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Attentional Bias towards Threatening *and* Neutral Facial Expressions in High Trait Anxious Children.

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200 Word Summary

Research suggests that anxious children display an increased attentional bias for threat-related stimuli. However, this research has typically been conducted in the spatial domain utilising visual probe methodology and findings here are equivocal. Moreover, few studies have allowed for the independent analysis of trials containing neutral (i.e., potentially ambiguous) faces. Here we report two temporal attentional blink experiments with high trait anxious (HTA) and low trait anxious (LTA) 8- to 11-year-old children. In the emotive experiment, we manipulated the valence of the second target (T2: a threatening, positive or neutral schematic face). Results revealed that: i) HTA, relative to LTA, children demonstrated more accurate performance on neutral trials; and ii) HTA children demonstrated a threat-superiority effect whereas LTA children demonstrated an emotion-superiority effect. In the non-emotive control experiment, where geometric shapes served as the T2, no differences between HTA and LTA children were observed. Results suggest that trait anxiety is associated with an attentional bias for threat in HTA children. Additionally, the neutral face finding suggests that HTA children, as compared to LTA children, bias attention towards ambiguity. These findings could have important implications for current anxiety disorder research and treatments.

150 Word Abstract

Research suggests anxious children display increased attentional biases for threat-related stimuli. However, findings based upon spatial domain research are equivocal. Moreover, few studies allow for the independent analysis of trials containing neutral (i.e., potentially ambiguous) faces. Here, we report two temporal attentional blink experiments with high trait anxious (HTA) and low trait anxious (LTA) children. In an emotive experiment, we manipulated the valence of the second target (T2: threatening/positive/neutral). Results revealed that HTA, relative to LTA, children demonstrated better performance on neutral trials. Additionally, HTA children demonstrated a threat-superiority effect whereas LTA children demonstrated an emotion-superiority effect. In a non-emotive control, no differences between HTA and LTA children were observed. Results suggest trait anxiety is associated with an attentional bias for threat in children. Additionally, the neutral face finding suggests HTA children bias attention towards ambiguity. These findings could have important implications for current anxiety disorder research and treatments.

Keywords: trait anxiety, children, attentional bias, ambiguity, threat, neutral faces, interpretation bias

Attentional Bias towards Threatening *and* Neutral Facial Expressions in High Trait Anxious Children.

Childhood-onset anxiety disorders are prevalent, debilitating conditions that have been linked to low academic performance (Asendorpf, Denissen, & van Aken, 2008; Kessler, Foster, Saunders, & Stang, 1995) and impaired social competence (Asendorpf et al., 2008; Spence, Donovan, & Brechman-Toussaint, 1999). They also pose significant risk factors for other affective and behavioural disorders (e.g., depression: Hayward, Killen, Kraemer, & Taylor, 2000; Lewinsohn, Holm-Denoma, Small, Seeley, & Joiner, 2008; eating disorders and substance disorders: Merikangas, Avenevoli, Dierker, & Grillon, 1999). It has been demonstrated that symptoms relating to anxiety follow a stable course from early life through to adolescence and adulthood (see Weems, 2008 for a review). Accordingly, researchers are increasingly attempting to understand the factors that play a role in the development and maintenance of anxiety over time. One such factor is trait anxiety, a relatively stable characteristic that, if high, predisposes an individual to respond anxiously to threatening objects and situations (Spielberger, 1972). According to Barlow (2002), higher trait anxiety is an important predisposition for the development of clinical anxiety. In the adult literature, it is now well established that higher levels of state and trait (i.e., non-clinical) anxiety, as well as clinical anxiety, are associated with an attentional bias for threat-related stimuli (e.g., see Barry, Vervliet, & Hermans, 2015; Cisler & Koster, 2010 for reviews).

A growing body of research involving child populations also appears to demonstrate anxiety-related biases of attention for threatening, relative to non-threatening, sources of information in both clinically anxious and non-clinically anxious children (e.g., see Schechner et al., 2012 for a review). To date, the vast majority of these past studies have focused on the spatial domain of attention utilising the visual probe paradigm (Staugaard, 2010). For example, it has been found that both clinically and non-clinically anxious children respond more rapidly to probes replacing threatening, compared with positive or neutral pictures and words, thus indicating an attentional bias towards threat (e.g., Hunt, Keogh, & French, 2007; Telzer et al., 2008; Waters, Wharton, Zimmer-Gembeck, & Craske, 2008). However, some research has also provided evidence of an attentional bias *away* from threat in a non-clinical sample of children with high levels of social anxiety (Stirling, Eley, & Clark, 2006) and those diagnosed with an anxiety disorder (e.g., Monk et al., 2008). Furthermore, recent child visual probe studies have shown that the direction of attentional bias is moderated by the type and severity of the anxiety disorder (e.g., Salum et al., 2013; Waters, Bradley, & Mogg, 2014). Additional studies utilising Stroop methodology have also provided conflicting findings. Here, some demonstrate interference effects of threat in both clinically (e.g., Taghavi, Dalgleish, Moradi, Neshat-Doost, & Yule, 2003) and non-clinically (e.g., Richards, French, Nash, Hadwin, & Donnelly, 2007) anxious children, whereas others demonstrate no interference effects in clinically (e.g., Dalgleish et al., 2003) and non-clinically anxious children (e.g., Hadwin, Donnelly, Richards, French, & Patel, 2009). Indeed, it has been argued that any effects observed in the emotional Stroop task may reflect later-stage cognitive processes that are unrelated to attention (Algom, Chajut, & Lev, 2004; de Ruiter & Brosschot, 1994; MacLeod, Mathews, & Tata, 1986).

More recently, a number of studies have begun to examine attentional bias for threat in the temporal domain (i.e., over time) utilising rapid serial visual presentation (RSVP; Potter & Levy, 1969). Here, either one or two target stimuli are embedded within a stream of task-irrelevant distracter stimuli presented in rapid succession. In versions of this paradigm utilising the latter method, two target stimuli, when the two target stimuli are presented in close temporal proximity (e.g., within 200-500ms), the accuracy with which participants are able to report the second target (T2) is typically impaired, a phenomenon termed the attentional blink (AB). It is postulated that the AB is caused by focusing attentional resources (e.g., attentional selection, working memory encoding, episodic registration and response selection) completely on the first target (T1), thus rendering resources temporarily unavailable for processing the T2 within this short time frame (Dux & Marois, 2009). However, when the T2 is emotionally salient, particularly threatening, it has been found that the AB effect is reduced; that is, participants are able to report the T2 picture or word with greater accuracy as it "breaks through" the blink (e.g., Bach, Schmidt-Daffy, & Dolan, 2014; Maratos, Mogg, & Bradley, 2008; Srivastava & Srinivasan, 2010; Yerys et al., 2013). In a second version of this paradigm (the emotional attentional blink paradigm), the emotionality of one or more task-irrelevant distracter stimuli is manipulated, rather than the target or targets. This, conversely, decreases accuracy in the reporting of the T2 goal-directed target (Arnell et al., 2004; Most et al., 2005). McHugo, Olatunji, and Zald (2013) suggest that these two paradigms differ with respect to the attentional mechanisms involved. Studies utilising emotional distracters demonstrate that an emotional item, which participants have *not* been instructed to respond to, impedes the detection of subsequent target items. This effect is argued to be due to the "automatic capture" of attention by emotional items. In contrast, studies utilising the standard AB paradigm demonstrate that emotional items, which participants *have* been instructed to attend to, receive prioritised processing in situations of limited attentional resources. That is, emotional T2 stimuli "break through" the typical blink period. A key distinction, therefore, is that the emotional attentional blink paradigm reflects automatic attentional capture, whereas the standard AB task with emotional T2 stimuli reflects preferential goal-directed processing under conditions of limited attentional resources. Consequently, the standard AB paradigm allows for the investigation of theorised heightened biases towards threatening information within goal-directed attention.

To date, a small number of studies utilising the standard AB paradigm have demonstrated that the attenuation of the AB effect is particularly pronounced for those with high levels of anxiety when the T2 target is threatening (e.g., Fox, Russo, & Georgiou, 2005; Trippe, Hewig, Heydel, Hecht, & Miltner, 2007). This research supports theory and cognitive/neurobiological models suggesting that *temporal*, as well as spatial, biases for threat are innate phenomena associated with automatic orientation and increased sensitivity to this stimulus type in high anxious individuals (Beck & Clark, 1997; Mogg & Bradley, 1998; Öhman, 2005). However, no study appears to have investigated this attentional bias for threat in anxious versus non-anxious children utilising the AB task, which is necessary if one is to argue that such rapid processing biases are innate (i.e., arguably present from birth), or at the very least contribute to the development of anxiety-related disorders from childhood onwards.

In addition, of the few AB studies that have included facial rather than word stimuli, only two appear to have investigated responses to neutral faces (Maratos, 2011; Maratos et al., 2008) and anxiety was not investigated here. This is notwithstanding: (a) the fact that neutral faces are more ambiguous in regards to emotional state than other facial expressions (Ekman & Friesen, 1976; Tottenham et al., 2013; Yoon & Zinbarg, 2008); and (b) the proposal that high trait anxiety can lead to ambiguous stimuli being perceived as threatening and consequently being attended to (Mogg & Bradley, 1998). Furthermore, cognitive models relating to anxiety and interpretation bias postulate that anxious individuals are more likely to interpret information that they are uncertain about as dangerous (e.g., Beck, Emery, & Greenberg, 1985; Muris & Field, 2008). Consistent with this are the findings of Yoon and Zinbarg (2008). Here, an incidental learning paradigm was used in which participants implicitly learned to associate different target locations with either positive (i.e., happy) or negative (i.e., angry and disgusted) faces. Following this, when neutral facial stimuli were introduced, high socially anxious adults responded more rapidly to neutral face targets appearing in locations previously associated with negative, relative to positive, face cues. This suggests that socially anxious individuals display an increased tendency to interpret neutral faces as threatening (see also Lee, Kang, Park, Kim, & An, 2008).

More recently, Tottenham et al. (2013) have investigated interpretation of ambiguous faces across childhood. They noted that across childhood, but especially in the younger children sampled (i.e., 6-9 years), neutral faces were significantly more likely to be associated with negative ("felt bad") rather than positive ("felt good") appraisals. In addition, neutral faces were also associated with corrugator activity, a reflexive response that indicates negative appraisals. Thus, Tottenham et al. conclude that early in life, interpretation of ambiguous stimuli such as neutral faces is predominantly negative. It is therefore surprising that few studies have investigated attentional bias for neutral faces in anxious children; especially given the inherent ambiguity of such faces and their subsequent potential for negative interpretation. One explanation for this lack of research is that the methods used in the spatial domain do not allow for the independent analysis of trials containing neutral stimuli. That is, across such paradigms (e.g., visual search, visual probe) where neutral, positive and negative faces have been used, neutral faces are typically included as the control stimulus. For instance, in visual probe studies, neutral faces are paired with either threatening *or* positive faces to establish threat/positivity biases, rather than as a level of the independent variable in their own right. Adding to this, in a recent meta-analysis of anxiety toward threat in children, a requirement of all included studies was that, "The study explored attentional bias to threat by comparing responses to threat-related stimuli with responses to neutral stimuli" (Dudeney, Sharpe, & Hunt, 2015, p. 68). In a substantial number of the studies therein, this entailed "neutral" faces serving as the comparison/control stimuli.

Accordingly, the purpose of the present study was to investigate the role of temporal attentional bias in high and low trait anxious children towards stimuli that are: (a) emotive, and in particular, threatening; and (b) neutral (and therefore potentially ambiguous). To this end, we used a modified version of the standard schematic AB task (Maratos, 2011; Maratos et al., 2008) in which emotive (angry and happy) and neutral faces served as target stimuli. We included schematic facial stimuli rather than photographs of real-life faces to avoid potential methodological confounds of low-level perceptual features, familiarity and individual variability (see Fox et al., 2000; Öhman, Lundqvist, & Esteves, 2001). Furthermore, emotive schematic faces may be more suitable for use with children since they are argued to offer a clear representation of the key features of emotional expressions (Juth, Lundqvist, Karlsson, & Öhman, 2005; Maratos, Garner, Hogan, & Karl, 2015). Our participant sample consisted of 8- to 11-year-old primary school children. The lower age bracket was incorporated since it has been found that only those children aged 8 years and above can successfully discriminate facial stimuli presented every 100ms (Croker & Maratos, 2011) – a rate that is comparable to adolescents and adults. The upper age bracket was used to ensure children were recruited from the same environment (i.e. school), as it has been found that older children / pre-adolescents experience more complex cognitive worries (Muris, Merckelbach, Gadet, & Moulaert, 2000; Schaefer, Watkins, & Burnham, 2003) that relate to characteristic features of their environment (Stevenson, Batten, & Cherner, 1992). An example would be the major transition and associated changes from primary (≤11 years) to secondary (≥11 years) school.

We hypothesised that high trait anxious children would demonstrate an attentional bias for threatening stimuli (i.e., threat-superiority), resulting in the AB phenomenon being reduced when an angry, rather than a neutral or positive, face appeared as the T2. Moreover, if attentional bias associated with trait anxiety is also moderated by stimulus ambiguity, we further hypothesised that high, relative to low, trait anxious children would demonstrate a reduction of the AB phenomenon when the T2 was neutral, given its potential for negative interpretation (i.e., for high trait anxious children, the T2 neutral face would also result in greater attentional prioritisation).

Experiment 1: The Attentional Blink, Anxiety and Facial Expressions

Method

In this section we report how we determined our sample size, all data exclusions, all manipulations and all measures in the study.

Participants.

A total of 183 children (90 female, 93 male) aged 8 to 11 years (*M* age = 9.61 years, *SD* = .93) were recruited from a primary school in the United Kingdom to take part in an initial pre-selection process. This involved completing the trait anxiety subscale of the State-Trait Anxiety Inventory for Children (STAIC-T; Spielberger, 1973) and the short version of the Children's Depression Inventory (CDI:S; Kovacs, 1992). Responses to the STAIC-T questionnaire were used to assign participants to groups of high and low levels of trait anxiety via the tertile split method; further data from children in the middle tertile were not collected. We utilised this pre-selection strategy given it is higher trait anxiety that is an important predisposition for the development of clinical anxiety, and examining trait anxiety as a continuous predictor variable would have considerably increased sample size and school commitment. In addition, participants who obtained a score of 65 or above on the CDI:S were deemed to have high levels of non-clinical depression and were excluded. These participants were removed since research suggests that attentional allocation differs as a function of specific affective disorder (e.g., Mogg & Bradley, 2005). This resulted in a final sample of 53 children (24 female, 29 male) aged 8 to 11 years (*M* age = 9.49 years, *SD* = .89) who participated in the AB task. This sample size is comparable to much research involving anxious and non-anxious populations (for a recent study, see Reinholdt-Dunne, Mogg, Vangkilde, Bradley, & Hoff Esbjørn, 2015). All children had normal or corrected-to-normal vision, spoke English as their first language, and were free from developmental disorders and learning disabilities, as reported by the teaching staff. Ethical approval was obtained from the local University Research Ethics Committee.

Stimuli.

Four schematic faces were incorporated as target stimuli in the experiment: an angry face, a happy face, and two neutral faces (N1 and N2). These were the same faces as used by Maratos and colleagues (Maratos, 2011; Maratos et al., 2008). Each of the facial stimuli differed with respect to the form of three key features: the eyebrows, eyes and mouth (e.g., when comparing the angry and positive faces, the eyebrows, eyes and mouth were inverted; when comparing the two neutral faces, one included straight eyebrows whilst the other included curved eyebrows, as well as a thicker line for the mouth). Thirty different distracter stimuli that comprised two key facial features in random positions and orientations were also included. These were similar to the scrambled face distracters used in previous research involving adults (e.g., Maratos, 2011; Maratos et al., 2008), with the exception that they had been simplified (by the removal of two facial features) to control for task difficulty following piloting. Other AB studies employing face stimuli have also included scrambled images as the distracters (e.g., Asplund, Fougnie, Zughni, Martin, & Marois, 2014; Bach, Schmidt-Daffy, & Dolan, 2014). Stimulus presentation was controlled with Inquisit™ (www.millisecond.com) utilising an Acer Aspire laptop (model number: AS5633QLMi) with a 15.4-inch screen. The screen had a resolution of 98 pixels per inch (PPI) and was set at a 60Hz refresh rate.

Procedure.

Children completed the state anxiety subscale of the State-Trait Anxiety Inventory for Children (STAIC-S; Spielberger, 1975) before undertaking the specific AB task. In the AB task (Figure 1a), trials contained a rapidly presented sequence (i.e., RSVP) of 20 stimuli comprising two target stimuli and 18 distracters. At the beginning of each trial, a small circle was presented for 134ms at the central fixation point. After this, the stimulus presentation events were as follows: an initial random sequence of distracters (either five or eight consecutive stimuli), the T1, a further random sequence of distracters (one, two, three or six consecutive stimuli), the T2, and then the remaining random distracter stimuli (ranging from four to twelve consecutive stimuli). This resulted in the T2 being presented at Lag 2 (268ms), Lag 3 (402ms), Lag 4 (536ms) and Lag 7 (938ms), depending on the number of distracter stimuli displayed between the T1 and T2. Note that Lags 2 and 3 were within the typical blink time frame, Lag 4 was within the recovery period and Lag 7 was outside of the blink time frame (e.g., Raymond, Shapiro, & Arnell, 1992; Reeves & Sperling, 1986). Also, at least one distracter stimulus was included between the T1 and T2 targets as evidence suggests that different mechanisms are responsible for performance when there are no distracter stimuli between the two targets (this is called "Lag-1 sparing"; see for example Chun & Potter, 1995; Hommel & Akyürek, 2005).

Of importance, for each trial, the T1 was always a neutral face (either N1 or N2), and the T2 was an angry, happy or neutral face. This resulted in three trial types dependent upon the emotive expression displayed as the T2: **Threat Trials** (Neutral T1–Angry T2); **Positive Trials** (Neutral T1–Happy T2); and **Neutral Trials** (Neutral T1–Neutral T2). The T1 was always different to the T2; so if the T1 was N1, the T2 was N2 and vice versa. All stimuli were presented for 134ms with no inter-stimulus interval (ISI), which is in accordance with previous research demonstrating that children aged 8 and above can reliably discriminate stimuli presented at this rate (Croker & Maratos, 2011).

The participants' task was to indicate which face or faces they had seen among the distracters. To provide a response, they were required to match the viewed face to an identical image on a Cedrus® RB-830 response pad. To indicate the emotional expression of the *first* or only face viewed, participants were asked to press an angry, happy or neutral face button on the *left* side of the pad. To indicate the emotional expression of the *last* face viewed, they were asked to press an angry, happy or neutral face button on the *right* side of the pad. In the case of neutral face responses, as there was only one button representing the first face viewed and only one button representing the second face viewed, an image of N1 was printed on the actual buttons and an image of N2 below the buttons (see Figure 1b.). After making their response/s, participants were required to press a blue button in order to proceed to the next trial. Participants were also required to press the blue button if they had not seen any faces. The AB task included a total of 120 test trials split into two blocks of 60. There were 10 trials for each of the 12 conditions resulting from the factorial combination of lag (2, 3, 4, or 7) by trial type (threat, positive or neutral). One block of 10 practice trials was also presented at the beginning of the task. The experimenter took this opportunity to monitor participants' responses and provide feedback in order to ensure that participants understood the task. Note that two (20%) single target trials were incorporated in the practice block to ensure that participants would not assume that test trials included double target trials only. This design also allowed experimental length to be kept to a minimum. On single target trials, the target was presented at serial position 8, 10, 12 or 16; that is, the same positions that the T2 appeared in for each lag in the test trials. Trial presentation was fully randomised throughout the entire task.

(Figure 1 about here)

Data screening.

One participant's dataset was removed due to poor accuracy in identifying both targets (i.e., below two SDs of the sample mean). This resulted in a final participant sample of 52 children (24 female, 28 male; *M* age = 9.5 years, *SD* = .90). These were 26 high trait anxious (HTA) (16 female, 10 male; *M* age = 9.58 years, *SD* = .81; *M* trait score = 45.12, *SD* = 3.02) and 26 low trait anxious (LTA) (8 female, 18 male; *M* age = 9.42 years, *SD* = .99; *M* trait score = 23.96, *SD* = 3.45) children. An independent measures t-test demonstrated that the HTA group had significantly higher trait anxiety scores than the LTA group, $t(50) = -23.52$, $p < .001$.

Results

A correct response consisted of accurately identifying both the T1 neutral face presented ***and*** the T2 face presented in chronological order (i.e., T1 = neutral; T2 = angry, happy or neutral) in the RSVP stream. The mean percentage of correct responses was 51%, comprised of 55% (*SD* = 25%) for HTA and 47% (*SD* = 19%) for LTA children (chance level = 11%). Table 1 shows the mean percentage of correct responses as a function of lag (2, 3, 4, 7) and trial type (threat, positive, neutral) for both HTA and LTA participants.

A mixed analysis of variance (ANOVA) with Lag (2, 3, 4, 7) and Trial Type (threat, positive, neutral) as the within-participants variables and Trait Anxiety (high versus low) as the between-participants variable revealed that there were main effects for both lag, $F(3, 150) = 4.31$, $p = .006$, $\eta_p^2 = .08$, and trial type, $F(1.64, 82.30) = 37.20$, $p < .001$, $\eta_p^2 = .43$, but not trait anxiety, $F(1, 50) = 1.69$, $p = .200$, $\eta_p^2 = .03$. There was, however, a significant interaction between trait anxiety and trial type, $F(1.73, 86.30) = 4.99$, $p = .012$, $\eta_p^2 = .09$ (see Figure 2). All further interactions were not significant ($p > .30$ in all cases).

(Table 1 about here)

(Figure 2 about here)

To clarify the interaction between trait anxiety and trial type, an independent t-test of the percentage of correct responses, with Trait Anxiety (high versus low) as the independent variable, was undertaken separately for each trial type. This revealed one significant group difference: HTA children performed better than LTA children on neutral trials, $t(44.92) = -2.23$, $p = .031$, $d = .62$. To investigate the significant anxiety by trial type interaction within participants, two repeated measures ANOVAs of the percentage of correct responses with Trial Type (threat, positive, neutral) as the independent variable were undertaken separately for the HTA and LTA children. Results revealed that there were significant main effects of trial type for both HTA children, $F(2, 50) = 9.10$, $p < .001$, $\eta_p^2 = .27$, and LTA children, $F(1.68, 42.97) = 31.33$, $p < .001$, $\eta_p^2 = .56$. For the HTA children, pair-wise Bonferroni corrected comparisons revealed more accurate performance on threat trials than on neutral trials (p = .002, d = .57), but not positive compared with neutral trials (p = .121). Additionally, there was marginally better performance on threat trials relative to positive trials (p = .069, d = .28). LTA children, however, performed better on both threat and positive trials compared with neutral trials (p < .001 in both cases, d = 1.15 and d = 1.14 respectively), although there were no differences in performance between threat and positive trials (p = .978). For the main effect of lag, pair-wise Bonferroni corrected comparisons revealed a typical AB effect. That is, participants performed worse on trials at Lag 2 compared with Lag 7 (p = .012, d = .21).

A further control analysis with Lag (2, 3, 4, 7) and Trial Type (threat, positive, neutral) as the within-participants variables and *state* anxiety (high versus low) as the between-participants variable revealed no effects.

Error data analysis.

An error consisted of either not seeing or incorrectly identifying one or both of the target faces, which occurred on 49% of all trials. To investigate further, error data were analysed for T2 errors only; that is, trials in which participants had accurately identified the T1 as being a neutral face but had not seen or had incorrectly identified the T2. The mean percentage of error data across *all* trials was 25% (13% for HTA and 12% for LTA children). For each trial type (threat, positive, neutral), errors could reflect either a “true blink” (i.e., no report of the T2) or misidentification of the T2 (e.g., report of a happy face when an angry face was presented as the T2) (see Table 2). Separate analyses were conducted for each trial type given that: (a) error rates varied as a function of trial type; and (b) misidentification of the T2 depended upon trial type (e.g., angry and happy for neutral trials; neutral and happy for threat trials etc.).

(Table 2 about here)

Threat trials.

For threat trials, a mixed ANOVA on the percentage of errors, with Error Type (true blink versus misidentification) as the within-participants variable and Trait Anxiety (high versus low) as the between-participants variable, revealed no main effects of error type or anxiety, nor an error type by anxiety interaction ($p > .10$ in all cases).

Positive trials.

For positive trials, a similar Error Type (true blink versus misidentification) by Trait Anxiety (high versus low) analysis revealed a marginally significant interaction between error type and anxiety, $F(1, 50) = 3.89$, $p = .054$, $\eta_p^2 = .07$. Here, follow-up within-subject analyses revealed that HTA children made more misidentification errors than true blink errors (14% versus 7%, respectively), $t(25) = 2.22$, $p = .036$, $d = .73$, with analyses of these misidentification errors revealing that HTA children were more likely to misidentify the happy faces as angry faces compared with neutral faces (10% versus 4%, respectively), $t(25) = -2.38$, $p = .025$, $d = .72$. No further comparisons reached significance.

Neutral trials.

For neutral trials, a similar Error Type (true blink versus misidentification) by Trait Anxiety (high versus low) analysis revealed only a main effect of error type, $F(1, 50) = 6.91$, $p = .011$, $\eta_p^2 = .12$. That is, on neutral trials, errors were more likely to reflect all children not reporting the T2 (i.e., a true blink) compared with misidentifying the T2.

Interim Discussion

These data demonstrate a between-group difference between the HTA and LTA children, in that HTA children performed better than LTA children on neutral trials. More specifically, when the T2 was neutral, HTA children demonstrated heightened processing of this stimulus as compared to LTA children. Within-subjects analyses further revealed that HTA children demonstrated a threat-superiority effect, whereas LTA children demonstrated an emotion-superiority effect. To expand, HTA children performed better on threat trials compared with neutral trials (and marginally better on threat trials compared with positive trials), whereas LTA children performed better on both threat and positive trials compared with neutral trials. Finally, error data analyses revealed that when erring on positive trials, HTA children were more likely to make misidentification errors as opposed to true blink errors.

As the same analyses performed including *state* anxiety as the between-subject variable revealed no significant differences, it can be argued that our results reflect the enduring and stable trait disposition rather than a transient anxious emotion/mood. However, in order to ensure that any AB effects were related to the effects of trait anxiety on temporal attention for emotive stimuli, rather than the effects of trait anxiety on temporal attention *per se* (see Rokke, Arnell, Koch, & Andrews, 2002), we conducted a control experiment in which participants were presented with geometric shape stimuli. Here we hypothesised that there would be no effects of trait anxiety since the stimuli were deemed neither emotive nor ambiguous.

Experiment 2: The Attentional Blink, Anxiety and Non-Emotive Stimuli

Method

Participants.

A total of 115 children (58 female, 57 male) aged 8 to 11 years (*M* age = 9.36 years, *SD* = .92) were recruited from three different primary schools in the United Kingdom utilising a similar method to that in the first experiment. This resulted in a final participant sample of 61, consisting of 30 HTA (16 female, 14 male; *M* age = 9.20 years, *SD* = .89, age range = 8-11 years; *M* trait score = 43.47; *SD* = 2.49) and 31 LTA (15 female, 16 male; *M* age = 9.52 years, *SD* = .99, age range = 8-11 years; *M* trait score = 27.81; *SD* = 3.50) children. All children had normal or corrected-to-normal vision, spoke English as their first language, and were free from developmental disorders and learning disabilities, as reported by the teaching staff. Ethical approval was obtained from the local University Research Ethics Committee.

Stimuli.

Three basic outline shapes were incorporated as target stimuli: a square, triangle and circle. These shapes have been used successfully in previous AB research with children (e.g., McLean, Castles, Coltheart, & Stuart, 2010). Thirty distracter stimuli were also included, which consisted of lines taken from each outline shape placed in random positions and orientations. Stimuli were produced utilising Adobe Photoshop and displayed on a black background at a viewing distance of 40cm. Stimulus presentation was again controlled with Inquisit™ utilising a 60Hz refresh rate.

Procedure.

In the non-emotive AB task, the trial events were as described for the emotive AB with the exception that there were six (rather than three) double target trial types. These were: Triangle–Square, Circle–Square, Square–Triangle, Circle–Triangle, Square–Circle and Triangle–Circle. After each RSVP stream, the participants were required to indicate the shapes that they had seen by matching them to identical images on a response pad. Participants were asked to indicate the identity of the *first* or only shape viewed by pressing one of three matching buttons (i.e., a square, circle, or triangle shaped button) situated on the *left* side of the response pad, and the identity of the *last* shape viewed by pressing one of three matching buttons situated on the *right* side of the response pad. After making a response, participants were required to press a blue button in order to proceed to the next trial. Participants were also required to press the blue button if they had not seen any shapes. The AB task consisted of one block of 10 practice trials and one block of 60 test trials.

Data screening.

All participants performed with acceptable accuracy levels (i.e., within two SDs of the sample mean). An independent measures t-test demonstrated that the HTA group had significantly higher trait anxiety scores than the LTA group, $t(47.69) = -10.70$, $p < .001$.

Results

A correct response consisted of accurately identifying both shapes presented as the T1 and T2 in chronological order (i.e., T1 = circle, square or triangle; T2 = circle, square or triangle). The mean percentage of correct responses (i.e., trials where both targets were accurately identified) was 78% (*SD* = 16%) for HTA children and 80% (*SD* = 16%) for LTA children (chance level = 11%). Table 3 demonstrates the mean percentage of correct responses as a function of lag (2, 3, 4, 7) and trait anxiety (high versus low). A mixed ANOVA with Lag (2, 3, 4, 7) as the within-participants variable and Trait Anxiety (high versus low) as the between-participants variable revealed a main effect of lag only, $F(3, 177) = 12.32$, $p < .001$, $\eta_p^2 = .17$. All other effects were non-significant ($p > .50$ in all cases).

For the main effect of lag, pair-wise Bonferroni corrected comparisons revealed a typical AB effect. That is, participants performed worse on trials at Lag 2 compared with Lags 3 ($p = .016$, $d = .36$), 4 ($p < .001$, $d = .55$), and 7 ($p < .001$, $d = .69$).

(Table 3 about here)

General Discussion

The purpose of the present study was to investigate key predictions from previous research and theory relating to anxiety and attentional bias. Specifically, we investigated whether trait anxiety is associated with prioritised processing of emotionally threatening and/or neutral (and therefore potentially ambiguous) facial expressions. Utilising temporal attentional blink methodology with emotive target stimuli, we found a between-group difference whereby high trait anxious (HTA) children performed better than low trait anxious (LTA) children on neutral trials. Within-subjects analyses further revealed that HTA children demonstrated a threat-superiority effect, whereas LTA children demonstrated an emotion-superiority effect. Finally, error data analyses revealed that when erring on positive trials, HTA children were more likely to make misidentification errors as opposed to true blink errors. In contrast, findings from the non-emotive control experiment demonstrated that there were no differences in performance between the HTA and LTA children, with both populations displaying a typical AB effect. These findings will now be discussed in turn, followed by a consideration of limitations and future directions.

The main finding of our research was that HTA, relative to LTA, children displayed an attentional bias for neutral faces. This finding is novel but somewhat in accordance with previous research where the processing of neutral faces has been investigated, as well as the cognitive-motivational model of attentional bias and anxiety proposed by Mogg and Bradley (1998). Importantly, previous research in both socially anxious adults (Yoon & Zinbarg, 2008) and typically developing children (Tottenham et al., 2013) has demonstrated that neutral faces are ambiguous, with this ambiguity generally leading to negative/threatening appraisals. Added to this, within the cognitive-motivational model of anxiety, it is proposed that high trait anxiety heightens appraisal of ambiguous stimuli (such as neutral faces) as threatening and, consequently, leads to greater attention to this information. Therefore, the finding that HTA children demonstrated better performance on the emotive AB task when the second target was neutral (as compared to LTA children) indicates that the processing of this neutral face was prioritised and subject to preferential goal-directed processing under conditions of limited attentional resources. This explains the performance difference between HTA and LTA children on neutral trials, and suggests that for HTA children, the T2 neutral (or ambiguous) faces were "weighted" as significant and/or potentially threatening, and hence received prioritised processing enabling this stimulus to break through the blink more often.

We have discussed elsewhere the potential brain mechanisms that could underlie such an attentional weighting mechanism for the prioritisation of (emotive) stimuli in visual working memory (Simione et al., 2014). In addition, given the rapidity of such attentional processes, we tentatively suggest that such biases are contributing factors in the development of anxiety-related disorders (see also Maratos & Staples, 2015). This proposal fits with Tottenham et al.'s (2013) study demonstrating that all children, but especially younger children, appraise neutral faces negatively but by adulthood, such biases only remain for those who report as anxious, as found by Yoon and Zinbarg (2008). Also of relevance here is research by Hadwin, Frost, French, and Richards (1997). Utilising a homophone-picture matching task, Hadwin et al. demonstrated that high, relative to low, anxious children were more likely to select pictures that reflected the threatening meaning of homophones (e.g., coffin versus fruit for "berry/bury"; angry versus symbol for "cross"). Thus, we would suggest that for HTA children, ambiguity is weighted as significant given its potential for threat, which then results in heightened processing of such stimuli. This accords well with interpretation bias accounts of anxiety (e.g., Beck et al., 1985; Muris & Field, 2008) in which it is posited that anxious individuals have a tendency to interpret information that they are uncertain about as dangerous.

The second finding of this research concerned the unambiguous angry T2 stimuli (i.e., performance on threat trials). Here, we found that HTA children were better at correctly identifying both targets when the T2 appeared as an angry, relative to a neutral face (but not when the T2 appeared as a happy, relative to a neutral face). HTA children were also marginally better at correctly identifying both targets when the T2 appeared as an angry, relative to a positive, face. This finding of a threat superiority effect for HTA children is consistent with previous visual probe research involving anxious children (e.g., Hunt et al., 2007; Telzer et al., 2008; Waters et al., 2008), as well as a number of models of attentional bias for threat in anxiety (Beck & Clark, 1997; Mogg & Bradley, 1998; Öhman, 2005). To expand, the heightened prioritisation of threatening stimuli by HTA children led to these children preferentially processing the angry T2 and, subsequently, this stimulus (when under conditions of limited attentional resources) broke through the blink, thus explaining better performance for HTA children on threat compared with neutral (or positive) trials. In comparison, for LTA children, T2 performance for angry and happy faces was equivalent (but better than for neutral T2 faces), hence, under conditions of limited attentional resources, an emotion superiority effect was observed. These findings indicate that a child's tendency to preferentially allocate attentional resources to emotive stimuli is affected by anxiety level, which is in accordance with previous AB studies investigating both clinical and non-clinical levels of anxiety in adults (e.g., specific phobias: D'Alessandro, Gemignani, Castellani, & Sebastiani, 2009; Reinecke, Rinck, & Becker, 2008; state and/or trait anxiety: Fox et al., 2005; Vaquero, Frese, Lupianez, Megias, & Acosta, 2006).

In addition, however, analyses of our error data pointed towards a further possible difference in responding between the HTA and LTA children. That is, when erring on positive trials, HTA children were more likely to make misidentification errors as opposed to true blink errors. These misidentification errors reflected HTA children incorrectly reporting the happy T2 as an angry face compared to a neutral face. Thus on positive trials, for HTA children, the second target was more likely to break through the blink, even if they could not correctly identify its emotional expression. Whilst our error data findings should be considered with caution (as the original interaction between error type and anxiety was only of marginal significance, i.e., .054), this result is important because it again potentially attests to the significance of ambiguity in anxiety. For HTA children, poorer performance on positive trials did not typically reflect processing limitations (i.e., a true blink), but rather the misinterpretation of the valence of the T2 stimuli under conditions of limited processing resources. This finding is consistent with interpretation bias: the bias for anxious individuals to interpret information as dangerous or threatening in situations of uncertainty.

Finally, although some previous research has indicated that affective disorders modulate processing of temporal attention *per se* (Rokke et al., 2002), our non-emotive control experiment revealed this not to be the case in a non-clinical sample of children. That is, in our non-emotive task, there were no differences in performance between the HTA and LTA children, with both populations showing the typical AB phenomenon. Hence anxiety influenced responding in the emotive version of the task only and did not reflect more general processing differences (e.g., heightened vigilance / rapid processing).

Limitations and Future Directions

Despite our results being largely consistent with theory and previous research in adults, our findings must be tempered by a number of considerations. For example, one difference between the current findings and the majority of adult AB studies is the lack of any interaction effects involving lag. In previous research, the *duration* of the AB has been found to be affected by the emotive content of the stimuli and/or the affective state of the individual. Specifically, Fox et al. (2005) found that the AB effect was more short-lived (i.e., up to 330ms / Lag 3 only) for fearful faces compared with happy faces (i.e., up to 440ms / Lag 4) in high anxious individuals. Similarly, Maratos et al. (2008) found that the attenuated AB for threatening, relative to positive and neutral, faces was only present when the T2 appeared within 257 to 388ms (i.e., Lags 2 to 3) of the T1. However, in the present study, effects were independent of the time period between the T1 and T2.

One possible explanation for the lack of interaction effects involving lag observed in our emotive experiment is that our results may have been confounded by task difficulty. To expand, the mean percentage of overall correct responses for the emotive experiment was 51%, whereas the mean percentage of overall correct responses for the non-emotive control experiment was 79%. As such, future research into anxiety and the AB in children should utilise a simplified version of the emotive AB task by ensuring that targets are less similar to distracter items, to decrease general task difficulty of the emotive AB task. This is because previous research has demonstrated a more severe AB effect with increased categorical or perceptual similarity between target and distracter items (e.g., Chun & Potter, 1995; Maki, Bussard, Lopez, & Digby, 2003). In addition, it may also be wise to implement a simpler response mode in future research.

A second very important difference between our research and that of previous AB research in anxious adults was the T1 stimulus category. To expand, whereas more recent research has tended to employ T1 and T2 stimuli from the same stimulus category (e.g., T1 and T2 are both faces with scrambled faces serving as distracters; e.g., Asplund, Fougnie, Zughni, Martin, & Marois, 2014; Bach, Schmidt-Daffy, & Dolan, 2014), previous research has tended to utilise T1 stimuli from a different category. For example, in the research by Fox et al. (2005), the T1 was an image of a flower or a mushroom, the distracters were neutral faces and the T2 stimulus was a threatening or happy face. We chose not to use this methodology given that switching from one stimulus mode (e.g., identifying nature images) to a second mode (e.g., identifying facial images) could be considered "task-switching", which could incur an additional response cost (with respect to both reaction times and error rates) above the cost of responding to two stimuli presented in rapid succession (e.g., Kiesel et al., 2010). The implication of this subtle task change is important when one bears in mind that our T1 stimuli were neutral faces, which, based on our findings as a whole, we suggest high anxious children might interpret as potentially threatening. Considering this in extension of our research, it may be useful to carefully evaluate the merits and limitations of using a "neutral" face as the T1 stimulus. Certainly, Schwabe and Wolf (2010) found that in their research using word stimuli, an aversive T1 extended the AB phenomenon irrespective of the emotional arousal value of the

T2. However, in their research participants did not explicitly report the T1 target, whereas in our research *correct* explicit report of the T1 target was a necessary requirement for analyses of T2 performance. Thus, in our research and analyses we can be assured that there was no ambiguity of the T1 stimulus, which may be critical in accounting for differences in their results and ours, and their lack of emotive T2 effects.

Finally, two further promising extensions of our research would be to investigate trait anxiety as a continuous variable (given the tertile split method removes variability), and incorporate the use of real face stimuli. Although we have previously shown that the schematic faces used in this research demonstrate similar brain responses to those recorded for real faces (Maratos et al., 2015), it would be useful to replicate our research utilising real-life expressions to allow greater generalisability of findings.

Conclusions

In conclusion, the present study revealed that HTA children demonstrate an attentional bias for threatening and, of novel value, neutral (or ambiguous) stimuli. Whilst our findings should be tempered with respect to the limitations outlined above, the presence of these attentional biases accords well with past research. Furthermore, our findings offer support for cognitive/neurobiological theories of threat processing in anxiety, as well as suggesting that ambiguity is a factor contributing to prioritised attentional processing in HTA children. As such, findings could have important implications for both research into anxiety and associated treatments, in particular the use of neutral faces as control stimuli in research paradigms, and in treatments aimed at the re-training of biases towards stimuli assumed to be neutral. For example, in current paediatric research (e.g., Eldar et al., 2012), it may not be optimal to train attention towards neutral faces if these could be perceived as threatening by anxious children.

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Table 1: *Mean Percentage of Correct Responses as a Function of Lag and Trial Type (with SDs in parentheses) for High and Low Trait Anxious Participants.*

	High Trait Anxiety	Low Trait Anxiety

Lag	Threat	Positive	Neutral	Threat	Positive	Neutral	**Total (Mean)**
2	60 (27)	55 (30)	42 (35)	55 (31)	48 (27)	28 (23)	48(25)
3	63 (25)	53 (28)	48 (35)	58 (26)	55 (24)	28 (27)	51(24)
4	63 (24)	55 (28)	48 (34)	57 (27)	59 (20)	29 (25)	52(23)
7	65 (28)	60 (27)	50 (32)	58 (27)	56 (25)	34 (26)	54(25)
Total (Mean)	63 (24)	56 (26)	47 (32)	57 (24)	55 (21)	30 (23)	

Table 2: *Mean Percentage of T2 Errors as a Function of Error Type and Trial Type (with SDs in parentheses) for High and Low Trait Anxious Participants*

	High Trait Anxiety			Low Trait Anxiety			**Total**
Error Type	Threat	Positive	Neutral	Threat	Positive	Neutral	**(Mean)**
True Blink	5 (5)	7 (6)	23 (25)	6 (7)	8 (6)	31 (22)	13(12)
Misidentification	9 (11)	14 (13)	17 (15)	6 (6)	8 (8)	14 (13)	12(11)
Total (Mean)	7 (8)	11 (10)	20 (20)	6 (7)	8 (7)	23 (18)	

Table 3: *Mean Percentage of Correct Responses as a Function of Lag and Trait Anxiety (with SDs in parentheses)*

Lag	High Trait Anxiety	Low Trait Anxiety	**Total (Mean)**
2	71(16)	73(18)	72(17)
3	77(16)	79(17)	78(17)
4	81(15)	82(17)	82(16)
7	81(16)	84(14)	83(15)
Total (Mean)	78(16)	80(17)	79(16)

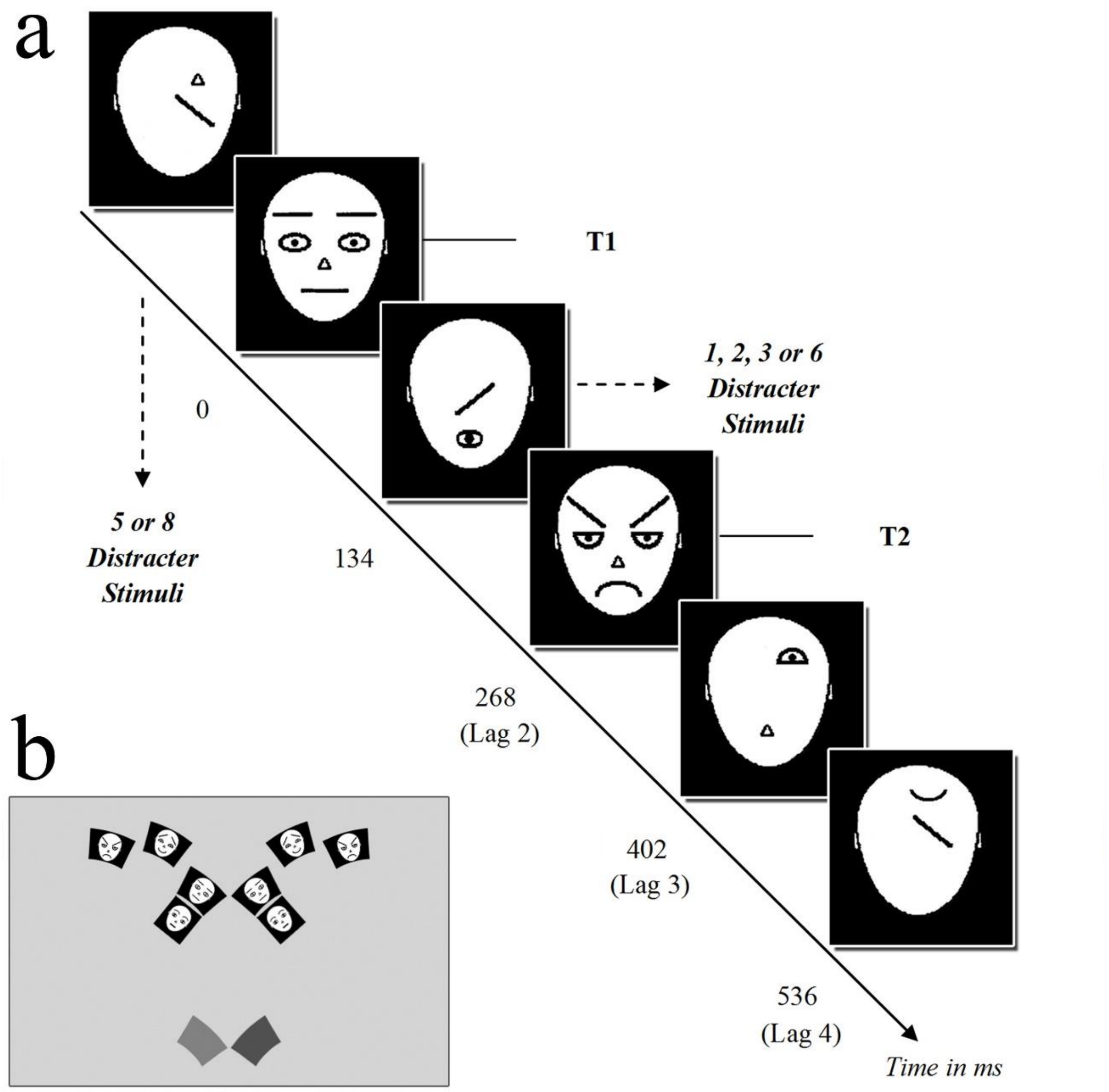

Figure 1: (a) Example of a double target trial in which the T1 was a neutral face and the T2 was an angry face. **(b)** The adapted Cedrus® RB-830 response pad used in the experiment. Participants responded with their left hand to record responses to the first face (left-side buttons) and their right hand to record responses to the second face (right-side buttons).

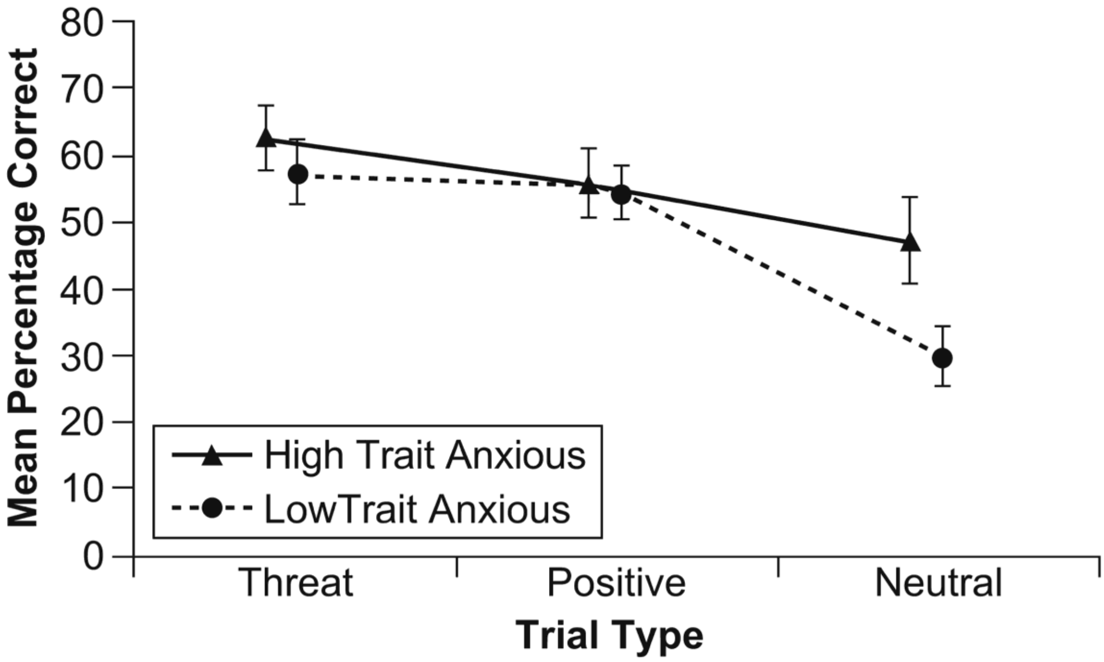

Figure 2: Mean percentage of correct responses as a function of Trial Type and Anxiety. Error bars represent one standard error of the mean. Points are offset horizontally so that error bars are visible.