Eye-Movement Methodology Reveals a Shift in Attention from Threat to Neutral Stimuli with Self-Reported Symptoms of Social Anxiety across Children, Adolescents and Adults

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Abstract

The current study used an eye-movement remote distractor paradigm (RDP) to examine the relationship between self-reported symptoms of social anxiety in children (9-11-year-olds), young adolescents (12-14-year-olds) and adults (18-43-year-olds) on saccade latencies to identify a target and saccadic errors to task irrelevant distractor angry, neutral and happy face stimuli. Distractor stimuli were presented at the same time, and either at the centre of the display, or at a contralateral parafoveal or peripheral location to the target. The presence of face distractors was associated with increased saccadic errors (indicating selective attention to task-irrelevant stimuli) and slower saccade latencies to identify a target. Saccadic errors decreased between age groups and saccade latencies and were greatest in the adolescent group. Symptoms of social anxiety in children were associated with increased saccade latencies in the presence of angry and neutral (versus happy) faces suggesting avoidance of these emotion expressions in this age group. In contrast, symptoms of social anxiety in adolescents and adults were respectively linked with longer latencies for neutral (versus angry), and neutral (versus happy and angry) faces, indicating an increasing salience of neutral faces in adulthood. The results support the proposition that neutral faces represent ambiguous and potentially negative stimuli for individuals who experience elevated social anxiety. Collectively, they fit with previous research that has questioned the role of neutral faces as non-emotional control stimuli in attention research and anxiety.

Keywords: Attention, faces, social anxiety, children, adolescents, adults

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Social anxiety is characterised by "persistent fear of one or more social and/or performance situations in which the person is exposed to unfamiliar people or to possible scrutiny from others" (American Psychiatric Association, 2013, p.202). While elevated symptoms of social anxiety can emerge in childhood (Chavira and Stein 2005; Franz et al., 2013), its prevalence has been found to increase in early adolescence and to follow a persistent pathway through development (Morales-Muñoz et al., 2022; de Lijster et al., 2017). Social anxiety can occur in up to 7% of adolescents, with around twice as many females (versus males) receiving a diagnosis (Merikangas et al., 2010). Social anxiety has been found to negatively impact the development of interpersonal relationships over time (Copeland et al., 2014), and individuals who experience more symptoms report increased isolation and avoidance of social activity (Chow et al., 2017). Theoretical frameworks and empirical research support the proposition that cognitive processes associated with threat detection play a role in understanding the aetiology and maintenance of social anxiety (e.g., reviews by Clark & McManus, 2002; Rapee & Spence, 2016). This research has been critical in the development of innovative prevention and intervention methods for the reduction of social anxiety symptoms that focus on the benefits of changing attention processes (e.g., Azriel et al., 2024).

Eye-movement measures are argued to provide a reliable and robust index of attention across development and this methodology has replicated and extended findings that have used reaction time indices to more fully understand the role of attention processes in anxiety (Chong & Meyer, 2020). Reaction time studies have, for example, demonstrated that children, adolescents, and adults who experience elevated symptoms or those with a clinical diagnosis of social anxiety automatically orient to environmental threat, as shown in faster reactions times to label a target that follows a threat stimulus (e.g., Abend et al., 2018; review by Valadez et al., 2022). Eye-movement studies have been similarly important in demonstrating that children (e.g., Seefeld et al., 2014) and adults (e.g.,

Schofield et al., 2012) with a diagnosis of social anxiety were more likely to direct their attention to an angry face, when viewing angry-neutral face pairs. Seefeld et al., further showed that when experiencing a social-evaluative threat (i.e., anticipation of delivering a recorded and assessed speech), children with a diagnosis of social anxiety showed an increased number of first fixations to angry faces.

Further eye-movement studies have highlighted challenges in attention disengagement from threat stimuli. For example, overall time spent looking at threatening faces when presented across extended time periods was found to increase in adults with elevated symptoms or a diagnosis of social anxiety (Buckner et al., 2010; Lazarov et al., 2016; 2021). In contrast, Dodd et al., (2015) found that early in development 3-4-year-olds with a diagnosis of anxiety (with most children meeting the criteria for social or separation anxiety), spent less time overall looking at angry and neutral faces, indicating avoidance. Reaction time studies have similarly found that increased symptoms of social anxiety in 6-11-year-olds were linked to avoidance of angry and fearful face stimuli (Stirling et al., 2006). Related research has also shown a negative association between self-reported symptoms of trait anxiety and saccade latencies to move attention away from centrally presented angry (versus happy) faces in children, adolescents and adults, suggesting avoidance (Manoli et al., 2021).

Other eye-movement studies have found that in individuals with a diagnosis of social anxiety that initial attention towards threat is followed by its avoidance over time, characterised as vigilance-avoidance (e.g., Schmidtendorf et al., 2018; Weiser et al., 2009; see Mogg et al., 2004). For example, Schmidtendorf et al., (2018) asked 9-13-year-olds with and without a diagnosis of social anxiety to passively view stimuli consisting of an angry face paired with a happy or neutral face or a non-face (house) stimulus for five seconds. When viewing an angry-house stimulus pair, all children and adolescents were more likely to make a first fixation towards and to spend longer looking at angry

faces. Across the viewing period, time spent looking at an angry face reduced, but only for individuals with a diagnosis of social anxiety.

A number of studies have considered the proposition that elevated anxiety is associated with a state of hypervigilance, where individuals maintain a broad focus of attention to enable monitoring of the environment for the detection of potential threat (Eysenck et al., 1992). This association has been demonstrated using scan path length measurements or by considering decision making in the absence of eye-movements. Longer scan paths (i.e., an increased number of fixations and saccades) are argued to reflect a more in-depth exploration of a visual display (review by Mahanama et al., 2022). Adults diagnosed with social anxiety disorder were faster to detect facial changes in an array of 16 neutral and emotional faces, as reflected in longer visual scan paths - characterised as hyper-scanning (Chen et al., 2015). Horley et al., (2004) similarly found longer scan paths in adults with a diagnosis of social phobia when viewing neutral and sad faces. Consistent with the notion of attention broadening, Richards et al. (2011) measured eye movements in a redundant signals paradigm to demonstrate that symptoms of trait anxiety were positively related to processing capacity (i.e., faster reaction times to respond to angry faces in the presence of multiple (angry) face targets), alongside fewer eye movements. The authors concluded that attention broadening worked to facilitate threat detection in the presence of multiple targets for individuals who reported increased symptoms of anxiety.

Pavlou et al., (2016) measured eye movements in a remote distractor paradigm (RDP; see Walker et al., 1997; Benson et al., 2008) in 9-11-year-olds to investigate links between attention processes and personality characteristics including neuroticism (a trait associated with elevated emotional instability and anxiety, see Widiger & Oltmanns, 2017). Children were asked to identify a target stimulus presented 4 or 8 degrees from the centre of the screen. They were told that a distractor stimulus (i.e., an angry, happy or neutral face) would be presented at the same time. The face distractor appeared either at the centre of the display, or at a contralateral location to the target.

One benefit of the eye-movement RDP is that it generates different indices of cognitive processes, including selective attention (indexed by an incorrect eye-movement or saccadic error to a face distractor stimulus), disengagement (reflected in increased saccade latencies to make an eye movement away from a centrally presented face distractor to a target), and hypervigilance or attention broadening (i.e., shown via increased saccade latencies to make an eye movement to the target in the presence of a face distractor presented 4 or 8 degrees from the centre. Pavlou et al., found that symptoms of neuroticism were associated with both hypervigilance and disengagement in the context of a neutral or angry face distractor. The study found no evidence of selective attention to threat.

While eye-movement studies have found evidence for cognitive processes associated with social anxiety, it has also revealed some inconsistencies between studies that may reflect participant age, diagnostic status, or the use of different methodologies and stimuli (review by Dudeney et al., 2015). For example, while studies have focused on angry, fearful and disgust faces as representations of threat, some researchers have suggested that a neutral face represents a potentially ambiguous and therefore threatening stimulus (e.g., Bas-hoogendam et al., 2019; Cooney et al., 2006), and have argued for further exploration of the processing of ambiguity in social anxiety (Bantin et al., 2016). Several studies using eye-movement measures or other indices of attention have found links between symptoms of anxiety and the processing of neutral faces (e.g., Dodd et al., 2015; Horley et al., 2003; Pavlou et al., 2016). In addition, Cooney et al., (2006) found that adults with a diagnosis of social anxiety (versus a non-clinical control group) were more likely to make negative judgements and showed increased right amygdala activation for neutral faces, compared with non-face stimuli. Further studies have similarly found that symptoms of social anxiety in adults were positively correlated with misattributions of anger to neutral faces (e.g., Peschard & Philippot, 2017). Consistently, in a ten second free viewing task 10-13-year-olds with a diagnosis of social anxiety disorder (versus those diagnosed with a different anxiety disorder or with no diagnosis) showed

increased selective attention to neutral (and not angry or happy faces), as reflected in shorter latencies to fixate on the eye region (Keil et al., 2018). Related studies have also found that 10-11-year-olds with elevated trait anxiety made increased misattributions of anger to facial expressions with low levels of emotion (Richards et al., 2007).

These findings sit alongside developmental research demonstrating that the processing of neutral faces changes across development. Rollins et al., (2021) found that neutral faces were typically judged to be negative in 7-11-year-olds and adults, and where adults spent longer fixating on the eye region in decision making. Tottenham et al., (2013) further showed that from middle childhood and through to late adolescence neutral faces were similarly typically judged to be negative, and corrugator muscle activity (an objective measure of emotion positivity or negativity; see Neta et al., 2009) showed no difference between neutral and angry faces. The results also highlighted that decision making slowed across childhood and into adolescence and the authors concluded that the ambiguity of the faces may become more salient in adolescents.

The current study utilised existing measures of self-reported symptoms of social anxiety in 9-11-year-olds (from and not reported in Pavlou et al., 2016) and explored associations with selective attention, disengagement, and hypervigilance for threat and neutral stimuli using the RDP. It extended this data to compare attention processes in childhood, adolescence and adulthood. Following Pavlou et al., (2016), we anticipated that symptoms of social anxiety would be positively linked with attention broadening (i.e., reflected in increased saccade latencies to make eye movements to a target stimulus) and increased time to disengage from angry and neutral faces. Consistent with the increased salience of neutral faces in development (Rollins, 2021; Tottenham, 2013), we anticipated that links between social anxiety and neutral faces would be most evident in adolescents and adults. Exploratory analysis further considered links between social anxiety with faster saccade latencies to the target in the presence of angry and neutral faces, that would indicate avoidance (see e.g., Manoli et al., 2021).

Method

Participants

N=95 participants took part in the current study including *n* = 42 children (17 females) aged between 9-11 years old (*M* = 10.40, *SD* = .54), *n* = 21 adolescents (*mean age* = 12.43, *SD* = .93, *age range* = 12-14 years, 14 females), and *n* = 32 adults (*mean age* = 27.34, *SD* = 5.01, *age range* = 18-43 years, 21 females). Children were recruited from Year 5 and 6 of a local school in the south of the UK. The social anxiety and eye-movement data from this group was drawn from that collected in a broader research programme and where parts of that project have been published elsewhere (Pavlou et al., 2016). Adolescent and adult participants were recruited via advertisements in a local newspaper, posters on the university campus and through opportunity sampling. Children and young people gave written assent and a parent or legal guardian provided written consent for their participation. Adults provided written consent for participation.

Remote Distractor Paradigm

Participants completed one practice block with 12 trials, and three experimental blocks each with 144 trials. Each experimental block included 48 single target trials and *N* = 96 distractor trials made up of either (*n* = 32) happy, angry or neutral face distractors. Distractor faces included sixteen models (8 males and 8 females) from the NimStim face set (all 165 x 256 pixels in size or 4.2° horizontally and 6.5° vertically at 70 cm viewing distance). Practice blocks included four additional models. Target stimuli included a white diamond and a white square that were 59 x 59 pixels (1.5° x 1.5° of visual angle) and viewed at a distance of 70 cm. In half of the experimental trials the target was a square. Stimuli were presented on a black background.

In single target trials a target was presented on its own in parafoveal or peripheral vision (i.e. at 4° and 8° from the centre of the screen respectively). In distractors trials a target and a distractor were presented simultaneously. The distractor could appear at the centre of the screen (foveal vision)

or to the left or right of the central fixation within parafoveal (at 4° from the centre of the screen) or peripheral vision (at 8° from the centre of the screen). In trials where the distractor appeared in the centre of the screen, the target was located at 4° or 8° degrees from the right or left edge of the distractor. In parafoveal and peripheral distractor trials the target always appeared in the mirror position of the distractor. The distractor appeared in different locations (parafovea left, parfovea right, periphery left, and periphery right) with equal frequency.

Each trial began with a centrally-located fixation cross presented for a minimum duration of 1000ms. We asked participants to fixate on the cross. They were required to look within 1.5 degree of its centre for 200ms after which it was then replaced with a trial display that contained either a single target (single-target trials) or a target and a distractor (distractor trials). The trial display was presented for 1500ms or until a key-press response was made. The instructions were to ignore the distractor and look at the target as quickly and accurately as possible, and press a response button to indicate whether it was a square or a diamond. Response buttons and experimental blocks were counterbalanced. The Eyelink 1000 Desk Mount eye-tracking system (SR Research Ltd.) was used to record right-eye vertical and horizontal eye-movements.

Eye Movement Attention Indices

The eye movement measures included a measure of selective attention as reflected in the (1) percentage of directional errors (i.e. first saccades towards the distractor of any type or eccentricity with an amplitude greater than 2°), a measure of attention broadening indexed by (2) the latency of accurate first saccades (i.e. the elapsed time from the onset of the experimental display to the initiation of a saccade towards the target) in the presence of a distractor, and measurements of disengagement reflected in (3) longer saccade latencies to the target with centrally presented stimuli, and avoidance as indicated by (4) faster saccade latencies to a target in the presence of distractor stimuli.

Questionnaire Measures

Social Anxiety

Children completed the Revised Children's Manifest Anxiety Scale - 2 (RCMAS - 2; Reynolds & Richmond, 2008), a 49-item questionnaire developed for children and adolescents aged between 6-19 years. The scale includes measurements of total anxiety (all items), physiological anxiety (12 items), worry (16 items) and social anxiety (12 items). It also includes a defensiveness scale (9 items), where high scores on this scale indicate inaccurate responses. Participants are required to respond "yes" or "no" to each item. The scale has been reported to show good construct validity (e.g., Lowe, 2014) and internal consistency (e.g., Wu et al., 2015). In the current study we only used the social anxiety subscale and scores were treated as a continuous variable (M = 4.83, SD = 3.74, *Range* = 0-12). N = 11 (26%) of children scored > 7 on the social anxiety subscale indicating elevated symptoms (see Reynolds & Richmond, 2008).

Social Anxiety Interaction

Adolescents and adults completed the social interaction anxiety scale (SIAS; Mattick & Clarke, 1998). The SIAS asks individuals to rate how characteristic 20 statements are of them using a 5-point scale, ranging from 0 to 4 (i.e., "not at all characteristic or true of me" to "extremely characteristic or true of me"). The statements include descriptions related to the initiation and maintenance of social interaction. The scale was originally developed for use with adults, but has been found to have good reliability and validity for adults (Mattick & Clarke, 1998) and adolescents (Jefferies et al., 2020), and between clinical and non-clinical populations (e.g., Brown et al., 1997). The mean SIAS scores for adolescents and adults were respectively M = 25.72 (SD = 11.42, *range* 0-59) and M = 16.89 (SD = 12-56, *range* = 1-55). Researchers have suggested that scores ≥ 36 indicate elevated scores (n = 2 adolescents (10%) and n = 4 adults (11%) in the current sample scored at or above this point).

Internal consistencies for both questionnaires and each group was > .80. Scores for both questionnaires were independently converted to standardised scores and these were used in all analyses.

Statistical Analyses

We used generalized linear mixed models (GLMMs) and a linear mixed-effects models (LMMs) from the lme4 package (Bates, et al., 2015) in R (R, Core Team, 2017) to fit our mixed models. GLMMs with a binomial distribution were used for the analysis of saccadic errors because this outcome variable is binary (0 = no error, 1 = error). LMMs were employed for analysing saccade latencies, as this was a continuous outcome variable. To extract and present the model summaries, including the p-values and degrees of freedom, we used the sjPlot::tab_model function (Lüdecke, 2023). P-values for the fixed effects were calculated using Satterthwaite's approximation for the degrees of freedom.

We examined symptoms of social anxiety (as a continuous variable), and distractor location (categorical variable – central, parafoveal and peripheral), distractor emotional expression (categorical variable – happy, angry, neutral) and participant age group (categorical variable – child, adolescent, adult) as fixed factors on saccadic performance, including saccade latency and saccadic errors. The random structure consisted of random intercepts for participants. The saccade onset latency was defined as the time elapsed from the presentation of the eccentric target stimulus until the first saccade made to the eccentric target. Saccade latencies below 80ms and 2 degrees amplitude were excluded from the dataset (1.5%). Saccade latencies were log-transformed to ensure normal distribution. A saccadic error included the first eye movement executed that was in the opposite direction to the one where the eccentric target appeared (directional errors were coded as a binary variable: 1=error, 0 =no error).

Analyses considered baseline task performance for each variable (distractor location, emotion expression, social anxiety and group) on saccade latencies and saccadic errors. We further explored

the two- and three-way interaction effects between group, distractor location and emotion expression with social anxiety on saccadic performance (latency and errors). The three-way interaction between distractor location, distractor emotional expression and social anxiety was not significant in either model (saccade latency: $p>.05$, and errors: $p>.05$), and thus was removed from the final models to enhance parsimony and statistical power. Only significant results are reported ($p \leq .05$). Pairwise comparisons were examined with Tukey adjustment using the emmeans package (Lenth, 2021). Since it is not possible to make an error for the centrally presented distractors, these were removed from the analysis of saccadic directional errors and the distractor location variable remained with two levels (parafoveal and peripheral).

Results

Table 1 shows the mean saccade latencies and saccadic errors for each distractor location and the emotional expression of distractors for children, adolescents and adults. Tables 2 and 3 summarise significant and non-significant main and interaction effects respectively for saccade latencies and saccadic errors. We present estimates for saccade latencies and odds ratios for saccadic errors, each with confidence intervals and significance levels.

Considering basic task performance, the results showed that saccade latencies were slower for trials with distractors ($M = 217.80$, $SD = 59.62$) compared to those without distractors ($M = 175.33$, $SD = 55.31$) ($\beta = .23$, $SE = .002$, $t = 108.4$, $p < .001$). Centrally presented distractors were associated with slower saccade latencies to the target ($M = 228.23$, $SD = 66.38$) compared to both parafoveal ($M = 214.74$, $SD = 55.00$) and peripheral distractors ($M = 214.43$, $SD = 57.70$). The difference between saccade latencies for parafoveal and peripheral distractors was not significant (Table 2). With respect to group differences, the results showed that saccade latencies to the target were significantly slower in adolescents ($M = 254.10$, $SD = 55.94$) compared to both adults ($M = 194.61$, $SD = 50.45$) and children ($M = 225.94$, $SD = 61.78$), and significantly slower in children compared with adults (Table

2). The analysis further revealed significant differences between distractor emotional expressions for saccade latencies. Table 2 shows that saccade latencies to the target were significantly longer in the presence of angry ($M = 222.36$, $SD = 65.31$) compared with neutral ($M = 218.14$, SD=57.79) and happy ($M = 218.95$, $SD = 58.88$) face distractors. There was no difference between neutral and happy face distractors.

Table 3 shows that saccadic errors were greater for peripheral (23.29%) compared to parafoveal distractors (16.13%). In addition, saccadic errors decreased significantly between the three age groups (children (30.50%) > adolescents (20.54%) > adults (8.18%); see Table 3). The analysis also showed significant differences between distractor emotional expressions for saccadic errors. Participants made significantly more saccadic errors towards angry (22.30%) compared to both happy (19.19%) and neutral (17.84%) distractors. Saccadic errors did not differ significantly between happy and neutral faces.

The distribution of the performance from the raw data (saccade latencies and saccadic errors) is graphically presented across age groups, emotional expressions and distractor locations by social anxiety in the supplementary material (see supplementary figures S1-S6).

Main Effects and Interactions with Social Anxiety: Saccade Latency

Symptoms of social anxiety showed no significant main effect for saccade latencies. However, a two-way interaction was found between social anxiety symptoms and distractor emotional expression on saccade latencies. Table 2 shows that social anxiety symptoms were positively associated with saccade latencies for neutral faces ($\beta = 5.14$, $SE = 0.83$, $t = -6.22$, $p < .001$) and happy faces ($\beta = 3.86$, $SE = 0.82$, $t = -4.72$, $p < .001$), compared with angry faces. Although the analysis from the LMMs showed a statistically significant interaction between happy and neutral faces (p = 0.037) with social anxiety for saccade latencies, follow-up post-hoc analyses from 'emtrends' did not reveal a statistically significant difference between happy and neutral face distractors in the effect of social anxiety on saccade latencies ($\beta = -1.28$, $SE = 0.82$, $t = -1.56$, $p < .26$) (see Figure 1a).

Table 2 further shows a significant three-way interaction between age group, distractor emotional expression and symptoms of social anxiety for saccade latencies. The LMM interaction effects were significant for the expression contrasts of angry versus neutral, happy versus angry and neutral versus happy when comparing children to adults. Further, interaction effects for the expression contrasts neutral and happy when comparing adolescents with children and adolescents with adults were also significant. Post-hoc analysis using estimated marginal trends ('emtrends') revealed the following trends in social anxiety and expression within each age group (children, adolescents, adults). Contrast estimates for the child group showed that social anxiety was associated with increased saccade latencies across all facial stimuli, with significant differences between happy and neutral, and happy and angry faces. The increase in latency was smaller for angry and neutral faces, indicating faster latencies for angry ($\beta = 0.03$, $SE = 0.01$, $t = 4.76$, $p < .001$) and neutral faces ($\beta = 0.01$, $SE = .01$, $t = 2.64$, $p < .05$), compared with happy faces, as social anxiety symptoms increase. The contrasts between neutral and angry faces for children were not significant after applying Tukey's correction for multiple comparisons ($\beta = 0.01$, $SE = .005$, $t = 2.20$, $p = .07$). For adolescents, the contrast between neutral and angry faces was significant, indicating that as social anxiety symptoms increase, saccade latencies for neutral faces increase significantly more than for angry faces ($\beta = 0.019$, $SE = 0.01$, $t = 3.24$, $p < .01$). However, the contrasts between happy and neutral faces ($\beta = 0.01$, $SE = .005$, $t = -1.54$, $p = .27$) and happy and angry faces ($\beta = 0.02$, $SE = .005$, $t = 1.78$, $p = .18$) were not significant after applying Tukey's correction for multiple comparisons. For adults, significant contrasts were found between neutral and angry as well as between neutral and happy faces. This indicates that as social anxiety symptoms increase, saccade latencies for neutral faces increase significantly more than for angry faces ($\beta = 0.028$, $SE = 0.01$, $t = 6.08$, $p < .001$) and happy faces ($\beta = 0.024$, $SE = 0.005$, $t = 5.21$, $p < .001$). The contrasts between happy and angry faces for adults were not significant ($\beta = 0.004$, $SE = .005$, $t = 0.91$, $p = .63$) after applying Tukey's correction for multiple comparisons (see Figure 1b).

Table 2 also shows a significant three-way interaction between social anxiety with distractor location and participant age group for saccade latency. The LMM analyses showed significant interaction effects for central versus peripheral distractor trials between children and adults, and for central compared to parafoveal and peripheral distractor trials between children and adolescents. The post hoc revealed that for children, as social anxiety symptoms increase, saccade latencies increased significantly more for peripheral distractors than for central distractors ($\beta = 0.01$, $SE = 0.01$, $t = 2.49$, $p < .05$). However, the increase in latency for parafoveal distractors compared with central distractors was not statistically significant ($\beta = 0.01$, $SE = 0.01$, $t = -2.22$, $p = .07$). Additionally, there was no significant difference between the increase in latencies for peripheral and parafoveal distractors ($\beta = 0.001$, $SE = 0.001$, $t = -0.32$, $p = 0.95$), after applying Tukey's correction for multiple comparisons (see Figure 2). For adults and adolescents, the contrasts between all distractor location pairs were not significant ($ps > .05$).

Main Effects and Interactions with Social Anxiety: Saccadic Errors

Symptoms of social anxiety showed no significant main effect on saccadic errors. Table 3 shows a two-way interaction between social anxiety symptoms and emotional expression for saccadic errors. Elevated social anxiety symptoms were associated with higher saccadic error rates for neutral faces compared with happy faces ($\beta = 0.17$, $SE = 0.07$, $z = 2.56$, $p < .05$) (Figure 3). In addition, table 3 shows a two-way interaction between social anxiety and distractor location, suggesting that social anxiety symptoms were related to increased error rates for peripheral compared with parafoveal distractors ($\beta = 0.11$, $SE = 0.05$, $z = 2.03$, $p < .05$).

The results further showed a three-way interaction between age group, expression and social anxiety with saccadic errors. The LMM interaction effects were significant for the expression contrasts of neutral versus happy and angry versus happy, when comparing children to adolescents. Post-hoc analysis using estimated marginal trends (emtrends) revealed the following trends in social anxiety within each age group (children, adolescents, adults). Contrast estimates for children showed

no significant differences in social anxiety trends between the emotional expressions ($p > .05$). For adolescents, the contrast between happy and neutral expressions approached significance ($\beta = -0.34$, $SE = 0.15$, $z = -2.30$, $p = 0.055$), indicating that social anxiety may lead to more saccadic errors when processing neutral compared to happy expressions. However, there were no significant differences for angry versus happy faces ($\beta = 0.21$, $SE = 0.14$, $z = 1.49$, $p = 0.30$) after applying Tukey's correction for multiple comparisons (see Figure 4). For adults, there were no significant differences in social anxiety trends between any of the emotional expressions ($ps > .05$).

The LMM results in Table 3 highlight a marginally significant three-way interaction between group, location, and social anxiety. The contrasts for this effect were between children and adults when comparing peripheral versus parafoveal distractor trials. Contrast estimates within the child group showed no significant differences for social anxiety trends between parafoveal and peripheral distractor locations ($\beta = -0.05$, $SE = 0.06$, $z = -0.83$, $p = 0.41$). In contrast, for adults, there was a significant difference ($\beta = -0.28$, $SE = 0.10$, $z = -2.87$, $p < .05$), with higher social anxiety symptoms associated with more saccadic errors for peripheral distractors compared to parafoveal distractors (see Figure 5).

Discussion

This study used measurements of saccadic errors and saccade latencies in an RDP to investigate links between self-reported symptoms of social anxiety in children, adolescents and adults and attention processes, including selective attention and avoidance, disengagement and hypervigilance in the presence of task-irrelevant emotional (angry and happy) and non-emotional (neutral) stimuli. Following previous studies (e.g., Pavlou et al., 2016; Lazarov, 2016; 2021), we anticipated a positive relationship between symptoms of social anxiety and saccade latencies to a target stimulus in the presence of angry and neutral (versus happy) distractor faces indicating both hypervigilance (for distractor faces presented at 4°and 8° from the centre) and challenges with

disengagement (for distractor faces presented centrally). Previous research has found that perceptions of ambiguity associated with neutral faces increases across development (e.g., Rollins et al., 2021; Tottenham, 2013) and negative misinterpretations of ambiguous facial stimuli have been linked to elevated symptoms of anxiety (e.g., Cooney et al., 2006, Peschard & Philippot, 2017; Richards et al., 2007). We anticipated that attention to neutral faces may increase across development and become increasingly salient for adolescents and adults who experience elevated social anxiety. Further analyses considered whether our results would be consistent with avoidance of threat in anxiety as reflected in faster latencies to the target in the presence of threat (see Manoli et al., 2021).

The results showed that baseline task performance in the RDP paradigm was consistent with previous results, demonstrating that saccade latencies to a target were slower in the context of distractor face stimuli, and for centrally presented distractors compared with those presented in the periphery or parafovea (e.g., Benson, 2008; Walker et al., 1997). Moreover, it replicated previous findings highlighting increased saccadic errors with distractor eccentricity (Benson, 2008). Consistent with typical reaction time (e.g. Van Damme & Crombez, 2009) and eye-movement indices of attention (e.g., Manoli et al., 2021), children in this study showed longer saccade latencies to meet task goals compared with adults. However, the adolescent group showed the longest overall saccade latencies. While this result was unexpected and requires replication in future studies, it fits with data from Tottenham et al., (2013) who found that reaction times in the context of interpreting facial stimuli increased from childhood to adolescence. Moreover, it sits within a broader literature that aims to understand the impact of biological and social change on social-cognitive processes and that has highlighted a "maladaptive shift" (Cracco et al., 2017, p. 909) during this period of development. Cracco et al., (2017), for example, asked 8-18-year-olds to outline strategies used to regulate negative emotions (i.e., sadness, anger, anxiety). The results showed that between 12-15 years of age adolescents reported a decrease in strategies known to be effective in the regulation of emotions (e.g., problem-solving, distraction) and an increase in those shown that are less successful

(e.g., giving up). Consistently, further research has found heightened brain reactivity to negative emotional stimuli and less recruitment of prefrontal regions important for emotional regulation in adolescents (compared with children and adults; Hare et al., 2008). Overall, the data suggest that social-cognition including emotion face processing continues to develop from childhood through to adulthood, and may be impacted during the adolescent period of development(e.g., Lee et al., 2020; Wiggins et al., 2016).

Previous studies have found selective attention biases to threat stimuli across typical populations (e.g., Dodd et al., 2020; LoBue & Perez-Edgar, 2014). This study similarly demonstrated slower saccade latencies to the target and more saccadic errors in the context of angry (versus happy and neutral) face distractors, indicating both hypervigilance and selective attention to threat. The study further found interactions between symptoms of social anxiety and emotional expression, highlighting that elevated social anxiety symptoms were associated with increased saccadic errors for neutral faces, and faster time to respond to targets in the context of angry face distractors, highlighting the salience of both threat and neutral faces for understanding attention biases in social anxiety (Bashoogendam et al., 2019; Cooney et al., 2006). While the basic task results fit with previous research, task performance in the current study was generally qualified by three-way interactions.

The results highlighted that the interaction between emotional expression and social anxiety was explained further by a three-way interaction that included age group. Within-group analysis demonstrated that for the child group social anxiety was positively linked to saccade latencies in presence of all face stimuli. This association was, however, smaller in the presence of angry and neutral (compared with happy faces), indicating faster latencies with elevated symptoms of social anxiety for these stimuli. Faster saccade latencies in this context suggests increased avoidance of neutral and angry faces in this age group (see also e.g., Manoli et al., 2021). While this result does not replicate earlier findings from the RDP showing that neuroticism traits were linked to

hypervigilance (i.e., longer saccade latencies) for angry and neutral faces, it fits well with research demonstrating avoidance of threat (angry and fearful faces) in children who experience elevated symptoms of social anxiety (Dodd et al., 2015; Stirling et al., 2006). Similar processes have been found in adults, but only in the context of social threat. Mansell et al., (1999), for example, demonstrated avoidance of negative emotional faces (i.e., of anger, disgust, fear, sadness) for adults who self-reported elevated symptoms of social anxiety, but where this association was only found in the context of adults anticipating having to deliver and be assessed on giving a speech.

While angry and neutral face distractors were linked to avoidance in childhood, symptoms of social anxiety were associated with increased saccade latencies for neutral (compared with angry) faces in adolescents and for neutral faces (compared with both angry and happy faces) in adults. The results support the proposition that neutral faces may represent an ambiguous stimulus that takes longer to process for individuals who report elevated social anxiety and where this effect emerges in adolescence, and is most evident in adults (Rollins et al., 2021; Tottenham et al., 2013). Evidence that task performance was impacted via slower saccade latencies to a target in the context of neutral faces in adolescents and adults fits with theoretical models which suggest that individuals who experience increased symptoms of social anxiety are more likely to misinterpret ambiguous social stimuli as threatening (Clark and McManus, 2002). With respect to face stimuli, Peschard & Philippot, (2017) found that adults who endorsed more symptoms of social anxiety were more likely to attribute anger to neutral faces and voices compared to those who reported fewer symptoms. Further research has shown that adults who were assigned to a high (versus low) social anxiety group based on self-reported symptoms made fewer attributions of happiness to ambiguous faces, where ambiguity was created by blending happy face smiles with the eye regions from angry, fearful and disgusted facial expressions (Gutierrez-García & Calvo, 2014). More recently, Loscalzo et al., (2018) extended research to similarly show that negative interpretation of ambiguous social-cognitive scenarios was positively associated with self-reported symptoms of social anxiety in adults.

These findings fit with recent arguments that slowed reaction times in cognitive tasks may represent a transdiagnostic index of difficulty for adolescents who report increased symptoms of internalising or externalising behaviour (Kramer et al., 2023). They are also consistent with the proposition that displays of threat become less overt across development. Several studies have suggested, for example, that expressions of anger dissipate with age as children and adolescents start to utilise attentional control to modulate its expression to adapt to socio-cultural expectations associated with its display (e.g., Cole et al., 2011; Ramsook et al., 2020). If individuals who experience social anxiety symptoms worry about social evaluation then with age attention may adaptively shift to less overt displays of potential anger.

Applications and Directions for Future Research

The current study has several limitations including small sample sizes in each age group and a focus on individual differences in social anxiety that largely reflect a typical range. Moreover, its cross-sectional nature limits conclusions about developmental change and longitudinal studies could address this element of the design. The study sits alongside research that has highlighted the relevance of utilising eye-movement methodologies to explore attention to threat and its association with symptoms of social anxiety. It highlighted that increased self-reported symptoms of social anxiety were associated with several distinct attention processes and indicated that signals of threat may shift with development. The results provide further insight into the development of a conceptual framework that supports a broadening of attention across development in individuals who experience elevated social anxiety, and an increasing salience of social-cognitive ambiguity, as depicted in neutral faces. Consistent with previous arguments, the results indicate that neutral faces may not be a helpful control stimulus when trying to understand social-cognitive processing in anxiety. The salience of threat and neutral faces in children and neutral faces in adolescents and adults links to theoretical models highlighting a negative impact of social-cognitive processing for the development of social relationships and interactive behaviours (e.g., reduced speech and eye contact) for

individuals who experience elevated social anxiety (review by Spence and Rapee, 2016). Moreover, they add to research that explores the relevance of attention frameworks in understanding an individual's ability to meet task goals at school or in the workplace in the presence of contextual threat that is mild or task-irrelevant, where a broadening of the attentional beam reduces attentional resources available for ongoing tasks (e.g., Chen et al., 2015; Richards et al., 2011).

The results support the increasing focus on interventions that target attention processes associated with the detection of threat and a negative interpretation of ambiguous stimuli, alongside those that aim to manage social anxiety symptoms, and the development of social skills (e.g., Beidel et al., 2014; Olivares et al., 2019). In the context of the impact of social anxiety on diverse aspects of cognitive processing that vary with age, the results further highlight the importance of understanding the nature of cognition in different age groups and for distinct stimuli in order to allow a more targeted approach to intervention and outcome. For example, therapeutic interventions can include attention bias modification to shift attention from threat to focus on positive stimuli (e.g., Krejtz et al., 2018), that work to understand its impact on negative interpretations across different age groups (e.g., Britton & Bailey, 20018, or that directly focus on changing interpretations of individuals who experience elevated anxiety (e.g., Salemink et al., 2009). Because of the increasing recognition that social anxiety symptoms impact different attentional processes that may vary with age, future research should also explore the relative benefits of intervention approaches that aim to train attentional control more broadly (e.g., Azriel et al., 2024; Beloe & Derakshan, 2020; Hadwin & Richards, 2016). Moreover, research should start to investigate the broader impact of intervention approaches beyond attention on positive social-cognitive change and an individual's day-to-day interactions.

Disclosure Statement

We have no known conflict of interest to disclose.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author, KP on request.

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Table 1

Mean Saccade Latencies and Proportion of Saccadic Errors for Central, Parafoveal and Peripheral distractors and between Age group and Expression

		Saccade Latency			Saccadic Errors		
		M(SD)			*%*		
		Angry	Happy	Neutral	Angry	Happy	Neutral
Children	Central	241.64(74.88)	235.47(69.43)	227.67(58.92)			
	Parafoveal	224.51(61.52)	226.18(60.90)	220.34(51.32)	31.66	25.00	22.01
	Peripheral	215.53(52.17)	219.29(58.51)	212.28(50.39)	39.00	33.46	31.77
Adolescents	Central	270.69(65.34)	254.88(53.06)	255.67(66.28)			
	Parafoveal	250.13(59.09)	242.10(42.40)	247.78(53.23)	19.54	15.00	14.07
	Peripheral	255.05(58.04)	252.64(45.11)	254.37(46.15)	27.88	21.92	24.47
Adults	Central	204.56(60.26)	199.07(50.93)	200.09(54.50)			

Parafoveal	189.98(42.17)	187.34(36.96)	131.97(43.76)	6.38	6.69	4.79
Peripheral	191.89(55.19)	191.06(52.25)	193.88(50.64)	10.06	11.43	9.70

Table note. Children N= 38; Adolescents = 21; Adults N= 32

Table 2

Linear Mixed Model Results for Saccade Latencies

	Saccade Latency		
Predictors	*Estimates*	*CI*	*p*
(Intercept)	5.39	5.36 – 5.41	**<0.001**
Group(Adolescents – Children)	0.13	0.06 – 0.19	**<0.001**
Group(Children – Adults)	0.15	0.09 – 0.21	**<0.001**
Group(Adults – Adolescents)	-0.28	-0.34 – -0.21	**<0.001**

Location(d2 – d8)	0.04	0.04 – 0.05	**<0.001**
Location(d4 – d2)	-0.05	-0.05 – -0.04	**<0.001**
Location(d8-d4)	0.00	-0.00 – 0.01	0.448
Social Anxiety	0.01	-0.01 – 0.04	0.314
Expression(Angry – Neutral)	0.02	0.01 – 0.03	**<0.001**
Expression(Happy – Angry)	-0.02	-0.03 – -0.01	**<0.001**
Expression(Neutral-Happy)	-0.00	-0.01 – 0.00	0.636
Group(Adolescents – Children)*Social Anxiety	-0.03	-0.10 – 0.03	0.291
Group(Children – Adults)*Social Anxiety	0.04	-0.02 – 0.09	0.170
Group(Adults – Adolescents))*Social Anxiety	-0.00	-0.07 – 0.06	0.900
Location(d2 – d8)*Social Anxiety	0.00	-0.01 – 0.01	0.781
Location(d4-d2)*Social Anxiety	0.00	-0.00 – 0.01	0.649

Location(d8-d4)*Social Anxiety	-0.00	-0.01 – 0.00	0.482
Expression(Angry-Neutral)*Social Anxiety	-0.02	-0.03 – -0.01	**<0.001**
Expression(Happy-Angry)*Social Anxiety	0.01	0.01 – 0.02	**<0.001**
Expression(Neutral-Happy)*Social Anxiety	0.01	0.00 – 0.01	**0.037**
Group (Children – Adults)*Location(d2 – d8)*Social Anxiety	-0.02	-0.04 – -0.01	**0.001**
Group(Adults-Adolescents)*Location(d2 – d8)*Social Anxiety	0.00	-0.01 – 0.02	0.747
Group(Adolescents-Children)*Location(d2 – d8)*Social Anxiety	0.02	0.00 – 0.04	**0.012**
Group(Adolescents-Children)*Location(d4-d2)*Social Anxiety	-0.02	-0.03 – -0.00	**0.012**
Group(Children – Adults)*Location(d4-d2)*Social Anxiety	0.01	-0.00 – 0.02	0.119
Group(Adults-Adolescents)*Location(d4-d2)*Social Anxiety	0.01	-0.01 – 0.02	0.224

Group(Adolescents-Children)*Location(d8-d4)*Social Anxiety	-0.00	-0.02 – 0.02	0.971
Group(Children – Adults)*Location(d8-d4)*Social Anxiety	0.01	-0.00 – 0.03	0.110
Group(Adults-Adolescents)*Location(d8-d4)*Social Anxiety	-0.01	-0.03 – 0.00	0.137
Group(Adolescents-Children)*Expression(Angry-Neutral)*Social Anxiety	-0.01	-0.02 – 0.01	0.331
Group(Children – Adults)*Expression(Angry-Neutral)*Social Anxiety	0.02	0.00 – 0.03	**0.020**
Group(Adults-Adolescents)*Social Anxiety*expression(Angry-Neutral)	-0.01	-0.02 – 0.01	0.260
Group(Adolescents-Children)*Expression(Happy – Angry)*Social Anxiety	-0.02	-0.03 – 0.00	0.055
Group(Children – Adults)*Expression(Happy – Angry)*Social Anxiety	0.02	0.01 – 0.04	**0.002**

Group(Adults-Adolescents)*Expression(Happy – Angry)*Social Anxiety	-0.01	-0.02 – 0.01	0.401
Group(Adolescents-Children) *Expression(Neutral-Happy)*Social Anxiety	0.02	0.01 – 0.04	**0.004**
Group(Children – Adults)*Expression(Neutral-Happy)*Social Anxiety	-0.04	-0.05 – -0.02	**<0.001**
Group(Adults-Adolescents)*Expression(Neutral-Happy)*Social Anxiety	0.01	0.00 – 0.03	**0.049**

Table 3

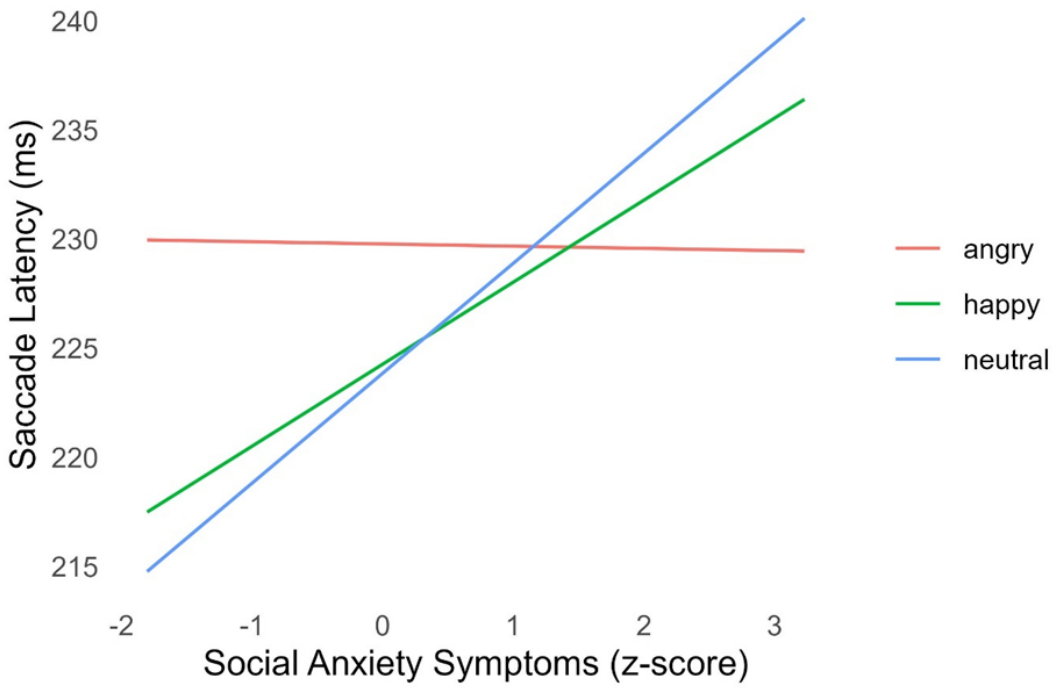
Linear Mixed Model Results for Saccadic Errors

	Saccade Accuracy		
Predictors	*Odds Ratios*	*CI*	*p*
(Intercept)	0.15	0.11 – 0.19	**<0.001**
Group (Adolescents – Children)	0.47	0.25 – 0.89	**0.019**
Group(Children – Adults)	6.73	3.85 – 11.78	**<0.001**
Group(Adults – Adolescents)	0.31	0.16 – 0.60	**0.001**
Location(d8-d4)	1.81	1.64 – 2.01	**<0.001**
Social Anxiety	0.96	0.75 – 1.23	0.776
Expression(Angry – Neutral)	1.37	1.22 – 1.55	**<0.001**
Expression(Happy – Angry)	0.80	0.71 – 0.91	**<0.001**

Expression(Neutral-Happy)	0.90	0.80 – 1.02	0.110
Group(Adolescents – Children)*Social Anxiety	1.14	0.62 – 2.12	0.669
Group(Children – Adults)*Social Anxiety	0.84	0.49 – 1.43	0.519
Group(Adults – Adolescents))*Social Anxiety	1.04	0.55 – 1.98	0.899
Location(d8-d4)*Social Anxiety	1.12	1.00 – 1.24	**0.043**
Expression(Angry-Neutral)*Social Anxiety	0.90	0.79 – 1.02	0.087
Expression(Happy-Angry)*Social Anxiety	0.94	0.83 – 1.07	0.332
Expression(Neutral-Happy)*Social Anxiety	1.18	1.04 – 1.35	**0.010**
Group(Adolescents-Children)*Location(d8-d4)*Social Anxiety	0.95	0.73 – 1.23	0.679
Group(Children – Adults)*Location(d8-d4)*Social Anxiety	0.80	0.63 – 1.00	0.054
Group(Adults-Adolescents)*Location(d8-d4)*Social Anxiety	1.32	0.98 – 1.78	0.063

Group(Adolescents-Children)*Expression(Angry-Neutral)*Social Anxiety	0.97	0.72 – 1.31	0.834
Group(Children – Adults)*Expression(Angry-Neutral)*Social Anxiety	1.01	0.77 – 1.31	0.964
Group(Adults-Adolescents)*Social Anxiety*expression(Angry-Neutral)	1.03	0.74 – 1.43	0.878
Group(Adolescents-Children)*Expression(Happy – Angry)*Social Anxiety	0.72	0.52 – 0.98	**0.037**
Group(Children – Adults)*Expression(Happy – Angry)*Social Anxiety	1.26	0.97 – 1.64	0.084
Group(Adults-Adolescents)*Expression(Happy – Angry)*Social Anxiety	1.11	0.78 – 1.57	0.558
Group(Adolescents-Children) *Expression(Neutral-Happy)*Social Anxiety	1.44	1.04 – 2.00	**0.027**
Group(Children – Adults)*Expression(Neutral-Happy)*Social Anxiety	0.79	0.61 – 1.03	0.080

Group(Adults-Adolescents)*Expression(Neutral-Happy)*Social Anxiety	0.88	0.61 – 1.25	0.474


240
235
230
225
220
215
Saccade Latency (ms)
-2
-1
0
1
2
3
Social Anxiety Symptoms (z-score)
angry
happy
neutral

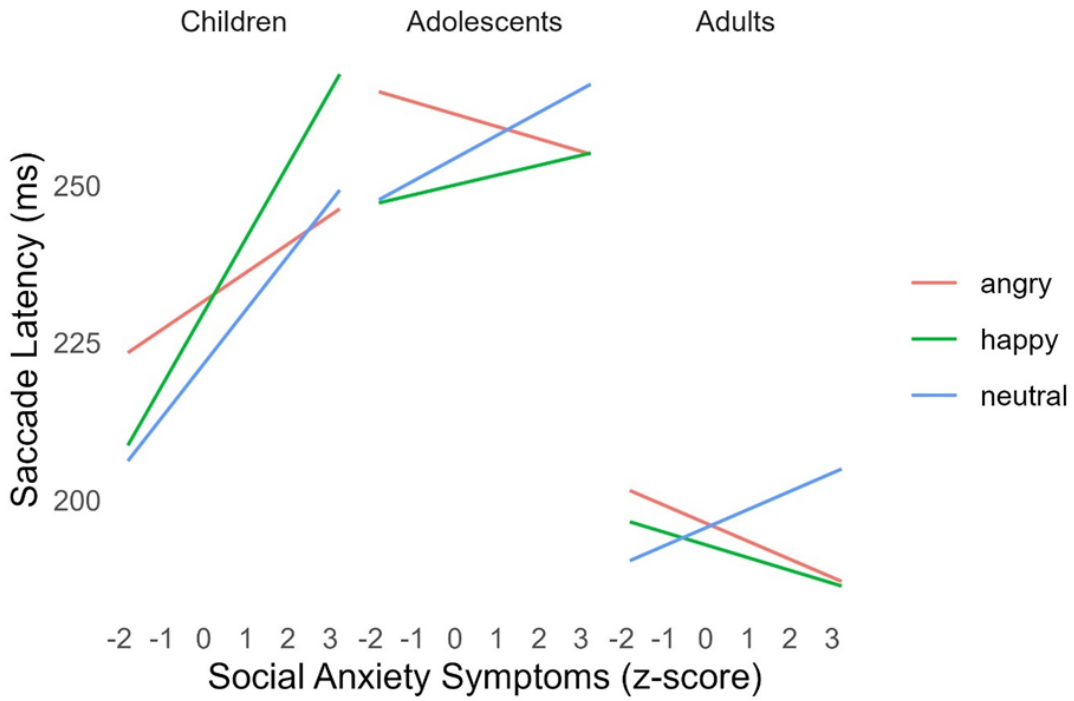


Figure 1a and 1b

Two-way Interaction between Expression and Social Anxiety Symptoms on Saccade Latencies (1a; top) and Three-way interaction between Participant Age Group and Expression with Social Anxiety Symptoms on Saccade Latencies (1b; bottom).

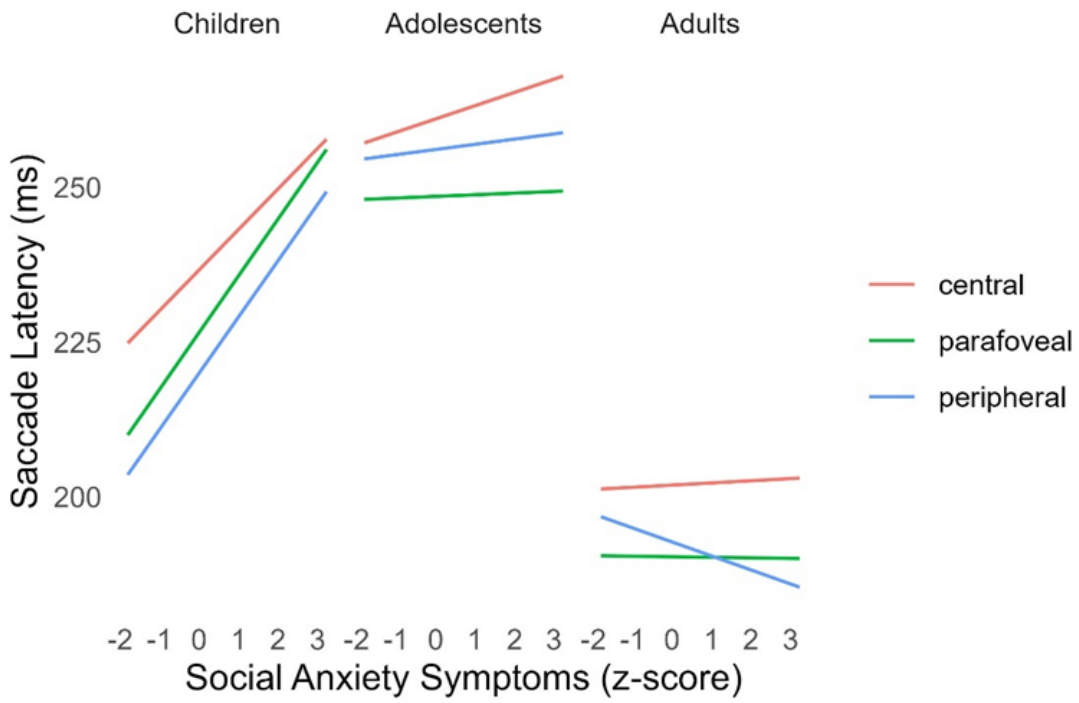


Figure 2

Interactive effects between Participant Age Group, Distractor Location and Symptoms of Social Anxiety on Saccade Latencies.

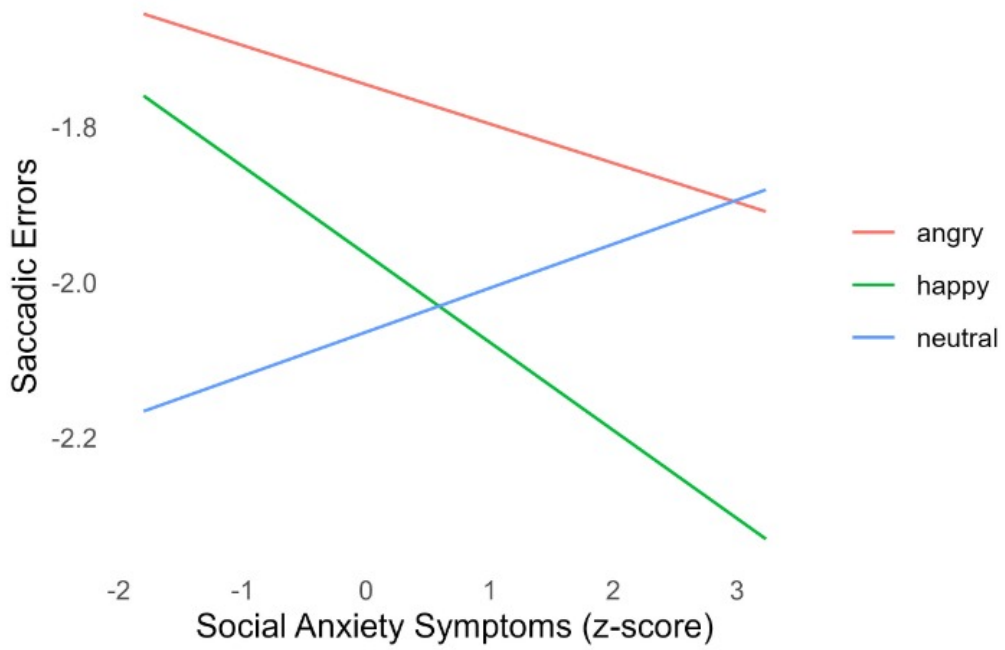


Figure 3

Two-way Interaction between Expression and Social Anxiety Symptoms on Saccadic Error Rates.

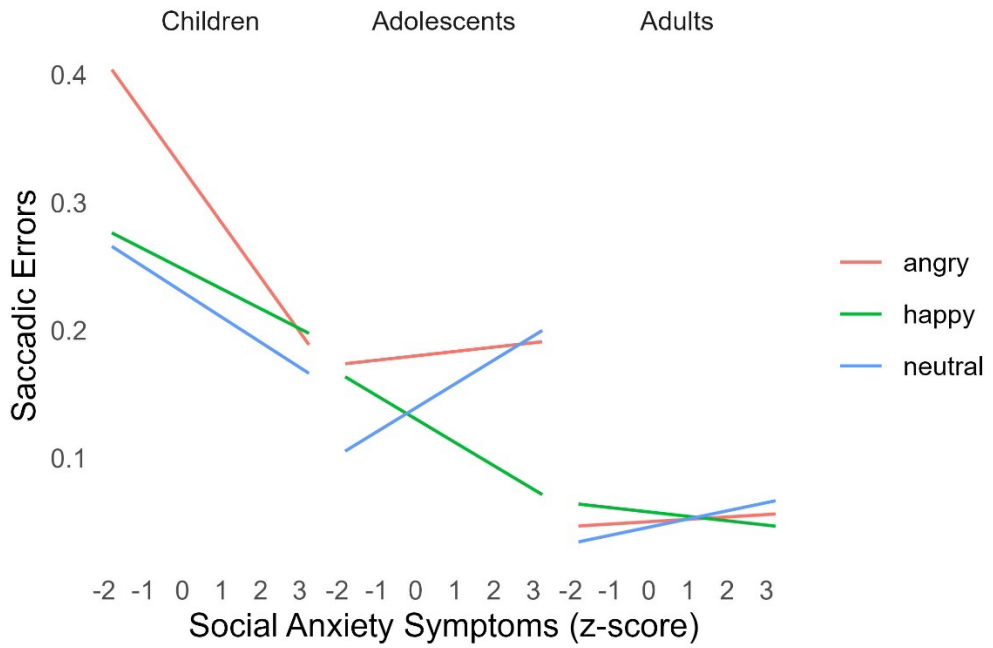


Figure 4

Interactive effects between Participant Age Group, Distractor Emotion and Symptoms of Social Anxiety on Saccadic Error Rat

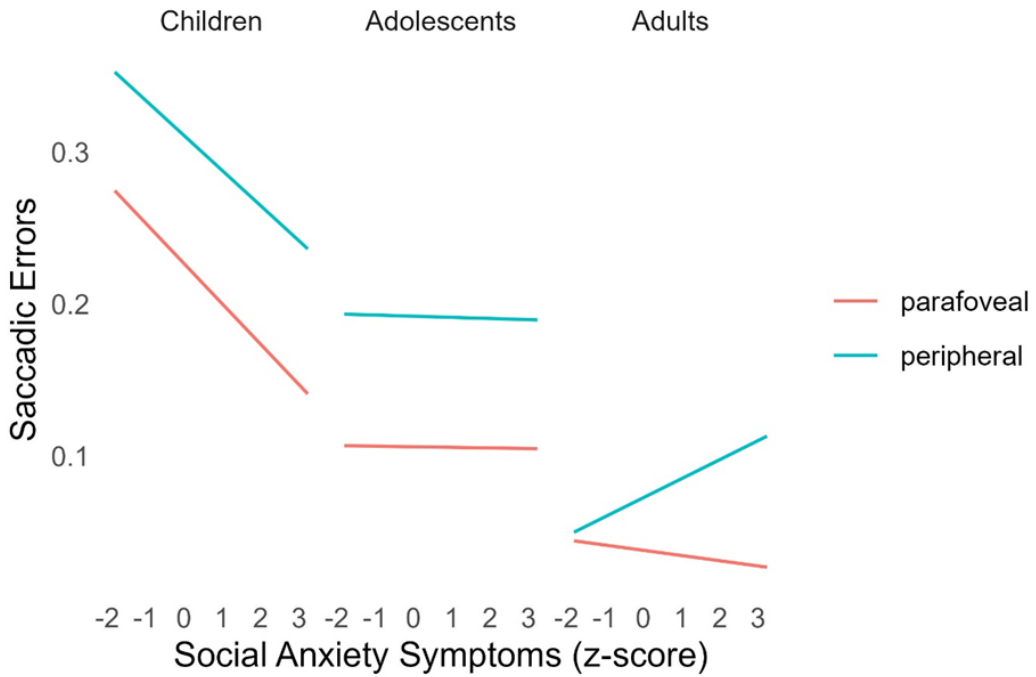


Figure 5

Interactive effects between Participant Age Group, Distractor Location and Symptoms of Social Anxiety on Saccadic Error Rates.