is compared to a healthy control group. However, as there were very few studies conducted with young children this cannot be assumed. There is at least one study showing that the relationship between interpretation bias and anxiety in young children differs when clinical anxiety is assessed as opposed to trait anxiety (Dodd, Hudson, Morris, & Wise, 2012). Thus, differences between the results reported in Papers 2 and 3 and results for a study using a clinical-control design are possible. As pointed out in section 7.4.3 the difference in terms of anxiety between our high and low anxiety groups used in Paper 2 and 3 may have resulted in an underestimation of anxiety differences. This point provides an additional reason to conduct these tasks with a clinical sample and a healthy control where the difference in anxiety between groups cannot be questioned.

6.6.5 Longitudinal work.

All the experimental work carried out in this thesis is cross-sectional in nature, the results of the meta-analysis in Paper 1 also relate to cross-sectional work. Therefore, results do not reflect causal relationships nor provide a definite picture of the influence or role of development in the associations between cognitive biases and anxiety in children. To truly understand the role of cognitive biases in the development of anxiety, longitudinal work is required.

The investigation of moderation of the cognitive bias-anxiety relationship by effortful control and age in Papers 2 and 3 were a strength of these papers and provide initial hypotheses for what longitudinal relationships may be expected. However, this is just the starting point, to truly gain a picture of the influence of such developmental factors on the cognitive bias-anxiety relationship, these relationships should be examined longitudinally. A longitudinal design measuring anxiety, cognitive biases, and developmental factors concurrently over at least three time points across several years, e.g. three, would allow moderation of the cognitive bias-anxiety relationship by developmental factors to be assessed. Such a design would also allow questions raised by the results of Papers 2 and 3 in this thesis to be investigated. These questions include: 1. if and when the pattern of anxiety related attention bias seen in younger children begin to resemble the pattern seen in older children and adults; 2. how does the relationship between interpretation bias and anxiety change over time and when does it resemble the interpretation bias seen in adults.

Knowledge of anxiety subtypes in young children is lacking, thus we do not have insight into how subtypes develop over time or how they contribute to the development of anxiety more broadly. As pointed out in the introduction and Paper 4, social anxiety is a subtype that has been shown to be present in young children with important implications in terms of outcomes for future emotional health. One reason for this paucity of insight could be a lack of valid measures of social anxiety in young children. To this end, Paper 4 set out to validate such a measure (SWAIY) for use with 4 to 8 year olds providing a brief parent report of social worries that researchers could use to fill the described gap in the literature. To understand the pattern of stability and development of social worries in young children and its relationship to other anxieties over time, longitudinal work using the SWAIY is now required.

The relationship between interpretation and attention biases themselves is unclear. Some theories suggests that both biases share the same processing mechanism (Williams et al., 1997) or that one may directly influence the other (Hirsch, Clark, & Mathews, 2006). Information processing models of anxiety (as laid out in section 1.5) suggest that in anxious individuals the threat detection system is hypersensitive resulting in biases at every proceeding stage of processing: firstly in the in allocation of attention and then, in further processing which includes evaluation of stimuli for meaning or interpretation. It would therefore seem that such models suggest that attention biases may influence the presence of other biases or are at least related temporally, with attention bias coming first. Indeed, there is evidence from experimental work in adults that attention bias to threat was having a cascading influence on interpretation bias (White, Suway, Pine, Bar-Haim, & Fox, 2011). There is also preliminary evidence for a positive relationship between attention bias and interpretation bias in 9 to 17 year olds (Rozenman, 2014). The relationship between the biases was not investigated in this thesis, as this did not fall within the main focus. However, the results Papers 1, 2 and 3 may be suggestive of how the biases may be temporally related in developmental time.

In Paper 3 an attention bias to all faces was seen in all children and the moderation by age analysis suggested that anxiety differences in attention bias were already present in children ages 4 to 8, only the nature of the bias was different between younger and older children in the sample. In Paper 2 the evidence for a common interpretation bias in all children is weaker than for attention bias in Paper 3. All children did show a bias toward interpreting ambiguity as negative, however the average proportion of ambiguous tones reported as negative was only 58%. Though this was found to be significantly larger than 50%, one could question the substantiality of this effect and whether this bias would be problematic for the individual. Also while anxiety differences in interpretation bias towards threat were found, they were confounded by developmental factors, again suggesting evidence for anxiety related differences were not as strong as in attention bias. The interpretation bias (58%) seen in all children and the confounded anxiety difference in interpretation bias may be pointing to interpretation bias, and perhaps anxiety differences in them, as only starting to emerge at 4 to 8 years. Paper 1, would then suggest that by age 11 there is a robust association between interpretation bias and anxiety. Thus, if the results from Papers 1, 2 and 3 are considered they may suggest that anxiety differences in attention bias are present before an interpretation bias (4 to 8), though the nature of the bias may be different across ages. Interpretation bias may be emerging at 4 to 8 years, though anxiety related differences are not convincing until age 11. How the two may be related or interact cannot be commented on. Use of a longitudinal design would not only allow concurrent relationships between biases to be investigated as previous studies have in youths (Rozenman, 2014) and adults (White et al., 2011), but also how the biases relate over time and allow mediation models to be tested i.e. does attention bias mediate the relationship between interpretation bias and anxiety. The suggestions regarding the temporal nature of cognitive biases outlined above could be used when generating hypotheses for a longitudinal study.

6.7 Conclusions

The primary aim of this thesis was to examine the association between anxiety and cognitive biases in children, with a particular focus on children aged between 4 and 8 years. A secondary aim was to develop a brief measure of early signs of social anxiety in young children to facilitate future research examining the early development of social anxiety as well as the content specificity of cognitive biases. The thesis has fulfilled the primary aim in several ways. Firstly, the meta-analysis established that there is a relationship between interpretation bias and anxiety in children and adolescents and highlighted the need for more studies investigating this relationship in young children. Secondly, this thesis has provided new tasks to assess interpretation and attentional biases in children ages 4 to 8. The new tasks developed to assess attention and interpretation bias have been shown to be feasible and appropriate for use with young children and are not unduly influenced by the child's overall cognitive ability. These tasks were used to investigate the associations between cognitive biases and anxiety and young children and found evidence that these relationships are present and are influenced by developmental factors such as age and effortful control. This thesis has fulfilled the secondary aim by providing a method of assessing social worries in children aged 4 to 8 years. The SWAIY, as a parent report measure for social worries in young children, showed initial evidence of good psychometric properties and being feasible as a way to measure social anxiety in young children.

This work advances our understanding of cognitive biases and anxiety in young children and provides some guidance for future research priorities. Taken together, the papers in this thesis indicate that it is possible to assess attention bias and interpretation bias in young children and anxiety-related differences emerge. The differences found were more nuanced and subtle than those found in older children and adults, perhaps indicating that the association between the biases and anxiety are still emerging in young children. Across all three studies investigating cognitive biases the nuanced anxiety differences in biases in this age group were revealed through moderation by developmental factors. This highlights the importance of considering development when investigating the association between anxiety and cognitive biases. These results have implications for models of the development of the anxiety-cognition relationship and the treatment of anxiety. To further the work in this thesis priorities for future work would include longitudinal studies and work with clinically anxious children.

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7. Appendices

7.1. Appendix 1: Investigation of Tone Rating Task

Aim: To assess whether the tones used in the interpretation bias task show a natural valence to children ages 6-8 yrs old outside of the task and are their ratings related to anxiety at baseline?

Questions:

Do the 3 sets of tones used in the interpretation bias task differ in their natural valence to children ages 6-8 yrs old outside of the task?

Are childrens' ratings of the tones related to trait anxiety?

Method

Participants

28 Parents complete questionnaires about themselves and their child. 40 children (28 females) 6 to 8 years old (M = 6.78, SD = .77) took part in the sound rating task at Bracknell Look Out Discovery Centre. No children were reported by parents as having a diagnosis of ADHD, but 3 children had been excluded from the study due to having a diagnosis of ASD. Given children with ASD were excluded from the interpretation bias task they were also excluded from this assessment as the purpose was to see whether these tones would have any natural valence to children ages 6-8 yr olds outside of the interpretation bias task and whether these tones would be related to children's trait anxiety.

Table 1.

Diagnosis of Participants

	ASD	ADHD	None	missing
Completed Sound task	3	-	32	8
Sound task + anxiety q	3	-	32	1

Table 2.

Demographics of 40 who completed without ASD

	n	mean	sd	range
Child gender	40			
female	28			
male	12			
Child age	40	6.78	.768	6-8
6yr olds	17			
7yr olds	15			
8 yr olds	8			
Parent age	29	38.86	4.962	25-50
Parent gender	31			
female	21			
male	10			
Primary caregiver	31			
yes	26			
Mother	21			
Father	5			
Parent ethnicity	31			
British	22			
White British	2			
Black British	1			
American British	1			
Polish	1			
European	1			
African-British	1			
Asian/Indian	2			

Measures

Spence Child Anxiety Scale (SCAS)

This is a parent report measure assessing child trait anxiety. It include items that ask the parent whether the child has fears or worries regarding events that actually could happen ("is afraid of meeting or talking to people") or the idea that an event could happen ("Worries that something bad will happen to his/her parents"). The measure also includes items regarding whether their child complains of physical discomforts that have no apparent cause ("My child complains of his/her heart suddenly starting to beat too quickly for no reason"). The measure also contains subscales that assess specific anxiety disorders for example, social anxiety and generalised anxiety disorder. The SCAS is a 38 item measure answered on a 4 point likert scale of 0 (never) – 3 (always) validated for use with 6-18 year olds. The SCAS showed good internal consistency of the subscales, discriminative validity between clinically anxious and controls, and between anxiety disorders (except GAD), and convergent validity with CBCL (Achenbach, 1991), another parent report of internalising behaviour. Parent child agreement was between self and parent report was adequate (Nauta, Scholing, Rapee, Abbott, Spence & Waters, 2004). The internal consistency of the total scale in this investigation was excellent ($\alpha = .91$) and acceptable for the social anxiety subscale ($\alpha = .61$).

Tone Rating Task

This task asks children to assess the valence of 15 tones used in the interpretation bias task. All 15 sounds were played in a random order for each participant and each child heard the sounds through a set of headphones adjusted during the practice trials to a volume that suited them. The task was written using DMDX and run on laptops. The child is first introduced to the SAM rating scale on a piece of paper, the scale consists of a line of faces whose expressions ranging from very sad/unhappy to very happy. Below each face is a corresponding number 1 to 5 where 1 is below very unhappy/sad. The paper remained infront of the child throughout the task. The child is first asked to define the extremes of the scale i.e. what does this face look like? *Pointing to the very happy face* and what about this one *Pointing to the very sad/very angry face.* Once the child could define the extremes the remaining faces and their position on the scale were pointed out i.e. 'this one is very happy, this one is a little bit happy, this one isn't happy or sad, this one is a little bit sad and this one is very sad'. The task consisted of 1 block with 2 practice trials and 15 experimental trials. The practice and experimental trials followed exactly the same structure. In each trial the child would first see a black screen with a galaxy print for 500ms. After this, with the graphic still on screen, a tone would be played for 250ms. Following each sound is another 500ms pause where the print remains on screen. Finally the SAM valence rating scale is displayed in the center of the screen and remains on screen until a response is made 1,2,3,4 or 5 and then the next trial commenced. If there was no response after 3 seconds the next trial started. The child was encouraged to press the response buttons themselves, but if they struggled with this the experimenter assisted with this by getting the child to verbally respond or point to a paper with valence scale on so that the experimenter could press the appropriate button. From the ratings four scores were extracted from this task. A mean total ratings calculated via the sum of all ratings divided by the number of trials they responded to. Then an individual mean rating for each set of 3 tones, high, low and ambiguous, respectively was also created from sum ratings for each set of tones divided by the number of responses made for each set. Reaction times were the time taken from stimuli onset to response. A mean was calculated for each participant over the all reaction times made, to the five low tones, high tones, ambiguous tones respectively and to the five instruments (3 tones each) respectively. It should be noted that in some instances experimenters assisted in responding for the child so reaction times, may not be entirely accurate.

Stimuli

Sounds were constructed on garageband and consisted of tones from 5 instruments: guitar, strings, sax, piano and wurlitzer. Three sets of five tones were created. In the first set a high tone was created using all 5 instruments. The second set consisted of 5 low tones 1 form each instrument. The final set was labeled ambiguous and was taken from the tonal point midway between the high and low set. 1000ms of each sound was recorded and saved as a .wav file to be played in the task. Two other electronic sounds were also recorded for the practice trials resembling beeps. These practice sounds were not related to the sounds used in the experimental trials.

Procedure

Parents of children 6 to 8 years old visiting the Look Out Discovery Centre were approached for themselves and their child to take part in the task. Parents were given an information sheet about the task, informed about confidentiality and their right to withdraw before being asked to sign a consent form. Parents were also given information about who to contact should they have any concerns about their child's anxiety. The parents were then asked to complete the questionnaire containing demographic information and the SCAS while the child completed the task.

Once informed consent had been given by the parent the task was described to the child and verbal assent from the child attained. The child was sat in front of a laptop in a quiet area of the center with the parent close by. First the SAM rating scale was described to the child. The child was told that they would hear a sound that an alien makes and we were wondering whether they think the alien who made the noise was happy or angry/sad. What we wanted them to do was to listen to each sound and then as soon as they had heard the sound press 1,2,3,4 or 5 depending on how happy or sad/angry they thought the alien was. Then the child was given headphones and taken through the practice trials, this allowed the experimenter to adjust the volume and ensure the child understood the task. The child then completed the 15 experimental trials. Once the child had finished they were given a sticker and a junior scientist certificate to thank them for their time.

Results

Responses and Reaction Times to Tones

Normality of each of the variables of the rating response variables were normally distributed so parametric t-tests were used to assess whether there were differences between the ratings. However, normality was violated in the variables related to reaction times therefore any tests carried out using these variables were non parametric. Normality was assessed via visual inspection of histograms and assessment of the skewness and kurtosis values against distance from zero and being between + and -3 respectively.

To assess whether the three sets of tones differ in their natural perceived valence outside the interpretation bias task a repeated measures ANOVA – within factor of tone (high, low, ambiguous) was used. DV was valence rating.

Table 3.

Overall means and sd's of Reaction Time and Valence Ratings (N=40):

	Valence rating (1-5)		Reaction time (ms)	
	Mean	SD	Mean	SD
All sounds	3.03	.40	2788.11	1664.33
High tones	3.81	.62	2852.81	1595.29
Low tones	2.41	.95	2632.87	1578.52
Ambiguous tone	2.89	.65	2827.90	2014.34
Instruments				
Guitar	2.97	.72	2567.64	1570.11
Piano	2.99	.73	2910.37	1881.87
String	3.2	.82	2964.59	1969.22
Wurlitzer	2.96	.91	2869.27	2044.74
Sax	3.07	.83	2708.18	2356.80

Main effect of tone

Sphericity was violated therefore Greenhouse Geiser values are reported $F(1.68) = 33.67$, $p < .001$, partial eta squared = .46

Individual paired sample t-tests were then performed to find out where the differences lay:

High vs low: $t(39) = 6.76$, $p < .001$, $d = 1.75$

High vs Ambiguous: $t(39) = 6.32$, $p < .001$, $d = 1.45$

Low vs Ambiguous: $t(39) = -2.96$, $p = .005$, $d = .59$

Tests suggested that there are differences between each other sets of tones with a large effect. When looking at the means these indicate that the high tones were rated slightly more positively than the low and the ambiguous tones and the low tones were slightly more negative than the ambiguous and the high. Though the difference looks slight they were significant.

The mean for the ambiguous tones looks very close to 3 which is indicates a neutral valence. To check if the mean valence rating of the ambiguous tones was significantly different from 3, a neutral score, a one sample t-test was conducted. This test found that there was no difference between the mean valence rating for ambiguous tones and a neutral score $t(39) = -1.08$, $p = .288$. This confirms that the ambiguous tones were rated as neither positive or negative in their valence.

Wilcoxon signed ranks test was used as a non-parametric equivalent of the paired sample t-test to test whether reaction times differed between the three sets. None of these tests proved to be significant. Therefore there was no difference in reaction time in responding to a low, high or ambiguous tone.

Anxiety related Differences

To see whether the ratings of children were related to anxiety (q2) three variables were created reflecting the proportion of positive, negative and neutral responses made. Positive valenced scores would be 4 or 5, negative valenced score would be 1 or 2 and neutral scores would be 3.

Scores were calculated via number of positive/negative/neutral responses made respectively divided by the total number of responses made multiplied by 100.

Table 4.

Means and Standard Deviations of Proportion of Valence Responses

	Mean	SD	range
Proportion of positive	41.63	12.45	20-80
Proportion of negative	38.79	12.76	0-60
Proportion of neutral	19.58	8.36	6.67-40

Anxiety: 28 children had complete anxiety measures and had completed the sound rating task (*Mage* = 6.89, *SD* = .79).

Both the total anxiety and social anxiety subscale were skewed towards the lower end of the scale. There were only a couple who were at the 'high' end of the scale though with the highest possible score being 114, 55 is not considered extreme. However, as normality was violated the relationship of these variables with the rating score variables were tested using non-parametric tests.

The boys mean was slightly lower than the norm for the age group (16) while the girls were slightly higher (15.9).

Table 5.

Descriptive Statistics of Responses to the Anxiety Measure

	N	Mean	sd	range
Child total anxiety	28	17.86	11	7-55
boys	8	15.25	8.28	7-29
girls	20	18.9	11.25	7-55
6yr olds	10	13.8	5.18	8-24
7yr olds	11	19.10	10.05	8-44
8yr olds	7	21.71	16.99	7-55
Child social anxiety	28	3.5	2.13	0-8

Table 6.

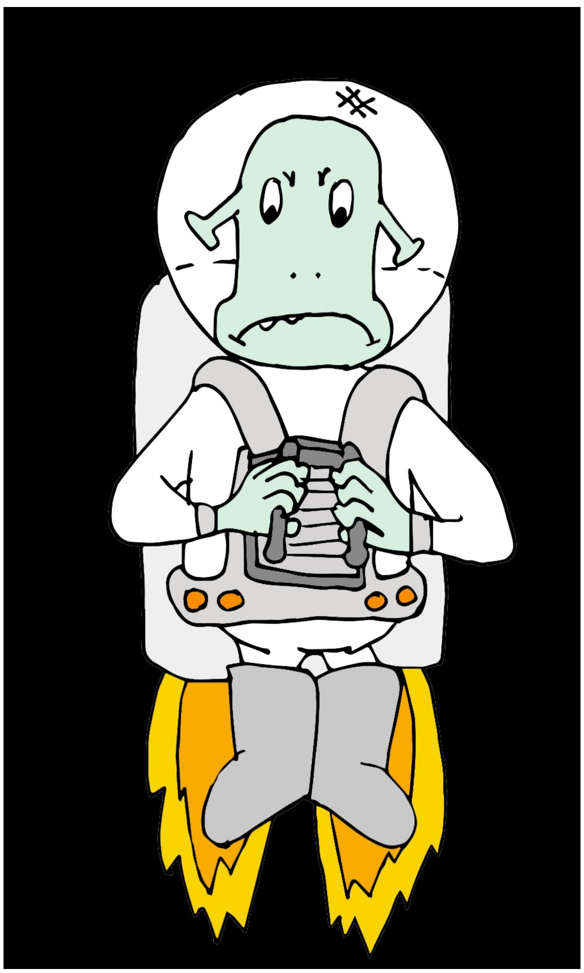
Correlations between Proportional Valence Responses and Anxiety Scores

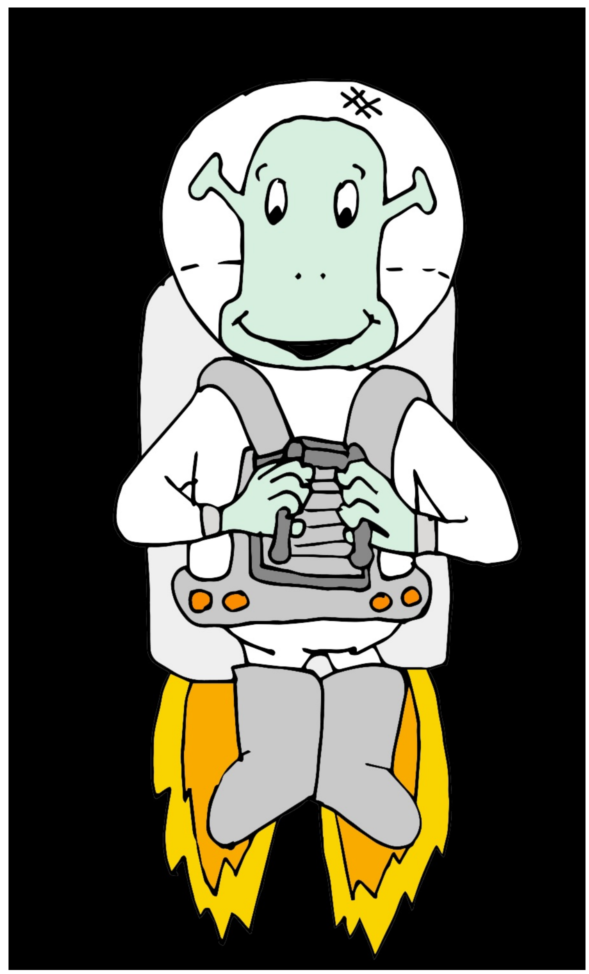
	Proportion of pos	Proportion of neg	Proportion of neu
Total anxiety scale	-.09	.17	-.08
Social Anxiety	-.06	.08	-.06

Note. *indicates a significant correlation. Pos = Positive. Neg = negative. Neu = Neutral.

Results indicate that the high tones have a naturally slightly more positive valence than the low and ambiguous tones, the low have a naturally slightly more negative tone than the ambiguous and high tones and that the ambiguous tones are rated as having a neutral valence when rated by 6-8 yrs old. These findings help us explain why we could not train children to associate an angry alien to a high tone or a happy alien to a low tone even when the child was able to verbalise what the rule was. It informs our study in that we now know outside of the context of the task the high and low tones do have a slightly natural valence to children ages 6-8 yrs old, but the ambiguous tones do not. Furthermore results indicate that anxiety is not related to the proportion of positive, negative or neutral ratings given across sounds in the task. This indicates that anxiety in children is not related to a global bias in assessing the valence of a sound. Finally which instrument was playing the tone did not influence childrens’ ratings and children did not differ in their reaction time between tones, but did differ in terms of their valence response.

7.2. Appendix 2: Examples of Alien stimuli used in the Ambiguous Tones Task





7.3. Appendix 3: Examples of Information Sheets and Informed Consent Sheets provided to the Parents

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Why is that some children are shy, nervous and worry a lot, while others are confident outgoing and nothing seems to faze them?

On average one child in every UK classroom is experiencing anxiety that significantly affects their day-to-day life.

At the moment we don't know very much about anxiety in young children, but we, at the University of Reading, are hoping to learn about the how children who are shy or worriers think about the world differently from children who are confident and easy-going.

With this information we hope to help prevent children from having problems with anxiety as they grow up.

We are inviting families whose children show a range of anxiety levels and are either 4/5 or 7/8 years old.

What will we be asking you to do?

1. Answer a questionnaire about your child's everyday behaviours and their reactions to different situations.
2. Answer a questionnaire about yourself and the extent to which statements best describe you.

The whole visit will take max. 2 hrs

What will we be asking your child to do?

1. Play a set of games where your child will identify and name pictures, use blocks to replicate simple designs, find missing pieces to complete a pattern and try to remember objects from a picture.

2. Play a game with an alien on a computer while we track your child's eye-movements using a camera on the computer. You child will be asked to first wither look towards a target or look away from a target. Next, your child will see two pictures or two faces with different facial expressions. Then a cartoon alien will appear on screen and your child will be asked identify whether the alien has its hands up or down, has one eye or lots of eyes by pressing a button.

3. Help the captain of a space ship with a special task to work out whether aliens approaching the ship are in a happy or angry mood by the sounds that they make. We will play different sounds to your child and ask them to decide whether the sounds belong to angry or happy aliens. We will also ask them to rate faces as positive or negative. While they do this we will ask them to wear two sensors above their eye-brows. These sensors will measure the activity of their facial muscles.

4. Listen to the researcher read different stories or scenarios accompanied by a picture, answer a question about how they feel about the story if they were in that situation and choose how they think the story would end from a choice of 2 pictures.

For taking part you child will go home with souvenirs of their completion of the Reading Space Quest including a certificate and a small gift. We will also help towards your travel cost

University of Reading

Things you need to know!

- Taking part is voluntary! You, nor you child have to take part if you don't want to.
- You are free to withdraw yourself and your child at any point. We will stop and you are free to go. You are also free to decide to only take part in some of the tasks, that is up to you. Withdrawing won't affect the compensation offered to you.
- All the investigators working with children have been subject to disclosure and barring checks and been approved by the School to work with children.

Your information will be kept confidential!

Not only will your information be confidential, but your answers will be anonymised.

We store all consent forms locked within the University and they are destroyed after 5 years.

All paper copies of the questionnaires are destroyed after the data is entered into an electronic spreadsheet. Electronic data will be stored on the secure University server and destroyed when no longer needed.

Who will see the Results?

The results form part of Suzannah Ravenscroft's PhD. This may include publications in scientific journals and presentations to other interested academics.

None of the data presented will be identifiable to you or your child!

If you would like a report of what we find let us know!

The university of Reading Ethics Committee has given this study a favourable opinion for conduct.

Our questionnaires will ask about worries or fears you might have.

If this raises any concerns you can contact (details on the back) any member of the research team who can provide you will appropriate contacts for support.

Parent Consent Form

University of Reading

Consent Form

1. I ………………………………………..……………………….. have read and understood

the accompanying Information Sheet relating to the project on:

Thinking styles and Childhood Anxiety

2. I have had explained to me the purposes of the project and what will be required of me, and any questions I have had have been answered to my satisfaction. I agree to the arrangements described in the Information Sheet in so far as they relate to my participation

3. I understand that participation is entirely voluntary and that I have the right to withdraw from the project any time, and that this will be without detriment.

4. This application has been reviewed by the University Research Ethics Committee and has been given a favourable ethical opinion for conduct.

5. I have received a copy of this Consent Form and of the accompanying Information Sheet.

Signing this form allows use your anonymised answers in our study.

Name: ………………………………………………………………………………

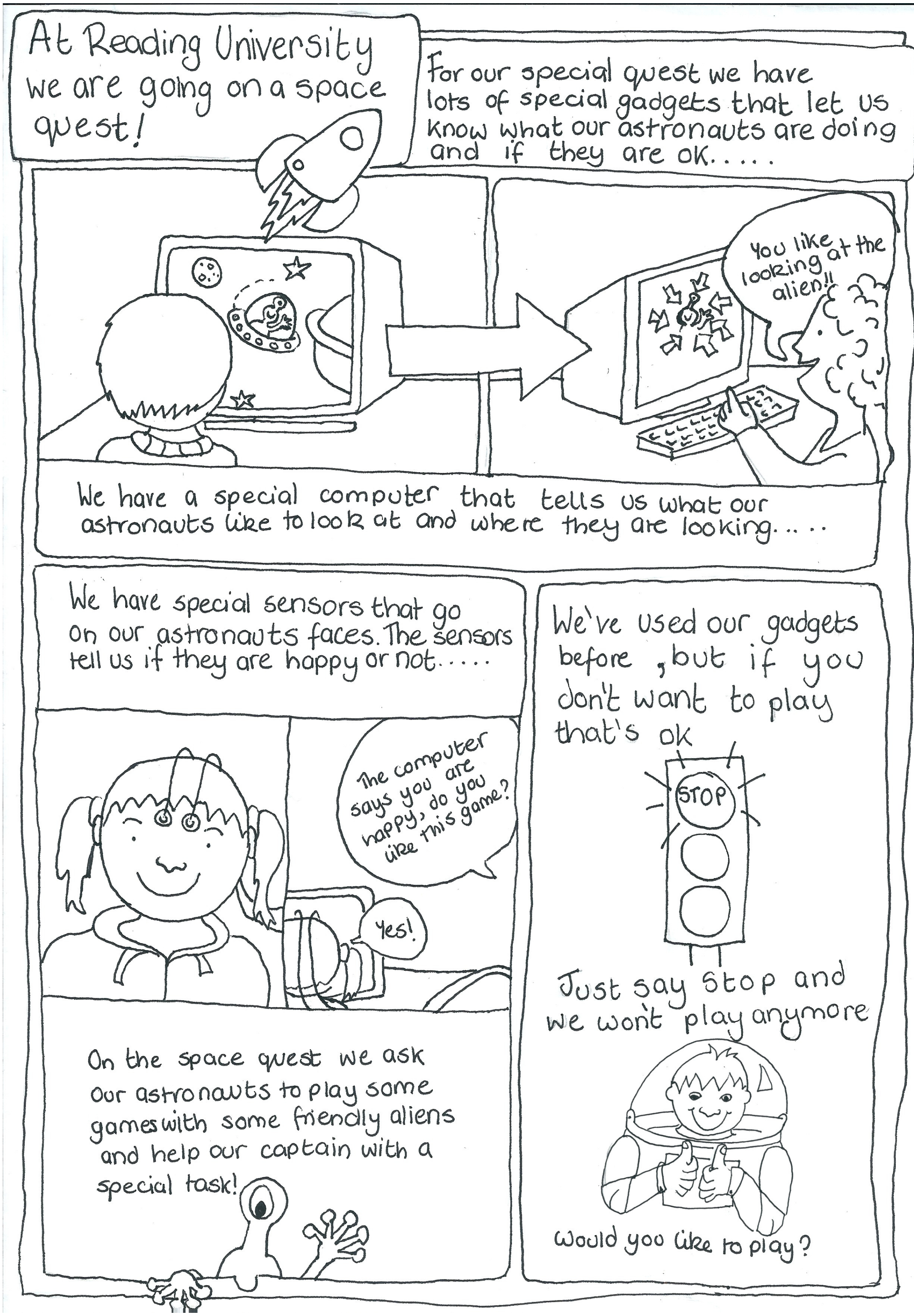
Name of child: ……………………………………………

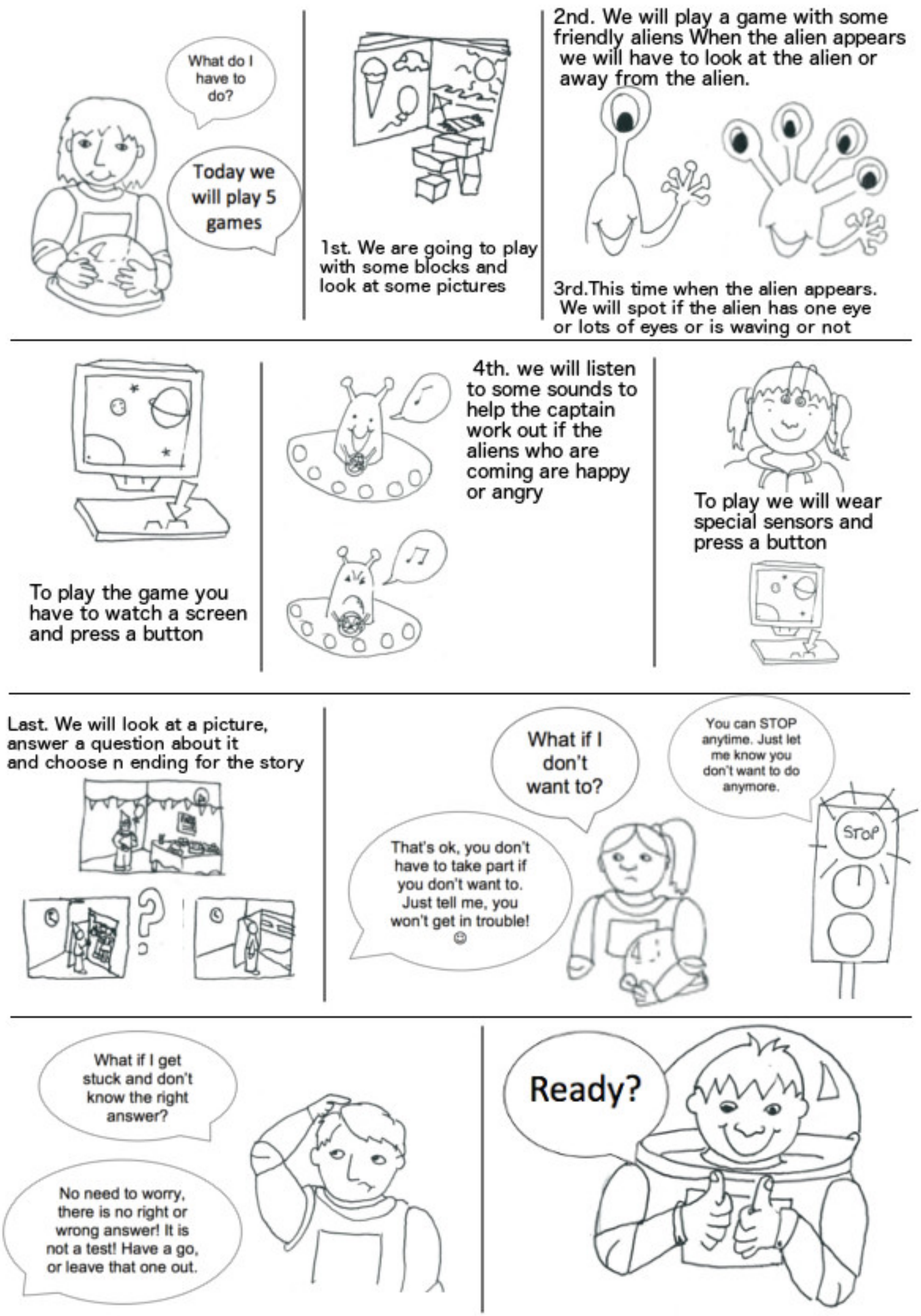
Signed: ………………………………………...………………………

Date: ………………………………………………...……………………

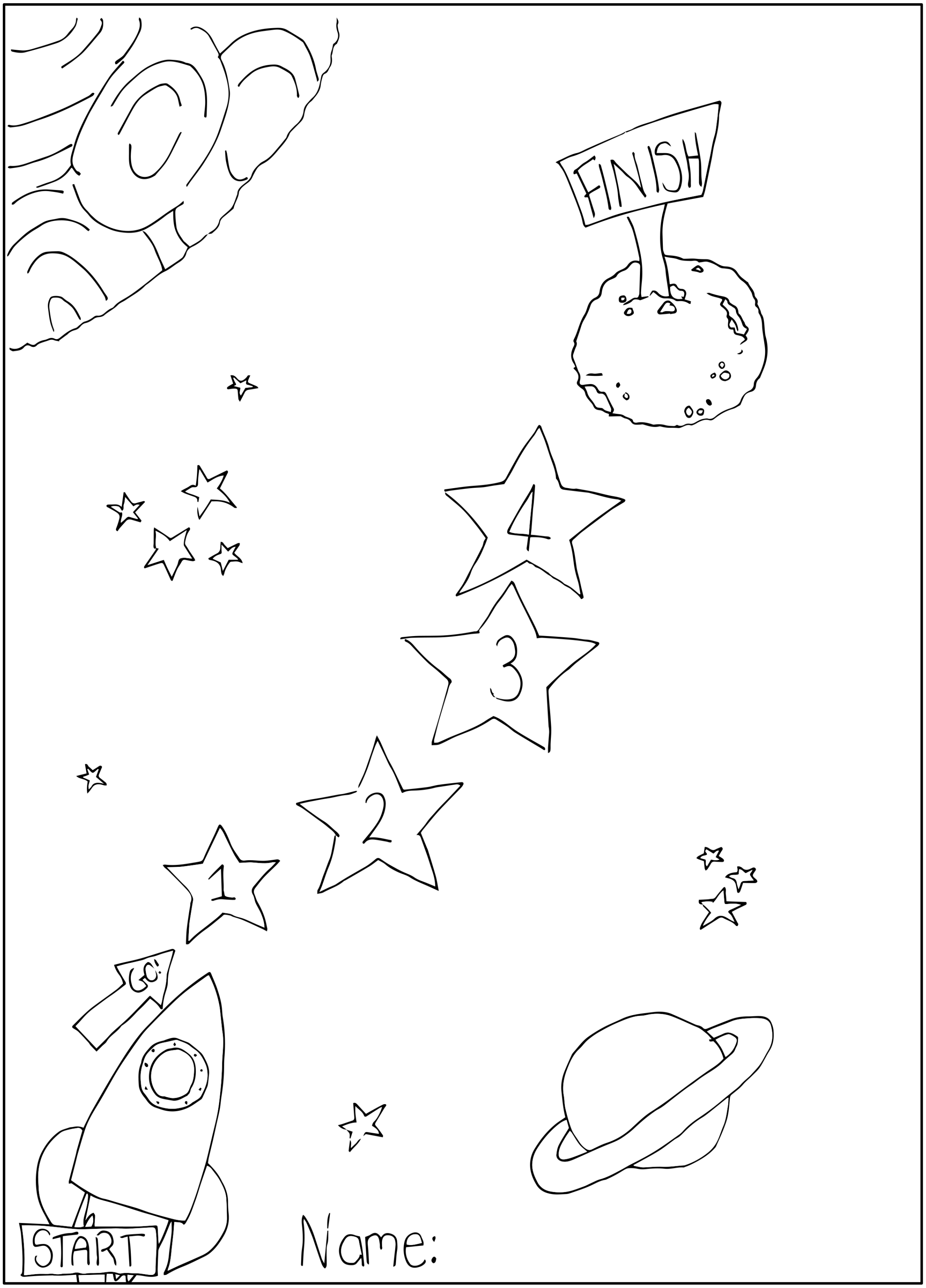
7.4. Appendix 4: Information and Assent Sheets for Children

(note the Assent Sheet for 4-6 year olds does not include the Ambiguous Scenarios Task)




What do I have to do?
Today we will play 5 games
1st. We are going to play with some blocks and look at some pictures
2nd. We will play a game with some friendly aliens When the alien appears we will have to look at the alien or away from the alien.
3rd.This time when the alien appears. We will spot if the alien has one eye or lots of eyes or is waving or not
To play the game you have to watch a screen and press a button
4th. we will listen to some sounds to help the captain work out if the aliens who are coming are happy or angry
To play we will wear special sensors and press a button
Last. We will look at a picture, answer a question about it and choose n ending for the story
What if I don't want to?
You can STOP anytime. Just let me know you don't want to do anymore.
That's ok, you don't have to take part if you don't want to. Just tell me, you won't get in trouble! ☺
STOP
What if I get stuck and don't know the right answer?
No need to worry, there is no right or wrong answer! It is not a test! Have a go, or leave that one out.
Ready?

7.5. Appendix 5: Example of Reward Chart



7.6. Appendix 6: Investigation of Technical Issues regarding the Demonstration of the Tones

Demo: Interpretation bias task

The demonstration within the interpretation bias task was set up to introduce the children to the sounds they would be hearing in the task and the alien/categories the sounds would be associated to. The demonstration first visually presented the children will an alien with a happy expression, then all 5 sounds associated to that alien were played. This was then repeated. Then an alien who was visually exactly the same as the happy alien, except for its facial expression, was presented to the children. This time the alien's expression was angry. The five sounds associated to the angry alien were then played. Again this was presented twice so the children were visually presented with both the alien when he was happy and when he as angry and the 5 sounds he made when he was feeling the respective emotions. The set of sounds associated with the angry and happy alien were played on the same five instruments and differed only in the tone in which they were heard: high or low.

Originally, the task was going to have two conditions: one where the children would be taught to associate a happy alien to a happy sound and an angry alien with a low sound, and in the other the happy alien with a low sound and an angry alien with a high tone. However, in the pilot the children could not learn the association between the alien being happy and a low tone, even when the child could verbalise the rule governing the association. Consequently the protocol in which happy was associated with a low tone was taken out of the study. Within the Eprime programming for the demonstration this involved leaving the protocol involving demonstration of the low tones as being associated to the alien when happy and the high tones being associated to the alien when angry in the program, but removing its inclusion within the block list by leaving the sample column indicating how many times the protocol should be played, blank. Unfortunately in October 2015, one year after the study had been running it was discovered that Eprime had nonetheless been counterbalancing whether the demo played to the participant included happy as high or happy as low. This resulted in 44 children having heard the demo where happy was high and 40 children having heard the demo where happy was low. They were all then however given the practice trials where happy was high and angry as low.

As can be seen in the Figures, while the group that heard happy as low in the demo do not, on average, reach the same percentage correct as the group who heard happy high they decrease the variation between the groups from 40-10% over the practice block prior to the final block. Children were said to have learnt the sounds if they achieved 60% or above correct, as defined by a binominal test. Therefore 60% was the learning threshold. While those that heard happy as low in the demo remain just below the learning threshold at the end of the practice block prior to the final practice block they begin the final practice block above the learning threshold and maintained their 10% variation from the group that heard happy as high in the demo over this final block.

It was then investigated whether which demo was heard impacted whether the children learnt the associations or not, and whether hearing the demo where happy was low and angry as high resulted in a more difficult task than for those who heard happy as high and angry as low in the demo. This was done in a number of ways. To investigate whether the demo version heard influenced whether the participant learnt the associations a t-test was conducted to see if there was a significant difference in the percentage of correct trials in the final practice the participant undertook before moving on between those that heard happy as high (M = 81.64%, SD = 18.53) and happy as low (M = 70.14%, SD = 18.95). The t-test indicated that the difference between the groups was significantly different from zero ($t(82) = -2.809$, $p = .006$, $d = -.61$) with a medium effect, where the group that heard happy as high had, on average, a higher percentage correct than the group that heard happy as low in the final practice before being moved on. Given the learning threshold is 60%, while the group that heard happy as high had on average a higher percentage, both groups on average were over the learning threshold at the end of the final practice.

A chi-squared test was conducted to test whether there was a significant difference between those that had learnt the associations between the two groups. The test revealed that there was no significant difference in whether the children learnt the associations or not between those that heard happy as high or happy as low in the demo ($\chi^2(1) = 2.04$, $p = .215$). These tests indicate that while those had heard happy as high in the demo may have, on average, a higher percentage correct in the final practice before moving on to the experimental trials, both groups were just as likely to learn the associations. This suggests that which demo was heard was not influencing whether the children learnt the associations or not.

To investigate whether hearing happy as low in the demo resulted in a more difficult task than for those that heard happy as high in the demo the number of practice blocks taken to learn the association were compared via a t-test. Those that did not learn the associations were excluded from the analyses resulting in 40 in the group that heard happy as high and 32 in the group that heard happy as low. Inspection of the means shows that those that heard happy as high (*M* = 1.33, *SD* = .77, *MIN* = 1, *MAX* = 3) in the demo needed less practice blocks than those that heard happy as low (*M* = 1.63, *SD* = 1.12, *MIN* = 1, *MAX* = 3) in the demo. However, the difference between the means was not significantly different from zero: (equal variances could not be assumed, Levene's test: $F(70) = 4.481$ $p = .038$) $t(59.57) = 1.822$, $p = .073$. The result indicates that which demo was heard did not influence the number of trials taken for participants to learn the associations between the sounds and the alien.

From the investigations carried out on the influence of which demo was heard on the participants ability to learn the associations and the difficulty of the task it appears which the demo was heard doesn't seem to influence whether or not the association has been learnt nor influence the time taken to learn the associations. It can therefore be concluded that who demo is heard during this interpretation bias task has no effect on the learning that takes place in the task.

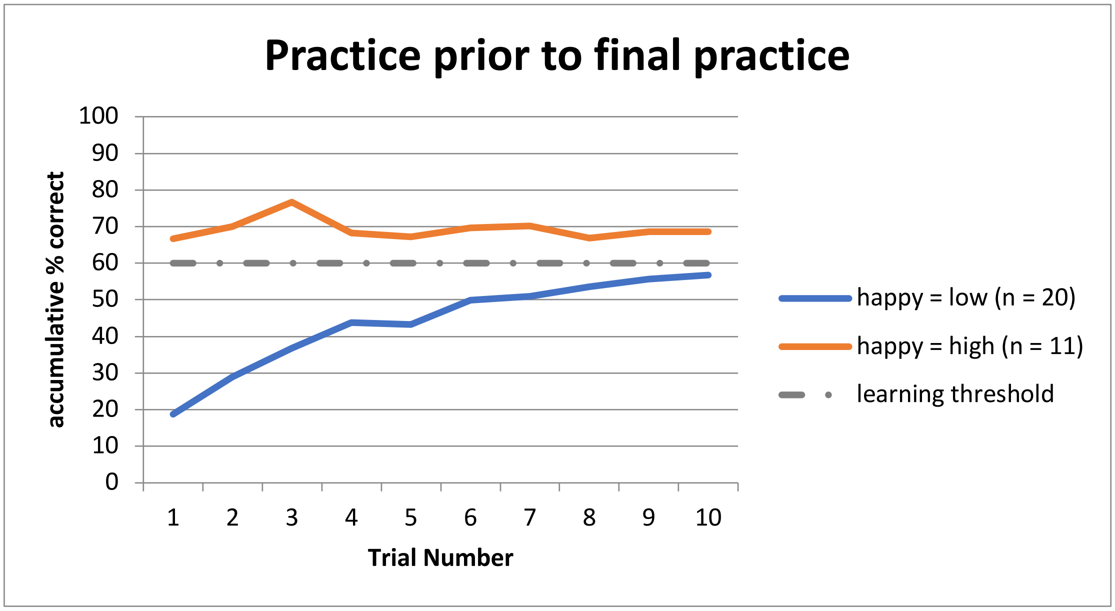


Figure 8. Accumulation of correct trials over the practice block prior to the final practice

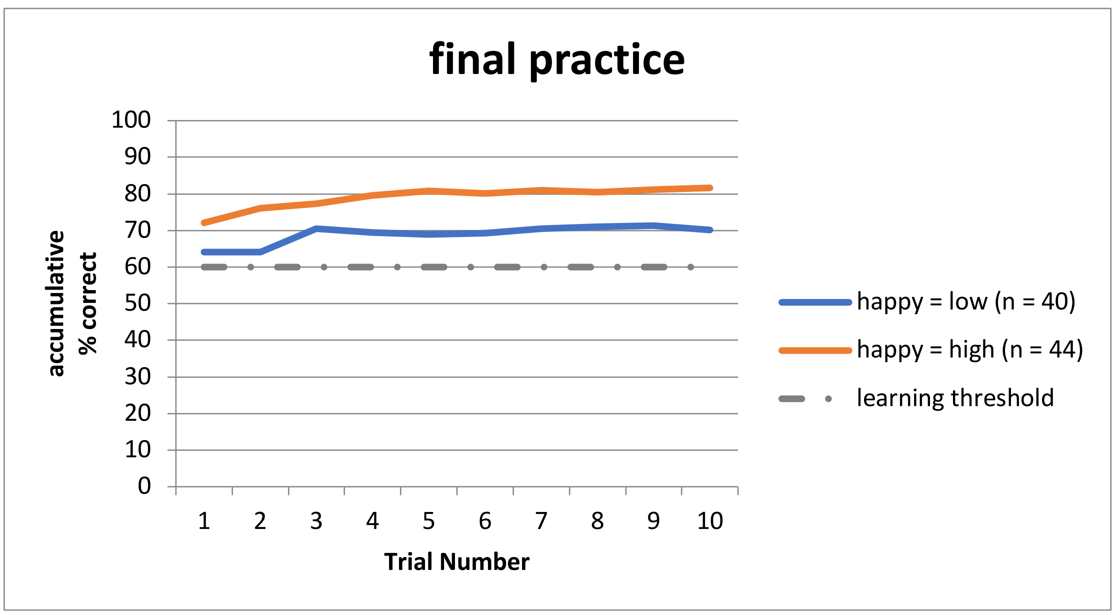


Figure 9. Accumulation of correct trials over the final practice block

7.7. Appendix 7: Example of Debrief Sheets for Parents (7-8 year olds)

Principal Investigator:
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RG6 6AL

Why is that some children are shy, nervous and worry a lot, while others are confident, outgoing and nothing seems to faze them?

Our idea is that this difference between children might be related to the way they process things in world around them.

For example a child who has fears and worries might focus on things in the environment that signal danger or may be more likely to interpret situations negatively.

You have answered questions about your child's worries and fears and your child has completed tasks that tells us about their development (.e.g. language). We are interested in how these things relate to their responses on the three games they played. Each game is explained overleaf.

Your child has taken part in three main tasks:

In the first game we recorded your child's eye movements whilst they watched pictures of faces and fun aliens.
•By tracking your child's eye-movements we were able to see how long they looked at the faces in the game and where they looked once the alien appeared on screen.
•From this we can see whether your child looked at faces more quickly or for longer when the face displayed an angry, happy or neutral expression.
•We are interested to see whether children with more worries and fears will look at the angry face sooner and for longer.

In the second game, we first taught your child which sounds belonged to aliens when they were happy or angry.
•Then we asked your child to say whether sounds they hadn't heard before belonged to angry or happy aliens.
•We were asking your child to 'interpret' what the sounds meant, (i.e. were the aliens angry or happy?)
•We are interested to see whether there is a difference between children in how they make this interpretation.

Finally, we asked your child to listen to some scenarios they might find themselves in, for example:
"You see the School Head teacher walking around the playground and she/he has been asking other children where you are. "
•We asked them to choose an outcome so we can see how different children interpret these ambiguous situations.

If you have any further questions, wish to participate further in the research we are doing regarding child anxiety or wish to receive a report of our findings please let one of researchers know or contact us using the details on this leaflet.

Questionnaires about Anxiety

Today you have answered questions about your own fears, worries and anxieties. If these questions have raised any concerns or worries regarding yourself or your child, this leaflet, which is given to all participants involved in our research, provides you with some potential sources of support.

If you would like to talk to someone, you may wish to consider talking to your General Practitioner, who will be able to offer support or arrange for you to be referred to a specialist.

A national organization, such as the Samaritans can also provide support. You can call the Samaritans on 08457 90 90 90, or you can call in at the local branch which is located at 59a Cholmeley Road, Reading, RG1 3NB (local branch phone: 0118 926 6333).

The Principal Investigator of the study you have taken part in, Dr. Helen Dodd, suggests these websites and books:

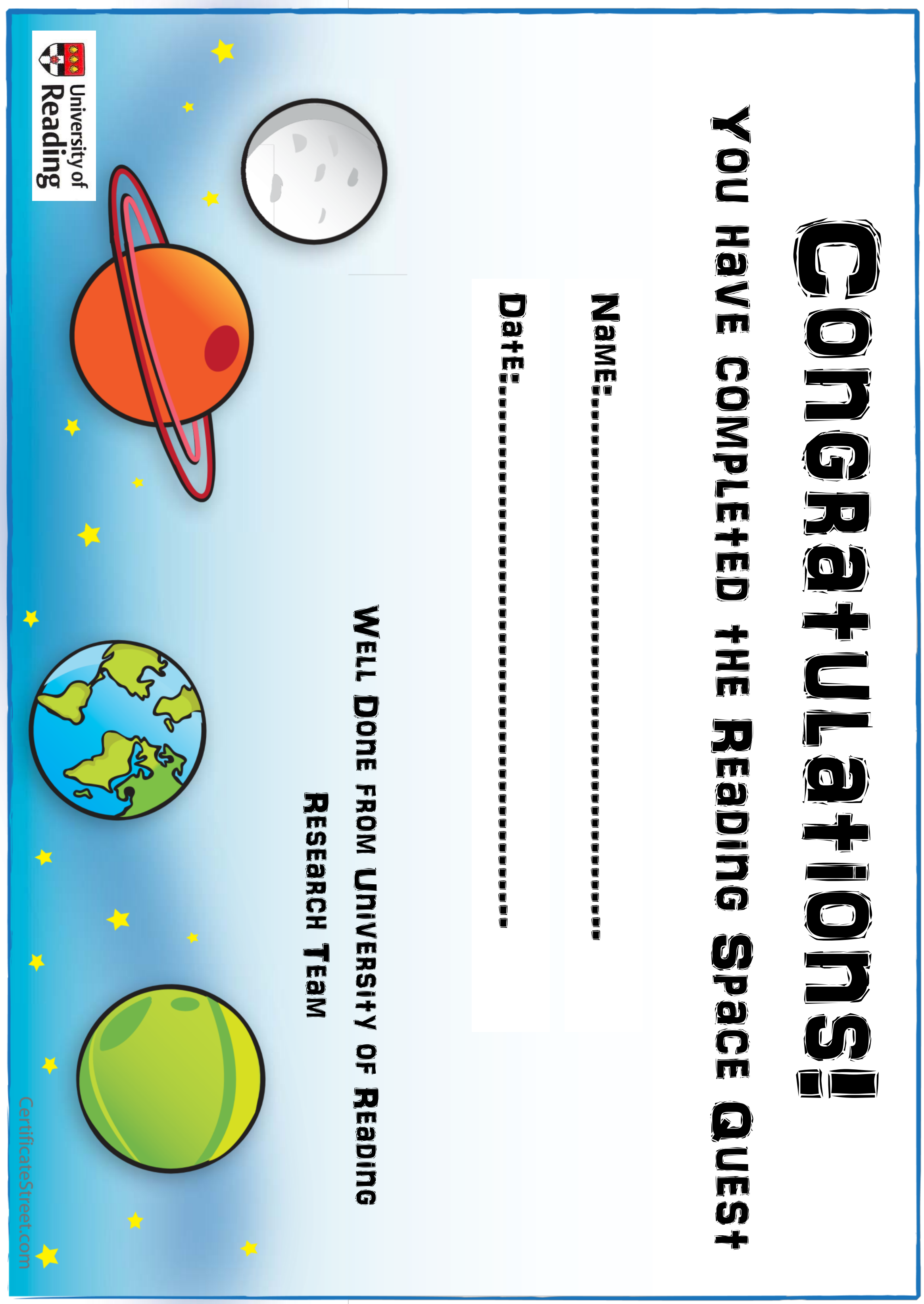
•www.anxietybc.com/parent : offers information for parents concerned about the anxiety their child experiences

•familylives.org.uk : offers a parenting helpline for instant support and advice.

• There are some good books that describe how as a parent you can support your child (all available online):
Helping your anxious child: A step by step guide by Ronald Rapee
Overcoming Your Child's Fears and Worries: A Self-help Guide Using Cognitive Behavioral Techniques by Cathy Creswell and Lucy Willets
Overcoming Your Child's Shyness and Social Anxiety by Cathy Creswell and Lucy Willets

•www.mind.org.uk provides information about adult anxiety including different treatment options and contacts. This can be found under the information support tab, by selecting anxiety and panic disorders from the "types of mental health problems".

7.8. Appendix 8: Certificate given to Children at completion of the Space Quest



7.9. Appendix 9: Examples of Stickers given as a Reward for Completion of the Space Quest

7.10. Appendix 10: Protocol of the Ambiguous Sound Task

Explaining the task:

- The captain of the ship was wondering if they could do a very special job for him. When we fly through space other aliens pass us, sometimes the aliens are happy and sometimes they are angry. We know whether they are happy or angry before we see them because of the sounds that they make. When the alien is happy he will make certain sounds and if he is angry he will make different sounds.
- The captain was wondering if you could help him work out if the aliens coming towards our ship are angry or happy. To do this we will first listen to the different sounds they make when they are happy or angry, then we will have a little practice and they we will have a go for the captain for real.
- First thing we are going to do is listen to what sounds the aliens make when they are angry and what sounds they make when they are happy. **Only do this when the sensors are on. Listen to the first couple together then let the child wear the headphones**
    - Play the Eprime program demo called "demo interpretation bias": If using psychophys - The powerlab does NOT record during this section.
        - This will play the sounds through 4 times (2 times the happy = high set and 2 time the angry = low set) indicating which emotion the sounds belong to.
        - This can be played as many times as the child wishes. Simply restart the program and label each consecutive session accordingly (1,2,3,4…).
    - When you and the child are happy move on to the practice trials
        - interpretation bias practice with psychophys code OR
        - interpretation bias practice NO psychophys code
    - Double click the corresponding EPrime program to start the practice and start the labchart recording– press the large play button at the same time.
    - Talk through the instructions, move through them by pressing any key on the keyboard. Tell the children to say 'Angry' if they think that the sound belongs to an alien that is angry and 'Happy' if they think that the sound

belongs to an alien that is happy. Tell them you will press the button for them so that they can look at the screen and concentrate on listening.

- The last slide before the practice begins is ‘lets practice’. Talk through the procedure: before anything happens we have to count to five, then they will hear the sound, they say ‘Happy’ if they think the alien is happy and say ‘Angry’ if they think the alien is angry. Explain once they decide whether the alien was happy or angry the computer will tell them if they are right or not and then show them the correct alien. If they are not sure that is ok they can guess. The important thing is that they give a response. Once you press any button on the keyboard the practice will begin. Remind them they are learning so it is ok if they get some wrong.
- The child will get feedback about whether they have correctly identified the sound. Make a comment such as ‘yay you got it right’ or ‘ohh that one must have been tricky’. After the feedback they will see which alien was correct comment ‘ahhh the alien was happy/angry’ ‘you were right the alien was happy/angry’.
- The practice sessions are in blocks of 10. Keep your eye on the feedback screen, at the bottom their accumulative accuracy is shown. Once they get 60% over the 10 trials they can move onto the experimental sessions. Between each trial is a break. They can move around and you can decide whether to do another block or not. To stop the practice trials press ctrl alt shift and agree to abort the experiment. There are six blocks in the program. If you need more you can start it again and mark each consecutive session (1,2,3,4….) when asked at the beginning.
- When you abort stop recording on labchart. Then start again when the task starts.

- Experimental trials:
    - Explain that the captain thinks they are ready to help him, we are going to do exactly the same thing, but this time the computer won’t tell you if you are right or not. Point out it is a lot more difficult in space to tell whether the alien is angry or happy so not to worry if they find it tricky. If they aren’t

sure they can guess. We will have a go on listening to a few aliens then have a break. We will see the captain in the break and he will let us know how he thinks you are doing.

- Open the appropriate EPrime program and remind them we will:
    - count to five
    - Hear a sound
    - Decide if the alien is happy or angry by saying 'Happy' or 'Angry'
    - This time the they computer won't tell us if they are getting it right or not.
- Move through the instructions by pressing any key on the keyboard. Point out the happy and angry faces on the mouse again. Start the lab chart recording.
- Once you hit the break, you will control how long the break is by by pressing a key on the keyboard to continue. Congratulate them and reassure them they are doing really well, the captain is pleased with them (point to computer where the captain has his thumb up). Explain that in the next bit we are going to do the practice again to help us remember which sounds the aliens make when they are happy and when they are angry, the computer is going to tell us how they are doing again.
- The procedure of experimental then practice trials repeats itself 4 times.
- Encourage the child to keep the sensors on all the time – if they come off we have to stop the game and they are doing so well.
- Stop labchart when the task is finished.

- When the task is over congratulate the child, emphasise how happy you think the captain is going to be with their help. Help them put another sticker on their progress chart and see how many they have done and how many they have left to do. Have a break. During the break they can remove the sensors if they like. The SCR sensors will not be needed again.
- Save the labchart file:
    - File save as: *participant id/date*
    - Copy the file into the 'back up interpretation bias task' folder

  - Move into the ‘interpretation bias data’ folder
  - Do not save over the ‘interpretation bias task’ labchart file/document.
- Save the eprime data:
  - The data files will appear with their participant number at the end in the same file where the Eprime program is stored.
  - Move 2 files into the participant data file:
    - The Edat file
    - The text file named with the participants number.
  - Copy these files into back-up.
  - There should be no data files in the interpretation bias task folder when the next participant is started.

7.11. Appendix 11: Further Examination of Whether the Ambiguous Tones Task Worked

Reminder of the task

The interpretation bias task was split into two phases, a learning phase and an experimental phase. The learning phase consisted of practice blocks of 10 trials where children were presented with 1 tone per trial and asked to verbally report whether the alien was happy or angry after which they were given feedback. Over 1 practice block children were presented with 5 high tones and 5 low tones that were associated with an alien who was happy and angry respectively. The sounds heard in the learning phase will be referred to as the trained sounds. The experimental phase consisted of experimental blocks of 7 or 8 trials, which was always followed by a practice block identical to those in the learning phase. In the experimental blocks children heard 5 ambiguous tones and 2 or 3 trained sounds.

Assessment of the Task

To assess whether the interpretation bias task is appropriate for all children ages four to eight years old and was actually assessing children's interpretation of the ambiguous sounds several questions need to be answered about their ability to learn the associations. Firstly, were children able to learn the associations between the tones and the alien when happy or angry. If they could not learn the associations at all then we can conclude that the task is neither appropriate for the age group and that responses to the ambiguous sounds are unlikely to represent anything more than chance responding. Second, did one group of children, for example gender, age group, or anxiety group, find it more difficult to learn the associations than another group? If this is the case then the task may not be appropriate for all children or these groups may need to be accounted for in further analyses. Third, were the children just as accurate with the 'angry' as the 'happy' sounds.

Fourth, of the children that learnt did they maintain their learning of the sounds they were trained on throughout the task? This can be further broken down into: did they maintain their learning during the practice blocks inbetween the experimental blocks; did they maintain their learning on hearing the trained sounds amongst the ambiguous sounds within the experimental blocks; did they maintain their learning across both practice blocks and trained sounds amongst experimental blocks. If the children did maintain their learning across the task then we can be more confident that the children are carefully categorising the sounds rather than responding by chance. If this is the case we can apply this assumption to their responses of the ambiguous sounds, that they are interpreting the sounds rather than responding by chance.

Finally, it is important to know whether the instrument with which the ambiguous sounds were played was not influencing children's interpretations. Five instruments were used to produce the sounds within the same frequency and they only differed on tone to create the happy, angry and ambiguous sounds. If, for example, one instrument when producing the ambiguous sound is generally responded to as belonging to the alien when it is 'happy' then this should be considered when interpreting the results assessing group differences.

Children were deemed to have learnt the associations between the tones and the emotion of the alien if they achieved >60% correct in the final block of practice trials, where they would hear each sound and be given feedback. It was always the final block that was consider as either children's learning was monitored throughout each block by a researcher and those who gained >60% were over one block were moved onto the experimental block. Or children had been through three or four practice blocks and not gained >60% were asked if they would like to continue or stop. Gaining greater than 60% correct was indicated by a binominal test to indicate children would not be relying on chance to answer.

To ascertain whether the interpretation bias task is appropriate for all children ages four to eight years old and was actually assessing children's interpretation of the ambiguous sounds each question will be assessed.

1. Did the children learn the associations?

110 children took part in the interpretation bias task. 97 children were able to learn the associations according to the learning criteria (< 60% correct over 1 practice block). Sample characteristics of the full sample, those that learnt and those that did not learn the associations can be found in Table 1.

Table 1.

Descriptive Statistics of Full sample split by those that learnt the sound associations

	n	%Females	%High Anxious	Mean age (SD)	Age range (yrs)
Full sample	110	40	63.7	5.69 (1.34)	4-8
Learnt group	97	39.2	63.9	5.78 (1.34)	4-8
Not learnt group	13	46.2	46.2	5.98 (1.19)	4-8

2. Did one group find learning the associations more difficult than the other?

The learnt and not learnt group did not statistically differ by gender proportions ($X^2(1) = .23$, $p = .630$) or membership to anxiety group ($X^2(1) = .50$, $p = .481$). There was also no difference in age between those that learnt and those that didn't (equal variances not assumed; $t(16.64) = 1.97$, $p = .066$). These results indicate there was no connection between not learning the associations and gender, anxiety group, or age.

Of those that learnt the average % correct over final practice block overall was 82.20% (*SD* = 13.65) and it took on average 1.33 *(SD* = .652) practice blocks to achieve the required >60% correct (range 1-3 practice blocks). Of those that learnt the associations 76% acknowledged the difference between the sounds, 18% were able to verbalise the rule correctly, 2% described the difference between sounds as light and dark, 3% as quiet and loud, 1% as faster and slower.

Given the task was constructed to assess differences in interpretation bias between high and low anxious groups if it important to find out if, if any, differences in learning the association exist between these groups as it may impact interpretation of results later on. Therefore differences between the high and low anxious group were checked for in the total percentage correct in the final practice block, the number of blocks taken to achieve >60% and ability of the anxiety group to verbalise the rule behind the associations.

In the low anxious group 23% were able to verbalise the rule, the average % correct over final practice block was 86.16% (*SD* = 11.89) and it took them on average 1.26 practice blocks (*SD* = .56, range 1-3) to achieve <.60%. In the high anxious group 16%

were able to verbalise the rule, the average % correct over final practice block was 79.64% (*SD* = 14.26) and it took them on average 1.46 practice blocks (*SD* = .69, range 1-3) to achieve <.60%.

High and low anxious groups showed no significant difference in the proportions of those being able to verbalise the rule underlying the association ($X^2(6) = 10.18$, $p = .117$) in the number of practice blocks taken to achieve >60% ($t(96) = .98$, $p = .329$), but did differ on % correct in the final practice block ($t(96) = 2.30$, $p = .02$) where the low anxious group scored higher. This indicates that the low anxious children were better at learning the associations in terms of % correct, however, on average both groups were way over the 60% learning level and the low anxious group were not faster.

It should be noted that due to a computer error not all children had valid trials in the experimental blocks. 81 children both learnt the associations and had at least one valid trial in the experimental blocks. Therefore assessment of the responses to trained sounds and ambiguous sounds beyond the practice phase of the task was conducted on these 81 children who both learnt the associations and had valid trials.

Table 2.

Descriptive Statistics of those that had valid trials and no valid trials in the experimental blocks

	n	%Females	%High Anxious	Mean age (SD)	Age range (yrs)
Valid Trials	81	41	65	5.82 (1.02)	4-8
No Valid Trials	17	38	64	5.72 (1.40)	4-8

The group with no valid trials did not statistically differ in proportion of gender ($X^2(1) = .002$, $p = .968$) or anxiety ($X^2(1) = .05$, $p = .823$) to the group with valid trials, nor did they differ on age ($t(96) = .182$, $p = .856$).

3. Were the children just as accurate with the 'angry' as the 'happy' sounds across the practices?

Accuracy was coded as '0' being incorrect and '1' being correct. Therefore average accuracy scores will range between 0 and 1. The overall average score for 'angry' sounds was .82 (*sd* = .38) and for the 'happy' sounds .80, (*sd* = .40). There was no difference between overall accuracy scores $t(2174) = 1.189$, $p = .2347$). This indicates that children were equally accurate when categorising the 'angry' and 'happy' sounds and therefore achieving the 60% accuracy was not driven by accurately categorising one group of sounds while guessing the category of the other.

4. Did the children that learnt the associations and had valid trials sustain their learning (>60%) on trained sounds throughout the task?

4.1 Did they achieve >60% over all the practice blocks within the experimental part of the task?

The maximum number of practice blocks between the experimental blocks the children completed was four. Table 3. shows how many children completed each number of practice blocks. Figure 1 shows the average % correct across the entire group and as the graph shows overall, on average children ages four to eight years maintained their learning across all the practice trials. Figure 2 shows that this did not change when the group was split into high and low anxious children. Both groups maintained their learning of the associations above the learning level. The group was also split by age to assist assessment of whether the task was appropriate for all children ages four to eight. As can be seen in Figure 3 the older children did much better at maintaining their learning than the younger children. The drop in block four and lack of children completing block 4 in the four and six year olds may illustrate that by this point the children's attention is waning by block 4. It should also be noted that a very small number of 8 year olds are included in this average at block 4. Four year old on average just maintained their learning across the first two blocks, but it was not maintained in the third block also demonstrating that perhaps they are struggling to keep their attention past the second practice block in the experimental phase of the task.

Table 3.

A Table to show the Number of Children who part in each Practice Block by Anxiety group and Age group

	1	2	3	4
Total	79	48	33	6
High Anxious	51	33	20	2
Low Anxious	28	15	13	2
Age 4	17	7	4	
Age 5	21	13	7	1
Age 6	18	13	11	4
Age 7	8	5	2	
Age 8	15	10	9	1

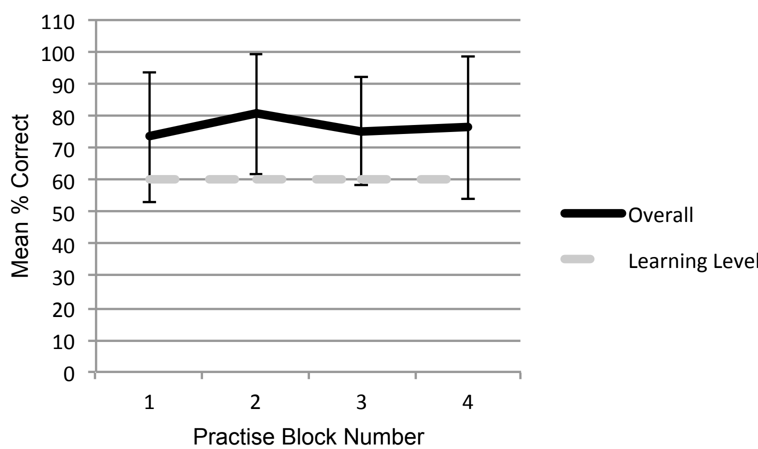


Figure 1. Line Graph to Average Percentage Correct of Trained Sounds over each Practice Blocks of the Experimental Phase of the Task. Error Bars represent Standard Deviations.

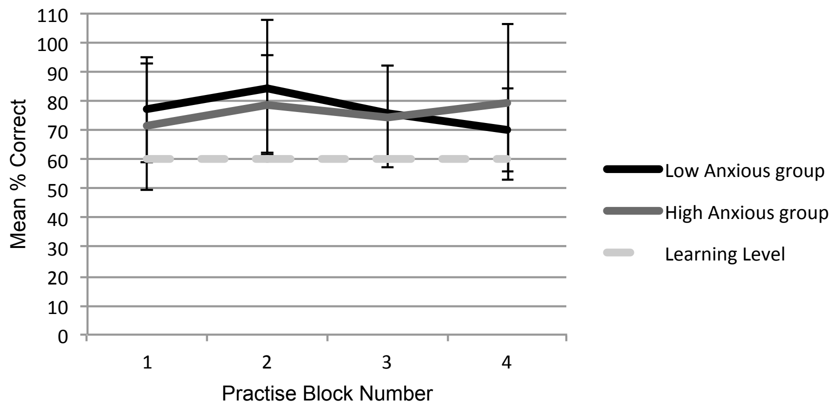


Figure 2. A Line Graph to show Average Percentage Correct on Trained sounds over each Practice Block within the Experimental Phase of the Task split by Anxiety group. Error Bars represent Standard Deviations.

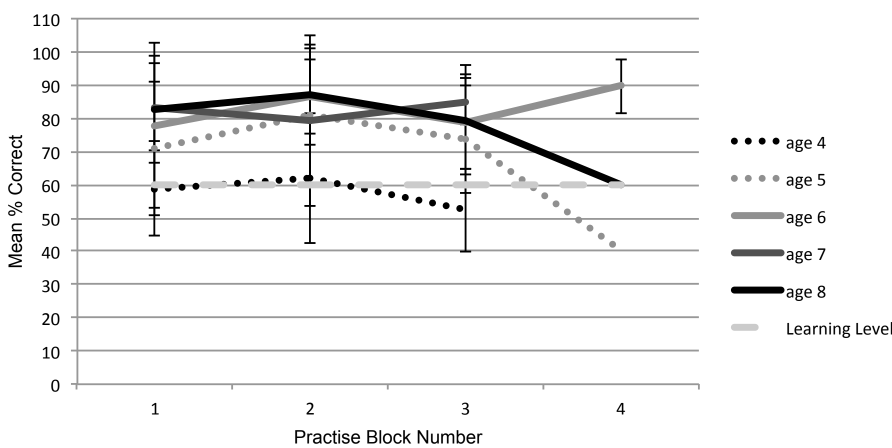


Figure 3. A Line Graph to show Average Percentage Correct on Trained Sounds over each Practice Blocks within the Experimental Phase of the Task split by age. Error Bars represent Standard Deviations for each group.

4.2 Did their percentage correct, on average, fluctuate over the 10 trials of the practice?

While Figures 1 to 3 indicate that overall children maintain their learning over the practice blocks, with older children doing better than younger children and four year olds losing attention faster than the older children, it would also be interesting to see what happens, on average with the practice blocks. Did they struggling to categorise the sounds correctly in the beginning, but get the final trials correct. As can be seen in Figures 4 and 5 overall and in the high and low anxiety, on average, children maintained their learning above 60% across all 10 trials of the practice blocks. On average, it seems it takes a couple of trials after listening to the ambiguous sounds for children to get the associations sorted in their head again, after which they, on average, respond correctly. Figure 5 again shows that as age increases the more accurate the children are in the trials, on average.

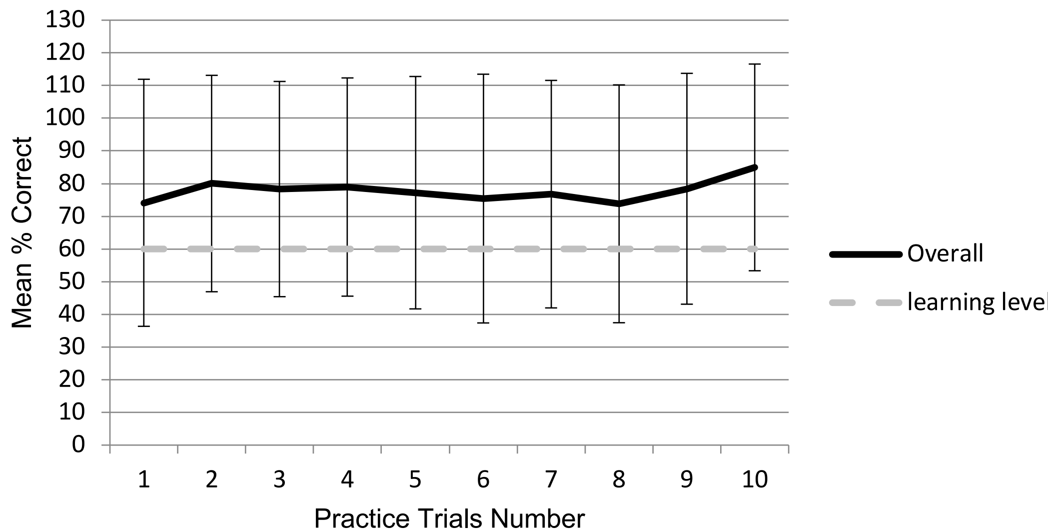


Figure 4. A Line Graph to show Average Percentage Correct achieved overall the Practice Blocks within the Experimental Phase of the Task by Trial. Error Bars represent Standard Deviations.

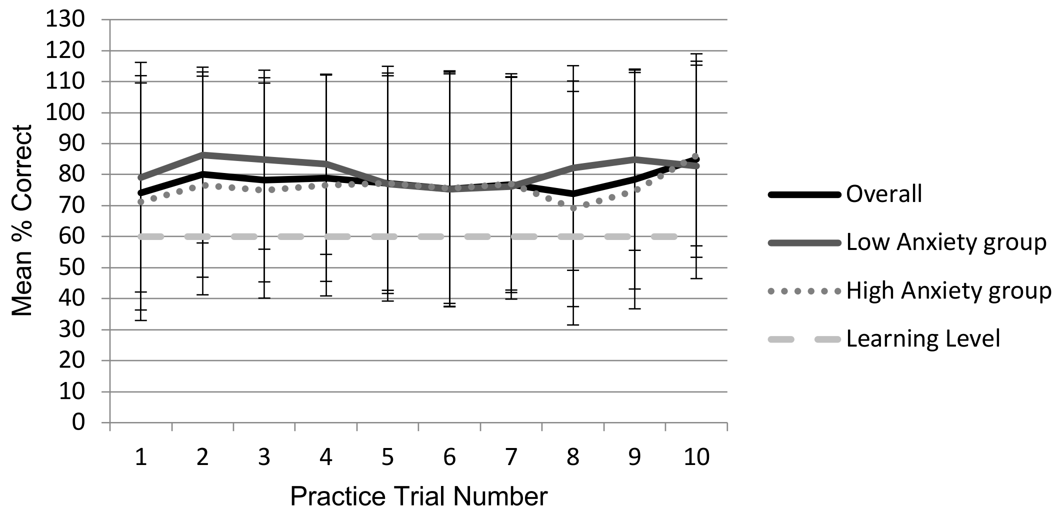


Figure 5. A Line Graph to show Average Percentage Correct Achieved overall the Practice Blocks within the Experimental Phase of the Task by Trial, split by Anxiety Group. Error Bars represent Standard Deviations.

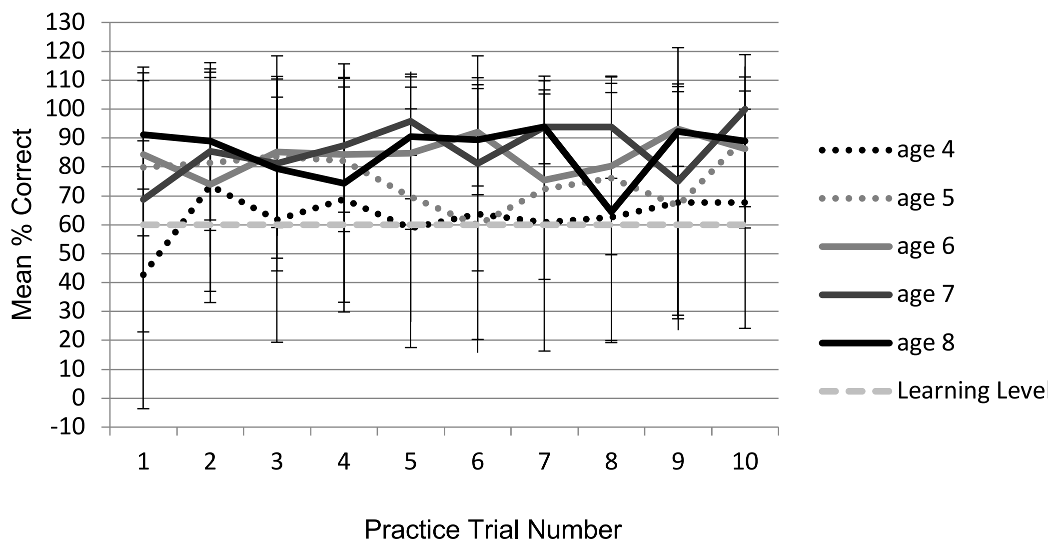


Figure 6. A Line Graph to show Average Percentage Correct Achieved overall the Practice Blocks within the Experimental Phase of the Task by Trial, split by Age. Error Bars represent Standard Deviations.

4.3 On average, did the children maintain their learning (>60%) on the trained sounds that were played amongst the ambiguous sounds in the experimental blocks?

Children were hearing 2 or 3 trained sounds per experimental block so could hear a maximum of 10 trained sounds over all four blocks, one of each possible trained tone. Figure 7 shows that across the sample, on average, children maintained their learning, their ability to categorise the trained sounds correctly when they were heard amongst the ambiguous sounds. Figure 8 shows this is also case within each anxiety group with the low anxious group doing better by the fourth experimental trials, but learning was still over the learning level of 60%. The first block was the lowest overall, within each anxiety group and age group (see Figures 7-9). For some children who achieved >60% on the first practice block this may be only the second time they are hearing the trained sounds so this is not surprising. Figure 9 shows that older children were better at correctly categorising the trained sounds than the younger children. Four year olds in particular, on average struggled to maintain their learning past the second block, this may be due to attention waning at this point. Five year olds seen to have maintained their attention slightly longer as their dip to the learning level was in block 4.

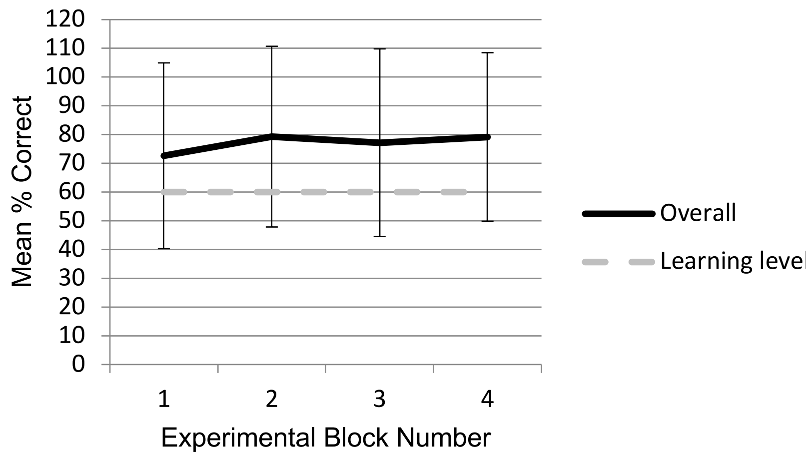


Figure 7. A Line Graph to over Average Percentage Correct on Trained Sounds within the Experimental Blocks. Errors Bars represent Standard Deviations

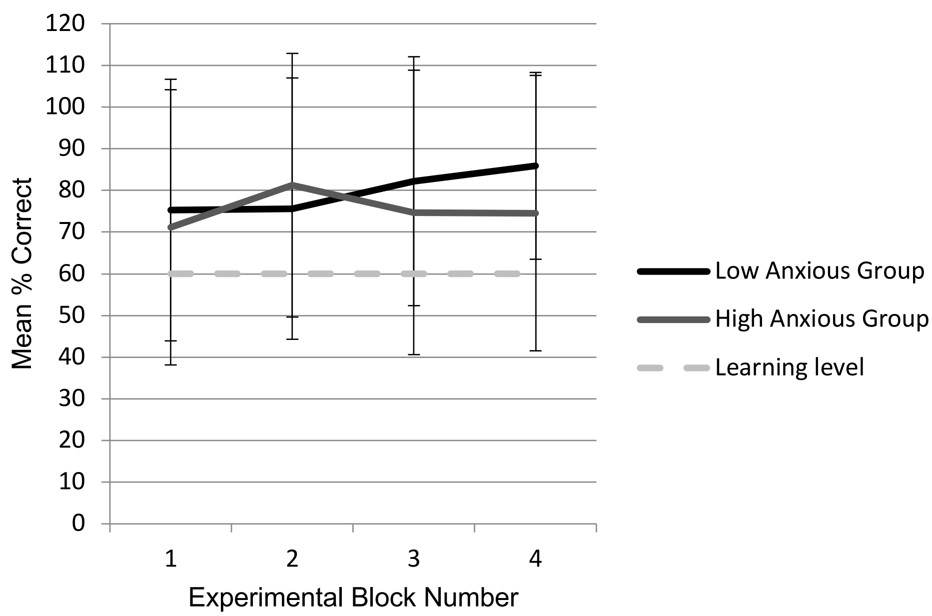


Figure 8. A Line Graph to over Average Percentage Correct on Trained Sounds within the Experimental Blocks, split by Anxiety Group. Errors Bars represent Standard Deviations.

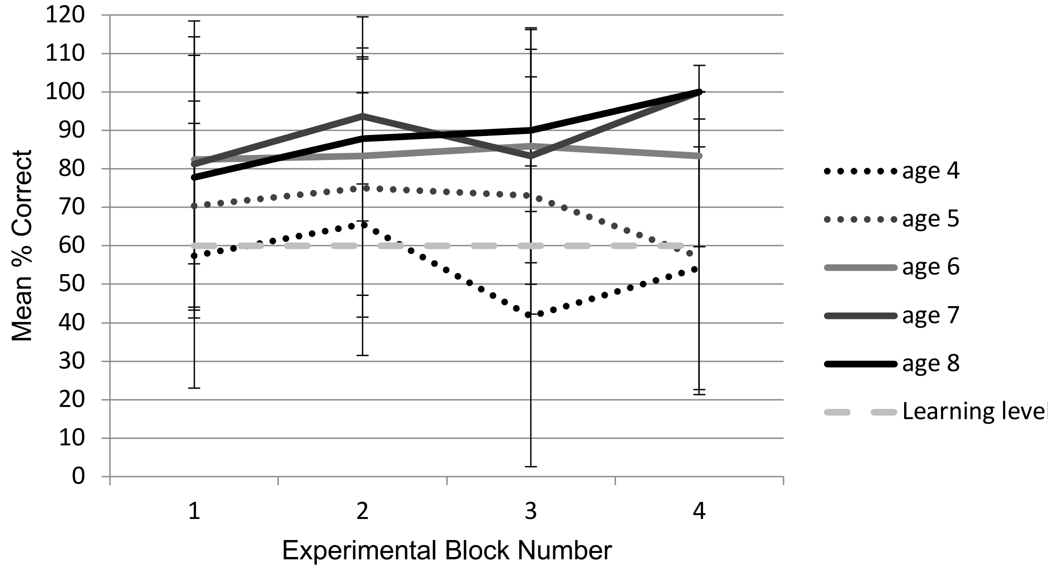


Figure 9. A Line Graph to over Average Percentage Correct on Trained Sounds within the Experimental Blocks, split by Anxiety Group. Errors Bars represent Standard Deviations.

4.4 Over both the trained trials and the practice blocks completed, did the children maintain their learning (>60%)?

As can be seen in Table 4 when the trained sounds heard across the complete experimental phase of the task, in the practice and experimental blocks, on average, overall, both anxiety groups and all ages maintained their percentage correct over 60%. Children age 4 only just maintained their learning and children aged 7 did the best across the experimental phase.

When differences in percentages correct in trained sounds over the experimental phase of the task were examined between anxiety groups and ages, no main effect of anxiety group ($F(1,71) = 1.95$, $p = .167$) was found, but there was a main effect of age ($F(4,71) = 7.28$, $p < .001$, $\eta_p^2 = .29$). Post hoc test with a bonferroni correction indicated that the difference in percentage correct across all trained sounds for children aged 4 was significantly greater than zero to ages 6(*Mdiff* = -19.96, $p = .001$), 7(*Mdiff* = -22.23, $p = .001$), and 8(*Mdiff* = -19.78, $p < .001$) where children aged 6, 7, and 8 achieved, on average higher percentages correct.

Table 4.

Overall % Correct of Trained Sounds over Complete Task (practice and amongst ambiguous trials)

	N	Mean %correct	SD %correct
total	81	78.48	15.05
total low anxious	29	81.17	15.01
total high anxious	52	76.98	15.01
total age 4	18	65.09	10.27
total age 5	22	76.47	14.88
total age 6	18	85.06	11.04
total age 7	8	87.33	17.04
total age 8	15	84.88	12.66

% accuracy as a proportion of correct responses to valid trials

5. Did the instrument that the ambiguous sounds were played in, influence whether they were reported as 'angry' or 'happy' in the experimental trials?

The instruments playing the ambiguous tones were selected as having a similar frequency and valence so it would not be expected that hearing a particular instrument would be more likely to be heard as belonging to angry or happy alien. The ambiguous sounds have been previously established, in a different sample, as being ambiguous in the sense that they were rated as belonging to aliens 'not happy or angry'. Figures 10 and 11 show the average percentage the ambiguous tones were categorised as belonging to an alien who is angry. Visual inspection of the overall bars in Figure 10 suggests there may be something about the guitar sounds that is resulting the children as being slightly less likely to report the ambiguous tone being from an angry alien. Likewise there may be something about the ambiguous tone from the Wurlitzer that is resulting in the children overall reporting the tone as being more likely to belong to the angry alien. However visual inspection of figure 10 suggests that on average the low anxiety group is reporting the tones as belonging to the angry alien less than the high anxious group. Visual inspection of Figure 11 also suggests that 8 year olds are consistently reporting all the sounds to be more likely to belong to an alien that is angry. However, when a repeated measure ANOVA was conducted to see whether there was a difference between instruments in the percentage of tone categorised as angry there was no main effect of instrument indicating which instrument was heard was not having an effect on categorisation ($F(1, 312) = 1.98$, p = .097).

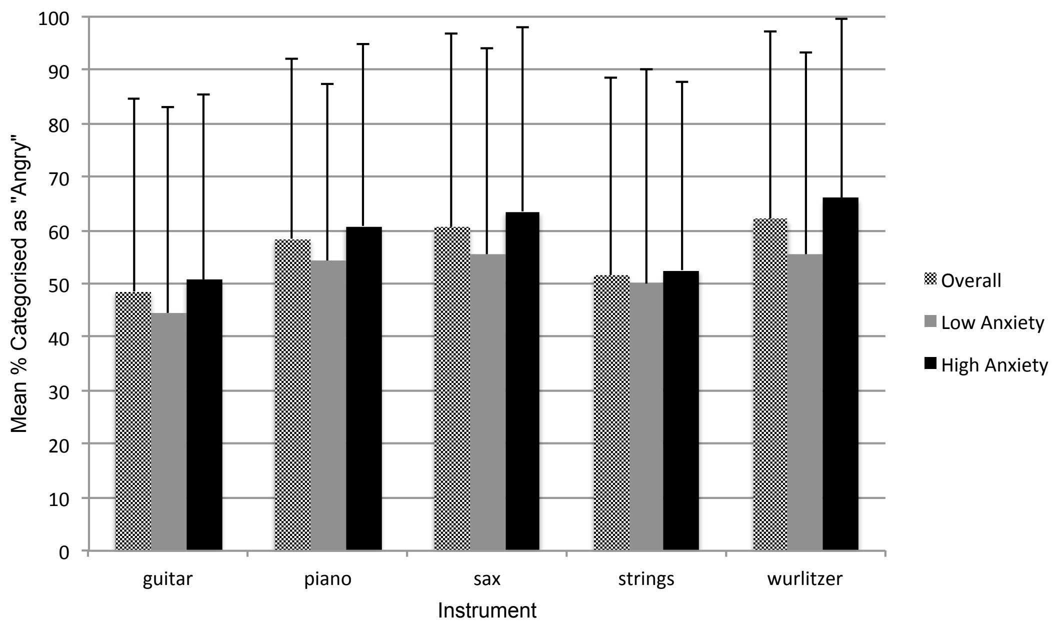


Figure 10. A Bar Chart to show the Average Percentage of Ambiguous Tones categorised as belonging to an angry alien split by Anxiety group. Error bars represent standard deviations.

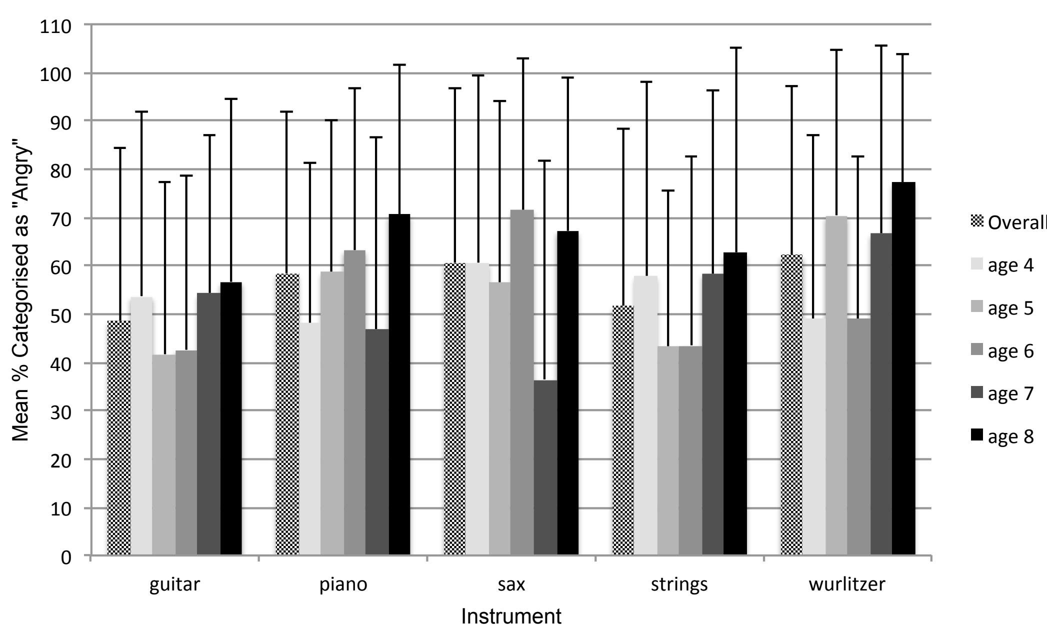


Figure 11. A Bar Chart to show the Average Percentage of Ambiguous Tones categorised as belonging to an angry alien, split by Age. Error bars represent standard deviations.

7.12. Appendix 12: Use of Galvanic Skin Response (GSR) in the Ambiguous Tones task

In the Ambiguous tones task, facial electromyography was investigated as a potential objective measure that may reflect children's valence appraisal of an ambiguous stimuli. In this task one further objective measure of galvanic skin response was also collected with the same aim in mind. The rationale for inclusion of this measure is below.

Like adults, children's psychophysiological responses have been found to reflect the emotional content of stimuli (McManis, Bradley, Berg, Cuthbert, & Lang, 2001). Skin conductance response or galvanic skin response (GSR) is related to our fight or flight response and activity related to arousal (Lang, Greenwald, Bradley, & Hamm, 1993). Sensors placed on the hands measure the conductance of the skin, as we sweat conductance increases; it then follows that the more arousing a stimulus is, the more we sweat and the higher the GSR is. GSR has been found to differentiate emotional pictures from neutral pictures based on arousal (Codispoti, Bradley, & Lang, 2001) and shows no difference in response evoked by auditory or visual stimuli (Zhou, Qu, Jiao, & Helander, 2014). It may well be that children find a positivity or pleasantness more arousing than a negativity or unpleasantness (Sharp, van Goozen, & Goodyer, 2006). In this way, GSR may differentiate between sounds associated with angry and happy aliens, with more GSR expected for happy than angry aliens. Thus, GSR could give us an objective measure of children's responses/interpretations of the ambiguous tones.

Galvanic skin response was recorded from the 110 children that took part in the task. However, this measure does not form part of the analysis in this thesis for a couple of reasons. Firstly, the signal was not of good enough quality and there was not enough valid data for analysis. On inspection of the data there were periods where the signal would flat line during the task and there were quick peaks and troughs that occurred over a second which is too fast for a GSR response. It is likely that the flat lining is due to the sensors losing contact with the skin meaning a signal was not being recorded. Four-year-old fingers are very small and the sensors were quite large which may have resulted in the sensors losing contact. The fast peaks and trough may be movement. Despite the instruction to children to stay still throughout the task, with continued encouragement to do so from the experimenters, the children still may have been moving. The children found the sensors uncomfortable and/or intriguing and while were sitting still would often twitch their fingers. Secondly, the design of the study was set up to accommodate fEMG rather than GSR. GSR was added as a secondary measure. This resulted in it being difficult to extract the genuine GSR response to the tone. In the task children verbally reported on the valence of the alien. The corrugator was chosen to ensure that this verbal report would not interfere greatly with the signal, but the verbal report may have affected the GSR response. Children were verbally reporting within three seconds of the onset of the tone stimuli. Recording of their verbal response triggered a change of screen. In the trained tone blocks this would trigger the presentation of feedback and in the experimental blocks this would trigger the start of a new trial. GSR is a slow response and three seconds is not long enough to be sure that the response has onset and peaked in response to the tones. This therefore makes it difficult to assess whether the GSR has already peaked before the onset of the next screen and how much this change in screen influenced the GSR response. Both reasons resulted in the data being too noisy to answer the questions posed by this thesis.

References

Codispoti, M., Bradley, M. M., & Lang, P. J. (2001). Affective reactions to briefly presented pictures. *Psychophysiology*, *38*, 474–478. http://doi.org/10.1111/1469-8986.3830474

Lang, P. J., Greenwald, M. K., Bradley, M. M., & Hamm, a O. (1993). Looking at pictures: affective, facial, visceral, and behavioral reactions. *Psychophysiology*, *30*, 261–273. http://doi.org/10.1111/j.1469-8986.1993.tb03352.x

McManis, M. H., Bradley, M. M., Berg, W. K., Cuthbert, B. N., & Lang, P. J. (2001). Emotional reactions in children:Verbal, physiological, and behavioral responses to affective pictures. *Psychophysiology*, *38*, 222–231.

Sharp, C., van Goozen, S., & Goodyer, I. (2006). Children's subjective emotional reactivity to affective pictures: Gender differences and their antisocial correlates in an unselected sample of 7-11-year-olds. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *47*, 143–150. http://doi.org/10.1111/j.1469-7610.2005.01464.x

Zhou, F., Qu, X., Jiao, J., & Helander, M. G. (2014). Emotion prediction from physiological signals: A comparison study between visual and auditory elicitors. *Interacting with Computers*, *26*, 285–302. http://doi.org/10.1093/iwc/iwt039

7.13. Appendix 13: Protocol for the Attention Bias Task

Introduce the child to tobii and the idea that when we play the games tobii is going to show them a cross/planet and tobii will be able to tell whether you are looking at the cross/planet. Tobii will play a game with you and the quicker you are to look at the fixation cross and the longer you look at it the more points you will win! Comment at the end they got looooadssss of points!

Attention bias: Eye-tracking task

- You should have control over the keyboard and the child will have access to the mouse. Make sure the mouse is connected to the **laptop** via USB. The mouse should have a coloured dot on the left and right side.
- The Eprime program for the practice is called "Practiceblockeye-trackingready.ebs". Open the program, to run press the button with the yellow running man at the top of the screen. It will ask you for participant ID and session number. Enter the same participant number (ID) as the other tasks and the session remains 1. If for any reason the task is aborted early label get consecutive session (2,3,4,…..).
- Once you have entered the session number Tobii will 'look for their eyes'. Make sure the white circles are in the centre of the box in the middle. Make sure the bar at the bottom is green and says 'both'. Press the space bar when both of these are true, you may have to press it again, then the calibration starts. Remind the child to follow the dot on the screen with only their eyes without moving their head just like before with the alien.
- Only accept the calibration if the lines stay within the circle. If not press cancel and start the whole procedure again.
- Once accepted a series of instruction screens will appear. Move through them with using any key on the keyboard. Read out each instruction and talk though each screen with the child.
- Tell the child that there are three aliens that tobii is going to show them and each alien will be doing two things. Their job is to tell me what the alien is doing. 'open',

‘shut’ for the eye-opening alien, ‘plant’, ‘no plant’ for the plant alien and ‘wrong way’, ‘right way’ for the upside down alien.

- Once you press the keyboard on seeing the ‘lets practice’ screen the practice trials will start. Remind them the alien will only appear once the faces have disappeared and that when they see the cross they should look straight at it and the quicker they do this the more points they will get.
- The trial will only start once the child looks at the fixation cross. If the trial doesn’t move on and the child is obviously looking at the fixation cross explain the computer has got confused, ask the child to look at you and then back to the screen, sit back in the seat or sit forward.
- There are 6 practice trials – 2 for each alien. The experimenter should press the appropriate mouse key depending on the child’s response.
    - “Open eye” = left mouse
    - “Shut” = right mouse
    - “Plant” = left mouse
    - “No plant” = right mouse
    - “Wrong way” = left mouse
    - “Right way” = right mouse
- At the end of each practice trials there is a feedback screen telling you if they are accurate or not. Once they have finished there is a ‘let’s go for real screen’. The task is not about their accuracy with the alien so if they keep getting it wrong it is not a problem to continue, however if they want to practice again this is fine. Abort the procedure and start the session again with session label 2.
- Now open the eye-tracking exps Eprime program called “eye-trackingready-short”. Again to run the program click on the yellow running man at the top of the screen, enter participant ID and session. This program should start with a calibration and then there should be a calibration after each break. You can warn them at the beginning that every now and again Tobii will want to check he can still see their eyes and show them the ball/dot. There are 6 blocks in this program, 1 alien per block, so the child will see each alien twice. In the break you can always play the game of ‘guess which alien tobii is going to show us next?’ For the calibration tell

them for tobii to see her will first look for their eye and then tobii will show them a dot that he will move around the screen. Tobii wants them to follow the dot again so they should follow the dot around the screen again with their eyes.Tobii will tell the children which alien they will be playing with.

- Then the calibration starts, only accept if the lines are within the circles.
- Once you accept the trials will start. Record the child's verbal responses to the alien in the same way as above:
  - "Open eye" = left mouse
  - "Shut" = right mouse
  - "Plant" = left mouse
  - "No plant" = right mouse
  - "Wrong way" = left mouse
  - "Right way" = right mouse
- The end of each break is controlled by the experimenter using the space bar of the keyboard.
- After each break there is a calibration so be sure to remind them to follow the dot around the screen before pressing any key to continue.
- Each new block will introduce which alien set you will be playing with. Be sure to talk through them and practice what they should say.
- Once they are complete congratulate the child. Let them choose another sticker for their progress chart. Have a break before doing the next task – could leave the room for a little bit – they could colour the progress chart – play with toys or read a page of a book.

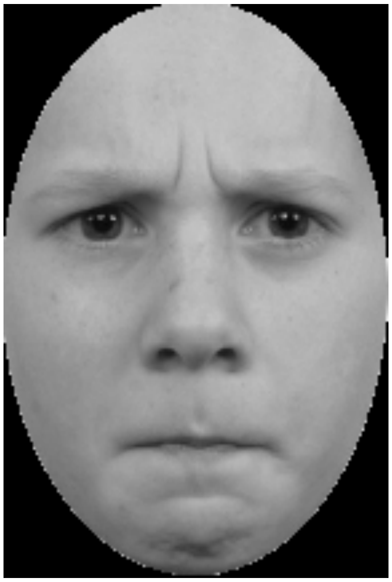
Data from eye-tracking tasks:

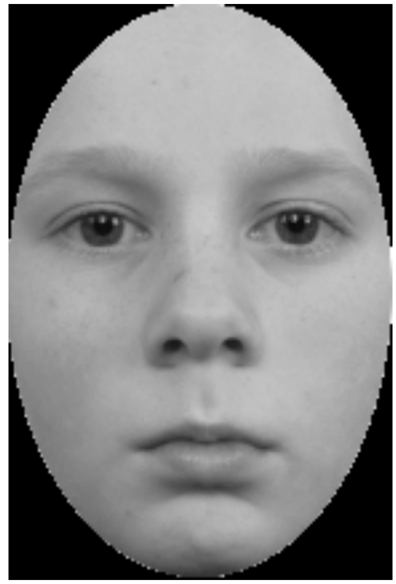
- The data will appear in the same folder as the Eprime programs for the tasks. Make sure that all the data for each participant is moved into the participant data folder and copied into the back up folder before continuing. There is one set of these per task.
- There should be three documents per task, each will have the participant's id and session number at the end:

  - Edata file
  - Save gaze data file
  - Text file
- Before the next participant is run the area of the folder where the program itself sits should be free of data files.

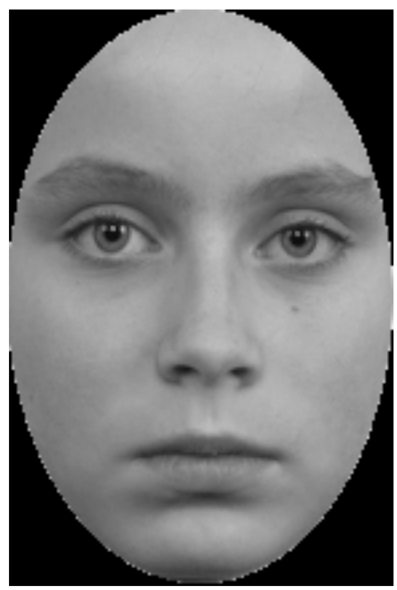
7.14. Appendix 14: Examples of Faces Used in the Attention Bias Task

Angry/Neutral counterparts

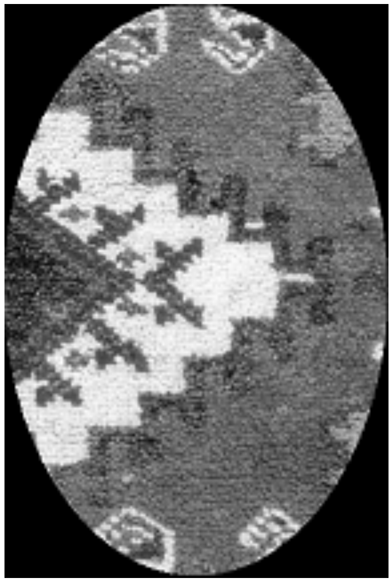




Happy/Neutral counterparts



7.15. Appendix 15: Example of IAPS Images used in the Attention Bias Task



7.16. Appendix 16: Examples of Aliens used in the Attention Bias Task

Alien Holding a plant/not holding a plant

7.17. Appendix 17: Full Mixed ANCOVA Table from Paper 4

Table 3.

Results of the Mixed ANCOVA's for Mean Proportions of Trials where the Initial look was to the Emotional Face

	df	F	η_p^2	p
Anxiety Differences				
Anxiety	1	.002	0	.968
Emotion type	1	.002	0	.966
Autistic Quotient	1	1.56	.02	.215
Anxiety x Emotion type	1	.001	0	.999
Moderation by Age				
Anxiety	1	1.01	.05	.325
Emotion type	1	.032	.002	.859
Autistic Quotient	1	2.5	.11	.128
Age	40	1.72	.77	.091
Anxiety x Emotion type	1	1.59	.07	.221
Anxiety x Age	10	.35	.14	.956
Emotion type x Age	40	1.79	.77	.078
Anxiety x Age x Emotion type	10	.20	.09	.993
Moderation by Effortful Control				
Anxiety	1	.57	.05	.467
Emotion type	1	2.04	.17	.183
Autistic Quotient	1	1.43	.13	.259
Effortful Control	76	1.66	.93	.194
Anxiety x Emotion type	1	.39	.04	.546
Anxiety x Effortful Control	7	.40	.22	.885
Emotion type x Effortful Control	76	.95	.88	.590
Anxiety x Effortful Control x Emotion type	7	1.62	.53	.236

Note. While Interactions with autistic quotient were included there are not in the table for brevity.

Table 4.

Results of the Mixed ANCOVA's for Mean Proportions of Time Spent Looking at Faces during Initial Looks

	df	F	η_p^2	p
Anxiety Differences				
Anxiety	1	.09	.001	.768
Emotion type	1	1.85	0	.966
Face Type	1	2.03	.03	.158
Autistic Quotient	1	.74	.01	.394
Anxiety x Emotion type	1	.19	.003	.668
Anxiety x Face type	1	.03	0	.873
Emotion type x Face type	1	1.16	.02	.285
Moderation by Age				
Anxiety	1	1.32	.06	.262
Emotion type	1	13.45	.39	.001***
Face type	1	.95	.04	.341
Autistic Quotient	1	.001	.986	.001
Age	40	2.77	.84	.007**
Anxiety x Emotion type	1	.95	.04	.341
Anxiety x Age	10	.66	.24	.746
Anxiety x Face type	1	.21	.01	.655
Emotion type x Age	40	1.65	.78	.341
Emotion type x Face type				
Age x Face type	40	2.64	.83	.01**
Anxiety x Age x Emotion type	10	2.06	.50	.078
Anxiety x Age x Face type	10	.40	.16	.933
Age x Emotion type x Face type	40	2.10	.80	.039*

Anxiety x Age x Emotion type x Face type	10	.57	.21	.822
Moderation by Effortful Control				
Anxiety	1	.39	.06	.558
Emotion type	1	.89	.13	.382
Face type	1	6.22	.51	.047*
Autistic Quotient	1	2.47	.29	.172
Effortful control	59	2.27	.96	.151
Anxiety x Emotion type	1	.04	.006	.857
Anxiety x Effortful control	6	1.18	.54	.151
Anxiety x Face type	1	.53	.08	.493
Emotion type x Effortful control	59	2.22	.96	.158
Emotion type x Face type	1	2.08	.26	.199
Effortful control x Face type	59	1.27	.93	.417
Anxiety x Effortful control x Emotion type	6	4.10	.80	.055
Anxiety x Effortful control x Face type	6	.60	.37	.728
Effortful control x Emotion type x Face type	59	3.37	.97	.064
Anxiety x Face type x Emotion type	1	.44	.07	532
Anxiety x Effortful control x Emotion type x Face type	6	1.99	.67	.211

Note. While Interactions with autistic quotient were included there are not in the table for brevity.

7.18. Appendix 18: Social Worries Questionnaire as used in Paper 1

Social Worries Anxiety Index for Young Children

Date: Child's name: Child's sex:

Child's age: School year: School Name:

Name of Parent completing the form:

Please put a circle around the rating which best describes the young person over the past 6 months. Please circle the 0 if the item is not true of him/her. Circle the number 1 if the item is sometimes true. If the item is mostly true of him/her then circle the number 2. If you don't feel the item applies to the experiences of your child please circle n/a. Please answer all items.

	Not True	Sometimes true	Very True	Not applicable
Avoids or gets worried about going to parties or play-dates	0	1	2	n/a
Avoids or gets worries about using or speaking on the telephone	0	1	2	n/a
Avoids or gets worried about meeting new people	0	1	2	n/a
Avoids or gets worried about presenting work to the class/ about putting their hand up or speaking infront of the class (show & tell)	0	1	2	n/a
Avoids or gets worried about attending groups, clubs or after school activities	0	1	2	n/a
Avoids or gets worried about approaching groups of kids to ask to join in/play	0	1	2	n/a

Avoids or gets worried about talking in front of a group of adults	0	1	2	n/a
Avoids or gets worried about going into a shop alone or to buy something or telling staff in a café what they would like to eat/drink	0	1	2	n/a
Avoids or gets worried about standing up for him/herself with other kids i.e. when someone takes their toy	0	1	2	n/a
Avoids or gets worried about entering a room full of people	0	1	2	n/a