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Article

Anxiety related Attention bias in Four to Eight-year-olds: An Eye-tracking Study

Suzannah Stuijfzand[1], Bobby Stuijfzand[2], Shirley Reynolds[1] and Helen Dodd[1,*]

[1] School of Psychology and Clinical Language Sciences, University of Reading, UK; suzannah.ravenscroft@chuv.ch
[2] Stuijfzand Data Consulting; bobby@stuijfzand-data.com
* Correspondence: h.f.dodd@reading.ac.uk

Abstract: (1) Background: There is robust evidence of an attention bias-anxiety relationship in children, but lack of appropriate methods has limited the number of studies with children younger than 8 years old. This study used eye-tracking as a measure of overt attention in young children. The aim of this study was to assess anxiety related attention bias in children aged 4 to 8 years. Age was considered as a moderator and the influence of effortful control was investigated. (2) Method: A community sample of 104 children were shown pairs of happy-neutral and angry-neutral faces. Growth curve analyses were used to examine patterns of gaze over time. (3) Results: Analyses revealed moderation by age and anxiety, with distinct patterns of anxiety-related biases seen in different age groups in the angry-neutral face trials. Effortful control did not account for age related effects. (4) Conclusions: Results support a moderation model of the development of anxiety in children.

Keywords: Anxiety; Child; Attention bias; Eye-tracking; Gaze; Development.

1. Introduction

Anxiety is one of the most prevalent mental health disorders in children and adolescents. Clinical anxiety affects an estimated 6.5% of children and adolescents worldwide at any one time [1] and it is estimated that before age twenty-one, 23.5% of youths have suffered from a clinically significant anxiety problem [2]. Given this, it is crucial to understand the mechanisms that cause and maintain anxiety in childhood.

Cognitive models of anxiety suggest that there are particular cognitive biases that predispose, cause and/or maintain anxiety (see [3] for an overview of these models). Attention, interpretation and memory biases are theorised to result from over-active threat-related schemas that guide the processing of incoming stimuli [4]. Cognitive models suggest that after an initial assessment for threat, anxious individuals have an attention bias whereby attention is disproportionately allocated to threat [3]. Two meta-analyses have found evidence of an anxiety related attention bias to threat in adults [5], and children [5,6], though the size of the relationship appears to be smaller in children than in adolescents and adults [6].

While there appears to be evidence for an anxiety-related attention bias in children, the nature of the bias is not clear. There is evidence of attentional vigilance, with anxious children showing a greater attention bias *towards* threat than non-anxious children e.g. [7-9]. However, there is also evidence that anxious children display an attention bias away from threat [10,11].

The vigilance avoidance hypothesis suggests that anxious individuals may show an initial vigilance towards threat, followed by avoidance of threat e.g. [12,13]. This may explain some of the inconsistency in findings if different studies evaluate attention bias at different points following stimulus onset [12]. Evidence for a vigilance avoidance pattern has been found in adults when the time course of attention was investigated [14,15] and in children with separation anxiety disorder [16].

A complicating factor in understanding the relationship between attention bias and anxiety in children is that the changing nature of children's abilities over time may influence the presence or magnitude of an attention bias-anxiety relationship. Field and Lester [17] suggested three models to describe how development in children may affect the attention bias-anxiety relationship. The 'integral' model sees attention 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). Finally, the 'acquisition' model proposes that the emergence of attention biases in children depends 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 Field and Lester's [17] review supported a moderation model. This model is further supported by the moderation by age effect found by Dudeney et al [6], where the bias-anxiety association was stronger in adolescents than children.

While some studies have found an influence of age on the presence or nature of the relationship between attention bias and anxiety [18,19], 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 [6] meta-analysis was 11.98 years old and only one study with children below age 8 was included. The authors highlighted the lack of studies with young children. This means that while moderation by age was found, this cannot be reliably extrapolated to children under 8 years. Thus, it is unclear if there is a relationship between attention bias and anxiety in young children. This is important for at least two reasons. First, from a theoretical perspective, to distinguish between the models described by Field and Lester [17] we need to know whether an attention bias is present in early childhood, and if it is related to anxiety. Secondly, from a treatment perspective attention bias modification (ABM) procedures e.g.[20,21] target attention biases to reduce anxiety. Understanding if an anxiety related attention bias exists in younger children and the nature of this bias will indicate whether the assumptions behind these approaches are appropriate, and if such approaches are appropriate for children experiencing elevated anxiety symptoms.

One theory of attention suggests that while vigilance to threat may be a result of saliency filters driven by bottom up reflex responses, the effortful withdrawal of attention or avoidance of threat may be depend upon voluntary top down control [22]. A review of the evidence suggests that attention bias depends on both bottom up and top down processing [23], at least in adults. Attention control is a top down process that has been proposed to influence attention biases [24]. Attention control is the ability to focus and shift attention and it develops across childhood [25]. It therefore follows that the avoidance of threat, which is likely driven by more voluntary control processes, may be particularly sensitive to developmental stage [21]. Indeed developmental differences in the avoidance component to threat have been found [21]. Regardless of anxiety, adults (18 years +) showed avoidance to social threat pictures, but adolescents (8 to 17 years old) did not show the same avoidance. No such differences were found for vigilance.

This is somewhat in line with the inhibition hypothesis, which argues 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 [26]. Kindt and colleagues [26] argue that all infants have a bias towards threat but as children's top down control of attention develops with age, most children become able to inhibit this attention bias. The bias therefore only remains for children with poor inhibition and this sustained attention to threat increases their anxiety. Evidence for this effect has been found [27] but not consistently [28]. Inhibition and attention control are both components of effortful control, defined as the ability to inhibit a dominant response to perform a subdominant response, to detect errors, and to engage in planning [25] Effortful control emerges in infancy [25] and shows considerable development between the ages of 4 and 8 [29,30]. Thus, when considering the relationship between attention bias and anxiety in younger children, i.e. under 8 years, their developing skills such as effortful control, which encompasses both inhibition and attention, should be taken into account.

One likely reason for the paucity of studies examining the relationship between attention bias and anxiety in younger children is that the main experimental methods used to assess attention bias are not suitable for younger children. The most commonly used tasks for assessing attention bias are the dot probe task and the emotional stroop task (see [3]) for a detailed description of these tasks). These tasks require participants to understand, remember and follow verbal instructions and maintain their concentration during the experiment. The measures of attentional bias rely on reaction time, and the tasks are sensitive to distraction, delay and motivation. These features call into question the appropriateness of such tasks for use with young children [31,32]. Beyond their appropriateness for children, both tasks have other significant limitations. For example, the dot probe task only provides a single measure of attention and cannot capture shifts or changes in attention over time. It has also been argued that processes other than attentional bias may drive differences on the emotional stroop task [33]; for example, anxious individuals may display behavioural freezing in the presence of threat, which operates independently of an attention bias [34].

In contrast to reaction time tasks, eye-tracking provides a continuous measure of overt visual attention. Eye-tracking can be used during a free viewing paradigm which simply requires children to look at images on a screen. The use of eye tracking therefore significantly reduces reliance on language and other cognitive abilities relative to traditional reaction time tasks [35]. Eye-tracking tasks have demonstrated attention biases to negative stimuli in children aged 4 to 10 [36,37], as well as differences in attention biases between adults and children. For example, in an eye-tracking study negativity bias was found to decrease with age [37]. Furthermore, eye-tracking tasks have shown differences between anxious and non-anxious children in their attention towards angry faces, vigilance avoidance patterns in anxious children [16] and avoidance of emotional faces in anxious young children [36]. Studies such as these show the potential of eye-tracking methodology to assess attention processes in children. However, only one of these studies included children 4 years and under [36] and none examined the influence of age or developmental factors such as effortful control on attention bias. Furthermore, none of these studies used data analysis techniques that could take full advantage of the continuous nature of eye-tracking data, such as growth curve analysis (GCA; [38]). GCA allows assessment of individual differences in the time course of visual attention to emotional stimuli, for example in [39,40].

This paper aims to establish if children aged 4 to 8 years show an anxiety related attention bias to emotional stimuli. It uses an eye-tracking task designed for children in which pairs of happy-neutral and angry-neutral faces are presented. Following the meta-analysis of Dudeney et al. [6] and evidence from recent eye-tracking studies, we hypothesised that all children will show an initial vigilance to emotional faces and this will be stronger for angry faces than happy faces. We further hypothesised that participants with higher levels of anxiety will show increased vigilance for angry faces followed by avoidance, relative to participants with lower levels of anxiety. Finally, we hypothesised that these anxiety-related effects would be moderated by age such that anxiety-related avoidance would be stronger in older than younger children. As theory and previous research suggest that effortful control may be a relevant developmental factor in the relationship between attention bias and anxiety it was investigated whether any age-related effects remained after controlling for effortful control. Following criticisms of previous tasks assessing attention bias in children, the influence of verbal and nonverbal cognitive abilities on task performance are also investigated.

2. Materials and Methods

2.1. Participants

Participants were recruited via magazine advertisements, newsletters, local newspapers, posters in public places and leaflets handed out by local schools and at children's groups. Parents of 351 children answered online screening questionnaires regarding their child's anxiety using the Preschool Anxiety Scale (PAS; [41]) or the Spence Children's Anxiety Scale (SCAS; [42]) depending on age (see below). Children identified by parents as having a diagnosis of Autism Spectrum disorder, Attention Deficit Hyperactivity Disorder, or as having a Learning Disability were not invited to participate because these conditions have a propensity for anxiety and/or particular cognitive processing difficulties that could influence findings (n = 8). Children identified as having high anxiety

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(>1 SD above the normed mean as reported on https://www.scaswebsite.com) or low anxiety (below the normed mean as reported on https://www.scaswebsite.com) were invited to participate.

One hundred and thirteen children were invited and completed the experimental tasks (65 males, M_{age} = 6.06, SD_{age} = 1.16, age range 4.08 to 8.83 years olds). Following data cleaning (see below), data from 104 children (62 males, M_{age} = 6.02, SD_{age} = 1.15, age range 4 to 8 years) were used in analysis. The final sample included 65 children with high anxiety and 39 children with low anxiety. The majority of parents were female (98.2%), identified their children's ethnicity as being British (90%; 3% European; 3% Mixed (Arabic and white British); 3% Australian)[1] and identified themselves as the primary caregiver (91%).

2.2. Measures: Parents

Parents completed measures of anxiety, effortful control and autistic traits.

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

Both anxiety measures yield a total score of general anxiety symptoms. On both measures, higher scores indicate higher anxiety.

Parents of 4 to 6-year-olds completed the PAS, a 28-item questionnaire answered on a five point likert scale. The measure has strong psychometric properties aligned with DSM-IV diagnoses and good construct validity [41]. In this study the total score of the PAS had excellent internal consistency (α = .93).

Parents of the 7 and 8-year-old group answered the parallel measure, the SCAS, a 38 item questionnaire. The SCAS has shown good psychometric properties [41,42] and in this study had excellent internal consistency (α = .94).

2.2.2. Child Behaviour Questionnaire – Effortful Control Scale (CBQ-EFC; [43])

Following Eisenberg et al [44], the Effortful Control Scale was formed from five subscales from the Children's Behaviour Questionnaire (CBQ; [43]): low intensity pleasure, inhibitory control, perceptual sensitivity, attentional control and attention shifting. The CBQ assesses individual differences in attentional self-regulation as a basic dimension of temperament. Parents answered 52 items. Higher scores indicate more effortful control. Internal reliability in this study was excellent for the total Effortful Control scale (α = .88).

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

Given the high correlation between anxiety and autistic traits, the AQ: Child was used to assess autism symptoms. The AQ: Child is a 50 item parent report measure of autistic traits with good psychometric properties [45]. Parents were asked to rate each item indicating to what extent they agree or disagree with the statements about their child. The higher the score the more autistic-like traits the child shows. In this study the full scale showed good internal consistency (α = .83).

2.3. Measures: Children

2.3.1. 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 aged 2 years 6 months to 7 years 7 months. The WPPSI is a highly reliable and valid measure of child general intelligence [46]. The individual scales, rather than the full test, of the WPPSI have been previously used for research purposes (e.g. [47]). In this study children completed the verbal comprehension subscale as an assessment of verbal abilities and block design subscale as an assessment of non-verbal abilities. 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 [48]. Age equivalence was used as a metric of verbal

[1] One hundred ethnicity information was only available for 39 children. However, we can assume ethnicity reported in this subsample to be reasonably representative of the entire sample given that the study took place in Berkshire, where the population is around 80% White and the remaining 20% represents a range of ethnicities (Office of National Statistics, 2012).

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and non-verbal cognitive abilities. To facilitate comparison between participants we chose to use the WPPSI-IV with the entire sample, despite some being aged above 7 years 7 months. Eight participants were aged above 7 years 7 months and scored at the highest age equivalence. This means that their scores may be slightly underestimated.

2.3.2. Attention bias task

Stimuli. Children were presented with a series of pictures of faces and objects displayed on a computer screen. Faces of children displaying anger, happiness and 'neutral' mood were selected from the Radboud standardised set [49]. Six models, (three male) were used, each presenting each emotion, thus resulting in a set of 24 faces. 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; [50]), matched on ratings of arousal, were also grey-scaled for use. Average luminosity across faces and objects was equal.

Cartoon pictures of aliens were designed for the task. Three pairs of aliens were produced that differed in one characteristic per pair. Average luminosity was equal across the alien images. The body of the alien was consistent across the aliens and only the eyes were present so no facial expression, and therefore emotion, could be interpreted from the alien's facial features.

Design. The task comprised of a practice block and six experimental blocks. The practice block consisted of six trials. Each experimental block included 12 trials followed by a self-timed break. A 5 point eye-tracking calibration was conducted before the practice block and before each experimental block.

Each practice trial started with the presentation of a fixation cross. Initial presentation time of the cross was jittered (randomly selected) between 50 and 100ms and then the cross remained on the screen until children had fixated upon it for 100ms. Next two faces or non-emotional images appeared to the right and left of the fixation cross. These images were presented for between 1500ms and 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. Participants were asked categorise the alien verbally, for example, whether the alien was holding a plant or not. This task design meant that the faces were not relevant to the child's task. Once the aliens had been displayed for 1000ms a blank screen appeared until the child's verbal response to the alien was recorded. Once the experimenter recorded the response with a mouse click, feedback appeared on screen for 1000ms. Feedback written on screen informed the children either "You're right" and a green tick or "Ooops" with a red cross. The aliens were included to engage the children and keep them actively attending to the task. No data is analysed for the section of the trials when the alien was on screen.

The experimental blocks of 72 trials involved presenting 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 except no feedback was given. Trial type was randomised within experimental blocks. One of the three alien pairs was randomly assigned to each experimental block and the alien presented on each trial was randomised. Face pairs were randomised such that the same number of emotion-neutral and neutral-neutral pairings were seen in each experimental block and that the actors were seen the same number of times over the task.

2.4. Procedure

Study procedures were approved by the University of Reading Ethics Committee (ref: 2014-025-HD). Participants attended a research session on campus during which the eye-tracking (attention bias) task and questionnaires outlined above were completed. During the same session participants also completed an interpretation bias task, the findings of which are reported separately for clarity and due to space limitations [51]. In addition, during the session we collected the following data, which we have no plans to publish: maternal anxiety; interpretation of ambiguous scenarios (for 7 and 8 year olds only).

When families arrived for the session parents provided informed consent for their child and verbal assent was obtained from the child. Parents completed the parent-report questionnaire measures while the child completed the experimental tasks. Generally, children completed the eye-tracking task,

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the WPPSI subtasks and then the interpretation bias task. On completion of all the tasks the parent was given a debrief sheet and £5 towards travel expenses. All children received a certificate, stickers and a token prize for their co-operation and time.

For the eye-tracking task children were introduced to the eye-tracking computer, the 5 point eye-tracking calibration was conducted and the practice block introduced. Children were told they would first see a cross, then some faces or pictures of objects would appear on the screen, and then an alien would appear at the top or bottom of the screen. Children were told that once the alien appeared, they should say if the alien was, for example, upside down or the right way up. Once the practice block was completed the first experimental block was introduced. Children were informed when they were half way through the experimental blocks and their willingness to continue was checked. Once the child had completed all six experimental blocks or refused to continue, the task ended.

2.5. Recording and Pre-processing of Eye-tracking data

Eye-tracking data was recorded using a Tobii T60, stimuli were presented via E-prime version 2.0 [52], and data was recorded through Tobii extension for Eprime [53]. 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 (4.5o) from the centre of the screen, with the inner edge of the image being 2o from the centre of the screen and the image subtended a visual angle of 4.9o. The cartoon alien images were 7.0o above and below the centre of the screen, with the inner edge being 3.5o from the centre of the screen and the alien images subtended a visual angle of 7.7o. Images were therefore placed within parafoveal vision of the children.

Eye-tracking data was pre-processed using Matlab version R2014b [54], R version 3.4.1(R Core Team, 2017) and R studio version .98.1103 [55] using gdata [56]. To assess whether eye-tracking data was valid, first, observation plots were checked to confirm that calibration was successful at the block, and if necessary, the trial level. Any trial or complete block that showed a systematic shift in eye tracking coordinates indicating poor calibration was removed from the dataset. Next, for a trial to be valid, 5 consecutive samples out of the 10 observations (160ms) before the onset of the faces/images had to be within 2° of the centre. This indicated that the child was looking at the centre when the faces/objects appeared on screen. Any trials deemed “not valid” by this phase were excluded.

To prepare the data for GCA, data deemed valid by the previous checks was passed through the pre-processing functions of R package EyetrackingR [57]. This package assessed whether the eye-tracker had registered the participant’s gaze per eye-tracking sample, if it had not, the sample was deemed invalid. If a trial contained 40% or more invalid observations it was excluded. Analyses was carried out using R packages eyetrackingR [57] and lme4 [58], as well as ggplot [59], matrix [60] and tidyverse [61].

2.6 Statistical Analysis

Initially we examined differences between children with high and low anxiety on potential confounding variables e.g. autistic quotient or gender. Any variables that showed as a potential confound and were not already in the analysis plan were included in further analyses. To evaluate the research hypotheses, two approaches were taken. First, conventional repeated ANOVA’s were conducted on summary statistics derived from the eye-tracking data following pre-processing. Next GCA was used to capitalise on the continuous nature of eye-tracking data and to build upon the summary statistic results. The details of each approach are provided within the relevant section of results below and further details can be found in the Technical Supplement.

3. Results

3.1 Differences between High and Low Anxious Groups

There were no age differences between children with high and low anxiety (high anxious group: $M = 6.04$, $SD = 1.15$; low anxious group $M = 5.99$, $SD = 1.22$; $t(80) = 0.172$ $p = .863$) or gender ($X^2(1) = 0.096$ $p = .76$). High and low anxiety groups were found to differ on autistic quotient score where, on average, the high anxious group ($M = 63.27$, $SD = 16.97$) showed more autistic traits than the low anxious group ($M = 54.62$, $SD = 15.38$) with a large effect size ($t(99) = 4.43$, $p < .0001$, $d = .89$). Autistic quotient scores were therefore included in further analyses as a covariate. Groups also differed on total effortful control score (*Mann Whitney U* = 1603.5, *p* = .02), where the high anxious group (*M* = 4.38, *SD* = 1.14), had lower scores than the low anxious group (*M* = 4.91, *SD* = .68). Effortful control was not used as a covariate because the effect of effortful control was already included in the planned analysis. There were no differences between anxiety groups on non-verbal cognitive abilities (high anxious group: *M* = 5.56, *SD* = 1.30; low anxious group: *M* = 5.56, *SD* = 1.30) or verbal cognitive abilities (high anxious group: *M* = 5.73, *SD* = 1.25; low anxious group: *M* = 5.93, *SD* = 1.32).

3.2 Repeated Measures Analysis

Two dependent variables (DV) were calculated for each child for use as summary statistics in mixed ANCOVAs. 'Initial vigilance' was calculated as the proportion of trials in which each child looked at the emotional face before the neutral face. 'Length of first look' was calculated as the average length of the first look at a face, as a proportion of the total time the child looked at faces across the trial. Three mixed ANCOVA's were run on each DV. The first examined anxiety differences and included one within participant factor (emotion; happy/angry), one between participant factor (anxiety group; high/low) and autistic quotient scores were entered as a covariate. The second examined age as a moderator, thus added age as a between participant factor to the first model. The main effects and interactions with age were included in this second model. The third ANCOVA examined the influence of effortful control on the age-related effects, thus effortful control was added as a between participant factors to the moderation model. For brevity, only results pertaining to the research questions will be described, although full results can be found in Appendix A Table A1.

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

Table 1 shows the average proportion of trials where the initial look was to the emotional face in the angry and happy trials by anxiety groups. The means in Table 1 suggest that children initially looked at the emotional face in around 60% of trials. This was significantly more often than chance (50%) for angry faces ($t(101)=3.92$, $p < .001$, $d = .78$) and for happy faces ($t(99)= 6.32$, $p < .001$, $d = 1.27$), suggesting that children were vigilant to both emotional faces. The mixed ANCOVA assessing anxiety differences revealed there were no differences between happy or angry trials on this DV and, importantly, no differences between children with high or low anxiety, and, no significant two-way interaction between emotion type and anxiety group (all p's > .2 for main effects and interactions). There were also no significant interactions between child anxiety and age or main effect of anxiety in the moderation by age model (all p's > .09 for main effects and interactions). Nor was there a main effect of effortful control when it was added to the moderation by age model in the third ANCOVA. Results from the ANCOVAs therefore 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 when controlling for autistic traits.

Table 1. Summary statistics of initial looks to the faces by anxiety group.

	Mean Proportions (SD)		
	Total	**High Anxious Group (n=65)**	**Low Anxious Group (n=39)**
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)

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

Table 1 also shows the average proportion of time anxious and low anxious children spent looking at each happy, angry or neutral face. Mixed ANCOVA analysis investigating anxiety differences showed no main effects of emotion type, face type or anxiety level and no significant interactions between emotion type and anxiety grouping. In the moderation by age analysis there were main effects of age ($F(40) = 2.77$, $p = .007$, $\eta_p^2 = .84$) and emotion type ($F(40) = 13.45$, $p = .001$, $\eta_p^2 = .39$). Furthermore, there was a significant interaction between age, face type and emotion type ($F(40) = 2.64$, $p = .01$, $\eta_p^2 = .83$). To 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 for the younger children ($F(1) = 4.45$, $p = .04$, $\eta_p^2 = .09$). The interaction indicated that, relative to happy trials, young children looked for a smaller proportion of time at the emotional face on angry trials ($M = .36$, $SD = .18$) and for a greater proportion of time at the neutral face ($M = .16$, $SD = .16$) (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 avoided the angry face by looking at it for less time before moving attention away. However, this pattern of attention was not affected by anxiety levels. In the final ANCOVA model adding effortful control to the moderation by age model did not substantially alter the results and the main effect of effortful control was not significant (See Appendix A Table A2 for full results).

3.3. Growth Curve Analyses: Initial Looks to Faces

3.3.1. Data Preparation

Growth curve analysis was conducted on eye-tracking data recorded while the faces were on screen (up to 2000ms) using data from the first look to the first face. Analysis was carried out following the procedures of Mirman et al. [38] as well as examples from Byrow, Chen and Peters [39] and Schofield, Inhoff, and Coles [62]. The dependent variable was bias in the proportion of time spent looking at an emotional face (proportion of observations per time bin on the emotional face minus the proportion of observations per time bin on the neutral face). Further details regarding data preparation and statistical analysis can be found in the Technical Supplement.

GCA was used to investigate whether there were differences between children with high and low levels of anxiety in the time course of their gaze patterns. Random intercepts and slopes were modelled. Four models were created to investigate the hypotheses. The first (Model 1) investigated whether there were anxiety-related differences in initial looks to the faces using bias scores by emotion type (happy or angry). Fixed effects of group (high and low anxious children; between subjects' variable), emotion type and time variables, and their interactions were entered in Model 1. Model 2 investigated moderation effects of age thus the main effects of age and interaction with age were entered alongside Model 1 predictors. Model 3 investigated whether the age-related effects remained after controlling for effortful control by adding effortful control to Model 2. Finally, in Model 4 cognitive and linguistic abilities were entered as main effects to Model 1. Autistic quotient was added as a predictor into all models as a covariate.

After pre-processing and preparation for analysis, 27177 samples from 104 children were included in the analysis. Given the number of models, model parameters and number of significant parameters found, focus is given here to results that pertain to the hypothesed main effects of emotion type, differences in the time course of visual attention influenced by anxiety (interactions with anxiety), moderation by age (interactions between age and anxiety) and the influence of effortful control (main effect), verbal and non-verbal cognitive abilities (main effects). For brevity, only significant main effects

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and interactions described above will be fully reported. The time course of bias scores by emotion type can be seen in Figure 1.

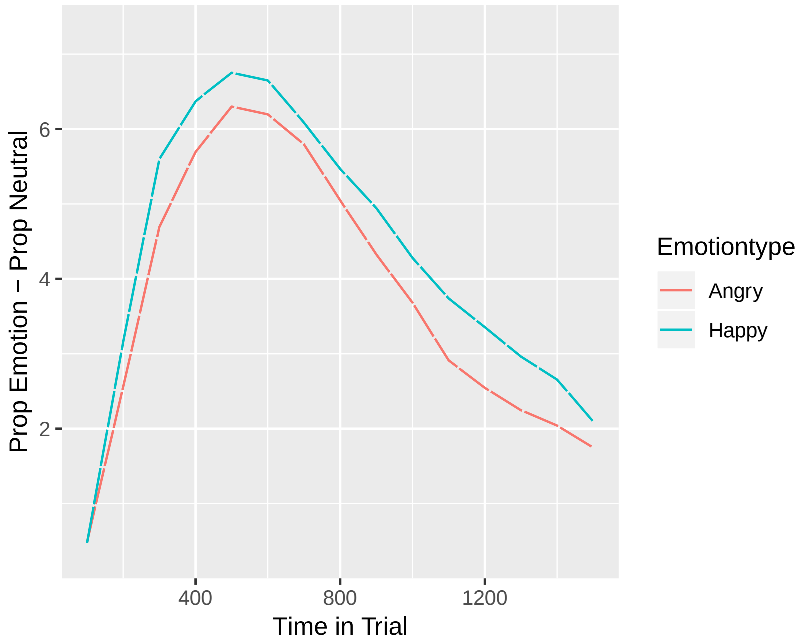

Figure 1. Time course of bias to emotional faces averaged over trials, split by emotion type. Standard errors in proportion of looking to AOIs can be seen as shaded areas surrounding the lines denoting emotion type.

3.3.2. Model 1: Influence of Anxiety level on Attention bias

The time course of bias scores by emotion and anxiety can be seen in Figure 2. The main effect of emotion indicates that on average children were more likely to look initially to an emotional face than a neutral face (b = -.07, SE = .02 t = -5.55, p <.001). There were also main effects linear time (b = -.87, SE = .06, t = -14.78, p < .001) and quadratic time (b = -.80, SE = .05, t = -14.76, p < .001) indicating that looking behaviour to faces changed over time. No other main effect or interactions were significant. However, the interaction between emotion, anxiety and linear time was close to significance (b = -.23, SE = .13, t = -1.82, p = .069). This result, in conjunction with Figure 2 are suggestive of a steeper decline over the trial in bias in the angry trials relative to the happy trials for the high anxious group only.

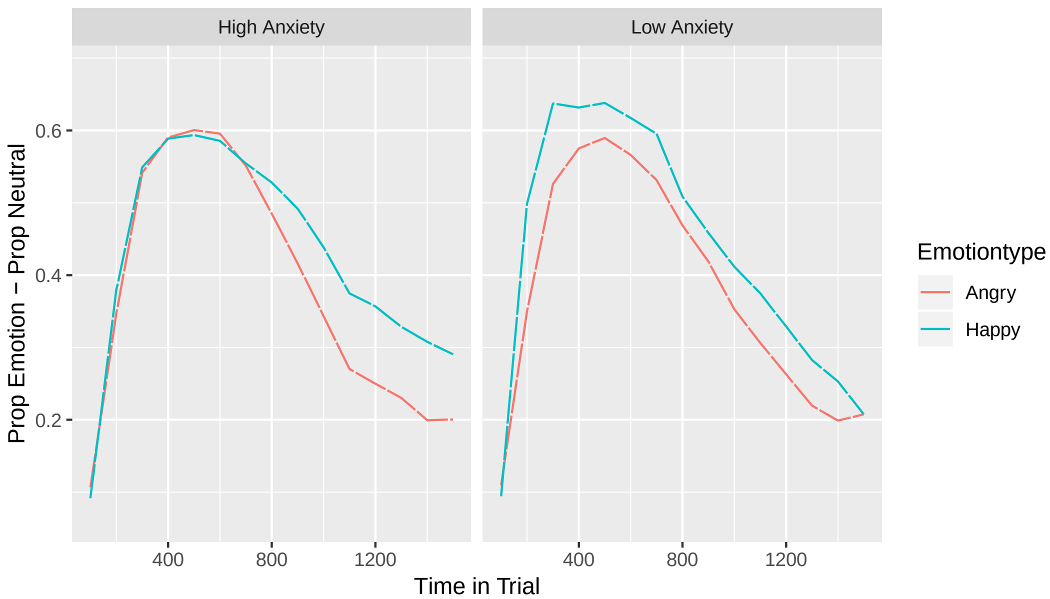

Figure 2. Time course of bias to looking at emotional face as the first face viewed averaged over trials, split by emotion type, and anxiety grouping. Standard errors in proportion of looking to AOIs can be seen as shaded areas surrounding the lines denoting anxiety groups.

3.3.3. Model 2: Moderation of the relationship between anxiety and attention bias by Age

Compared to the model assessing differences in gaze between anxious and low anxious children, adding age improved the model fit (χ^2 (20) = 58.35, $p < .05$) and explained some residual variance (3.13%).

There was one significant three-way interaction between emotion type, anxiety and age (b = .08 SE = .02 t = 3.48, $p < .001$). No other interactions reached significance. However, a number of other interactions approached significance: the three-way interaction between emotion type, anxiety and linear time (b = -.22 SE = .13 t = -1.77, p = .078); emotion type, age and quadratic time (b = .11, SE = .06 t = 1.88, p = .06); emotion type, anxiety, age and linear (b = .18 SE = .11 t = 1.66, p = .098), and quadratic time (b = .19 SE = .12 t = 1.65, p = .099). These are relevant given that including age significantly improved the model. These results in combination with Figure 3, which visualises the four-way interaction, suggest that if there are any age-related anxiety effects they are being driven by the younger children in the high anxious group. For all other groups the decline in bias between the emotions from the beginning to end of the trial runs relatively parallel, but for the younger anxious group the decline in bias across the trial appears to be steeper in the angry trials compared to the happy trial. This difference likely underpins the significant emotion, anxiety and age interaction, as young, high anxious children how a difference in gaze to angry relative to happy that is not seen in other groups. Figure 3 also suggests that older children in the high anxious group show the reverse pattern to all other groups in initial bias: older children in the high anxious group show a larger initial bias to the *angry* face then the happy face, all other groups show a larger initial bias to looking at the *happy* face than the angry face.

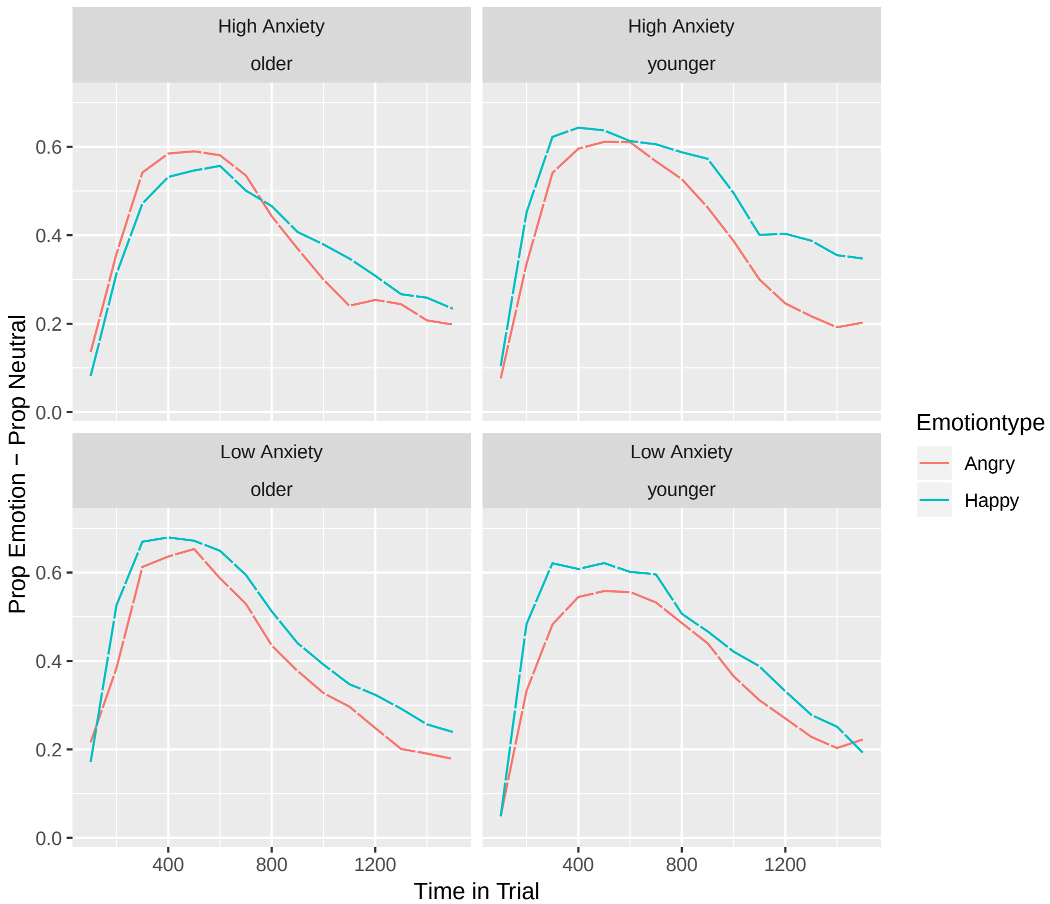

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Figure 3. Time Course of bias to looking at emotional face as the first face viewed averaged over trials, split by emotion type, age and anxiety grouping. Standard errors in proportion of looking to AOI's can be seen as shaded areas surrounding the lines denoting anxiety groups.

3.3.3. Model 3: Do age effects remain when controlling for Effortful Control?

Model fit was improved relative to Model 2 ($\chi^2(32) = 58.13$, $p < .05$) and explained some variance on the subject level (7.23%). Despite this, there were no main effects of effortful control and the results were very consistent with those for model 2 (see above). suggesting that when the common variance between age and effortful control was removed from the model, age effects remain. Thus, age effects cannot be accounted for by effortful control.

3.3.4. Model 4: Influence of Verbal and Non-Verbal Cognitive abilities on initial looks to faces

The results were similar to those found in examining anxiety differences (see Model 1). Model fit was not improved over Model 1 ($\chi^2(20) = .89$, $p > .05$) and explained a small amount of variance on the level of the subject (1.35%). There were no main effects of verbal or non-verbal cognitive abilities suggesting they were not influencing initial looking behaviour to the faces.

4. Discussion

Some support was found in this study for the hypothesis that all children would show an initial vigilance to emotional faces. Results from conventional analyses (t-tests and ANCOVAs) indicated that children were vigilant to both emotional faces in terms of first looks. Support for this hypothesis can also be seen in the growth curve (GCA) models where there is a clear steep rise in proportion of looking to emotional faces relative to neutral faces within the first 500ms of trials. However, neither the conventional nor the GCA analyses indicated there were differences between the emotions thus no support was found for the hypothesis that initial vigilance would be stronger for angry faces than happy faces.

We further hypothesised that participants with higher levels of anxiety would show increased vigilance for angry faces followed by avoidance, relative to participants with lower levels of anxiety. Neither the results from the conventional analyses nor the GCA models suggested differences in vigilance between anxiety groups. Though it should be noted that the results of the moderation by age analysis hinted towards the older children in the high anxious group having a larger initial bias to angry faces than happy, which was not observed in any other groups. However, there was some evidence for anxiety differences in avoidance. The interaction between anxiety group, emotion and linear time suggested that for young children in the low anxious group the decrease in first looks to the angry face was steeper than to the happy face, though it should be noted that this interaction did not quite reach significance. Thus, any moderation by age effects are likely driven by the young children in the high anxious group, where younger children in the high anxious group may be avoiding the angry face relative to the happy face in a way that older and less anxious children do not. This is in fact the reverse of our final hypothesis where we stated that anxiety-related effects would be moderated by age such that anxiety-related avoidance would be stronger in older than younger children.

As theory and previous research suggest that effortful control may be a relevant developmental factor in the relationship between attention bias and anxiety it was investigated whether any age-related effects remained after controlling for effortful control. Adding effortful control did improve model fit over the moderation by age model and explained some variance on the subject level. However, the results of the moderation by age model remained unchanged when effortful control was added as a main effect and effortful control was not a significant predictor. These results indicate that age-related effects suggested by the moderation by age model were not driven by common variance shared with effortful control.

There was no evidence of any influence of verbal and nonverbal cognitive abilities on task performance. Neither model fit indices showed improvement over the model investigating anxiety differences nor were verbal and nonverbal cognitive abilities significant predictors of bias scores. This is important to note as previous tasks used with young children have been criticised as performance

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on these tasks was dependent on verbal and non-verbal cognitive abilities. Our results suggest that such criticisms would not apply to this task and that the task was appropriate to the developmental level of the sample in terms of verbal and non-verbal cognitive abilities.

4.1. Differences between children with high and low anxiety symptoms

Unlike the adult literature, there was little evidence of threat related anxiety differences in visual attention. The vigilance for emotional faces over neutral faces regardless of anxiety levels is consistent with both previous research on attention bias in young children [36] and the broader developmental literature on children's attention to emotional faces and the salience of emotional faces over neutral faces e.g. [63-65]. Though these two literatures are not often linked when considering the development of anxiety it is important that our results are consistent with developmental work showing that all young children have a bias towards emotional faces. Within other studies of attention bias and its relationship to anxiety in older children (+8 years) a bias towards emotional stimuli (angry and happy) over neutral across anxiety groups has been found e.g. [66-68]. However, these studies have also found that this bias is stronger in more anxious children. This could indicate that a general vigilance is present early in childhood but anxiety-related vigilance only emerges when children get older. It seems plausible that vigilance remains in children who remain anxious but that non-anxious children stop being vigilant for threat as they get older. This would be in keeping with the moderation model of Field and Lester [17]as well as the Inhibition Hypothesis [26].

4.2. Anxiety effects moderated by Age

It was expected that anxiety-related attention biases would be moderated by age where the avoidance component would be stronger in older children. There was no evidence to support this hypothesis and some indication that the opposite relation may exist, with younger children driving any moderation effects of age. Although it didn't reach significance there was an indication that high anxious young children were more avoidant of angry faces, relative to happy and to other groups. This is contrary to what would be expected from theories of attention where withdrawal of attention or avoidance is thought to be dependent on top down control [22]. As top down processes, such as attention control, develop across childhood [25] it was suggested that older children would have more top down control, and hence show more avoidance, than younger children. Given this, perhaps the pattern of results is driven by a relatively automatic withdrawal of attention over time; young high anxious children may have a reflexive reaction to threat which moves their attention away from the threat once detected. This is very speculative, in particular given that this effect was not hypothesised, so replication of the effect is important here.

We had anticipated moderation by age following previous work that found differences in anxiety related attention bias by age [18,19] as well as a recent meta-analysis of the anxiety-bias relationship [6]. However, the present sample is younger than the age groups in any previous research examining moderation effects of age, which may explain why this effect was not supported. In addition, the differences in results may be due to different methodologies (free viewing versus dot probe tasks) or differences in the nature of the sample (clinical vs. community).

4.3. Influence by Verbal and Non-Verbal Cognitive Abilities

Verbal and non-verbal cognitive abilities were not significant predictors of the time course of visual attention indicating that the task was not dependent on these abilities. It should be acknowledged that it is unlikely that the task is entirely independent of these abilities, but that these factors are unlikely to be driving performance and influencing anxiety-related results. Previous tasks used to assess attention biases in children, i.e. the dot probe, have been criticised for their complex instructions and reliance on developing abilities. By avoiding the use of reaction times 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.

4.4. Implications for Treatment

We found little evidence for an anxiety-linked attention bias for threat in young children. This suggests that Attention Bias Modification (ABM) approaches to changing bias used with older children and adults e.g. [69,70] are unlikely to be appropriate in early childhood. Given that participants were recruited from the community, it remains possible that an anxiety-linked bias would be observed in clinically diagnosed young children. This seems unlikely given that Dodd and colleagues [36] did not find an anxiety-linked bias in their sample of diagnosed 3 and 4 year olds, but replication with a clinical sample would be beneficial.

4.5. 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 neglected by the literature until now. This adds to the growing body of evidence using eye-tracking to assess attention bias in children. One of the strengths of the study is the use of GCA. Using this technique allowed for a fine-grained analysis of overt attention to emotional stimuli that reaction time data and conventional assessment of eye-tracking data cannot provide. The GCA revealed particular patterns that were not apparent in the conventional analyses, such as the withdrawal of attention from faces in young, high anxious children.

A further strength is the consideration of developmental factors that may influence task performance and moderate the associations of interest. We demonstrated that task performance was relatively unaffected by children's verbal and non-verbal cognitive abilities. In addition, the results suggest that development (age) may influence the anxiety-attention bias relationship. Until now, it has been rare for the impact of 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 relevant for the attention bias anxiety relationship [17].

There are limitations concerning the sample. As participants were recruited via adverts, the sample is self-selecting and the study focused on recruitment in Berkshire, an area predominantly made up of white British families [71], which is reflected in our sample. Both these factors limit the generalisability of the results. After experiencing problems recruiting very low anxious children, we adjusted the eligibility criteria for the low anxious group to those with anxiety scores below the normed mean. This resulted in a smaller difference in anxiety between groups than originally intended. As discussed above, it may be that future studies using a sample made up of clinically anxious children versus healthy controls may find stronger effects of anxiety. Furthermore, the absence of significant findings, but close to significance findings may be due to a lack of power of the study. While the sample was powered to look at anxiety effects, models also included random effects, random slopes and a lot of interactions with time which would have limited the power of the study to detect significant multi-way interactions. Future studies with children aged 4 to 8 years with greater power should be conducted to confirm the nature of anxiety related biases.

A further limitation is that the influence of development was assessed within a cross-sectional design. To really understand the role of development, as well as the role of cognitive biases in the development of anxiety, longitudinal work is required. To get a clearer picture of the nature of bias and how or if this changes over time, eye-tracking methods analysed with growth curve models would be employed over different developmental time points. In this study a Tobi60 eyetracker was used to collect data. However, eyetrackers with a much higher sampling rate are now available, and suitable for use with children; that may also allow greater precision in mapping the time course in visual attention and elucidating differences.

The lack of results concerning the influence of effortful control may also be due to the measure of effortful control being a parent questionnaire rather than a direct performance based measure. Effortful control reflects a set of skills that children use to control their behaviour, however, the parent measure reflects parents' perception of a particular set of behaviours derived from observations in order to infer children's effortful control abilities. Performance based measures of attention control and inhibition may provide a more direct measure of effortful control. For example the anti-saccade task [72,73] could be adapted for a young age group and used to assess the influence of effortful control on the relationship between attention bias and anxiety in young children. In this study only the influence of effortful control on moderation by age effects were assessed, however, ideally effortful control would have been assessed as a moderator. As the measure was restricted to a parent report moderation was not assessed, however should a performance based measure be used moderation by effortful control could be investigated. Future research may also look at other potential moderators including social and emotional factors, not considered here, which may explain changes with age. For example, previous research has considered the impact of attachment style on the relationship between social anxiety and attentional biases [39]. Socioemotional factors such as emotion regulation or facial emotion recognition may also be important [17].

5. Conclusions

This study used a novel, child-friendly eye-tracking task to assess if there is evidence of an anxiety related attention bias to threat in children aged 4 to 8. There was little evidence of anxiety differences in initial looks to faces; all children showed vigilance for emotional faces over neutral face. Analysis of moderation by age revealed nuanced differences in visual attention to faces between anxiety groups across age. Specifically, there was some indication of more pronounced differences between anxiety groups in the younger children. Results are broadly consistent with a moderation model. Future studies should extend this work to a clinical sample and use a longitudinal design to capture the nature of role of developmental factors in the anxiety-attention bias relationship in young children.

Supplementary Materials: The following are available online at www.mdpi.com/xxx/s1, Technical Supplement.

Author Contributions: Conceptualization, S.S., H.D., and S.R.; methodology, S.S. and H.D.; formal analysis, S.S., B.S., H.D.; data curation, S.S.; writing—original draft preparation, S.S.; investigation, S.S., resources, S.S., Software, S.S., validation, S.S. and B.S., writing—review and editing, H.D. and S.R.; visualization, S.S. and B.S..; supervision, H.D. and S.R.; project administration, S.S.; funding acquisition, S.S., H.D. and S.R. All authors have read and agreed to the published version of the manuscript.

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Appendix A

Table A1. 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
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
Influence by Effortful Control				
Anxiety	**1**	**.49**	**.002**	**.829**
Emotion type	**1**	**2.04**	**.17**	**.183**
Autistic Quotient	**1**	**1.85**	**.16**	**.160**
Effortful Control	**1**	**3.15**	**.14**	**.091**
Age	**40**	**1.85**	**.79**	**.071**
Anxiety x Emotion type	**1**	**1.46**	**.07**	**.241**
Anxiety x Age	**10**	**.54**	**.21**	**.845**
Emotion type x Age	**40**	**1.70**	**.77**	**.101**
Anxiety x Age x Emotion type	**10**	**.20**	**.09**	**.994**

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

Table A2. 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
Influence by Effortful Control				
Anxiety	1	1.35	.06	.257
Emotion type	1	2.36	.10	.139

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Face type	1	.04	.002	.840
Autistic Quotient	1	1.40	.06	.250
Effortful control	1	1.79	.08	.194
Age	41	2.26	.81	.022*
Anxiety x Emotion type	1	.68	.03	.419
Anxiety x Age	11	1.08	.35	.421
Anxiety x Face type	1	.16	.01	.695
Emotion type x Age	41	2.68	.83	.008*
Emotion type x Face type	1	1.33	.06	.260
Age x Face type	41	1.94	.78	.049*
Anxiety x Age x Emotion type	11	1.36	.41	.259
Anxiety x Age x Face type	11	.58	.22	.828
Anxiety x Emotion type x Face type	1	.64	.03	.431
Age x Emotion type x Face type	41	.95	.64	.566
Anxiety x Age x Emotion type x Face type	11	.16	.07	.998

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