King's Research Portal

Document Version
Publisher's PDF, also known as Version of record

Link to publication record in King's Research Portal

The Relationship Between Attention, Interpretation, and Memory Bias During Facial Perception in Social Anxiety

Chantel J. Leung

The University of Hong Kong and King's College London, Institute of Psychiatry, Psychology and Neuroscience

Jenny Yiend

King's College London, Institute of Psychiatry, Psychology and Neuroscience

Tatia M.C. Lee

The University of Hong Kong and Center for Brain Science and Brain-Inspired Intelligence

Although cognitive theories suggest the interactive nature of information processing biases in contributing to social anxiety, most studies to date have investigated these biases in isolation. This study aimed at (a) testing the association between social anxiety and each of the threat-related cognitive biases: attention, interpretation, and memory bias; and (b) examining the relationship between these cognitive biases in facial perception. We recruited an unselected sample of 188 adult participants and measured their level of social anxiety and cognitive biases using faces displaying angry, disgusted, happy, and ambiguous versions of these expressions. All bias tasks were assessed with the same set of facial stimuli. Regression analyses showed that social anxiety symptoms significantly predicted attention avoidance and poorer sensitivity in recognizing threatening faces. Social anxiety was, however, unrelated to interpretation bias in our sample. Results of path analysis suggested that attention bias influenced memory bias indirectly through interpretation bias for angry but not disgusted faces. Our findings suggest that, regardless of social anxiety level, when individuals selectively oriented to faces displaying anger, the faces were interpreted to be more negative. This, in turn, predicted better memory for the angry faces. The results provided further empirical support for the combined cognitive bias hypothesis.

Keywords: social anxiety; combined cognitive bias hypothesis; attention bias; interpretation bias; memory bias

INDIVIDUALS WITH SOCIAL ANXIETY are characterized by the fear of being evaluated and by apprehension of social or performance situations. A compelling body of research supports the notion that socially anxious individuals display attention bias (e.g., Klumpp & Amir, 2009; Mogg et al., 2004). They also have a propensity to interpret emotionally ambiguous information in a negative fashion (e.g., Amir et al., 2012; Beard & Amir, 2009) and selectively retrieve negative or threatening information (e.g., Amir et al., 2000; Foa et al., 2000).

The Interrelationship Between Cognitive Biases

A central tenet of cognitive models of anxiety is the interrelationship *between* the cognitive biases involved in threat-related processing (e.g., Beck & Clark, 1997; Mathews & MacLeod, 1994). Hirsch et al. (2006), among others, have used the term "combined cognitive bias hypothesis" (CCBH), suggesting that cognitive biases influence

and interact with one another. The combination of biases is also proposed to have a greater impact on sustaining anxiety, compared to the single contribution of each bias.

Currently, there are different hypotheses regarding how the selection of novel emotional information during attention might impact the later stage of processing. Consistent with Everaert and Koster (2020), we expected that information processing could occur in two ways: the *attention–interpretation–memory bias pathway* and the *attention–memory–interpretation bias pathway*. Some cognitive models hypothesize that attention vigilance toward emotional materials may result in biased interpretation through the extensive elaboration of threat. The assigned negative meaning may then be consolidated in the long-term memory, enhancing the retrieval of threat materials (e.g., Clark & Wells, 1995; Williams et al., 1988). In other words, these models predict that selective attention regulates memory via its impact on interpretation bias (i.e., the attention–interpretation–memory bias pathway).

On the other hand, in the attention–memory–interpretation bias pathway, Everaert and Koster (2020) proposed that attention bias can directly improve memory for emotional material by increasing the probability and extent of encoding, through the action of *sustained* attention. In other words, the "interpretation" of a stimulus, prior to its encoding into memory, may not be inevitable. Instead, a mental representation of the "uninterpreted" stimulus could be formed, including any ambiguity that was present. In this pathway, *selective* attention can later influence which cues are used to guide (and therefore bias) memory search during retrieval. The later memory–interpretation part of this proposed pathway may comprise, for example, the retrieval of an ambiguous stimulus, which is then "interpreted" only at the point of retrieval through biased elaborative processing. This could result in the negative interpretation of the ambiguity that was originally encoded in memory. This is in line with Ingram's (1984; Ingram & Kendall, 1987) information processing analysis, which highlights how elaborative appraisal of emotional materials could be activated by the corresponding memory network. Thus, the second proposed pathway suggests that selective attention can influence the interpretation of information *via its direct impact* on memory processes (i.e., the attention–memory–interpretation bias pathway).

Delineating the trajectory of cognitive processes has both theoretical and clinical importance. Theoretically, it could inform researchers how cogni-

tive biases work in concert in governing the development of social anxiety, which could improve the methodology of studying biased information processing. Clinically, if the different cognitive biases involved in processing are related in a certain way, then modifying one bias should theoretically impact another bias. This could offer important direction in the development of cognitive bias modification (CBM), which is a computerized procedure that aims to directly alter individual biases to achieve symptomatic improvement, or other benefits. The distinction between these two pathways thus could help decide which cognitive bias clinical researchers should target to attain the desired transfer effects.

The Limitations of Prior Studies

One way of investigating the relationship between cognitive biases is through the examination of correlations between bias indices (see Everaert et al., 2012; Everaert & Koster, 2020, for a comprehensive review). However, it is important to note that most of the existing correlational studies used unrelated tasks and different stimulus materials when studying the relationship between cognitive biases in anxiety. These studies are unable to substantiate the theoretical role of how various cognitive biases interact in the processing of emotional information. These studies are also expected to elicit weaker bias–bias associations than when identical materials are used across all tasks because any transfer of effects must take place across *two* different domains: from one type of stimulus material to another (faces/text) and from one type of cognitive process to another.

To advance insight into the pathway of cognitive biases during information processing, multiple biases should be investigated in a single experiment while utilizing matching stimulus properties (either words or pictures only) in a related context. To the best of our knowledge, only Everaert et al. (2013, 2014) have, to date, examined the interrelationship between attention, interpretation, and memory biases with matching stimuli in a single study. Everaert et al. demonstrated an indirect effect of selective attention toward words of negative valence on memory via interpretation bias in subclinically depressed individuals, providing initial support for the attention–interpretation–memory bias pathway. But none has yet utilized the same set of emotional facial stimuli to study the interplay of various cognitive biases in social anxiety. As facial expressions convey crucial social information about others' evaluation (Rapee & Heimberg, 1997), it is ecologically important to further delineate the underlying relationship

between cognitive biases with naturally occurring stimuli.

The Measures of Facial Cognitive Biases

Commonly assessed by the visual probe task (Staugaard, 2010), both attention vigilance toward threat (e.g., Klumpp & Amir, 2009; Mogg et al., 2004) and avoidance of threat (e.g., Chen et al., 2002; Mansell et al., 1999) are evident among participants with clinical and subclinical social anxiety. Facial memory bias is usually explicitly measured by a recognition task. Patients with social phobia were found to exhibit enhanced recognition for negative expressions compared to nonanxious controls (e.g., Coles & Heimberg, 2005; Foa et al., 2000).

As there is less consensus regarding the measurement of facial interpretation bias, we selected three common types of index in this study: emotion identification of ambiguous emotions, emotion intensity rating, and social cost estimation. Prior studies showed that social anxiety was associated with enhanced detection of anger and disgust in ambiguous faces when the objective proportion of emotion displayed in the facial expression was low (Button et al., 2013; Gutiérrez-García & Calvo, 2017). Compared to controls, individuals with social anxiety disorder were more likely to select the ambiguous negative faces as more intense (Yoon et al., 2009). Socially anxious individuals were also found to estimate higher perceived cost of social interaction with people displaying disgust expression, regardless of its emotional intensity (Schofield et al., 2007).

The Present Study

To establish the relationships between attention, interpretation, and memory biases related to social anxiety, we studied the association between social anxiety symptoms and each of the threat-related biases. Based on the theoretical assumption of a bidirectional causal relationship between cognitive biases and social anxiety symptoms (Amir et al., 2005; Hirsch & Clark, 2004), we modeled social anxiety symptoms as the predictor of cognitive biases instead of the other way around for two reasons. First, as our data were cross-sectional, our measure of social anxiety did not precede that of the bias, which would (arguably) be the usual requirement to empirically test the "bias predicts symptoms" theoretical assumption. Without temporal precedence of any of our variables, we preferred the more conservative approach in which the experimental measure, here cognitive bias, was used as the dependent variable. Second, we included other variables (e.g., general negative

mood, the emotional valence of facial stimuli) whose association with bias we wished to examine in the same model. Thus, social anxiety symptoms predicting cognitive biases was selected as the current analytical approach.

For attention bias, we did not present a strong hypothesis as to whether social anxiety would predict attention toward or away from threatening (angry and disgusted) faces because the switching time from vigilance to avoidance of threat remains debated (Staugaard, 2010). However, we anticipated observing a corresponding pattern in memory bias according to what was observed in attention bias. For instance, if social anxiety symptoms predicted vigilance toward threatening facial stimuli, better recognition of threatening faces would be expected correspondingly. For interpretation bias, we hypothesized that social anxiety symptoms would predict more negative interpretation of ambiguous faces, which is specifically defined as follows: higher accuracy of emotion identification, the tendency of rating threatening faces as being more intensive, and socially costly to interact with. We then verified the relationship between attention, interpretation, and memory bias indices. In view of the limited empirical evidence on the relationship between cognitive biases (Everaert et al., 2013, 2014), we examined both the attention–interpretation–memory bias pathway (the indirect effect of interpretation bias on the relationship between attention and memory bias) and the attention–memory–interpretation bias pathway (the indirect effect of memory bias on the relationship between attention and interpretation bias) using path analysis to further our understanding of the underlying mechanism of emotional facial processing.

Method

PARTICIPANTS AND STUDY DESIGN

A total of 188 Chinese participants ages 18–40 years, having normal or corrected-to-normal vision, were recruited at the University of Hong Kong. Those who had any self-reported past or current psychotic and neurological disorder history were excluded. Details about study design and materials are presented in the supplementary document.

Attentional Probe Task

The modified probe task was used to assess attention bias. It comprises 8 practices and 128 (32 face pairs × 2 clear/ambiguous × 2 top/bottom) main trials. The 32 face pairs included 8 angry, 8 disgusted, and 16 happy faces. Each trial began with a centered fixation cross presented on the com-

puter screen for 1,000 ms. The cross was then replaced by a face pair displayed at the top and bottom of the screen for 350 ms. The presentation time was decided based on a previous eye-tracking study, which showed that the first overt attentional shift may happen after 350 ms (Garner et al., 2006). A probe (either E or F) then appeared at the center of one of the two faces until the participant had made a response. Each face pair was presented twice, once with the emotional stimulus face at the top and once at the bottom. This is to control the potential effect of habitual attention toward the top stimulus. The chance that the probe replaces each facial stimulus was 50%. The trials were presented in a fully randomized order. Participants sat 75 cm from the computer screen, resulting in a 5° visual angle for the distance between the center of the screen to the center of the top and bottom faces. Participants were instructed to keep their gaze at the central cross and after the faces disappeared, identify the letter by pressing the corresponding button on the keyboard as soon as possible.

Memory Bias Task

Memory bias was assessed by a face recognition task. To avoid the recency effect during recognition, participants were asked to prepare for the speech presentation (described below in "Stress Induction Task") for 3 minutes. In the unexpected recognition phase, 60 faces were presented to participants in a random order, one at a time. Thirty of the faces were old ones, and 30 were new faces. Participants were asked to indicate whether they saw new or old pictures by pressing the key as quickly and accurately as possible ("1" for old and "2" for new). Each face was displayed for a maximum of 4 s.

Emotion Interpretation Task

Participants were asked to identify the predominant affective facial expression in the ambiguous facial stimuli. The task included 39 (13 angry, disgusted, and happy) facial stimuli that were presented in the previous attentional probe and facial recognition task.[1] Each trial began with a fixation cross presented for 1,000 ms and replaced by a face stimulus that was shown for 500 ms. Participants were then asked to label the facial expression by pressing one key out of the five emotions (happy, angry, sad, disgust, fear) as quickly and

accurately as possible. Participants were informed in advance that some of the faces displayed low-intensity emotion and were asked to choose the emotion that first came to their mind. This forced-choice task was to encourage participants to detect subtle expressions, from which we could assess interpretation bias. Subsequently, they were asked to judge the intensity of the emotion on a 7-point Likert scale (1 = *least intensive* to 7 = *most intensive*). In the social cost task adopted from Schofield et al. (2007), participants were asked to rate the cost of interacting with the person in the picture on a scale from 1 (*It would be very bad for me*) to 7 (*It would be very good for me*). There were 8 practice trials and a total of 78 trials. All faces were shown twice. The task was broken into three blocks for rest to prevent fatigue.

Self-Reported Questionnaires and Stress Induction Task

The Social Interaction Anxiety Scale (SIAS; Mattick & Clarke, 1998) was adopted as self-report measures of social anxiety. The current study adopted the Chinese version of the SIAS translated by Stella Wan. The Depression Anxiety Stress Scales–21 (DASS-21) was administered to assess whether cognitive biases are predicted by general negative mood or by social anxiety. The Chinese version of the DASS was adopted in the current study with the approval from Calais Chan. Details about the psychometric properties of the questionnaires are presented in the supplementary document.

Previous research evidence reported that cognitive biases may be more likely to occur under social-evaluative stress (Pérez-López & Woody, 2001; Van Bockstaele et al., 2014). Thus, all participants were given a stress induction task to enhance the sensitivity of the difference of state anxiety on cognitive biases for people with high or low social anxiety. To induce social evaluative stress, the present study adopted the procedure designed by Garner et al. (2006). Details about the stress induction procedure are presented in the supplementary document. With the use of the visual analogue scale (VAS), ranging from 0 to 10, participants' self-reported state anxiety before ($M = 4.40$, $SD = 1.90$) and after ($M = 4.85$, $SD = 2.43$) stress induction had significantly increased, $t(187) = -2.55$, $p = .01$. It showed that the stress induction procedure was successful.

PROCEDURE

This study was approved by the Human Research Ethics Committee for Non-Clinical Faculties of the University of Hong Kong (ethics no. EA1709016).

---

[1] In this emotion interpretation task, we presented both ambiguous and clear facial stimuli to participants. The inclusion of clear stimuli was for a separate investigation. Since interpretation bias by definition refers to ambiguous stimuli, we reported only the relevant data here.

Table 1
Demographic Characteristics and Self-Reported Measures (N = 188)

Variable	Group (N)	Gender		
	Whole sample (N = 188)	Male (N = 60)	Female (N = 128)	
Age (SD)	19.62 (2.42)	20.07 (2.39)	19.41 (2.41)	$t(186) = 1.73$
DASS				
Depression	7.97 (7.28)	9.30 (8.49)	7.34 (6.56)	$t(186) = 1.72$
Anxiety	8.46 (6.28)	10.10 (7.17)	7.69 (5.66)	$t(186) = 2.49^*$
Stress	12.00 (7.96)	13.77 (9.21)	11.17 (7.16)	$t(186) = 2.10^*$
SIAS	34.38 (12.05)	35.35 (11.95)	33.93 (12.08)	$t(186) = 0.75$

Note. SD = standard deviation; DASS = Depression Anxiety Stress Scale; SIAS = Social Interaction Anxiety Scale.
* $p < .05$.

After obtaining written informed consent, participants were first asked to fill in their demographic information and questionnaires on a tablet. After going through the stress induction procedure and the VAS rating, participants then began with the attentional probe task, face recognition task, and last, the emotion interpretation task. The experiment procedure was fixed and not randomized because it is theoretically necessary to assess participants' recognition of faces after the attention task to infer a direct relationship between them. The interpretation bias task was completed last because of concerns that the time participants needed to make judgmental responses might vary, and this could affect the time gap between the attention task and the memory task. The VAS data were used as an indicator of participants' state anxiety and were collected each time participants finished a task. A one-way analysis of variance (ANOVA) showed that the administration of different cognitive bias tasks did not have a significant effect on participants' state-level anxiety, $F(2, 561) = 0.047$, $p = .954$. Before debriefing, participants were told that giving a speech was not required. Participants were either awarded 50 Hong Kong dollars (~7 U.S. dollars) or course credits as remuneration. Each session lasted approximately 1 hour. All participants were tested in a standard experimental room on the campus. Details about the plan of statistical analysis are presented in the supplementary document.

Results

PARTICIPANTS' CHARACTERISTICS AND DATA PREPARATION

Demographic characteristics and self-reported mood measures of participants are presented in Table 1. Men reported a higher level of anxiety and stress compared to women. No gender difference was found in other measures. Means and standard deviation of each cognitive bias index are presented in Table 2. Details about data preparation and reliability estimates for each cognitive bias assessment are presented in the supplementary document.

MAIN ANALYSES

Analysis 1: The Association Between Social Anxiety Symptoms and Individual Cognitive Biases

In the first step of the hierarchical regression analysis, most of the models (except emotion identification) were not significant.[2] This indicated that age, gender, and general negative mood alone did not predict most of the cognitive bias indices. After simultaneously entering emotion type and their interaction terms in the second step of the SIAS, the predictive value of all models significantly increased (all at least $p < .05$). All VIF were below 5. (A summary of each hierarchical regression model is presented in Table 3. For details of regression coefficients for each interpretation bias index, see Appendix Table A).

For attention bias, Model 2 in Table 3 shows that self-reported stress level and social anxiety symptoms were significant predictors; higher stress was related to attention vigilance toward threatening faces (both angry and disgusted) while higher social anxiety symptoms were associated with attention avoidance. None of the interaction terms were significant. The full model explained 6% of

---

[2] Gender was found to be a significant predictor of emotion identification. Females were more accurate in identifying emotions, which was consistent with previous findings (Wingenbach et al., 2018).

Table 2
Means and Standard Deviation of Cognitive Bias Indices ($N = 188$)

Emotions	Attention bias	Memory bias	Interpretation bias		
	Attentional probe task	Face recognition task	Emotion identification	Intensity rating	Social cost estimation
Amb angry	2.41 (15.96)	0.61 (0.87)	0.62 (0.39)	3.41 (0.97)	4.67 (0.90)
Clear angry	2.37 (18.57)	0.97 (0.81)	–	–	–
Amb disgusted	-0.40 (16.61)	0.66 (0.89)	0.63 (0.54)	3.88 (1.03)	4.58 (0.82)
Clear disgusted	1.97 (19.77)	0.63 (0.78)	–	–	–

Note. Amb = ambiguity.

Table 3
Summary of Hierarchical Linear Regression Analyses Predicting Different Cognitive Bias Indices ($N = 188$)

Variable	Attention bias			Interpretation bias (composite)			Memory bias		
	β	t	Partial r	β	t	Partial r	β	t	Partial r
Model 1									
Age	.08*	2.03	.08	.06	1.22	.06	.02	0.39	.01
Gender	−.06	−1.66	−.06	.13*	2.50	.13	.03	0.68	.03
DASS Depression	−.03	−0.63	−.02	−.14*	−2.01	−.10	−.01	−0.20	−.01
DASS Anxiety	.00	0.03	.00	−.00	−0.04	−.00	.00	0.01	.000
DASS Stress	.08	1.32	.05	.17*	2.06	.11	−.03	−0.42	−.02
R^2 (F for change in R^2)	0.02 (2.30)			0.03 (2.47*)			0.002 (0.31)		
Model 2									
Age	.07	1.80	.07	.06	1.15	.06	.01	0.33	.01
Gender	−.06	−1.49	−.06	.13*	2.52	.13	.03	0.74	.03
DASS Depression	.00	−0.05	.00	−.14	−1.89	−.10	.00	−0.07	.00
DASS Anxiety	.04	0.75	.03	.01	0.10	.01	.01	0.16	.01
DASS Stress	.12*	2.08	.08	.18*	2.19	.11	−.02	−0.26	−.01
SIAS	−.16*	−2.21	−.08	−.08	−1.07	−.06	−.16*	−2.12	−.08
Emotion ambiguity	.00	−0.04	.00	/	/	/	.22***	4.24	.15
Emotion	−.08	−1.60	−.06	.03	0.20	.01	.03	0.64	.02
Ambiguity × Emotion	.06	0.96	.04	/	/	/	−.20**	−3.23	−.12
SIAS × Ambiguity	−.04	−0.54	−.03	/	/	/	.06	0.78	.03
SIAS × Emotion	−.06	−0.88	−.03	.06	0.39	.02	.15*	2.08	.08
SIAS × Ambiguity × Emotion	.03	0.37	.01	/	/	/	−.07	−1.00	−.037
R^2 (F for change in R^2)	0.06 (5.01***)			0.04 (1.43*)			0.04 (4.26***)		

Note. DASS = Depression Anxiety Stress Scale; SIAS = Social Interaction Anxiety Scale.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

the variance in attention bias, $\Delta R^2 = 0.04$, $p < .001$, $F(12, 739) = 3.91$, $p < .001$.

For memory bias, the main effect of social anxiety symptoms was qualified by its interaction with emotion type, showing that high social anxiety symptoms were related to poorer memory for angry faces compared to disgusted faces. Emotion ambiguity and its interaction with emotion type were also significant predictors of memory bias. Clear angry faces were found to be recognized better in general. As shown on Table 3, the full model explained 4% of the variance in memory bias,

$\Delta R^2 = 0.02$, $p < .001$, $F(12, 739) = 2.62$, $p = .002$. Consistent with the finding of attention avoidance, the results of poorer recognition of angry faces suggested a congruent memory bias. It provided support for our first hypothesis that social anxiety symptoms were associated with a corresponding attention and memory bias, specifically for angry faces.

As presented in Appendix Table A, participants' gender was a significant predictor for the first interpretation bias index: emotion identification. It indicated that female participants had a higher

accuracy rate in correctly identifying emotions in general. The full Model 2 accounted for 4% of the variance in emotion identification, $\Delta R^2 = 0.004$, $p = .675$, $F(8, 367) = 2.06$, $p < .039$. The second model of interpretation bias index—intensity rating—showed that ambiguously disgusted faces were rated as more intensive in general. Model 2 explained 8% of the variance in emotion intensity ratings, $\Delta R^2 = 0.07$, $p < .001$, $F(8, 367) = 3.75$, $p < .001$. The third interpretation bias index—social cost estimation—yielded no significant predictors. The full model explained 2% of the variance in social cost ratings, $\Delta R^2 = 0.01$, $p = .595$, $F(8, 367) = 0.77$, $p = .627$.

Although none of the three interpretation bias indices appeared to be related to social anxiety symptoms, they were related to one another in two aspects. First, higher accuracy in correctly identifying emotions was associated with lower intensity rating of faces, $r = -.155$, $p = .034$. Second, ambiguous faces that were rated with higher intensity were correlated with higher social cost estimation, $r = .216$, $p = .003$. In other words, when ambiguous faces were more difficult to decipher, they were rated as more intensive and more socially costly to interact with. We combined all three biases into a composite interpretation bias score by averaging the z scores of each index. Composite measures may be a more reliable and parsimonious approach in increasing measurement precision without losing information (Evans, 1996). As shown in Table 3, results of the regression analysis indicated that gender and stress were significant predictors of interpretation bias. Females and those who were under stress interpreted ambiguous faces as more negative. Model 2 explained 4% of the variance in the composite interpretation bias index, $\Delta R^2 = 0.01$, $p = .235$, $F(8, 367) = 2.081$, $p = .037$. However, contrary to expectation, social anxiety symptoms and the interaction terms did not significantly predict any of the individual interpretation bias indices.

Overall in our sample, we did not find any interaction effect between social anxiety symptoms and emotion ambiguity, as well as their interaction with specific emotion type across attention and memory bias indices. This suggested that the ambiguity level of emotion did not have any impact on the attention and memory of facial stimuli in participants with various levels of social anxiety symptoms. Thus, to simplify model specification, we collapsed the indices of ambiguous and clear emotional faces for attention and memory biases in subsequent analyses to examine the interrelationship between cognitive biases.

Analysis 2: The Relationship Between Cognitive Biases

Correlation Analyses. Zero-order correlations of different cognitive bias indices were analyzed. As previous studies suggested qualitative differences between response to angry (direct threat) and disgusted (indirect threat) facial expressions (Staugaard, 2010), we conducted separate analyses for the two emotions (see Table 4). For angry faces, results were consistent with the findings of regression analyses. Social anxiety symptoms were significantly and negatively associated with attention bias ($r = -.17$, $p = .020$) and memory bias ($r = -.16$, $p = .028$) but not with the interpretation bias composite score ($p > .05$). Composite interpretation bias was significantly associated with attention bias ($r = .22$, $p = .001$) and memory bias ($r = .16$, $p = .026$). However, attention and memory bias were not significantly correlated ($r = -.06$, $p > .05$). For disgusted facial stimuli, social anxiety symptoms were significantly associated with greater attention avoidance ($r = -.24$, $p = .001$) but not with composite interpretation bias and memory bias. None of the other bias indices are correlated ($p > .05$).

Path Analysis of Indirect Effect Model. The absence of a significant correlation between attention and memory bias (for both angry and disgusted facial stimuli) indicated that an indirect

Table 4
Correlations Between Cognitive Bias Indices for Angry and Disgusted Faces ($N = 188$)

	Angry faces			Disgusted faces		
	1	2	3	1	2	3
SIAS	—			—		
Attention bias	−0.17[*]	—		−0.24[**]	—	
Interpretation bias (composite)	-0.07	0.22[**]	—	−0.03	−0.09	—
Memory bias	−0.16[*]	−0.06	0.16	0.02	−0.06	0.08

Note. SIAS = Social Interaction Anxiety Scale.
[*] $p < .05$.
[**] $p < .01$.

effect between attention and interpretation bias via the encoded memory (the attention–memory–interpretation bias pathway) was not supported in this study. The hypothesized attention–interpretation–memory bias pathway, on the other hand, appeared to be only applicable in the cognitive bias indices of angry facial stimuli. Despite the absence of a direct correlation between attention and memory bias, we proposed that it was still possible for interpretation bias, which was associated with both attention and memory bias, to be an intervening factor. Theoretically, cognitive models support the hypothesized sequence of information processing (Beck & Clark, 1997; Rapee & Heimberg, 1997). Statistically, it has been argued that the absence of significant total or direct effect does not preclude the possibility of observing indirect effects (MacKinnon et al., 2000; Mathieu & Taylor, 2006).

In our proposed attention–interpretation–memory bias pathway model, age and gender were entered as covariates. In addition, as social anxiety symptoms were found to be correlated with attention and memory bias, social anxiety might influence the relationship between attention and memory bias. Thus, while modeling the relations between cognitive biases, we also considered the effect of social anxiety on the proposed model. This was to ensure that the observed pathways among biases are not solely the result of influences of the common variable: social anxiety symptoms (Everaert et al., 2014; Fairchild & McDaniel, 2017).

Figure 1 illustrates that the bias-corrected bootstrapping procedure yielded a small but significant indirect effect of attention bias on memory bias through interpretation bias (B = .002, SE = 0.001, 95% CI [0.0002, 0.005]). Examination of the completely standardized indirect effects revealed that effect size was small (ab_{cs} = 0.038, SE = 0.022, 95% CI [0.003, 0.087]). As expected, the direct effect (Path c'), B = −.007, $t(182)$ = −

1.751, p = .082, and total effect (Path c), B = −.005, $t(183)$ = −1.266, p = .207, were both non-significant. These findings indicated that there was no direct relationship between attention and memory bias. However, the data supported our attention–interpretation–memory bias pathway hypothesis that attention vigilance toward angry faces exerted a positive influence on the memory of these faces through negative interpretation. All predictors together accounted for 6.56% of variance in the memory of angry faces, $F(5, 182)$ = 4.45, p = .029.

Discussion

This study investigated the relationship between attention, interpretation, and memory biases related to social anxiety symptoms in facial perception. First, we sought to establish an association between social anxiety symptoms and each cognitive bias. We expected a corresponding pattern in attention and memory bias. We also anticipated that social anxiety symptoms would be associated with more negative interpretations of ambiguous faces. Second, we employed path analysis to test the relationship among the three bias indices, examining both the attention–interpretation–memory bias and the attention–memory–interpretation bias pathways.

MAIN FINDINGS

The Association Between Social Anxiety Symptoms and Individual Cognitive Biases
Our results showed that social anxiety symptoms, but not general negative mood, were significantly associated with attention and memory bias. Participants with elevated social anxiety symptoms showed more attention avoidance and poorer sensitivity in recognizing threatening faces (both angry and disgusted faces). These results aligned with previous findings that attention avoidance (Chen et al., 2002; Mansell et al., 1999) and poor memory (Pérez-López & Woody, 2001) are more
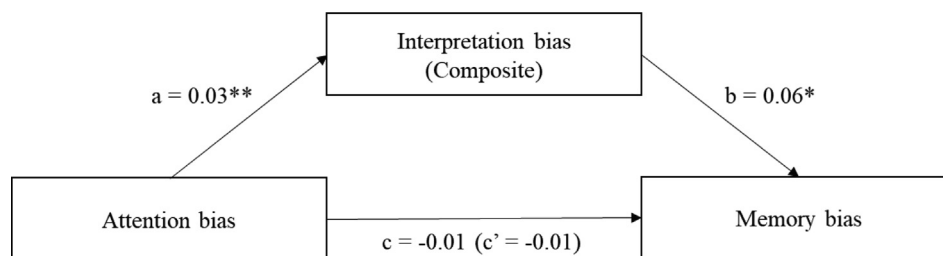

FIGURE 1   The indirect effect model displaying the unstandardized coefficients of attention bias on memory bias via interpretation bias using angry facial stimuli. Direct effect presented in parentheses. *Note.* *p < .05, **p < .01.

apparent under the induction of threat. Our findings were also in line with the results of prior study and our hypothesis of threat avoidance and corresponding memory performance (LeMoult & Joormann, 2012).

Contrary to expectations, neither social anxiety symptoms, nor any of its interaction terms, predicted any of the interpretation bias indices (both individual and composite bias scores) in our sample of participants. Indeed, evidence stemming from studies of facial interpretation bias in social anxiety is generally inconsistent. While there are studies supporting the association between social anxiety symptoms and interpretation bias (e.g., Button et al., 2013; Gutiérrez-García & Calvo, 2017), quite a number of studies found null results (e.g., Bell et al., 2011; Jusyte & Schönenberg, 2014; Philippot & Douilliez, 2005). A recent meta-analysis reported a large effect size for the relationship between social anxiety and interpretation bias ($g = 0.83$) but further analyses revealed a significantly smaller effect size for visual than verbal stimuli, with facial photographs showing the smallest effect size ($g = 0.60$). A possible explanation for the current results may be the general difficulty of assessing interpretation bias using posed facial expressions in experiments. The key of detecting facial interpretation bias may be to increase the resemblance of experimental stimuli with real-life social situations. For instance, the use of dynamic ambiguous facial expressions that are naturally elicited and the provision of contextual information may enhance the detection of facial interpretation bias (Schoth & Liossi, 2017). The second possibility may be the difficulty of capturing facial interpretation bias using explicit measures. Currently, most bias measures require participants' conscious elaboration and explicit response of their interpretation. However, facial interpretation bias may exist implicitly and influence other cognitive processes. The third possibility could be related to the ambiguousness of the facial stimuli used in this task. Although a pilot study was conducted to determine the adopted morph percentage for each face, there were only 12 participants and they might not be representative enough to determine the optimal ambiguous level of facial stimuli, hence affecting the validity of this task in this sample. Future research is thus needed to further develop the measurement of facial interpretation bias.

The Relationship Between Attention, Interpretation, and Memory Bias

Our data supported the attention–interpretation–memory bias pathway but not the attention–memory–interpretation bias pathway in the processing of novel facial expressions. The findings showed that attention bias influences memory bias indirectly through interpretation bias during the processing of angry faces. In other words, when individuals selectively orient to faces displaying anger, the faces were perceived to be more negative. This, in turn, predicted better memory of angry faces. Our indirect effect model suggested that even though no direct relationship was identified between social anxiety symptoms and interpretation bias in our first set of analyses, interpretation bias was still related to attention and memory bias when angry faces were being processed. This suggested the role of interpretation bias in cognitive processes. In fact, Everaert et al. (2013) also reported a similar mediation relationship among these three cognitive biases despite the absence of an association between depressive mood and attention bias.

However, it is important to note that this indirect effect model was applicable only to facial stimuli displaying angry expression but not disgust in our study. A reason might be due to the difference between direct threat (anger) and indirect threat (disgust). Although both emotions are considered as socially threatening, the former entails higher salience in conveying overt aggression, while disgust is a relatively more subtle sign of disapproval (Jusyte & Schönenberg, 2014). Salience theory suggests that more resources are devoted to the processing of salient stimuli (Peschard & Philippot, 2015), which may explain the more consistent overall finding in tasks utilizing angry faces.

The current findings suggested that people with elevated social anxiety tend to avoid paying attention to and exhibit poorer memory for threatening faces. However, within the same sample, regardless of social anxiety level, when individuals selectively oriented to faces displaying anger, the faces were perceived to be more negative. In other words, while the more socially anxious people in our sample were generally avoidant of threat, when attention toward threat did occur it enhanced both interpretation and memory for those stimuli. Observing both effects simultaneously may be the result of our large sample size, which permitted sufficient variance within the data to capture a wide range of related but distinct effects.

Implications

Our indirect effect model lends further support to the combined cognitive bias hypothesis (Hirsch et al., 2006). The experiment was cross-sectional and the correlational data precluded examining

causal relationships. Nevertheless, we employed the same set of facial stimuli across sequential cognitive bias assessments. The study design did allow us to preliminarily draw sequential inferences concerning attention bias as the antecedent to memory and interpretation bias. Despite not being able to completely mimic the course of information processing, the predicted attention–interpretation–memory bias pathway was theoretically driven with the support of findings from previous research (Everaert et al., 2013, 2014) and our data. The absence of a direct relationship between attention and memory bias also suggested that the interpretation of facial expressions might play a role in regulating what was remembered. Our data thus further supports the value and importance of considering multiple types of mood-congruent bias simultaneously.

Our results also have some important clinical implications for the development of CBM. The support of the attention–interpretation–memory bias pathway inferred that CBM-Attention could exert influence on interpretation bias while CBM-Interpretation could transfer its impact on memory bias. This notion was supported by previous studies (e.g., Bowler et al., 2017; White et al., 2011; Woud et al., 2012). In addition, if targeting one bias should have consequences for the other biases, targeting several biases at once might be the most effective or even provide disproportionate gains. Indeed, researchers in recent years have proposed combined cognitive bias modification (CCBM), which targets multiple cognitive biases simultaneously to maximise its therapeutic effect (Beard et al., 2011; Brosan et al., 2011). Currently, we know of only three studies examining the relative efficacy of single and combined CBM (Naim et al., 2018; Yang et al., 2017; Yeung & Sharpe, 2019). While all of them found single CBM to be more effective, none of them used the same set of stimuli for all cognitive bias tasks and assessments. These studies also varied greatly in their experimental methodology, such as the number of training sessions, the delivery mode, and the training method of CBM. Further investigation is needed to verify the optimal CBM design to attain the best symptomatic improvement.

These sets of findings also have research implications, suggesting that (as might be expected) transfer effects may most likely occur when stimulus properties are matched across all tasks. As evident from neuroimaging studies, words and faces are at least partially subserved by distinct neural mechanisms (Behrmann & Plaut, 2012). The visual word form area (VWFA) primarily responds to visually presented words, while the fusiform face area (FFA) is selectively activated by faces (Plaut & Behrmann, 2011). Thus, the use of stimuli matching in content and format across different processes increases the likelihood of the same neuronal network being used for processing. For example, the transfer effects of attention bias modification on the interpretation of the same facial stimuli should be theoretically stronger than that on some unrelated text-based scenarios.

Study Limitations
Some limitations regarding the design of the present study should be noted. First, although we attempted to follow the sequence of information processing (how the selection of newly encountered emotional information during attention contribute to the later stages of conscious processing) in our study design, longitudinal or experimental manipulation designs are required to draw causal conclusions about the direction of effects in the relationship between attention, interpretation, and memory. Replication of our findings that considers the temporal administration sequence of cognitive bias measurements is needed.

Second, we adopted happy faces rather than the traditional netural faces as the comparator stimuli to threatening faces in the attentional probe task. Since the contrast between the negative–positive face pairs is likely to be stronger than the negative–neutral ones, it is possible that the effect size of the attention bias found in this study was overestimated. Third, we used an unselected sample in our study to capture cognitive biases across different levels of social anxiety. However, replication of our findings in a clinical population is warranted to ascertain the relationship of cognitive biases in clinical social anxiety. Fourth, we focused only on the study of cognitive biases in social anxiety utilizing facial stimuli, so more studies are needed to replicate our findings in other types of anxiety or disorders and using other types of stimuli.

A further limitation was that the observed reliability estimates of our attentional probe task and memory bias task were quite low (see Appendix Table B). Attention bias reliability ranged from .35 to .43, comparable to those reported in the literature (0 to .59; e.g., Waechter & Stolz, 2015). This is partly related to the statistical limitation of using reaction time-based difference scores (McNally, 2019). Although there have been recent efforts to improve attention bias score reliability (e.g., using trial-level bias scores or variability measures), doubts have remained in the literature (Carlson & Fang, 2020; Kruijt et al., 2016; Swick & Ashley, 2017). This suggests that future

research should continue to work on developing attention bias tasks that use other forms of dependent measure, not derived from reaction times—for example, Macleod et al.'s (2019) probe identification accuracy measure. Previous research has also suggested that the number of trials can affect a task's reliability estimates (Reynolds & Willson, 1985). It is likely that this contributed to low task reliabilities in the present study, especially on the memory bias task, which had the lowest number of trials.

In addition, we obtained rather small effects from the regression and path analyses. Although the typical effect sizes obtained in experimental assessments of cognitive biases are known to be small (Bantin et al., 2016), the small effects we found implied that there may be other unknown factors that could have accounted for the cognitive biases. Last, the absence of an association between social anxiety symptoms and interpretation bias in our study requires further investigation. Future research is needed to examine the replicability of our findings.

Conclusion

Our data provided preliminary empirical evidence for the association between social anxiety symptoms and cognitive biases, as well as the linkage between attention and memory bias via interpretation bias in facial perception. Specifically, the current findings suggested that people with elevated social anxiety, in general, tend to avoid paying attention to and exhibit poorer memory for threatening faces. However, when individuals selectively orient to faces displaying anger, the faces were perceived to be more negative. This, in turn, predicted better memory of angry faces. These findings further corroborate the combined cognitive bias hypothesis and emphasize the importance of matching stimulus properties when studying or manipulating multiple cognitive biases.

Conflict of Interest Statement

The authors declare that there are no conflicts of interest.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.beth.2022.01.011.

References

Amir, N., Beard, C., & Bower, E. (2005). Interpretation bias and social anxiety. *Cognitive Therapy and Research, 29*(4), 433–443. https://doi.org/10.1007/s10608-005-2834-5.

Amir, N., Foa, E. B., & Coles, M. E. (2000). Implicit memory bias for threat-relevant information in individuals with generalized social phobia. *Journal of Abnormal Psychology, 109*(4), 713–720. https://doi.org/10.1037//0021-843x.109.4.713.

Amir, N., Prouvost, C., & Kuckertz, J. M. (2012). Lack of a benign interpretation bias in social anxiety disorder. *Cognitive Behaviour Therapy, 41*(2), 119–129. https://doi.org/10.1080/16506073.2012.662655.

Bantin, T., Stevens, S., Gerlach, A. L., & Hermann, C. (2016). What does the facial dot-probe task tell us about attentional processes in social anxiety? A systematic review. *Journal of Behavior Therapy and Experimental Psychiatry, 50*, 40–51. https://doi.org/10.1016/j.jbtep.2015.04.009.

Beard, C., & Amir, N. (2009). Interpretation in social anxiety: When meaning precedes ambiguity. *Cognitive Therapy and Research, 33*(4), 406–415. https://doi.org/10.1007/s10608-009-9235-0.

Beard, C., Weisberg, R. B., & Amir, N. (2011). Combined cognitive bias modification treatment for social anxiety disorder: A pilot trial. *Depression and Anxiety, 28*(11), 981–988. https://doi.org/10.1002/da.20873.

Beck, A. T., & Clark, D. A. (1997). An information processing model of anxiety: Automatic and strategic processes. *Behaviour Research and Therapy, 35*(1), 49–58. https://doi.org/10.1016/S0005-7967(96)00069-1.

Behrmann, M., & Plaut, D. C. (2012). Bilateral hemispheric processing of words and faces: Evidence from word impairments in prosopagnosia and face impairments in pure alexia. *Cerebral Cortex, 24*(4), 1102–1118. https://doi.org/10.1093/cercor/bhs390.

Bell, C., Bourke, C., Colhoun, H., Carter, F., Frampton, C., & Porter, R. (2011). The misclassification of facial expressions in generalised social phobia. *Journal of Anxiety Disorders, 25*(2), 278–283. https://doi.org/10.1016/j.janxdis.2010.10.001.

Bowler, J. O., Hoppitt, L., Illingworth, J., Dalgleish, T., Ononaiye, M., Perez-Olivas, G., & Mackintosh, B. (2017). Asymmetrical transfer effects of cognitive bias modification: Modifying attention to threat influences interpretation of emotional ambiguity, but not vice versa. *Journal of Behavior Therapy and Experimental Psychiatry, 54*, 239–246. https://doi.org/10.1016/j.jbtep.2016.08.011.

Brosan, L., Hoppitt, L., Shelfer, L., Sillence, A., & MacKintosh, B. (2011). Cognitive bias modification for attention and interpretation reduces trait and state anxiety in anxious patients referred to an out-patient service: Results from a pilot study. *Journal of Behavior Therapy and Experimental Psychiatry, 42*(3), 258–264. https://doi.org/10.1016/j.jbtep.2010.12.006.

Button, K., Lewis, G., Penton-Voak, I., & Munafò, M. (2013). Social anxiety is associated with general but not specific biases in emotion recognition. *Psychiatry Research, 210*(1), 199–207. https://doi.org/10.1016/j.psychres.2013.06.005.

Carlson, J. M., & Fang, L. (2020). The stability and reliability of attentional bias measures in the dot-probe task: Evidence from both traditional mean bias scores and trial-level bias scores. *Motivation and Emotion, 44*(5), 657–669. https://doi.org/10.1007/s11031-020-09834-6.

Chen, Y. P., Ehlers, A., Clark, D. M., & Mansell, W. (2002). Patients with generalized social phobia direct their attention away from faces. *Behaviour Research and Therapy, 40*(6), 677–687 http://www.ncbi.nlm.nih.gov/pubmed/12051486.

Clark, D. M., & Wells, A. (1995). A cognitive model of social phobia. In R. G. Heimberg, M. R. Liebowitz, D. A. Hope, & F. R. Schneier (Eds.), *Social phobia: Diagnosis, assessment, and treatment* (pp. 69–93). Guilford Press.

Coles, M. E., & Heimberg, R. G. (2005). Recognition bias for critical faces in social phobia: A replication and extension. *Behavior Research and Therapy, 43*, 109–120.

Evans, L. D. (1996). A two-score composite program for combining standard scores. *Behavior Research Methods, Instruments, and Computers, 28*(2), 209–213. https://doi.org/10.3758/BF03204767.

Everaert, J., Duyck, W., & Koster, E. H. W. (2014). Attention, interpretation, and memory biases in subclinical depression: A proof-of-principle test of the combined cognitive biases hypothesis. *Emotion, 14*(2), 331–340. https://doi.org/10.1037/a0035250.

Everaert, J., & Koster, E. H. W. (2020). The interplay among attention, interpretation, and memory biases in depression: Revisiting the combined cognitive bias hypothesis. In T. Aue & H. Okon-Singer (Eds.), *Cognitive biases in health and psychiatric disorders: Neurophysiological foundations* (pp. 193–213). Elsevier. https://doi.org/10.1016/b978-0-12-816660-4.00009-x.

Everaert, J., Koster, E. H. W., & Derakshan, N. (2012). The combined cognitive bias hypothesis in depression: A state-of-the-art. *Clinical Psychology Review, 32*(5), 413–424.

Everaert, J., Tierens, M., Uzieblo, K., Koster, E. H. W., & Dunantlaan, H. (2013). The indirect effect of attention bias on memory via interpretation bias: Evidence for the combined cognitive bias hypothesis in subclinical depression. *Cognition and Emotion, 27*(8), 1450–1459.

Fairchild, A. J., & McDaniel, H. L. (2017). Best (but oft-forgotten) practices: Mediation analysis. *American Journal of Clinical Nutrition, 105*(6), 1259–1271. https://doi.org/10.3945/ajcn.117.152546.

Foa, E. B., Gilboa-Schechtman, E., Amir, N., & Freshman, M. (2000). Memory bias in generalized social phobia: Remembering negative emotional expressions. *Journal of Anxiety Disorders, 14*(5), 501–519.

Garner, M., Mogg, K., & Bradley, B. P. (2006). Orienting and maintenance of gaze to facial expressions in social anxiety. *Journal of Abnormal Psychology, 115*(4), 760–770. https://doi.org/10.1037/0021-843X.115.4.760.

Gutiérrez-García, A., & Calvo, M. G. (2017). Social anxiety and threat-related interpretation of dynamic facial expressions: Sensitivity and response bias. *Personality and Individual Differences, 107*, 10–16. https://doi.org/10.1016/j.paid.2016.11.025.

Hirsch, C. R., & Clark, D. M. (2004). January). Information-processing bias in social phobia. *Clinical Psychology Review, 24*, 799–825. https://doi.org/10.1016/j.cpr.2004.07.005.

Hirsch, C. R., Clark, D. M., & Mathews, A. (2006). Imagery and interpretations in social phobia: Support for the combined cognitive biases hypothesis. *Behavior Therapy, 37*(3), 223–236. https://doi.org/10.1016/j.beth.2006.02.001.

Ingram, R. E. (1984). Toward an information-processing analysis of depression. *Cognitive Therapy and Research, 8*(5), 443–477. https://doi.org/10.1007/BF01173284.

Ingram, R. E., & Kendall, P. C. (1987). The cognitive side of anxiety. *Cognitive Therapy and Research, 11*(5), 523–536. https://doi.org/10.1007/BF01183856.

Jusyte, A., & Schönenberg, M. (2014). Threat processing in generalized social phobia: An investigation of interpretation biases in ambiguous facial affect. *Psychiatry Research, 217*, 100–106. https://doi.org/10.1016/j.psychres.2013.12.031.

Klumpp, H., & Amir, N. (2009). Examination of vigilance and disengagement of threat in social anxiety with a probe detection task. *Anxiety, Stress, and Coping, 22*(3), 283–296. https://doi.org/10.1080/10615800802449602.

Kruijt, A. W., Field, A. P., & Fox, E. (2016). Capturing dynamics of biased attention: Are new attention variability

measures the way forward? *PLoS One, 11*(11), 1–22. https://doi.org/10.1371/journal.pone.0166600.

LeMoult, J., & Joormann, J. (2012). Attention and memory biases in social anxiety disorder: The role of comorbid depression. *Cognitive Therapy and Research, 36*(1), 47–57. https://doi.org/10.1007/s10608-010-9322-2.

MacKinnon, D. P., Krull, J. L., & Lockwood, C. M. (2000). Equivalence of the mediation, confounding and suppression effect. *Prevention Science: The Official Journal of the Society for Prevention Research, 1*(4), 173–181.

Mansell, W., Clark, D. M., Ehlers, A., & Chen, Y. P. (1999). Social anxiety and attention away from emotional faces. *Cognition and Emotion, 13*(6), 673–690. https://doi.org/10.1080/026999399379032.

Mathews, A., & MacLeod, C. (1994). Cognitive approaches to emotion and emotional disorders. *Annual Review of Clinical Psychology, 45*, 25–50.

Mathieu, J. E., & Taylor, S. R. (2006). Clarifying conditions and decision points for mediational type inferences in organizational behavior. *Journal of Organizational Behavior, 27*(8), 1031–1056. https://doi.org/10.1002/job.406.

Mattick, R. P., & Clarke, J. C. (1998). Development and validation of measures of social phobia scrutiny fear and social interaction anxiety. *Behavior Researh and Therapy, 36*(4), 455–470.

McNally, R. J. (2019). Attentional bias for threat: Crisis or opportunity? *Clinical Psychology Review, 69*, 4–13. https://doi.org/10.1016/j.cpr.2018.05.005.

Mogg, K., Philippot, P., & Bradley, B. (2004). Selective attention to angry faces in clinical social phobia. *Journal of Abnormal Psychology, 113*(1), 160–165. https://doi.org/10.1037/0021-843X.113.1.160.

Naim, R., Kivity, Y., Bar-Haim, Y., & Huppert, J. D. (2018). Attention and interpretation bias modification treatment for social anxiety disorder: A randomized clinical trial of efficacy and synergy. *Journal of Behavior Therapy and Experimental Psychiatry, 59*, 19–30. https://doi.org/10.1016/j.jbtep.2017.10.006.

Pérez-López, J. R., & Woody, S. R. (2001). Memory for facial expressions in social phobia. *Behaviour Research and Therapy, 39*, 967–975.

Peschard, V., & Philippot, P. (2015). Social anxiety and information processing biases: An integrated theoretical perspective. *Cognition and Emotion, 30*(4), 762–777. https://doi.org/10.1080/02699931.2015.1028335.

Philippot, P., & Douilliez, C. (2005). Social phobics do not misinterpret facial expression of emotion. *Behaviour Research and Therapy, 43*(5), 639–652. https://doi.org/10.1016/j.brat.2004.05.005.

Plaut, D. C., & Behrmann, M. (2011). Complementary neural representations for faces and words: A computational exploration. *Cognitive Neuropsychology, 28*(3–4), 251–275. https://doi.org/10.1080/02643294.2011.609812.

Rapee, R. M., & Heimberg, R. G. (1997). A cognitive behavioral model of anxiety in social phobia. *Behavior Researh and Therapy, 35*(8), 741–756.

Reynolds, C. R., & Willson, V. L. (Eds.). (1985). *Methodological and statistical advances in the study of individual differences*. Plenum Press.

Schofield, C. A., Coles, M. E., & Gibb, B. E. (2007). Social anxiety and interpretation biases for facial displays of emotion: Emotion detection and ratings of social cost. *Behaviour Research and Therapy, 45*, 2950–2963. https://doi.org/10.1016/j.brat.2007.08.006.

Schoth, D. E., & Liossi, C. (2017). A systematic review of experimental paradigms for exploring biased interpretation of ambiguous information with emotional and neutral associations. *Frontiers in Psychology, 8*, 171. https://doi.org/10.3389/fpsyg.2017.00171.

Staugaard, S. R. (2010). Threatening faces and social anxiety: A literature review. *Clinical Psychology Review, 30*, 669–690. https://doi.org/10.1016/j.cpr.2010.05.001.

Swick, D., & Ashley, V. (2017). Enhanced attentional bias variability in post-traumatic stress disorder and its relationship to more general impairments in cognitive control. *Scientific Reports, 7*(1), 1–10. https://doi.org/10.1038/s41598-017-15226-7.

Van Bockstaele, B., Verschuere, B., Tibboel, H., De Houwer, J., Crombez, G., & Koster, E. H. W. (2014). A review of current evidence for the causal impact of attentional bias on fear and anxiety. *Psychological Bulletin, 140*, 682–721. https://doi.org/10.1037/a0034834.

Waechter, S., & Stolz, J. A. (2015). Trait anxiety, state anxiety, and attentional bias to threat: Assessing the psychometric properties of response time measures. *Cognitive Therapy and Research, 39*(4), 441–458. https://doi.org/10.1007/s10608-015-9670-z.

White, L. K., Suway, J. G., Pine, D. S., Bar-Haim, Y., & Fox, N. A. (2011). Cascading effects: The influence of attention bias to threat on the interpretation of ambiguous information. *Behaviour Research and Therapy, 49*(4), 244–251. https://doi.org/10.1016/j.brat.2011.01.004.

Williams, J. M. G., Watts, F. N., MacLeod, C., & Mathews, A. (Eds.). (1988). *Cognitive psychology and emotional disorders*. Wiley, pp. ix, 226.

Wingenbach, T. S. H., Ashwin, C., & Brosnan, M. (2018). Sex differences in facial emotion recognition across varying expression intensity levels from videos. *PloS One, 13*(1), e0190634. https://doi.org/10.1371/journal.pone.0190634.

Woud, M. L., Holmes, E. A., Postma, P., Dalgleish, T., & Mackintosh, B. (2012). Ameliorating intrusive memories of distressing experiences using computerized reappraisal training. *Emotion, 12*(4), 778–784. https://doi.org/10.1037/a0024992.

Yang, R., Cui, L., Li, F., Xiao, J., Zhang, Q., & Oei, T. P. S. (2017). Effects of cognitive bias modification training via smartphones. *Frontiers in Psychology, 8*, 1370. https://doi.org/10.3389/fpsyg.2017.01370.

Yeung, E. S., & Sharpe, L. (2019). Cognitive bias modification for social anxiety: The differential impact of modifying attentional and/or interpretation bias. *Cognitive Therapy and Research, 43*, 781–791. https://doi.org/10.1007/s10608-019-10012-3.

Yoon, K. L., Joormann, J., & Gotlib, I. H. (2009). Judging the intensity of facial expressions of emotion: Depression-related biases in the processing of positive affect. *Journal of Abnormal Psychology, 118*(1), 223–228. https://doi.org/10.1037/a0014658.