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# Resonating emotions: an embodied perspective on alterations in facial emotion processing in autism and social anxiety

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# Chapter 2:

# Who Gets Caught by the Emotion? Attentional Biases toward Emotional Facial Expressions and Their Link to Social Anxiety and Autistic Traits

## Abstract

The emotional facial expressions of other individuals are a valuable information source in adapting behaviour to situational demands, and have been found to receive prioritized attention. Yet, enhanced attentional biases, such as a bias to social threat in Social Anxiety Disorder (SAD), or blunted attention to emotional information, as assumed in Autism Spectrum Disorder (ASD), can easily become maladaptive in daily life. In order to investigate individual differences in attentional biases toward different emotional expressions (angry, happy, sad, and fearful versus neutral) and their links to social anxiety and autistic traits, we tested 104 healthy participants with an emotional dot-probe paradigm on a touch screen, and measured clinical trait levels associated with ASD and SAD. While confirming the presence of attentional biases toward all emotional expressions, we did not find robust evidence for systematic links between these biases and either clinical trait dimension. Only an exploratory Bayesian analysis pointed to a less pronounced bias towards happy facial expressions with higher autistic trait levels. Moreover, a closer examination of the attentional bias towards angry facial expressions suggested that alterations in this bias might depend on a complex interplay between both trait dimensions. Novel approaches in the assessment of attentional biases might yield the potential to describe disorder-specific biases in attention to emotions more validly.


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**Data availability statement:**

The datasets and materials generated and/or analysed during the current study are available on Dataverse NL: https://doi.org/10.34894/UVQHHD

**Supplementary material:**

Online Resource 1

Online Resource 2

Living in a world rich in (visual) stimulation, the human perceptual system requires guidance to filter the environment for crucial information. Emotional stimuli have been shown to strongly capture and hold attention in various modalities and impact subsequent behaviour (Carretié, 2014). Already in the first years of life, infants use their caregivers' emotional expressions to evaluate the current situation, which is commonly referred to as social referencing (e.g., Möller et al., 2014). Further, also in some non-human primates, emotional expressions of conspecifics have been found to receive prioritized attention, resulting in faster responding (e.g., Kret et al., 2016; van Berlo et al., 2020). Thus, the phenomenon of attention being automatically directed to emotional expressions of others seems to be a deeply-rooted, adaptive mechanism in social animals.

Experimental paradigms have confirmed attentional biases toward various emotional facial expressions and body postures in healthy individuals (Bradley et al., 1997; Carlson & Mujica-Parodi, 2015; Valk et al., 2015; Wirth & Wentura, 2020).In individuals with a diagnosis of Autism Spectrum Disorder (ASD) or Social Anxiety Disorder (SAD), alterations in attention to emotional information have been suggested as one potential mechanism underlying social interaction difficulties (Bantin et al., 2016a; Kliemann et al., 2010). However, research on altered attentional biases in these clinical conditions has mainly focused on social threat perception (i.e., displays of anger), whereas humans are exposed to a broad range of emotional displays in daily life. Moreover, different mechanisms have been proposed to underlie altered attention to emotion in the two clinical conditions. With the current study, we therefore aimed to take a step towards the identification of potential systematic alterations in the attention to emotional expressions in ASD and SAD by examining the link between variations in trait levels associated with the two conditions and attentional biases toward different emotional expressions.

**Attention to Emotional Facial Expressions and the Dot-probe Paradigm**

In the non-verbal communication of affect, facial expressions are particularly salient and have been shown to effectively capture attention. Most studies so far have focussed on biases to negative stimuli and have identified an "anger superiority effect" (Hansen & Hansen, 1988). This effect describes the rapid and preferential detection of angry faces among others, highlighting the importance of threatening information. Yet, recent studies have shown that also positive stimuli, including smiling faces, attract attention compared to neutral stimuli

(Pool et al., 2016). To systematically investigate biased attention to certain stimuli, namely biases to threat stimuli in individuals with a depression or anxiety disorder, the dot-probe task was developed (MacLeod et al., 1986). Since then, it has been used to investigate a variety of biases to a variety of stimuli in different populations (see van Rooijen et al., 2017). While the specific content and parameters differ between studies, they all share the general structure: a trial starts with the presentation of two stimuli for a pre-specified duration on two sides of the screen and equidistant to the centre. After they disappear, a probe appears on one of the two picture location which the participant has to react to. If the target stimulus (e.g., an emotional one) is replaced by the probe, the trial is defined as 'congruent'. In contrast, in an 'incongruent' trial, the probe appears on the location of the control stimulus (e.g., a neutral one). The attentional bias is then usually calculated by looking at a difference value between reaction times during congruent and incongruent trials.

Studies looking at attentional biases to emotional facial expressions using this task have reported attentional biases to both positive (e.g., Wirth & Wentura, 2020) and negative facial emotional expressions (e.g., Bradley et al., 1997; Carlson & Mujica-Parodi, 2015). However, when contrasting different emotion categories in the dot-probe task, some studies only found a bias towards specific emotions (e.g., Valk et al., 2015) while other studies found no bias in reaction times at all (e.g., Puls & Rothermund, 2018). Methodological differences between studies, for example, in the timing of the stimuli or the stimulus content have been suggested as potential explanations for the mixed evidence (Cooper & Langton, 2006; van Berlo et al., 2020). Importantly, inconsistent findings can also be driven by individual differences (Yiend, 2010). For example, an altered processing of emotional (facial) stimuli, including attentional processes, has been described in various mental health conditions (Kret & Ploeger, 2015).

**Attention to Emotion in Social Anxiety**

Being characterized by a disproportionate and impairing fear of scrutiny in social situations, Social Anxiety Disorder (SAD) is a mental health condition that already suggests altered attentional allocation to social information by definition (DSM-V; American Psychiatric Association, 2013). The most prominent cognitive-behavioural models on the development and maintenance of SAD all describe a shift in attention to the self as a social object once a social situation is entered or

even anticipated (Clark & Wells, 1995; Heimberg et al., 2010, 2014; Hofmann, 2007; Rapee & Heimberg, 1997). This altered attention entails an increased awareness of negatively biased cognitive self-representations and physiological arousal. The *cognitive-behavioral model of anxiety in social phobia* (Rapee & Heimberg, 1997; updates: Heimberg et al., 2010, 2014) additionally posits that attention is tuned to external cues in order to inform mental self-representations. Facial expressions are one example of these cues which can indicate possible negative evaluations by others, which people with SAD fear. This theoretical assumption has been confirmed in various empirical studies showing altered attention to angry facial expressions, representing social threat, in socially anxious individuals (e.g., Lazarov et al., 2021). In line with this, findings from dot-probe studies overall, yet not consistently, report an attentional bias towards threat faces (for a review, see Bantin et al., 2016). Different mechanisms have been suggested to underlie biased attention to threatening stimuli, namely (a) an initial vigilance to threat which; (b) is followed by avoidance after longer exposure (Mogg, Bradley, et al., 2004), as well as; (c) a prolonged attentional capture by threat stimuli, (i.e., difficulty in disengagement; Cisler & Koster, 2010). In the dot-probe task, the difficulty to disengage from threat with higher social anxiety was predominantly found in non-clinical samples (Salemink et al., 2007), whereas a vigilance to threat was prevalent in clinical samples (Klumpp & Amir, 2009).



Importantly, even though different types of emotional expressions appear in a social context and could provide relevant (evaluative) information about other people (Heimberg et al., 2010, 2014; Rapee & Heimberg, 1997), there is only limited research on altered attentional biases toward emotional facial expressions other than anger (Mogg, Philippot, et al., 2004). In these few studies, (altered) biases, if present at all, were less pronounced compared to the anger bias. The number and breadth of these studies is, however, too limited to draw any conclusions on biased attention to emotions other than anger in social anxiety. Thus, our study aims to contribute to a better understanding of altered attention to emotional expressions associated with social anxiety by including various emotional facial expressions.

**Attention to Emotion in Autism**

Another clinical population that has been found to show alterations in attention to emotional facial expressions are autistic individuals. They tend to attend to

faces and, specifically the eye and mouth region, less (Chita-Tegmark, 2016), which might contribute to difficulties in identifying emotions (Kliemann et al., 2010). It has been long assumed that the active avoidance of the eye region, conveying emotional information, would be driven by an unpleasant hyperactivation of the amygdala in autistic individuals (relevance detection theory; Zalla & Sperduti, 2013). Recently, however, avoidance of the eye region was claimed to be the result of preventing both hypo- and hyperarousal (two pathway model; Cuve et al., 2018). Attention to facial emotional expressions thus seems to be related to unpleasant arousal levels in autistic individuals. Yet, biased attention towards threatening faces specifically was observed in autistic children and adults (Fan et al., 2020). This led to the claim that the "anger superiority effect" (Hansen & Hansen, 1988) as basic adaptive phenomenon would be unaltered in autistic individuals (Gaigg, 2012). As an alternative explanation, given the high comorbidity between social anxiety and autism (Spain et al., 2018), the question was raised whether the threat bias observed in autistic individuals could be attributed to comorbid social anxiety. Specifically in the social domain, autistic and socially anxious individuals show similar patterns, such as choosing to be alone and avoiding or disliking social situations (White et al., 2012). Apart from one exception (Hollocks et al., 2016), experimental studies, however, have found no evidence for an influence of anxiety symptoms on the threat bias in ASD using the dot-probe task (Hollocks et al., 2013; May et al., 2015). Importantly, as most of the available dot-probe studies examine alterations in ASD, these studies were performed with a developmental sample (children/teenagers), thus limiting the generalizability of the results.

Similarly, alterations in biases to emotional expressions other than anger have mostly been investigated in autistic children. Here, one study found no evidence of a bias to happy (nor angry) facial expressions (May et al., 2015), whereas another study found no biases toward happy or sad expressions (García-Blanco et al., 2017) in both neurotypical and autistic children. The inconclusive evidence from developmental samples is also reflected in the scarce adult literature on this topic: In one study, only adults with low but not with high autistic trait levels, showed an attentional bias to fearful expressions (Miu et al., 2012). In another study, in contrast, no differences in attentional biases between autistic and non-autistic adults were found. Both groups showed attentional biases to happy and angry faces, but not to sad faces (Monk et al., 2010). Examining all existing evidence together, it is not clear whether attentional biases to specific emotional expressions exist in

autistic adults. In the current study, we attempted to diminish this knowledge gap by measuring autistic trait levels and relating them to attentional biases toward various emotional expressions.

**Present Study**

The goal of this study was to examine whether variability in attentional biases toward different emotional facial expressions can be explained by trait levels associated with ASD and SAD in the general population. More specifically, we administered a modified version of the emotional dot-probe task on a touchscreen (see van Berlo et al., 2020) in public settings (community sample) as well as in a lab setting (student sample). To replicate as well as expand current findings on attentional biases to specific emotions, we paired angry, happy, sad, and fearful expressions with neutral expressions in the dot-probe task, and assessed autistic and social anxiety traits via self-reports. The hypotheses, including statistical models to test them, were preregistered on the Open Science Framework after data collection but before accessing the data (see https://osf.io/8pwgy for the preregistration, including a more detailed description of the hypotheses). In line with the proposed adaptive function of increased attention to emotions serving as communicative signals (Crivelli & Fridlund, 2018) as well as the results from most dot-probe studies to date (however, see Puls & Rothermund, 2018), we expected to observe an attentional bias toward all emotions. Given the high relevance of angry facial expressions as (social) threat signals, attentional biases might especially be pronounced for expressions of anger (e.g., Valk et al., 2015). We expected that variability in this bias could be explained by social anxiety traits, particularly that higher social anxiety trait levels would be associated with stronger biases. The possibility of a stronger attentional bias to other emotional expressions in individuals with higher levels of social anxiety traits was additionally explored, including the goal to contrast increased initial vigilance with a difficulty to disengage from emotional expressions. Given the inconclusive literature on the relationship between autism and attentional biases in adults, we hypothesized that, due to an avoidance of the eye region, a less pronounced bias to emotional facial expressions should become apparent with higher autistic trait levels. The bias to angry faces should, however, not be linked to autistic trait levels, as suggested by past research in clinical populations (Fan et al., 2020). Further, the comorbidity between social anxiety and autism has been discussed, yet not confirmed, as being a potential source of a threat bias in individuals with ASD (e.g.,

May et al., 2015). Therefore, we also aimed to explore whether the link between autistic trait levels and the attentional bias towards angry faces would depend on simultaneously heightened social anxiety trait levels (i.e., a moderation effect) in our healthy sample.

## Method

### Participants

We tested 104 participants (75 female) with a mean age of 31.4 years (*SD* = 14.5, Range: 17 -71) and the majority (*n* = 95) being right-handed. All participants reported to have no prior or current psychological or neural disorder and performed the experiment either in English (*n* = 14) or in Dutch (*n* = 90). Data was collected in three different settings in the Netherlands: the primate park 'Apenheul' in Apeldoorn (*n* = 30), the science festival 'Night of Discoveries' in Leiden (*n* = 22) and a laboratory at Leiden University (*n* = 52). One participant at the primate park and one participant at the science festival had incomplete task data and were disregarded from the analysis (*N* = 102). Sample characteristics for each location can be found in Table S1 in Online Resource 1. The total sample size was not predetermined as we could not predict the motivation of the primate park/science festival to participate in our study. Yet, the sample size for the laboratory setting was matched to the public settings to balance our sample. All participants provided informed consent prior to participation and there was no monetary reward in either setting but student participants could receive one course credit. The study was conducted in accordance with the Declaration of Helsinki and received approval by the local ethics committee of the Faculty of Social and Behavioural Sciences at Leiden University.

### Stimuli and Task

To create our facial emotional expression stimuli, six identities (three female) displaying acted angry, happy, sad, fearful and neutral expressions were chosen from the NimStim database (Tottenham et al., 2009). The face (including the neck) of each stimulus was cut out and the remainder replaced by a grey background (RGB: 145, 145,145), matching the colour of the task background. In order to ensure that observed effects in the dot-probe task were likely to not be caused by systematic differences in low-level features between emotion categories (e.g., de Cesarei & Codispoti, 2013), we employed the Protosc toolbox (Stuit et al., 2021) to

unveil potential features significantly predicting category membership. Significant features could not be found for any of the available feature spaces (Fourier magnitudes, Fourier phases, HOGs, colour distributions and pixel intensities. The dot-probe task was programmed in E-Prime 2.0 and conducted on an Iiyama T1931SR B1 touchscreen (38 x 30 cm).



A trial was initiated by tapping on a black dot (Ø 6 cm) in the centre of the screen. Immediately afterwards, two pictures appeared (each 11 x 15 cm), one on the left side (7 cm from the left edge) and one on the right side (31 cm from the left edge) of the screen. Apart from the baseline trials in which only neutral stimuli were presented, one picture contained a neutral expression and the other picture contained an emotional expression of the same identity. After 300 ms (according to the recommendation by van Rooijen et al., 2017), one of the pictures was replaced by a black dot (Ø 6 cm) which the participant had to tap on as fast as possible. In line with the existing dot-probe terminology, a trial was labelled as congruent when an emotional (i.e., target) expression was replaced by the dot, whereas the replacement of a neutral expression was regarded as an 'incongruent' trial. The participant's reaction time to this second dot was measured in each trial as the variable of interest. After participants successfully reacted to the second dot, the screen turned blank (grey) for 2 s after which the start dot of the next trial appeared (see Figure 1). For each emotion category (angry, happy, fearful, sad) paired with a neutral stimulus, the dot could appear in the congruent or incongruent location, resulting in eight potential combinations. Each of the combinations was presented using each of the six stimulus identities and with the emotional stimulus in either the left or right location. Further, participants completed 12 trials in which two neutral stimuli were shown after which, due to a coding error, the dot always replaced the left stimulus. Thus, every participant had to complete 108 trials in total (8 x 6 x 2 + 12).

**Procedure**

After signing the informed consent form, participants received written instructions on how to perform the dot-probe task on the touchscreen. They then completed eight practice trials with flower pictures as stimuli. Due to the self-initiation of each trial by tapping on the start dot, participants could go through the experiment in a self-paced manner and take breaks whenever necessary. After performing the task (duration around 7 min), participants completed the clinical trait questionnaires and were debriefed.

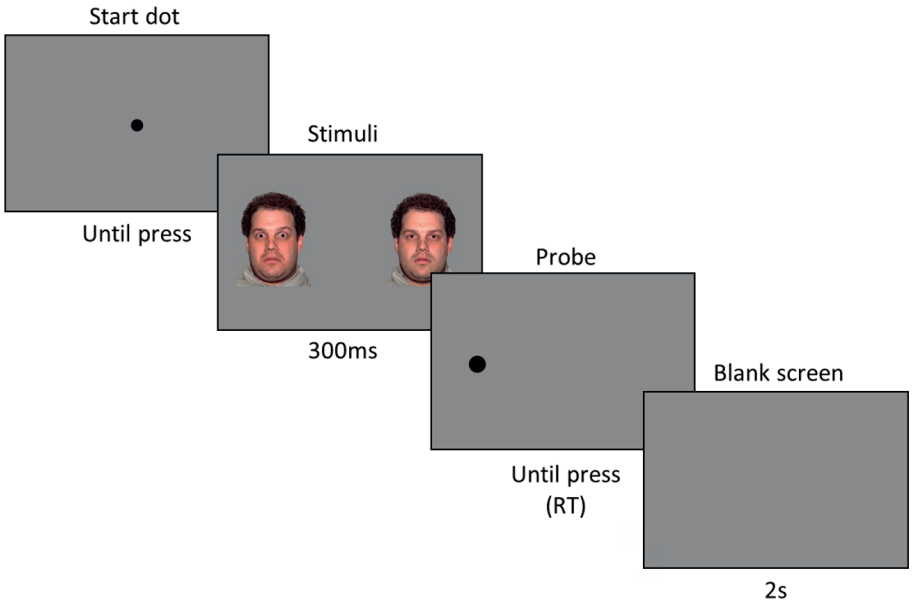


**Figure 1.** Structure of a trial in the dot-probe task. Participants were instructed to press the dot on the touch screen, and the reaction time (RT) to the second dot (probe) was measured. With the probe appearing behind the emotional face, the displayed trial represents a congruent trial. Stimuli were taken from the NimStim set of Facial Expressions (Tottenham et al., 2009).

## Questionnaires

### *Social Anxiety Traits*

We used the self-report version of the Liebowitz Social Anxiety Scale (LSAS; Liebowitz, 1987) to measure social anxiety traits in our healthy sample. The LSAS was originally developed to quantify fear and avoidance in individuals with social phobia and consists of 24 items describing different social situations that typically evoke performance or social anxiety. Fear and avoidance with regard to each item is rated separately on a 4-point Likert scale, ranging from 0 (fear rating: none; avoidance rating: never) to 3 (fear rating: severe; avoidance rating: usually). Sum scores across all items, including both fear and avoidance ratings, are calculated as an overall social anxiety trait measure, with potential scores ranging from 0 to 144. Given that one participant did not complete the questionnaire at all, we had data from 103 participants. Further, for six participants, single items were imputed (see Online Resource 2). Our final sample's LSAS scores ($N$ = 101; participants without task data excluded) ranged between 4 – 83 ($M$ = 37.1, $SD$ = 17.2). The distribution of the LSAS scores had a skewness of 0.43 and a kurtosis of 2.81, thus being close

to normal with a light right skew and mesokurtic shape. Internal consistency of the LSAS in our sample was excellent (α = .91, 95% CI [.89, .94]).

***Autistic Traits***

We used the Autism-Spectrum Quotient (AQ; Baron-Cohen et al., 2001) to measure variations in traits associated with Autism Spectrum Conditions in our sample. The AQ consists of 50 items associated with five different domains in which alterations are typically observed: social skill, attention switching, attention to detail, communication, and imagination. Ten items belong to each domain respectively and build one subscale of the AQ. In this questionnaire, respondents rate the degree to which items apply to them on a 4-point Likert scale, from 1 = *definitely agree* to 4 = *definitely disagree*. Some items are reverse coded and all scores are eventually transformed to binary values (1/2 to 0 and 3/4 to 1). A higher sum score of all items, potentially ranging between 0 and 50, reflects higher autistic trait levels. Three participants did not complete the AQ at all and we imputed missing items for four participants who had incomplete data (see Online Resource 2). The AQ sum scores encompassed values between 2 – 38 ($M$ = 18.3, $SD$ = 7.6) in our sample ($N$ = 99; participants without task data excluded). With a skewness of 0.69 and a kurtosis of 3.33, the AQ score distribution was also close to normal, yet slightly right-skewed and platykurtic. The AQ in our sample showed a good internal consistency (α = .84, 95% CI [.79, .88]).

**Data Analysis**

Before fitting the models, reaction times smaller than 250 ms were excluded given that they likely represent random responses (see van Berlo et al., 2020). Further, for each participant, trials exceeding their median reaction time + 2.5 median absolute deviations were excluded to filter out trials in which participants might have been distracted, thus resulting in relatively unusual high RTs. This lead to an exclusion of 9.47 % of all trials (angry: 8.83 %, happy: 9.24 %, sad: 10.25 %, fearful: 10.02 %, neutral: 8.59 %). All analyses were performed in R 3.6.3 (R Core Team, 2020; see Online Resource 2 for further information).

***Pre-registered Data Analysis***

For all hypotheses, we aimed to fit multiple linear mixed models on reaction times. Looking at the model diagnostics, we did not spot major divergences from assumptions. The selection of the basic fixed and random effect structure

for all models was informed by model comparisons based on the first model (see Online Resource 2). Eventually, we included random intercepts for *Subject* and *Trial* . The two three-way interactions *Age*Congruency*Emotion category* and *Sex*Congruency*Emotion category,* as well as all two-way interactions and main effects, were defined as predictors in all models.

To test our first hypothesis, namely that there is an attentional bias to emotional expressions and that this bias is specifically pronounced for angry expressions, we looked at the interaction between *Emotion category* and *Congruency* (controlled for by *Age* and *Sex*) as hypothesis-specific predictor in our model. Both factors, *Emotion category* and *Congruency*, were sum-coded in all analyses. To test our second and third hypotheses, namely that the attentional bias to emotions and specifically to threat expressions is enhanced with higher social anxiety traits, a three-way interaction between *Emotion category*, *Congruency* and *Social anxiety traits* was added as hypothesis-specific predictor to the model (including all two-way interactions).

Since we could not find a link between attentional biases and *Social anxiety traits* for any emotion, we did not explore a potential moderating effect of context in this interaction, as indicated in the preregistration[2]. Based on the same rationale, we did not conduct the second planned exploratory analysis, which aimed to disentangle whether an alteration in attentional bias would be due to heightened vigilance for emotional expressions or a stronger difficulty to disengage from emotional expressions with elevated social anxiety traits.

In order to test the presence of a general reduction in attentional bias to emotions with higher autistic levels, with the exception of angry expressions (hypotheses 5), we added a three-way interaction between *Emotion category*, *Congruency* and *Autistic traits* as hypothesis-specific predictors to the general model (including all two-way interactions). Given that, there was indeed no link between the attentional bias towards angry expressions (as to all other expressions) and *Autistic traits*, we tested for a potential moderating effect of *Social anxiety traits* on *Autistic traits* in the prediction of the bias to angry expressions. More specifically, we fitted a model on the reaction times in trials with angry expressions with a three-way

2 To confirm that the attentional bias effect was comparable in all experimental settings, we tested for a modulation of the congruency effect by the specific location (primate park, science festival and lab) as well as by the context (public [primate park + science festival], lab). Neither interaction was significant.

interaction between *Congruency*, *Social anxiety traits* and *Autistic traits,* including all two-way interactions and the control predictor terms.

***Exploratory Data Analysis***

As we did not observe the expected links between attentional biases and clinical trait dimension, and could not exclude that this might be due to a lack of power, we ran additional explorative data analyses, using Bayesian mixed models. Bayesian models were created in the Stan computational framework and accessed using the brms package (Bürkner, 2017, 2018), version 2.17.0. We sum coded all factorial predictors, and scaled and centered all continuous predictors. All models were run with 4 chains and 5000 iterations, of which 1000 were warmup iterations. We checked model convergence by inspecting the trace plots, histograms of the posteriors, Gelman-Rubin diagnostics, and autocorrelation plots (Depaoli & Van de Schoot, 2017). We found no divergences or excessive autocorrelation.



For the exploratory analyses, we used the same dataset as for the pre-registered analyses in which extremely fast and slow reaction times were excluded by subject (see first paragraph of Data analysis section). However, for the exploratory analyses we rescaled our dependent variable in order to filter out the effect of handedness*probe location (*Probe distance*) and to ease setting a prior for the intercept. Thus, we centered the reaction times within *Subject* within *Probe distance* level (close vs. far). Thereby, we removed the distance effect and removed overall differences in reaction times between participants.

First, we explored attentional biases within each emotion category by creating a model with centered reaction time as dependent variable and *Congruency* and *Emotion Category* and their interaction as predictors. Furthermore, we allowed the effects of all predictors to vary by *Subject*. Second, we explored whether attentional biases within each emotion category were linked to *Autistic traits* and *Social anxiety traits* by including the interactions *Congruency*Emotion Category*Autistic traits* and *Congruency*Emotion Category*Social anxiety traits*. We used regularizing Gaussian priors with $M = 0$ and $SD = 5$ for all fixed effects, a Gaussian prior with $M = 0$ and $SD = 1$ for the intercept, and default half Student t priors with 3 degrees of freedom for the random effects and residual standard deviation. We used multiple measures to summarize the posterior distribution resulting from our models: (I) the median estimate and the median absolute deviation of this estimate, (II)

the 95% credible interval, and (III) the probability of direction (pd). The 95% CrI indicates the range within which the effect falls with 95% probability, while the pd indicates the proportion of the posterior distribution that is of the median's sign (Makowski et al., 2019).

## Results

### Pre-registered Analyses

#### *General Attentional Bias to Emotions*

As expected, we found a significant congruency effect in the general model on the reaction times in the dot-probe task, $B$ = -5.79, 95% CI [-9.80, -1.78], $t$(8697.27) = -2.83, $p$ = .005 (see Figure 2A). Confirming an attentional bias to emotional expressions, participants were on average 5.79 ms faster when the dot appeared behind the emotional expression and 5.79 ms slower when the dot appeared behind the neutral expression than their average reaction times in trial with an emotion-neutral pair. There was, however, no evidence for an enhanced attentional bias to angry compared to other facial expressions, that is, no significant interaction between *Emotion category* and *Congruency*. In addition to the general congruency effect, we also observed significant effects of the included control predictor terms. Unsurprisingly, reaction times depended on *Age*, $B$ = 2.94, 95% CI [1.78, 4.10], $t$(98.96) = 5.04, $p$ < .001. While older participants overall reacted more slowly to the dot probe than younger participants, this effect was less marked in trials including a happy face, $B$ = -0.27, 95% CI [-0.47, -0.07], $t$(8708.16) = -2.70, $p$ = .007, as revealed by the significant interaction between *Age* and *Emotion category*. Lastly, *Probe distance* significantly predicted reaction times, with slower responses to far probes (i.e., a mismatch between handedness and probe location) compared to close probes (i.e., handedness and probe location matched), $B$ = 30.94, 95% CI [27.62, 34.25], $t$(8703.67) = 18.30, $p$ < .001. For an overview of the model fit, see Table 1 as well as Table S3 in Online Resource 1 for the coefficients of all factor levels.

#### *Social Anxiety Traits and the Attentional Bias to Emotions*

Against our hypothesis, we did not find any alteration in the overall or emotion-specific attentional bias related to social anxiety trait levels. Further, the congruency effect which we observed in the general model did not reach significance in the model including *Social anxiety traits* ($p$ = .166). Yet, the effect of *Age* on reaction

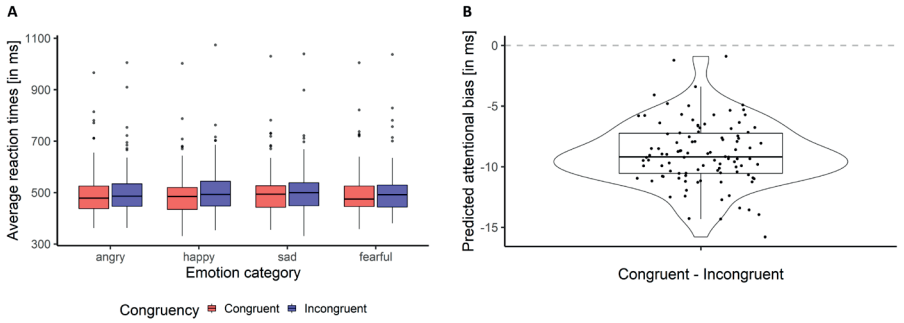


**Figure 2.** (A) Average reaction times per subject to the probe in congruent versus incongruent trials for each emotion category. Boxes enclose all values between the first and third quartile (Inter-quartile range, IQR) and the whiskers extend to +/- 1.5 IQR from the respective quartile. As outliers in reaction times were defined on an individual basis, outliers in this plot represent subjects with slow reaction times on average (see also Table S2 in the Supplementary Materials). (B) Mean predicted attentional bias (difference in reaction times between congruent and incongruent trials) per subject across emotion categories and trials. The data distribution is visualized by the violin as well as by the box (same definition as above), and single data points represent subjects. This graph shows the significant congruency effect, i.e., the general bias towards emotional facial expressions.

times to the dot probe was again significant, $B = 3.01$, 95% CI [1.83, 4.20], $t(96.96) = 5.05$, $p < .001$, as well as the interaction between *Age* and *Emotion category*. The slowing in reaction time with higher age was less pronounced if a happy facial expression (compared to the other emotions) was included in the emotion-neutral pair, independent of the probe position, $B = -0.28$, 95% CI [-0.48, -0.08], $t(8617.1) = -2.78$, $p = .005$. As observed in the general model, a far *Probe distance* was associated with slower reaction times, $B = 30.81$, 95% CI [27.50, 34.13], $t(8613.15) = 18.20$, $p < .001$. Table 2 provides an overview of the model fit and Table S4 in Online Resource 1 describes all coefficients.

### *Autistic Traits and the Attentional Bias to Emotions*

In the attentional bias model including *Autistic traits*, there was a significant interaction between *Autistic traits* and *Emotion category*. More specifically, responses after emotion-neutral pairs with an angry facial expression were faster with higher autistic traits, $B = -0.62$, 95% CI [-1.00, -0.24], $t(8444.09) = -3.22$, $p = .001$. In contrast, emotion-neutral pairs with sad facial expressions were related to slower responses with higher autistic traits, $B = 0.39$, 95% CI [0.01, 0.78], $t(8443.17) = 2.03$, $p = .042$. Importantly, these effects were independent of the probe location (i.e., *Congruency*) and we did not observe the expected link between the attentional bias and *Autistic traits*. Further, a closer examination of the effects revealed that none of the slopes were significantly different from zero. In line with the general

model on the attentional bias to emotions, *Congruency*, $B$ = -7.48, 95% CI [-13.06, -1.90], $t$(8439.91) = -2.63, $p$ = 0.009, as well as the control terms *Probe distance*, $B$ = 30.11, 95% CI [26.81, 33.41], $t$(8439.65) = 17.90, $p$ < .001, and *Age*, $B$ = 3.12, 95% CI [1.87, 4.37], $t$(94.96) = 4.97, $p$ < 0.001, were significant predictors of reaction times in the model including *Autistic traits*. Participants reacted faster in congruent trials, as well as when the probe appeared on the side of their dominant hand and when they were younger. We also found a significant interaction between *Emotion category* and *Age*. Here, the slowing in reaction times with higher age was more pronounced in trials with angry facial expressions, $B$ = 0.24, 95% CI [0.03, 0.44], $t$(8446.75) = 2.23, $p$ = .026, and less pronounced in trials with happy facial expressions, $B$ = -0.32, 95% CI [-0.52, -0.11], $t$(8432.03) = -3.01, $p$ = .003. A summary of the model fit can be found in Table 2 and a closer description of all coefficients in Table S5 in Online Resource 1.

### *Autistic Traits, Social Anxiety Traits and the Attentional Bias to Angry Facial Expressions*

In line with previous research, the two questionnaire scores, indicating autistic trait and social anxiety traits, were significantly positively correlated in our sample, $r_s$ = .30, $p$ < .001. Zooming in on a potential moderating effect of *Social anxiety traits* on the link between *Autistic traits* and the attentional bias to angry facial expressions, our model revealed a significant three-way interaction between *Congruency*, *Social anxiety traits* and *Autistic traits*, $B$ = 0.03, 95% CI [0.01, 0.06], $t$(2056.63) = 2.52, $p$ = .012. An examination of the predicted value plots (see Figure 3) as well as slope comparisons (see Table 3) at three different values on one of the trait dimensions (mean – 1*SD*, mean, mean + 1*SD*) suggested that this interaction is likely to be driven by a decrease in attentional bias with higher autistic traits at a relatively "high" social anxiety trait level (mean + 1*SD*) and/or an increase in attentional bias with higher social anxiety traits at a relatively "low" autistic trait level (mean – 1*SD*). In the context of this three-way interaction, the two-way interactions between each trait dimension and *Congruency* were also approaching significance (see Table 2). However, when running the same model without the three-way interaction added, this was not the case. Similar to the previous models with multiple emotion categories, *Congruency*, $B$ = 23.36, 95% CI [1.01, 45.72], $t$(2056.92) = 2.05, $p$ = .041 , as well as the control predictors *Age*, $B$ = 3.48, 95% CI [2.19, 4.78], $t$(92.90) = 5.33, $p$ < .001, and *Probe distance*, $B$ = 36.69, 95% CI [29.94, 43.44], $t$(2056.97) = 10.66, $p$ < .001, were significant predictors in this model (see Table 2 for an overview of the model fit as well as Table S6 in Online Resource 1 for all coefficients).

**Table 1** Results of the Linear Mixed-Effects Models Predicting Reaction Times to the Dot Probe. Output for the Fixed and Random Effect Terms for the Model without Clinical Traits and its Interactions as Predictor, as well as for the Models with Social Anxiety Traits and Autistic Traits, Respectively, are Shown.

| | General model | | | | Social anxiety traits model | | | | Autistic traits model | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fixed effects | *df1* | *df2* | *F* | *p* | *df1* | *df2* | *F* | *p* | *df1* | *df2* | *F* | *p* |
| Emotion category | 3 | 8705.6 | 1.44 | .230 | 3 | 8620.7 | 1.50 | .212 | 3 | 8441.7 | 1.01 | .389 |
| Congruency | 1 | 8697.3 | 8.03 | **.005** | 1 | 8624.9 | 1.92 | .166 | 1 | 8441.7 | 6.91 | **.009** |
| Age | 1 | 99.0 | 25.41 | **< .001** | 1 | 97.0 | 25.47 | **< .001** | 1 | 95.0 | 24.69 | **< .001** |
| Gender | 1 | 99.0 | 0.16 | .687 | 1 | 97.0 | 0.03 | .867 | 1 | 95.0 | 0.21 | .645 |
| Probe distance | 1 | 8703.7 | 334.82 | **< .001** | 1 | 8613.2 | 331.29 | **< .001** | 1 | 8439.7 | 320.41 | **< .001** |
| Clinical traits | | | | | 1 | 97.0 | 0.56 | .456 | 1 | 95.0 | 0.19 | .665 |
| Emotion category*Congruency | 3 | 8696.1 | 0.96 | .412 | 3 | 8607.1 | 0.46 | .707 | 3 | 8435.2 | 0.75 | .524 |
| Emotion category*Age | 3 | 8711.9 | 2.68 | **.045** | 3 | 8620.3 | 2.98 | **.030** | 3 | 8443.0 | 3.66 | **.012** |
| Congruency*Age | 1 | 8704.0 | 0.91 | .339 | 1 | 8617.6 | 0.74 | **.388** | 1 | 8438.8 | 0.55 | .458 |
| Emotion category*Gender | 3 | 8708.1 | 0.36 | .780 | 3 | 8617.6 | 0.36 | .781 | 3 | 8440.7 | 0.51 | .674 |
| Congruency*Gender | 1 | 8712.0 | 0.97 | .325 | 1 | 8618.9 | 1.37 | .242 | 1 | 8441.6 | 1.08 | .298 |
| Emotion category*Clinical traits | | | | | 3 | 8624.8 | 0.86 | .462 | 3 | 8445.5 | 3.92 | **.008** |
| Congruency*Clinical traits | | | | | 1 | 8624.7 | 0.31 | .578 | 1 | 8454.6 | 1.04 | .308 |
| Emotion category*Congruency*Age | 3 | 8693.2 | 1.17 | .321 | 3 | 8601.1 | 1.02 | .382 | 3 | 8427.5 | 0.70 | .551 |
| Emotion category*Congruency*Gender | 3 | 8704.0 | 0.40 | .754 | 3 | 8611.4 | 0.49 | .689 | 3 | 8437.1 | 0.33 | .801 |
| Emotion category*Congruency*Clinical traits | | | | | 3 | 8613.3 | 1.02 | .381 | 3 | 8441.6 | 0.19 | .905 |
| **Random effects** | **Variance** | | | | **Variance** | | | | **Variance** | | | |
| Intercepts | Subject | | | | Subject | | | | Subject | | | |
| | *N* = 102 | | 7045.49 | | *N* = 101 | | 7112.70 | | *N* = 99 | | 7161.27 | |
| | Trial | | | | Trial | | | | Trial | | | |
| | *N* = 108 | | 52.37 | | *N* = 108 | | 49.74 | | *N* = 108 | | 57.10 | |
| Residual variance | | | 6267.42 | | | | 6221.84 | | | | 6016.66 | |

Note. df1 = numerator degrees of freedom; df2 = denominator degrees of freedom.

**Table 2.** *Results of the linear mixed-effects models predicting reaction times to the dot probe in trials with angry facial expressions.*

| **Fixed effects** | ***df1*** | ***df2*** | ***F*** | ***p*** |
|---|---|---|---|---|
| Congruency | 1 | 2056.91 | 4.20 | **.041** |
| Age | 1 | 92.90 | 28.44 | **< .001** |
| Sex | 1 | 92.81 | 0.06 | .813 |
| Probe distance | 1 | 2056.97 | 113.60 | **< .001** |
| Autistic traits | 1 | 92.89 | 0.01 | .921 |
| Social anxiety traits | 1 | 93.07 | 1.44 | .233 |
| Congruency*Age | 1 | 2056.57 | 0.50 | .479 |
| Congruency*Sex | 1 | 2056.53 | 0.09 | .768 |
| Congruency*Autistic traits | 1 | 2056.69 | 3.86 | **.050** |
| Congruency*Social anxiety traits | 1 | 2056.71 | 7.51 | **.006** |
| Autistic traits*Social anxiety traits | 1 | 93.09 | 0.63 | .428 |
| Congruency*Autistic traits*Social anxiety traits | 1 | 2056.63 | 6.37 | **.012** |
| **Random effects** | | | | **Variance** |
| Intercepts | Subject *N* = 99 | | | 7204.31 |
| Residual variance | | | | 6362.83 |

*Note.* Df1 = numerator degrees of freedom; df2 = denominator degrees of freedom.

**Table 3.** Difference in the slopes between congruent and incongruent trials (congruency effect) with higher levels on one clinical trait dimension at the trait scores mean -1SD, mean and mean +1SD on the respective other clinical trait dimension

| | **Slope difference : congruent – incongruent [SE]** | **95% CI** | **df** | ***t*** | **p-value** |
|---|---|---|---|---|---|
| *Autistic traits* | | | | | |
| Mean LSAS – 1SD [19.96] | -0.82 [0.67] | -2.13, 0.48 | 2057 | -1.24 | .216 |
| Mean LSAS [37.26] | 0.32 [0.49] | -0.65, 1.28 | 2056 | 0.64 | .520 |
| Mean LSAS + 1SD [54.57] | 1.46 [0.67] | 0.15, 2.77 | 2056 | 2.18 | **.030** |
| *Social anxiety traits* | | | | | |
| Mean AQ – 1SD [10.64] | -0.87 [0.34] | -1.53, -0.21 | 2057 | -2.58 | **.010** |
| Mean AQ [18.18] | -0.37 [0.23] | -0.83, 0.09 | 2057 | -1.59 | .112 |
| Mean AQ + 1SD [25.73] | 0.13 [0.27] | -0.40, 0.66 | 2057 | 0.47 | .638 |

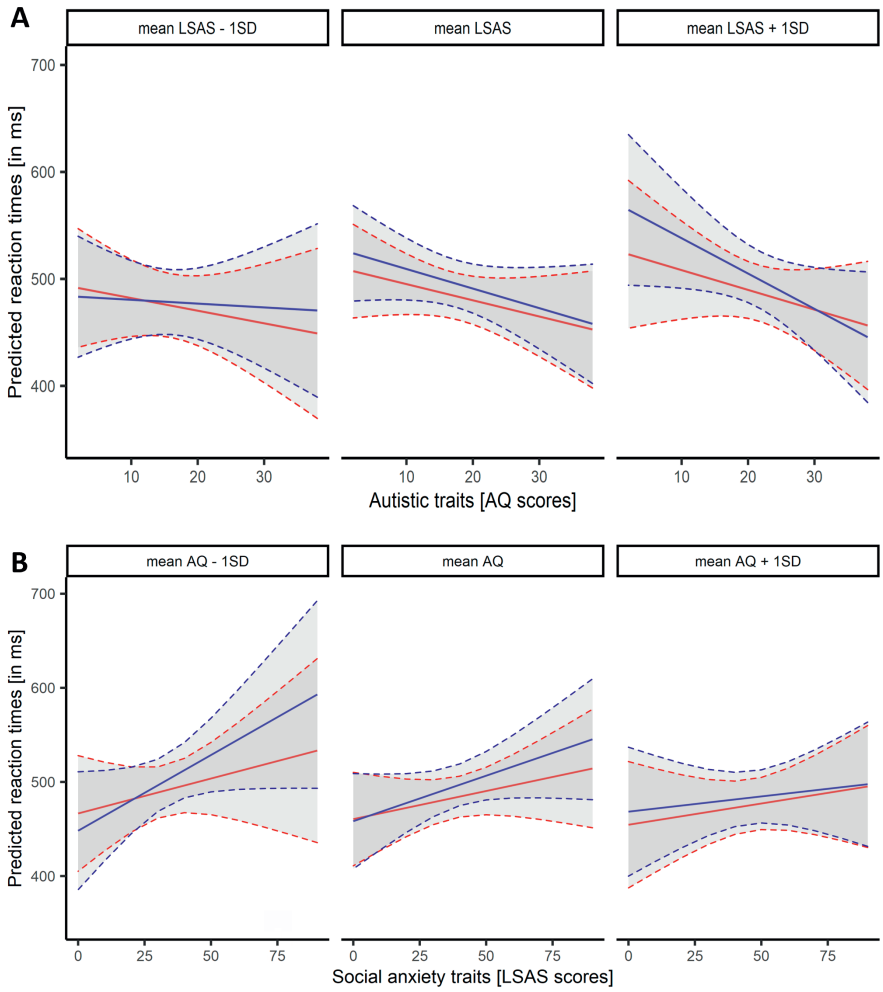


**Figure 3.** Effects of levels on one trait dimension on reaction times at distinct levels on the other trait dimension in congruent (red) vs. incongruent (blue) trials. Effects are displayed at the mean -1SD, mean and mean +1SD of the other trait dimension respectively.

## Exploratory Analyses

First, we explored whether participants showed attentional biases within each emotion category using a Bayesian mixed model (Table S7 in Online Resource 1). We found clear effects of *Congruency* within each level of *Emotion category* (Figure S1 in Online Resource 1), with participants responding faster on trials where the probe replaced the emotional stimulus versus neutral stimulus (Angry: -9.21 ms [3.39], 95% CrI [-15.86, -2.31], *pd* = 1.00; Happy: -13.30ms [3.27], 95% CrI [-19.59,

-6.98], *pd* = 1.00; Sad: -6.37 ms [3.13], 95% CrI [-12.57, -0.13], *pd* = .98; Fearful: -6.65 ms [3.38], 95% CrI [-13.34, 0.02], *pd* = .98). Note that the 95% CrI for Fearful spans just over zero. However, the directionality of the effect (*pd*) was clear and consistent with the other categories.

Next, we explored whether *Autistic traits* and *Social anxiety traits* moderated the effect of *Congruency* within each level of *Emotion Category* (Table S8 in Online Resource 1). We compared the effect of *Congruency* at –1*SD* with +1*SD* of the scaled *Autistic traits* and *Social anxiety traits* variables. With regard to *Autistic traits,* we did not find robust evidence that autistic trait levels moderated the effect of *Congruency* within any level of *Emotion category* (Figure 4A; Table 6). However, we observed that participants with low autistic trait levels had a stronger attentional bias for happy faces than participants with high autistic trait levels. Although the 95% CrI spanned over 0, the directionality of the effect was clear (*pd* = .94). Looking at *Social anxiety traits,* we did not find robust evidence for an effect on *Congruency* (Figure 4B; Table 4). Even though the results indicated that people who scored higher on the social anxiety trait scale had stronger attention biases for sad, happy and angry expressions, the 95% CrIs spanned over 0, and the directionalities were relatively low (Table 4).

**Table 4.** Difference in the congruency effect at between –1SD and +1SD of the AQ scale (Autistic traits) and LSAS scale (Social anxiety traits) for each emotion category.

| | **Median [MAD]** | **95% CrI** | ***pd*** |
|---|---|---|---|
| *Autistic traits (AQ)* | | | |
| Angry | 4.57 [7.32] | -9.71, 19.41 | .74 |
| Happy | 10.12 [6.74] | -3.00, 23.61 | .94 |
| Sad | 5.28 [6.93] | -8.13, 18.71 | .78 |
| Fearful | 0.28 [7.18] | -14.03, 14.47 | .52 |
| *Social anxiety traits (LSAS)* | | | |
| Angry | -6.49 [7.19] | -20.80, 8.01 | .81 |
| Happy | -7.58 [6.87] | -20.97, 5.71 | .87 |
| Sad | -6.40 [6.78] | -19.82, 7.14 | .83 |
| Fearful | 7.27 [7.28] | -7.15, 21.26 | .84 |

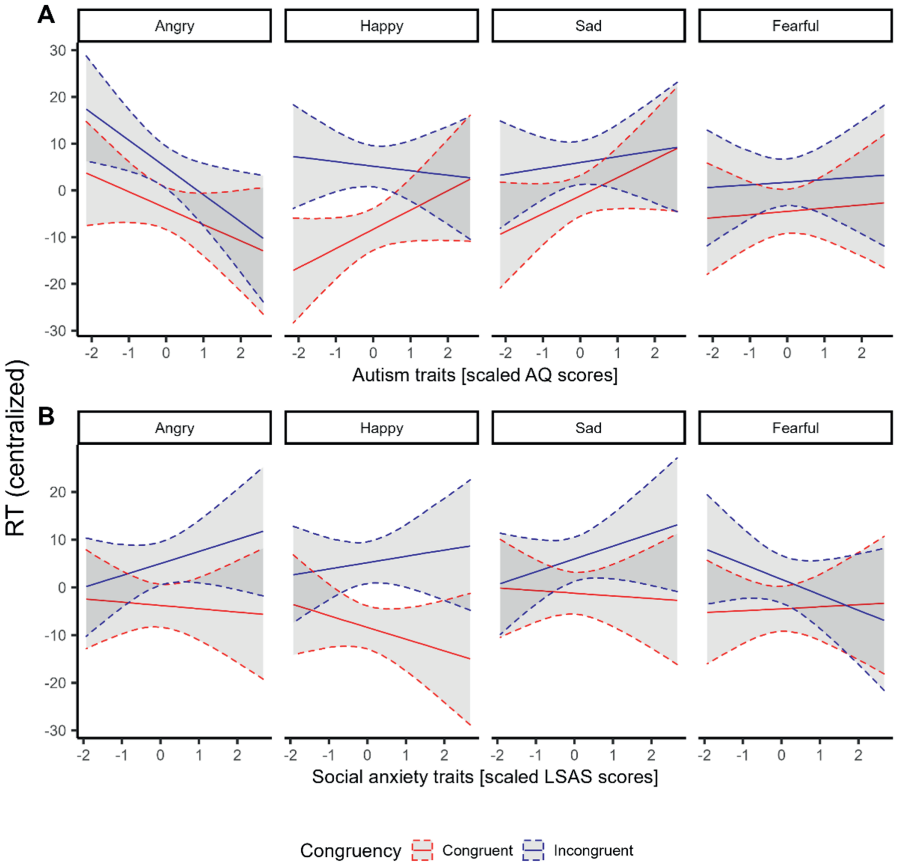


**Figure 4.** Effect of the interactions between congruency and social anxiety traits (LSAS) and congruency and autistic traits (AQ) on reaction times. Shaded areas reflect 95% credible intervals

## Discussion

In the current study, we examined attentional biases toward facial emotional expressions and their association with autistic traits and social anxiety in a general population sample. In line with most previous research, we observed attentional biases toward various emotional facial expressions, using both frequentist as well as Bayesian analysis approaches. In contrast to our hypothesis and a vast amount of literature, higher social anxiety trait levels were overall not associated with a stronger bias to angry facial expressions (i.e., social threat). There was also only an indication of a decreased attention to emotional expressions with higher autistic trait levels for happy facial expressions within our exploratory Bayesian

analysis. Yet, independent of the probe location (congruent vs. incongruent), reaction times were faster with higher autistic trait levels for trials displaying an angry face, while they were slower for trials displaying a sad face. When zooming in on the attentional bias towards angry facial expressions, we found a significant interaction between autistic trait levels, social anxiety trait levels and congruency. This suggests that the link between the attentional bias to threat and the two trait dimensions might be more complex and require further exploration.

**Social Anxiety and the Attentional Bias to Emotion**

Surprisingly, an enhanced attentional bias to angry facial expression was not observed in people with higher levels of trait social anxiety. Possibly, the absence of this effect can be the result of the stimulus presentation duration that we employed in this study. According to a meta-analysis examining the link between social anxiety and the threat bias (Bantin et al., 2016a), shorter stimulus durations (< 200 ms) were associated with stronger biases. Nevertheless, attentional biases toward angry facial expressions could still be found at 500 ms and 600 ms presentation duration. Further, higher levels of social anxiety have not consistently been linked to stronger attentional biases toward angry facial expressions (Bantin et al., 2016a). A recent study in a healthy student sample reported that the half of individuals with higher social anxiety trait levels were found to have the lowest attentional bias whereas the other half was partially showing vigilance toward and partially avoidance of angry faces (Neophytou & Panayiotou, 2022). Crucially, even biases on the individual level were shown to be invariant, meaning that they change over time, and to depend on the assessment tool (MacLeod et al., 2019). The present study was the first to use a touchscreen to examine the association between social anxiety and the threat bias . Given the instability of attentional biases as well as , an interplay between various factors could explain not finding the expected effect.

When comparing the effect of social anxiety traits on the threat bias at different autistic trait levels (three-way interaction), the attentional bias only seemed to be stronger with higher social anxiety traits at low autistic trait levels. This suggests that attentional biases in social anxiety might highly depend on additional individual characteristics. As a consequence, interventions focusing on treating maladaptive attentional biases, such as Attentional Bias Modification (ABM) training (MacLeod et al., 2002), might not be beneficial for every individual. Accordingly, ABM trainings

have been reported to neither consistently nor robustly result in a modification of the attentional bias toward threat (van Bockstaele & Bögels, 2014). Further, one study which found a small reduction in the bias in the visual dot-probe after ABM training, also showed that this bias is not generalizable to other tasks measuring attention to threat (van Bockstaele et al., 2017). Acknowledging the specificity of this effect, the dot-probe paradigm might not be the ideal candidate on which to directly base clinical interventions. Instead, it can be regarded as a useful additional descriptor in the complex relationship between social anxiety and the attention to emotional facial expressions.



**Autistic Traits and the Attentional Bias to Emotion**

We expected to observe a weaker attentional bias to all emotion facial expressions, apart from anger, with higher autistic trait levels due to a decreased processing of emotional information from the faces. In contrast to our expectations, there was only an indication of this effect for happy facial expressions in our exploratory analysis. Past research in autistic children (García-Blanco et al., 2017; May et al., 2015) as well as autistic adults (Monk et al., 2010) has found no evidence for alterations of the attentional bias to happy facial expressions. Next to the essential difference of examining a clinical population, these studies also used longer presentation times (i.e., 500 ms and/or 1500 ms) which could have allowed for a more elaborate (and less automatic) processing of the stimuli. As an alternative to arousal-related explanations (e.g., Cuve et al., 2018; Zalla & Sperduti, 2013), alterations in face processing in autistic individuals were suggested to result from "deficits" in processing social rewards, such as faces (G. Dawson et al., 2005). Studies displaying happy facial expressions directed towards the participant, as used in our study, indeed suggest that those faces are associated with lower reward values in autistic individuals compared to neurotypical individuals (Dubey et al., 2015). A recent meta-analysis, however, has challenged the idea of altered social reward processing in ASD by unveiling less reward processing for both social and non-social stimuli (Bottini, 2018). In our study, we did not investigate mechanisms which could underlie a weaker attentional bias toward happy facial expressions with higher autistic trait levels. To get a better understanding of altered face perception in ASD, future studies should not only examine whether a weaker attentional bias towards happy facial expressions is present in autistic individuals, but also what the underlying mechanism of this alteration might be.

Unexpectedly, reaction times to the dot probe in trials with angry or sad facial expressions were systematically linked to autistic traits, independent of whether the probe appeared behind the emotional or the neutral expression (i.e., congruency). Higher autistic trait levels were associated with relatively faster reaction times after the presentation of an angry face and with slower reaction times after the presentation of a sad face. A potential explanation of this finding could be that the mere presence of the expressions affected the observer's arousal more strongly with higher autistic trait levels. More specifically, independent of their location, angry expressions could have elicited increases in arousal and sad expressions decreases in arousal, which would result in faster and slower reaction times, respectively. Yet, differences in reaction times between emotion categories in the general model could not be found. Further, the slopes for the links between autistic traits and reaction times in trials with angry and sad facial expressions were not significantly different from zero. Thus, the reaction times for angry and sad expressions were only different compared to the average link between reaction times to all expressions and autistic traits.

Finally, we observed a significant interaction between social anxiety traits and autistic traits in predicting the attentional bias to angry faces. Individuals with higher autistic traits showed a reduced attentional bias towards angry faces, but only when social anxiety trait levels were also high. This was in contrast to our expectations. We assumed that high social anxiety levels would go along with a stronger attentional bias to angry faces in individuals with higher autistic trait levels, as angry expression might be perceived as more threatening. Looking at the predicted value plots, the reduced attentional bias seemed to be driven by faster reaction times to the probe in incongruent trials (i.e., probe replaces neutral faces) with higher autistic traits. This potentially supports the idea of a generally heightened arousal for angry expressions. Nevertheless, given the complexity of explaining this three-way interaction, the high overlap of confidence intervals and the lacking support of previous literature in clinical populations (Hollocks et al., 2013; May et al., 2015; Monk et al., 2010), future research should examine the interplay between autistic and social anxiety traits on attentional biases to emotion.

**Limitations & Future Directions**

While some previous research did not report an attentional bias toward (certain) emotional facial expressions (Puls & Rothermund, 2018; Valk et al., 2015), we found an attentional bias toward emotions for all emotion categories. This bias did not differ significantly between the expressions and ranged around 10 ms (6.37 ms – 13.30 ms) which is comparable with previous research (e.g., Monk et al., 2010). Thus, emotional facial expressions seem to automatically receive prioritised attention, highlighting their suggested communicative function as salient signals for conspecifics. Yet, caution has to be taken in the interpretation of results on attentional biases, as their appearance/significance might depend on various additional factors. One important factor that has been raised in the debate on the validity of attentional biases is the impact of low-level features (e.g., de Cesarei & Codispoti, 2013). Differences between stimulus categories regarding features such as spatial frequency are a general problem in interpreting results from dot-probe studies. We did not control our stimuli for these features to keep them as natural as possible and therefore cannot exclude this as a potential influence. Nevertheless, we compared our emotion categories with regard to specific low-level features (Stuit et al., 2021, see Methods section) and could not identify any significant differences. While there were no systematic differences between emotion categories, this comparison does not rule out the existence of differences in, for example, spatial frequency or colour distribution between distinct stimuli, which might have added noise to the data. Future studies investigating attentional processes in the field of emotion should try to account for those.

Another limitation of our study is that we did not collect data in clinical populations and could, therefore, only investigate the influence of trait levels associated with ASD and SAD on attentional biases. This complicates the direct comparison to previous research with clinical samples as well as the formulations of potential implications for clinical practice. Yet, the view of a "continuum of impairment" has become more popular regarding both social anxiety (Rapee & Spence, 2004) and autism (Robinson et al., 2011), with disorders lying on the extremes of clinical traits in the general population. While clinical relevance of symptoms is eventually determined by difficulties in daily life, alterations in information processing, as well as their underlying mechanisms, may not be qualitatively different along the trait dimension. Thus, our findings in heightened trait levels may also be informative for clinical populations.

As highlighted earlier, the link between social anxiety trait levels and attentional biases to social threat seems to depend on additional individual characteristics, such as autistic traits. This indicates that the extent to which different individuals with SAD shift their attention to external evaluative cues in social situations might also vary. Socially anxious individuals who automatically shift their attention to expressions of others might indeed benefit from trainings which aim at modifying this automatic shift to prevent the perception of social threat. In socially anxious individuals who do not show disproportionate attentional biases toward external cues, other factors might contribute more strongly to the maintenance of the disorder. While this still has to be investigated further, our results generally favour a more individualized approach, which targets specific maintenance factors in the treatment of SAD (for suggestions, see Hofmann, 2007). Since we did not find evidence for a reduced attentional bias toward emotional expressions with higher autistic trait levels, difficulties in identifying others' emotions might likely not arise from altered allocation of early visual attention (300 ms in our study) toward those. Other factors might play a more important role, such as altered physiological arousal in the presence of emotional expressions, which could also explain the earlier-mentioned effects on reaction times in our study. Future studies should specifically explore these factors, as well as their link to real-life social outcomes, to inform clinical practice.

Finally, ways of capturing attentional biases more validly have recently been suggested, such as investigating trial-level attentional biases (Zvielli et al., 2015) or using response-based measures (Evans & Britton, 2018). The use of eye-tracking as an alternative technique in examining attention towards emotional versus neutral stimuli has further been encouraged to unveil individual differences in attentional processes at different stages of information processing (Clauss et al., 2022).

**Conclusion**

With the current study, we aimed to unveil specific links between variations in the attentional bias to emotional facial expressions and social anxiety and autistic trait levels. While an attentional bias towards all emotional facial expressions, namely angry, happy, sad and fearful, was found in our study, there was only weak evidence for systematic links between these biases and clinical traits. More specifically, our exploratory analyses suggested that only the attentional bias to happy facial expressions was decreased with higher autistic trait levels. We did, however,

additionally observe general alterations in reaction times after the presentation of certain emotional stimuli (angry, sad) with higher autistic trait levels, and the bias to angry facial expressions seemed to depend on a combination of both autistic traits and social anxiety traits in our study. Taken together, the link between clinical traits and attention, as measured by reaction times in this study, appears to be highly complex. While the dot-probe task allows to tap into general attentional tendencies toward emotional expressions, more naturalistic scenarios might be of higher informative value for revealing biases in real-life attentional processing associated with clinical conditions and build a stronger basis for clinical support.