Current Psychology (2024) 43:4129–4141
https://doi.org/10.1007/s12144-023-04624-y

Social interaction anxiety, social phobia, and cognitive control: controlled reactions to facial affect during an emotional face flanker task

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Accepted: 27 March 2023 / Published online: 17 April 2023

Abstract
Trait social anxiety may predict differences in the cognitive control of emotional distraction when emotional face discrimination is required. This effect can be investigated using an emotional face flanker task. This study addresses an important research gap, as previous studies did not separate the effects of trait social interaction anxiety from the effects of trait social phobia upon emotional face flanker task performance. In this laboratory based behavioural experiment, the 87 participants (mean age 24.3) were university students or staff recruited via departmental adverts. We used an emotional (happy versus fearful) face flanker task, and assessed sub-clinical social anxiety with the SIAS/SPS. Elevated trait social phobia was related to an increased reaction time (RT) congruency effect, whereas trait social interaction anxiety was not. Elevated trait social interaction anxiety was related to a decreased happy face RT advantage for central target faces, but the effect of trait social phobia was very weak. Trait social interaction anxiety and trait social phobia may predict subtle differences when the cognitive control of reactions to emotional facial expressions is required.

Keywords Social interaction anxiety · Social phobia · Social observation anxiety · Emotional faces · Flanker task · Cognitive control

Introduction

Social anxiety is a spectrum condition that includes both trait social anxiety, and clinical levels of social anxiety (Rapee & Heimberg, 1997). Social anxiety can relate to a dislike of social situations, due to the perceived risk of negative evaluation from other people (Morrison & Heimberg, 2013a). Social anxiety can also relate to a dislike of positive evaluation in social situations, as this can attract the attention of other people (Weeks et al., 2008). Social anxiety can therefore reduce any perceived reward from social interactions (Kashdan & Collins, 2010). The development and maintenance of social anxiety disorder may be related to phenotypical variations in cognitive processing biases, and/or the reactivity of the biological systems that manifest affective personality traits (Kimbrel, 2008). Therefore, it is important to reveal any cognitive-emotional processing biases that covary with trait levels of social anxiety. This study tests how subtypes of trait social anxiety predict cognitive control in an emotional face flanker task.

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Social anxiety

Versions of the DSM have included the phrases *clinical social phobia* and *social anxiety disorder* as interchangeable descriptions of the same disorder. However, it has recently been decided that the single phrase *social anxiety disorder* should be used (American Psychiatric Association, 2022). According to the DSM-5 social anxiety disorder involves an excessive experience of fear and anxiety relating to social situations where a person feels that they are being evaluated and scrutinized by other people. However, the definition includes a performance anxiety only specifier that refers to fears that are specific to performing/speaking in public (American Psychiatric Association, 2013). Sensitivity shift theory proposes that social anxiety disorder relates to the experience of social anhedonia, and therefore to the experience of reduced positive affect, and to the infrequent use of social approach behaviours (Richey et al., 2019). However, the social anxiety spectrum is considered to include two experientially distinct phenomena: social interaction anxiety (fearfulness and avoidance of situations where social interaction with other people is a requirement); and social observation/performance anxiety (fearfulness and avoidance of situations where observation or scrutiny from other people is likely; Hughes et al., 2006; Kashdan, 2002). Elevated levels of trait social interaction anxiety tend to be more strongly related to the experience of low levels of positive affect, rather than to high levels of physiological arousal. By contrast, elevated levels of trait social phobia (social observation/performance anxiety tend to be more strongly related to the experience of high levels of physiological arousal and symptoms similar to panic, rather than to low levels of positive affect (Hughes et al., 2006).

A biobehavioural perspective based on revised reinforcement sensitivity theory (rRST, Gray & McNaughton, 2000) suggests that levels of social anxiety are related to differential levels of reactivity in neuropsychological systems that underlie the motivation to approach or avoid social situations (Kimbrel, 2008). In rRST (Gray & McNaughton, 2000) the behavioural inhibition system (BIS) is a defensive approach system which resolves cognitive or emotional goal conflict, The BIS is active when anxiety is elevated, and incorporates a hierarchy of interconnected brain regions implicated in emotion and cognitive control: the periaqueductal gray, medial hypothalamus, amygdala, septo-hippocampal system, posterior cingulate, and the prefrontal dorsal stream. In rRST a fight-flight-freeze system (FFFS) is a defensive avoidance system that manifests fear responses. The FFFS also incorporates a hierarchy of interconnected brain regions implicated in emotion and cognitive control: the periaqueductal gray, medial hypothalamus, amygdala, anterior cingulate, and prefrontal ventral stream. By contrast, in rRST the behavioural approach system (BAS) processes anticipated reward, manifests extraversion, and incorporates reward processing brain regions such as the ventral striatum / basal ganglia (McNaughton & Corr, 2004). From this perspective, social anxiety disorder and trait social anxiety relate to the increased reactivity of the FFFS, the increased reactivity of the BIS, and to the reduced reactivity of the BAS (Kimbrel, 2008). From a rRST perspective, in social situations where any potential risk outweighs any potential reward the FFFS would manifest fearfulness and avoidance behaviour, as the BIS only enters conflict resolution mode when the motivational value of competing goals is similarly weighted (McNaughton & Corr, 2004). In these social situations, where perceived social risk outweighs potential social reward, people with social anxiety would likely exhibit increases in FFFS activity, and an attentional bias for threat-related social information (Kimbrel, 2008).

In some contrast to biobehavioural perspectives such as rRST (Gray & McNaughton, 2000), the cognitive perspective referred to as attentional control theory (ACT, Eysenck et al., 2007) suggests that anxiety relates to an impairment in cognitive control, and thus increased distractibility. ACT (Eysenck et al., 2007) is based upon the idea that increases in cognitive interference, and thus distraction, in high anxiety are due to a reduction in the influence of a goal-directed attentional system, and an elevation in the influence of a stimulus-driven attentional system, as described in the theory of attention proposed by Corbetta and Shulman (2002). Thus, from this perspective, people high in anxiety would experience the preferential processing of peripheral threat related stimuli, by their stimulus-driven attentional system (Eysenck et al., 2007). Meta analysis (Shi et al., 2019) supports the ACT (Derakshan & Eysenck, 2009, Eysenck et al., 2007) based suggestion that anxiety relates to slower response rates but not impaired accuracy during experimental tasks that require cognitive control. Moreover, self-report studies show that both trait social interaction anxiety and trait social phobia are negatively correlated with dispositional attentional control (Morrison & Heimberg, 2013b).

In summary, two conceptually different theories: ACT (Eysenck et al., 2007), and rRST (Gray & McNaughton, 2000), imply that stimuli that relate to social threat will often be processed as a priority in elevated levels of social anxiety. Moreover, both ACT and rRST imply that levels of social anxiety may relate to variability in how cognitive control is maintained. However, ACT describes impairments in attentional control that are driven by an imbalance of two attentional systems. By contrast, rRST describes the BIS as a conflict resolution system that is activated by the concurrent approach and avoidance stimulation that often precedes feelings of anxiety.

Social anxiety and emotional facial expression discrimination

Social interaction usually involves both verbal and nonverbal communication, and occurs in varying contexts, with varying numbers of people (De Jaegher et al., 2010). Emotional facial expressions convey information about a person's feelings and intentions from one person to another

(Keltner & Ekman, 2000). Experimental research shows that, on average, people are faster to identify positive emotional facial expressions relative to negative emotional facial expressions (Leppanen & Hietanen, 2004). This bias might result from the automatic use of a cognitive shortcut that aids the identification of happy facial expressions (Calvo & Beltran, 2014). By contrast, elevated trait social anxiety predicts the slower discrimination of happy facial expressions relative to lower levels of trait social anxiety (Silvia et al., 2006). Further evidence has confirmed that although mean reaction times (RTs) are faster for happy faces relative to threat-related faces when the discrimination of emotional facial expressions is required, elevated trait social anxiety is negatively correlated with the happy face RT advantage (du Rocher & Pickering, 2019). In elevated social anxiety the cognitive shortcut that aids the identification of happy facial expressions (Calvo & Beltran, 2014) might be less accessible, and attention might instead be directed to perceptual information that indicates a possible threat-related facial expression (du Rocher & Pickering, 2019). These cognitive effects also resonate with the sensitivity shift theory proposal that social anxiety disorder relates to the experience of social anhedonia (Richey et al., 2019).

Social anxiety and flanker tasks

We have discussed how social anxiety relates to the discrimination of single emotional facial expressions. However, in real-life faces are often not encountered in isolation but in the presence of other faces within social contexts. One way of providing a context in laboratory experiments is to use an emotional face flanker task (modified from the original Eriksen flanker task; Eriksen & Eriksen, 1974). In the emotional face flanker task participants might, for example, respond with a key press to photographs of either a central negative or central positive facial expression. The central facial expressions are flanked on either side by photographs of a facial expression depicting either the same emotion for congruent trials, or the alternative emotion for incongruent trials. Mean RTs for correct responses to congruent trials are on average faster than mean RTs for correct responses to incongruent trials (illustrating a RT congruency effect). In order to perform well on incongruent trials, participants must exert cognitive control to inhibit the attentional capture, and resulting emotional response conflict, activated by the emotionally conflicting flankers (Munro et al., 2007).

A simple extension of the *trial-to-trial* effects of social anxiety described above (whereby the happy face RT advantage is reduced when discriminating single happy faces from single threat-related faces) might predict the following *within-trial* effects of elevated social anxiety: incongruent fearful flanker faces might slow responses to central happy faces more than incongruent happy flankers faces slow responses to central fearful faces. There is already some evidence on the effects of anxiety on flanker task performance as elevated trait general anxiety can increase the RT congruency effect in a *non-emotional* flanker task that used arrow stimuli (Berggren & Derakshan, 2013). This effect resonates with attentional control theory (ACT) which predicts that anxiety relates to increased cognitive interference / distraction (Eysenck et al., 2007). The biobehavioural perspective on anxiety described in rRST also implies that BIS activity is elevated following the detection of goal conflict, and that motor responses to repeated experiences of the conflicting stimuli would be slowed (Gray & McNaughton, 2000). If this motor response slowing effect is magnified in elevated dispositional BIS sensitivity, then this might also explain why elevated trait general anxiety predicts an increase in the mean RT congruency effect in flanker tasks.

Surprisingly, preliminary evidence suggests that trait social anxiety might not modulate the RT congruency effect in emotional face flanker tasks (Chen et al., 2016; Dickter et al., 2018; Moser et al., 2008). However, these studies did not conclusively answer the question here, because they also found that trait social anxiety also did not modulate RTs to the central negative (fearful, angry, or disgusted) faces, or the positive (happy or surprised) faces. If there is no effect of social anxiety on RTs to the central target facial emotion, then one might not expect an effect on the emotional flanker congruency effects either. Thus, more work is required to determine how cognitive control operates in social anxiety, when conflicting arrays of emotional facial expressions are presented, and emotional facial expression discrimination is required.

The present study

There are several gaps in the research literature that need addressing. The above studies on the emotional face flanker task used several different measures of social anxiety. Moser et al. (2008) used the social phobia inventory (SPIN, Connor et al., 2000), which measures fear, avoidance, and physiological symptoms of social phobia. Chen et al. (2016) used a Chinese adaptation of the Liebowitz Social Anxiety Scale (Liebowitz, 1987), which includes questions concerning avoidant behavior and/or fear as well as anxiety. Moreover, Dickter et al. (2018) used the Social Phobia and Anxiety Inventory (SPAI-23; Roberson-Nay et al., 2007). There is therefore an important gap in the literature as these studies did not differentiate the cognitive correlates of trait social interaction anxiety (fearfulness and avoidance of situations where social interaction with other people is a requirement) from those of trait social phobia / social observation anxiety (fearfulness and avoidance of situations where observation or scrutiny from other people is likely). This is an important omission, as the two subtypes of trait social anxiety may differentially predict cognitive control, as indexed by the RT congruency effect, and/or differentially predict the speed of the discrimination of emotional facial expressions. In the present study we used an emotional flanker task that assesses the discrimination of central target emotional facial expressions, and the cognitive control of flanker conflict.

Based on the above literature, we hypothesised that elevated trait social anxiety would bias fearful face processing, thus reducing the *trial-to-trial* happy face RT advantage for the identification of the emotion depicted by the central target stimuli. However, our key interest concerned how social anxiety relates to the RT congruency effects. Social anxiety might predict an increased overall RT congruency effect if social anxiety relates to a general impairment in the cognitive control of emotional response conflict. However, if the *trial-to-trial* bias for fearful face processing relative to happy face processing extends to the *within-trial* effect of flanker processing, then there may be an interaction whereby social anxiety increases flanker interference more for trials with happy targets (and fearful flankers) relative to trials with fearful targets (and happy flankers). In this case, we would expect social anxiety to relate to an emotion x flanker congruency interaction. As discussed above, the literature is not developed enough to make a specific prediction concerning whether trait social interaction anxiety or trait social phobia will differentially predict any RT congruency effects when there is also an effect of anxiety on RTs to target faces.

In order to test these hypotheses, we created an emotional flanker task with 8 faces completely surrounding the target face stimulus. This loosely mimics a social situation where a face is immersed in a crowd of faces. We contrasted happy faces with fearful faces because fearful faces signal an indirect threat to the observer, and anxiety is related to uncertainty and anticipation concerning possible threat-related situations (Grupe & Nitschke, 2013). We used a set of stimuli including photographs of several different people posing the emotions. This should force participants to focus on the emotional expressions of the target faces, as opposed to any easily learned featural differences in any one person's facial expression, when distinguishing between the emotions (Munro et al., 2007). Following this rationale, we also made sure that in each trial the person posing the emotional expression of the target face was a different person than the person posing the emotional expression of the flanker faces. We also note here that sometimes behavioural and psychophysiological effects of anxiety can be detected in emotional face flanker tasks, in the absence of any significant overall main effect of RT flanker congruency (Yu et al., 2018). We measured trait social anxiety using the social interaction anxiety scale (SIAS) and social phobia scale (SPS; Mattick & Clarke, 1998). The SPS scale (which measures the fear of social scrutiny; Mattick & Clarke, 1998) is sometimes retitled as a measure of social observation anxiety (e.g., Gomez et al., 2022; Kramer & Rodriguez, 2018).

Method

Participants

Participants (N = 87; 70% female) aged 18–46 (mean 24.3; SD 6) were recruited from Goldsmiths, University of London via departmental advertisements and were either psychology undergraduates who participated for course credit (24%), or students/staff who were paid £10 for participation. Ethical approval was obtained from the Goldsmiths Department of Psychology. All participants gave informed written consent. We based our power and sample size calculation on correlation as our main interests are the effects of the anxiety traits. The effect of trait anxiety on the RT congruency effect in the flanker study by Berggren and Derakshan (2013) was moderate ($r = 0.4$). Accordingly, our sample size was chosen to allow 80% power for two-tailed tests at $p = 0.05$, for a slightly weaker correlation of 0.3. Correlations of this magnitude are quite common for personality-behaviour associations. We note here that the key results of the present study are initially tested using ANCOVA, but the effect of a covariate is identical to correlations/regressions of anxiety with task effects. Moreover, our results are further illustrated using correlations between anxiety and task effects. Hence it is appropriate to power the study using a correlation coefficient. As one participant did not fully complete the SIAS/SPS the analyses of the social anxiety effects include 86 participants.

Materials

Psychometric measures

Trait social anxiety

Social anxiety was measured using the Social Interaction Anxiety Scale (SIAS) and the Social Phobia Scale (SPS; Mattick & Clarke, 1998). The SIAS and SPS require participants to read statements and indicate the degree to which they feel that the statements are characteristic or true of them. Participant self-ratings are recorded using a five-point Likert type scale, with each numerical anchor point described by a verbal descriptor ranging through: *not at all*, *slightly*, *moderately*, *very*, and *extremely*. The SIAS includes 19 statements such as *when mixing socially I am* *uncomfortable*; *I am at ease meeting people at parties, etc.*; and *I am nervous mixing with people I don't know well*. Two of the SIAS items are reverse scored. The SPS includes 20 statements such as *I feel self-conscious if I have to enter a room where others are already seated*; *I get tense when I speak in front of other people*; and *I feel awkward and tense if I know people are watching me*. None of the SPS items are reverse scored. In the present study, both the SIAS and SPS had a good degree of internal consistency (Cronbach's alpha = 0.90 for both scales). Participants SIAS scores (sample mean = 21.2, SD = 12.1) and participants SPS scores (sample mean = 17.3, SD = 11.9) were positively correlated ($r[84] = 0.71$, $p < 0.001$).

Self-reported attentional control

Attentional control was measured using the Attentional Control Scale (ACS; Derryberry & Reed, 2002). The ACS requires participants to indicate how often they experience the effects of attention described in 20 statements such as *my concentration is good even if there is music in the room around me*, and *I can quickly switch from one task to another*. Participants self-ratings are recorded using a four-point Likert type scale with each numerical anchor point described by a verbal descriptor ranging through: *almost never*, *sometimes*, *often*, and *always*. Eleven of the ACS items are reverse scored. In the present study the ACS (sample mean = 49.5, SD = 9.2) had a good degree of internal consistency (Cronbach's alpha = 0.86).

Fig. 1 Examples of stimuli used. The examples depicted clockwise from top left are an incongruent happy trial, an incongruent happy trial, an incongruent fear trial, a congruent happy trial, a congruent fear trial, and a congruent fear trial

Visual stimuli

The emotional face stimuli were from the NimStim (Tottenham et al., 2009). The individual face pictures were 20 mm high x 16 mm wide and were formed into grids of 9 faces, thus the overall grid dimensions were 60 mm high and 48 mm wide when presented on a 15.5-inch laptop computer screen. We created three stimulus sets containing different people's faces. Each of the three face sets included happy and fearful facial expressions (with versions of each expression included that had both open mouths and closed mouths) posed by six different models. Thus, in each set, images of each of the six models were used, with both closed and open mouths (for both facial expressions). The individual pictures of emotional faces were used to create the flanker stimuli as illustrated by Fig. 1.

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Procedure

Participants were tested individually in a purpose-built testing booth. Participants were informed that they would be asked to complete a facial emotion recognition task (using one of the three possible face sets). Participants were asked to sit as close to the screen as was comfortable for their eyes (typical viewing distance was approximately 70 cm). The task instructions were presented on the screen. To start the task the first screen instructed participants that they would have to judge the emotional expression showing on photos of faces. Participants were then shown examples of the various stimulus combinations they might see and reminded to concentrate on the central face and ignore any others. They were told to rest their index fingers over the response keys (z and /) and to respond as fast as possible while maintaining high accuracy levels. They were verbally told by the experimenter that a high-pitched tone following a response would indicate a correct response, whereas a low-pitched tone following a response would indicate an incorrect response.

The experimental stimuli were displayed until a response key was pressed. Following the response there was a 500 millisecond (msec) interval before the start of the next trial. The first 300 msecs of this interval were when the feedback tone was sounded. Unbeknown to the participants, at the beginning of the task, there were twelve congruent trials and twelve incongruent trials included as practice trials (drawn from the same stimuli set as the main trials); these were discarded and not analysed. The main experimental stimuli that followed consisted of 120 incongruent trials and 120 congruent trials. The emotional stimuli also consisted of 120 happy face trials and 120 fearful face trials. Thus, there were 60 happy incongruent trials and 60 happy congruent trials (and 60 fearful incongruent trials and 60 fearful congruent trials). Half of each of these sets of 60 stimulus types had open mouths whereas half had closed mouths. The identity of the flanker person was always different from the identity of the central target person, but both persons had the same mouth type. The trial sequence was created using a random number generator but with the requirements that at no point was a person's identity from a previous trial (target or flanker) to be used in the following trial (target or flanker). The task lasted for approximately ten minutes. The left/right finger response key mappings were counterbalanced across participants. Each participant experienced only one of the three stimuli sets (which were administered in approximately equal proportions across participants).

Results

Task effects

Our analysis is based upon a within-subjects general linear model (GLM). The RT data for correct responses were subjected to a 2 (emotion; happy central face versus fearful central face) x 2 (flanker congruency; congruent versus incongruent) factorial ANOVA. After excluding extreme scores (RTs < 200 msecs and RTs > 1250 msecs) 92.2% of correct responses were included in the analysis. Mean RTs for each of the individual trial types are shown in Fig. 2 (panel A).

The main effect of emotion was significant ($F[1,86] = 40.4$, $p < 0.001$, $\eta^2 = 0.319$), as overall happy faces were responded to faster (mean RT: 754 msecs, SE: 0.019) than fearful faces (mean RT: 791 msecs, SE: 0.021). This illustrates the happy face RT advantage. The main effect of flanker congruency was small, and did not reach statistical significance ($F[1,86] = 2.9$, $p = 0.092$, $\eta^2 = 0.033$) as congruent trials (mean RT: 769 msecs. SE: 0.02) were not responded to significantly faster than incongruent trials (mean RT: 776 msecs, SE: 0.02). The emotion x flanker congruency effect was not significant ($F[1,86] = 0.2$, $p = 0.685$, $\eta^2 = 0.002$).

Although out main interest was the RT effects, we analysed the proportion correct data using a 2 (emotion; happy central face versus fearful central face) x 2 (flanker congruency; congruent versus incongruent) factorial ANOVA. The main effect of emotion was significant ($F[1,86] = 5.8$, $p = 0.018$, $\eta^2 = 0.063$), as happy faces (mean proportion correct: 0.94; SE: 0.005) were recognised more accurately than fearful faces (mean proportion correct: 0.93; SE: 0.006). There were no other significant effects or interactions (all Fs < 1.0, all ps > 0.700).

Social anxiety and RTs

We repeated the above GLM analysis twice whilst adding standardised SIAS scores as covariates in the first ANCOVA, and then standardised SPS scores as covariates in the second ANCOVA. This allows us to test the relationship between the subtypes of trait social anxiety and the specific effects of emotion (the happy face RT advantage), trial type (the flanker congruency effect), and their potential interaction. SIAS scores significantly interacted with the main effect of emotion ($F[1,84] = 4.1$, $p = 0.047$, $\eta^2 = 0.046$), but not the main effect of flanker congruency ($F[1,84] = 0.1$, $p = 0.742$, $\eta^2 = 0.001$), or the emotion x flanker congruency interaction ($F[1,84] = 0.1$, $p = 0.712$, $\eta^2 = 0.002$).

SPS scores did not significantly interact with the main effect of emotion ($F[1,84] = 1.4$, $p = 0.240$, $\eta^2 = 0.016$), but they did significantly interact with the main effect of flanker congruency ($F[1,84] = 7.3$, $p = 0.008$, $\eta^2 = 0.080$). SPS scores did not significantly interact with the emotion x flanker congruency interaction ($F[1,84] = 1.8$, $p = 0.185$, $\eta^2 = 0.021$), which indicates that any effects of trait social phobia on the congruency effect did not differ when the flankers were fearful relative to when they were happy. Importantly, this interaction shows that during incongruent trials trait social phobia did not relate to increased attention to fearful flankers relative to happy flankers. Testing this effect was one of the key goals of the present study.

To further illustrate the interaction between SIAS scores and the main effect of emotion we calculated an index of the happy face RT advantage [mean RT fearful faces – mean RT happy faces], which was (as one would expect from the ANCOVA results) significantly correlated with SIAS scores ($r[84] = -0.22$, $p = 0.047$). Thus, as SIAS scores increased, the happy face RT advantage decreased. However, further correlations showed that SIAS scores were not related to either RTs for happy face trials, or RTs for fearful face trials (both rs < 0.08, both ps > 0.500). SPS scores were very weakly and non-significantly related to the index of the happy face RT advantage ($r[84] = -0.13$, $p = 0.240$). These correlations are depicted in Fig. 2 (panels B and C).

To further illustrate the interaction between SPS scores and the main effect of flanker congruency we calculated an index of the RT flanker congruency effect [mean RT incongruent trials – mean RT congruent trials], which was (as one would expect from the ANCOVA results) significantly correlated with SPS scores ($r[84] = 0.28$, $p = 0.008$). Thus, as SPS scores increased, the flanker congruency effect increased. However, further correlation showed that SPS scores were not related to either RTs for congruent trials, or RTs for incongruent trials (both rs < -0.08, both ps > 0.400). As one would expect from the above ANCOVA, SIAS scores were not correlated with the index of the RT flanker

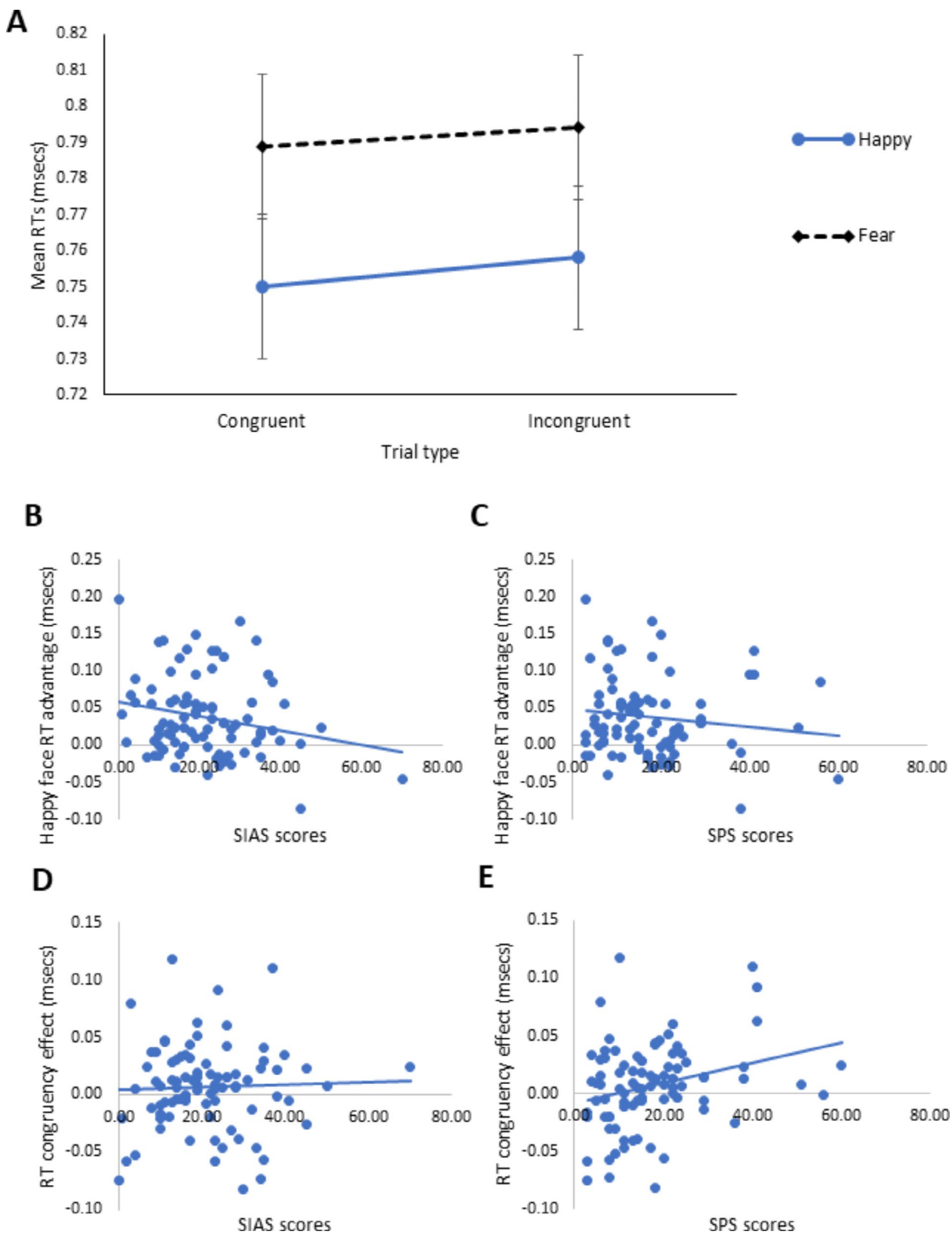

Fig. 2 Panel A shows the mean RTs for each of the four trial types. Error bars represent one standard error (SE) of the mean. Panels B and C show the zero-order correlations between the happy face RT advantage and SIAS and SPS scores respectively. Panels D and E show the zero-order correlations between the RT congruency effect and SIAS and SPS scores respectively

congruency effect (r[84] = 0.04, $p = 0.742$). These correlations are depicted in Fig. 2 (panels D and E).

Controlling for general RT variance

When correlating SIAS or SPS scores with the RT difference between happy and fearful faces (or the RT difference between congruent and incongruent trials), general sources of variance in RTs are removed from the RT difference computation. Critically, when one follows up a correlation of SIAS or SPS scores with any RT difference score to ascertain if either one or both RT variables are correlated with SIAS or SPS scores, the general sources of RT variance are not removed from the correlations. This can obscure these correlations, so we computed a general RT factor and controlled for this factor using partial correlation.

Specifically, we calculated a general RT factor to enable us to clarify which of the two emotional facial expressions were driving the SIAS correlation with the main effect of emotion, and which trial type was driving the SPS correlation with the main effect of flanker congruency. To compute the general RT factor, we used a similar method as used in prior research (du Rocher & Pickering, 2019). To estimate the general RT factor, we used principal components analysis to extract two factors. Here we used mean RTs from each participant for each of the 4 stimulus types. The model explained 98.2% of the variance. Factor 1 was clearly the general RT factor (loadings on each of the 4 mean RTs were > 0.97), which accounted for 96.4% of the variance. Factor 2 was much smaller and accounted for 1.8% of the variance. The loadings on each of the 4 mean RTs were < +/- 0.18 for incongruent trials and < +/- 0.10 for congruent trials (with the sign of the loadings being + for fear trials and - for happy trials). Thus, factor 2 was most likely related to the specific trial types.

When controlling for the confounding effects of general RT variance using the general RT factor as the control variable, partial correlation showed that SIAS scores were negatively correlated with RTs to fearful faces (r[83]=-0.25, $p = 0.020$), and positively correlated with RTs to happy faces (r[83] = 0.25, $p = 0.021$). Thus, as SIAS scores increase, RTs for correct responses to fearful faces become faster, and RTs for correct responses to happy faces become slower. As one might expect from the above analysis, these correlations were weak and non-significant when the analysis was run with the SPS measure: r[83] = 0.12, $p = 0.291$ for happy faces, and r[83]=-0.12, $p = 0.262$ for fearful faces.

When controlling for general RT variance partial correlation showed that SPS scores were negatively correlated with RTs to congruent trials (r[83]=-0.29, $p = 0.007$), and positively correlated with RTs to incongruent trials (r[83] = 0.27, $p = 0.013$). Thus, as SPS scores increased, RTs for correct responses to congruent trials become faster, and RTs for correct responses to incongruent trials become slower. As one might expect from the above analysis, these correlations were not significant when the analysis was run with the SIAS measure: r[83]= -0.06, $p = 0.594$ for congruent trials, and r[83] = 0.02, $p = 0.851$ for incongruent trials.

Controlling for self-reported attentional control and age

When controlling for self-reported attentional control and age by using partial correlation, SPS scores were *still* significantly positively correlated with the RT flanker congruency effect (r[81] = 0.30, $p = 0.006$), whereas SIAS scores were *still* not significantly correlated with the RT flanker congruency effect (r[81] = 0.03, $p = 0.765$). Moreover, when controlling for self-reported attentional control and age by using partial correlation, SIAS scores were *still* significantly negatively correlated with the happy face RT advantage (r[81]= -0.22, $p = 0.046$), whereas SPS scores were *still* weakly and non-significantly related to the happy face RT advantage (r[81]= -0.17, $p = 0.123$).

We confirmed that age was not significantly correlated with SIAS scores, SPS scores, or the RT flanker congruency effect (all rs < +/- 0.12, all ps > 0.270). By contrast, age was significantly correlated with the happy face RT advantage (r[85]= -0.23, $p = 0.033$). We also confirmed that self-reported attentional control was not significantly correlated with the happy face RT advantage, or the RT flanker congruency effect (both rs < − 0.03, all ps > 0.840). However, self-reported attentional control was significantly negatively correlated with SPS scores (r[83]= -0.24, $p = 0.030$), and weakly but non-significantly correlated with SIAS scores (r[83]= -0.16, $p = 0.139$).

Social anxiety and proportion correct

Although out main interest was the relationship between both SIAS and SPS scores and the RT effects, we analysed the proportion correct data using a 2 (emotion; happy central face versus fearful central face) x 2 (flanker congruency; congruent versus incongruent) factorial ANCOVA adding standardised SIAS scores as covariates in the first ANCOVA, and then standardised SPS scores as covariates in the second ANCOVA. Neither SIAS or SPS scores shared any significant interactions with the main effects or their interaction (all Fs < 1.7, all ps > 0.190).

Discussion

Our emotional face flanker task produced a robust main effect of emotion as on average there was a clear RT advantage for the identification of happy facial expressions relative to fearful facial expressions. However, increases in trait social interaction anxiety were significantly related to a reduction in the happy face RT advantage. We also showed that, after removing the effect of general RT variance, increases in trait social interaction anxiety were related to faster responses to fearful faces, and slower responses to happy faces. In the present study trait social phobia was weakly and non-significantly related to the discrimination of the target emotions. The need for the exertion of cognitive control over the presence of flanker conflict may have affected the cognitive processing resources of participants with elevated trait social phobia, so that cognitive resources were occupied with flanker inhibition as opposed to the mechanisms that drive the happy face RT advantage.

A purely cognitive explanation of the effect of trait social interaction anxiety on the happy face RT advantage in the present study would suggest that the cognitive shortcut that aids the identification of happy facial expressions (Calvo & Beltran, 2014) was less accessible in elevated trait social interaction anxiety, and attention was instead directed to perceptual information that indicated a possible threat-related facial expression (as proposed by du Rocher & Pickering, 2019). Moreover, SIAS scores tend to be inversely related to self-reported levels of positive affect (Hughes et al., 2006). This might also affect the speed of the recognition of happy faces in trait social interaction anxiety. If future studies find that a reduction of self-reported positive affect, *and* a reduction in the happy face RT advantage, are important in the nosology of social interaction anxiety, then the results would resonate with sensitivity shift theory. That is to say, sensitivity shift theory proposes that social anxiety disorder relates to social anhedonia, and reduced positive affect (Richey et al., 2019).

Our emotional face flanker task also produced a small and non-significant main effect of flanker congruency. However, our study shows that flanker congruency effects can be manifested as a reliable effect of a trait individual difference variable, in the absence of any reliable flanker congruency effect that is detectable when averaging across the whole sample.

Increases in trait social phobia (but not trait social interaction anxiety) were related to significant increases in the flanker congruency effect. This effect resonates with the finding that trait general anxiety can increase the RT congruency effect in *non-emotional* flanker tasks (Berggren & Derakshan, 2013). Critically, in the present study the effects of trait social phobia on the flanker congruency effect did not differ when the flankers were fearful relative to when they were happy. This suggests that during incongruent trials trait social phobia did not relate to increased attention to fearful flankers relative to happy flankers. Taking these results at face value one might suggest that the increase in the flanker congruency effect in trait social phobia provides evidence for ACT (Eysenck et al., 2007), and that trait social phobia (and thus trait social observation anxiety) relates to increased cognitive interference / distraction. However, the removal of general RT variance showed that as trait social phobia scores increased, RTs for correct responses to congruent trials became faster, *as well as* the RTs for correct responses to incongruent trials becoming slower. If the effect of trait social phobia on the RT congruency effect was simply an effect of increased distraction, then SPS scores would correlate with RTs to incongruent trials only. By contrast, SPS scores were also correlated with RTs to congruent trials. Thus, elevated trait social phobia, and thus anxiety about being observed by other people, may relate to rapid emotion discrimination when the emotions are displayed in a congruent fashion by several faces at once. We also note here that the effect of trait social phobia upon the RT congruency effect was not explained by the self-reported ability to control attention, as captured by scores on the ACS (Derryberry & Reed, 2002).

The biobehavioural account of social anxiety (Kimbrel, 2008), that is based on rRST (Gray & McNaughton, 2000), can be used to offer a different explanation of our data. For example, in the emotional face flanker task, the BIS should be particularly active because of the uncertainty over which emotional target stimulus (a central happy face, or a central fearful face) is going to appear on any single trial. An rRST based exposition of the happy face RT advantage in the present study would suggest that in elevated trait social interaction anxiety general task related uncertainty may have elevated BIS activity, which may have slowed motor responses to (reward-related and thus BAS-related) happy faces, thus favouring faster motor responses to the (threat-related and thus FFFS-related) fearful faces. This effect might be partly driven by BIS mediated restraints being placed on the cognitive shortcut that aids the identification of happy facial expressions, that was proposed by Calvo and Beltran (2014). This rRST based prediction of a reduction in BAS activity in elevated trait social interaction anxiety is consistent with the prediction of a reduction in positive affect (or increased anhedonia) in trait social interaction anxiety (Hughes et al., 2006), and with the predictions of sensitivity shift theory (Richey et al., 2019).

The effect of trait social phobia on the flanker congruency effect might also be partly understood from the perspective of rRST (Gray & McNaughton, 2000). When BIS activity is elevated, motor responses to any conflicting stimuli should be slowed if the BIS restrains approach related BAS activity (Gray & McNaughton, 2000; Smillie et al., 2006). This could explain the slower mean RTs to emotionally conflicting incongruent trials, as SPS scores increase. However, as SPS scores increased, mean RTs to congruent trials decreased (regardless of the emotion depicted). An rRST based explanation might tentatively suggest that when a lack of (emotional) goal conflict is detected by participants with elevated trait social phobia, the BIS rapidly releases any restraints on approach related BAS activity, which would allow rapid motor responses to occur. However, this tentative suggestion requires some substantial experimental testing.

In summary, the rRST based exposition of our data suggests that in elevated trait social interaction anxiety BIS activity may operate by resolving goal conflict in situations where there is uncertainty about which emotional facial expression will appear next. This seems to reduce the speed of motor responses to target happy faces, and seems to facilitate rapid motor responses to target fearful faces. By contrast, in elevated trait social phobia (trait social observation anxiety) BIS activity might operate by resolving goal conflict caused by the uncertainty of whether the next array of faces will display emotionally congruent or emotionally incongruent facial expressions. Thus, in this situation the BIS may operate by speeding the detection of, and motor response to, facial expressions surrounded by emotional congruence, and also by decreasing the speed of motor responses to facial expressions surrounded by emotional incongruence.

Future implications

Our analysis suggests that there are a number of important future implications to consider. If the effects of the two social anxiety subtypes in the emotional face flanker task reflect effects of social cognition in the real world, then trait social interaction anxiety might modulate the processing of emotional facial expressions of individuals in everyday social interactions, whereas trait social phobia (trait social observation anxiety) might modulate the detection of, and response to, the emotional congruency of expressions present in crowds of observers. However, these suggestions need to be tested in novel experimental paradigms, or in real-world social situations. Moreover, both traditional computer-based (Amir et al., 2009), and virtual reality (VR) based (Urech et al., 2015), attentional bias modification interventions have been used to train attention away from negative facial stimuli (and towards neutral facial stimuli) in social anxiety. Based on our analysis, we suggest that future VR intervention studies might consider a method that trains attention towards happy facial stimuli, as well as training attention away from negative facial stimuli.

Self-report studies have reported zero-order correlations showing that both trait social interaction anxiety and trait social phobia are positively correlated with BIS sensitivity, FFFS-flight/freeze sensitivity, and negatively correlated with BAS sensitivity and FFFS-fight sensitivity (e.g., du Rocher & Warfield, 2022; Gomez et al., 2022). Although a comparison of multiple regression analyses across different studies can show inconsistent results concerning which reinforcement sensitivity is the most prominent predictor of SIAS or SPS scores (e.g., du Rocher & Warfield, 2022; Gomez et al., 2022; Kramer & Rodriguez, 2018), these analyses do suggest that the rRST measures can explain a moderate amount of variance in both SIAS scores, and SPS scores. Future studies might test the relationship between self-reported BIS, BAS and FFFS sensitivity and the happy face RT advantage, as well as the RT congruency effect in the emotional face flanker task. This may reveal if, and how, the underlying levels of dispositional reinforcement sensitivity that relate to trait social interaction anxiety and to trait social phobia, also relate to the cognitive processes that are active in the emotional face flanker task.

The DSM-5 definition of social anxiety disorder includes a performance anxiety only specifier that refers to fears that are specific to performing/speaking in public (American Psychiatric Association, 2013). It has been shown that if those with social anxiety disorder have this specifier, they report lower levels of social anxiety, depression, clinical severity, and comorbidity, compared to those with social anxiety disorder but without the performance anxiety only specifier (Fuentes-Rodriguez et al., 2018). Fuentes-Rodriguez et al. suggested that performance anxiety only, may relate to a milder form of social anxiety disorder and that their results are consistent with a dimensional structure of the disorder. In the present study trait social phobia (trait social observation anxiety), but not trait social interaction anxiety was related to faster RTs to congruent arrays of emotion, and slower RTs to incongruent arrays of emotion. Thus, it would be useful to test whether these RT congruency effects are more strongly predicted by social anxiety disorder patients with the performance anxiety only specifier, compared to those without the performance anxiety only specifier. This would further extend the literature as at present our analysis has focused upon sub-clinical subtypes of social anxiety.

Limitations

Although our results and analysis offer an important contribution to understanding some of the cognitive-emotional processes that can covary with trait social interaction anxiety and trait social phobia, our study does have some limitations. Firstly, our study was not designed to assess the effects of perceptual load on flanker processing. It is not easy to quantify the exact level of perceptual load in our flanker experiment as although there were eight flanker faces present, there was always a maximum of two emotional expressions present. Distractor inhibition may be somewhat easier when several distractors are presented, and perceptual load is higher, relative to when fewer distractors are presented, and perceptual load is lower (Lavie, 1995). It has been shown using a variant of the letter stimulus flanker task that the RT congruency effect is present in high social anxiety, but not in low social anxiety, when perceptual load is high. By contrast, the RT congruency effect is present in both high and low social anxiety, when perceptual load is low (Moriya & Tanno, 2010). In the present study the emotional flanker congruency effects appeared as a reliable effect of trait social phobia in the absence of any reliable mean RT congruency effect that was present when averaging across the whole sample. It is possible that this could change in the whole sample if levels of perceptual load were to be manipulated. Future studies might investigate how perceptual load modulates any RT effects in the emotional face flanker task. Moreover, future studies might test whether perceptual load manipulations have any consequent effects upon the relationships between the RT congruency effect and trait social interaction anxiety and/or trait social phobia.

Secondly, we are aware that type 1 error rates can increase when using correlation based statistical techniques as a means of controlling for confounding variables if there is any measurement error in the control variable, and that this problem can be magnified when sample sizes are large (Westfall & Yarkoni, 2016). However, in the present study the control variables were age, which should not contain measurement error, and the ACS (Derryberry & Reed, 2002), which produced large alpha reliabilities. Moreover, the sample size we used was not particularly large.

Thirdly, we did not control for IQ in our analysis. Elevated levels of anxiety in clinical generalised anxiety disorder patients can predict an elevated IQ, whereas low levels of anxiety in healthy controls can also predict an elevated IQ (Coplan et al., 2012). If a relationship between anxiety and IQ can be positive in clinical patients, but be inverse in healthy controls, then a future replication might benefit from controlling for IQ in the analysis of the effect of the two subtypes of trait social anxiety on performance during the emotional flanker task. However, analyses controlling for IQ could also be affected by the limitations discussed by Westfall and Yarkoni (2016).

Conclusion

Elevated trait social interaction anxiety was related to a decreased happy face RT advantage when discriminating happy faces from fearful faces in the emotional face flanker task. This seems to be due to elevated trait social interaction anxiety relating to faster RTs for fearful faces, and to slower RTs for happy faces. Trait social phobia, but not trait social interaction anxiety, was related to an increased RT congruency effect in the emotional face flanker task. This seems to be due to elevated trait social phobia relating to faster RTs to congruent arrays of emotion, and slower RTs to incongruent arrays of emotion. Thus, trait social interaction anxiety and trait social phobia (trait social observation anxiety) seem to have some subtle differential effects when the cognitive control of visual emotion is required.

Funding This work was funded by Goldsmiths, University of London.

Data Availability The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of Interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

Compliance with ethical standards Participants gave informed consent and had the right to withdraw. The study was performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki.

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