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Are avoidance biases in social anxiety due to biases in stimulus coding or in post-coding behavioral tendencies?

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ABSTRACT

On the Approach-Avoidance Task (AAT) high socially anxious (HSA) individuals exhibit increased behavioral avoidance of faces displaying emotional expressions. Two accounts could explain these findings: 1) HSA individuals have a heightened readiness to code faces in terms of emotionality, and all individuals behaviorally avoid faces coded as emotional (pre-behavior coding bias hypothesis), or 2) everyone is equally ready to code faces in terms of emotionality, but when faces are coded as emotional HSA have a heightened tendency to behaviorally avoid such stimuli (post coding behavioral bias hypothesis). To test these hypotheses, we created the Stimulus-Coding AAT. Participants categorized emotional and non-emotional faces in terms of either gender or emotional expression, before making a standard AAT response. Time to make each type of categorization, and to execute AAT responses following categorization, was assessed in 32 HSA and 32 LSA participants. Groups did not differ in their relative speed to categorize face stimuli on the two dimensions. When participants coded faces in terms of their emotionality, HSA relative to LSA participants demonstrated increased behavioral avoidance of emotional faces. We conclude that these findings are inconsistent with the pre-behavior coding bias hypothesis and support the post-coding behavioral bias hypothesis.

Elevated dispositional anxiety is characterized by heightened behavioral avoidance of potentially negative situations. For example, people whose Obsessive-Compulsive Disorder is characterized by fear of contamination tend to exhibit increased behavioral avoidance of stimuli representing potential sources of contamination (Gillan et al., 2014; Najmi, Kuckertz, & Amir, 2010). Likewise, individuals with a specific fear of snakes tend to exhibit increased behavioral avoidance of snakes (Castagna, Davis, & Lilly, 2017; Dymond, Dunsmoor, Vervliet, Roche, & Hermans, 2015). Similarly, while many people find interacting with emotionally demonstrative people to be stressful, individuals with elevated social anxiety exhibit increased behavioral avoidance of such people (Hofmann, 2007).

Such anxiety-linked avoidance of potentially negative stimuli may reflect an increased readiness to engage in avoidance behavior once the negativity of such stimuli has been recognized. Alternatively, it is possible that it instead may reflect increased readiness to code such stimuli in a manner that renders their negativity salient, thereby eliciting the behavioral avoidance that everyone would show for stimuli coded in this manner. For example, if two individuals differing in social anxiety encounter a situation that may involve social interaction with others, they may code this equivalently but respond with differing degrees of behavioral avoidance. Alternatively, the socially anxious individual may more readily code the situation as being emotionally confronting and may consequently exhibit the behavioral avoidance that anyone coding situations in this manner would exhibit.

A frequently used measure of behavioral avoidance is the Approach-Avoidance Task (AAT; Rinck & Becker, 2007). In the AAT, participants are presented with an image and required to make either a behavioral avoidance or approach response by pushing or pulling a joystick with their dominant hand. Typically, each image is accompanied by a cue that instructs the participant whether to make an approach or avoidance response. A commonly used cue is image format, with portrait and landscape formats each indicating the need to make a particular behavioral response (i.e. push or pull). The image decreases in size when the joystick is pushed, strengthening the sense of avoidance, and increases in size when it is pulled, strengthening the sense of approach.

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The dependent variable is the time taken to execute the push and pull responses. Relative speeding to execute the push response, compared to the pull response, for a target type of image reveals the degree to which participants exhibit heightened behavioral avoidance of such stimuli.

The AAT has proven effective in demonstrating behavioral avoidance of fear-relevant images in a range of anxious populations, including high spider fearful individuals (Rinck & Becker, 2007), and people with fear of contamination (Najmi et al., 2010). Of particular relevance to the current research, Heuer, Rinck, and Becker (2007) have shown that, on the AAT, individuals high in social anxiety, unlike those low in social anxiety, display heightened relative speeding to push away images of faces exhibiting emotional expressions, compared to images of faces displaying a neutral expression, indicating behavioral avoidance of emotionally expressive faces.

In their study, Heuer et al. (2007) recruited high and low socially anxious participants and had them complete an AAT in which they were exposed to images of emotional and non-emotional faces and required to make either a push or pull response on a joystick. They found that the high socially anxious, relative to the low socially anxious participants, showed greater speeding of push relative to pull responses when the image of the face displayed an emotional expression rather than a non-emotional expression. Heuer et al. (2007) concluded that the high socially anxious were more likely than the low socially anxious to demonstrate behavioral avoidance of faces displaying emotional rather than non-emotional expressions. This effect has now been replicated in other similar AAT studies (Lange, Keijsers, Becker, & Rinck, 2008; Roelofs et al., 2010).

In seeking to explain this anxiety-linked behavioral avoidance of emotionally expressive faces observed on the AAT, it is important to recognize that an observed behavioral effect may have its origins in processes that precede observed behavior. For example, as indicated by the extensive literature on dual-process models, associative processing and rule-based processing each can influence behavior (cf. Strack & Deutsch, 2004). Avoidance of emotionally expressive faces may be a behavioral rule followed by high socially anxious, but not low socially anxious individuals. Alternatively, the observed behavioral difference between these groups may be driven by a discrepancy in the type of associative processing they engage in when coding the stimuli. There is evidence that equivalent stimuli can be coded in different ways, and also that highly anxious individuals sometimes code fear-related stimuli in ways that differ from those lower in anxiety (e.g. Cook & Mineka, 1989; Rossignol, Anselme, Vermeulen, Philippot, & Campanella, 2007; Yang, Yoon, Chong, & Oh, 2013). Hence, it is possible that high socially anxious individuals may be disproportionately inclined to code faces in terms of whether or not they are emotionally expressive (rather than in terms of other dimensions such as age or gender). Even if high and low socially anxious individuals are both inclined to exhibit behavioral avoidance of faces they code as emotionally expressive, such avoidance would be more evident in high socially anxious individuals if such people are disproportionately inclined to code faces in this manner.

It follows from the above considerations that the heightened avoidance of emotionally expressive faces, exhibited by high socially anxious individuals on the AAT, could logically be accounted for by two different theoretical explanations. One candidate theoretical account is that both high socially anxious and low socially anxious participants, when presented with images of faces are equally likely to code whether or not these are emotionally expressive. However, after all participants have coded that a face displays an emotional expression, high socially anxious individuals demonstrate greater behavioral avoidance of such coded faces than the low socially anxious participants. According to this first theoretical account the locus of the anxiety-linked difference resides in biased behavioral responding occurring following equivalent stimulus coding. We will term this the *post-coding behavioral bias hypothesis.* An alternative theoretical account is that all participants would demonstrate behavioral avoidance of faces they code as displaying emotional expressions, but that high socially anxious individuals are disproportionately inclined to code faces in terms of the emotionality of their expressions, rather than in terms of other dimensions (such as age or gender). According to this second theoretical account the locus of the anxiety-linked difference resides in biased stimulus coding preceding the behavioral approach or avoidance response. We will term this the *pre-behavior coding bias hypothesis*.

The conventional AAT is unable to determine the validity of these two hypotheses. However, this could be achieved by introducing a small but important amendment to the AAT methodology. This amendment involves requiring participants, on each trial, first to impose an instructed classification on the exposed image, to ensure that it is coded by participants in a predetermined manner. By measuring the speed taken to impose alternative classifications, it becomes possible to assess group differences in the readiness to code these stimuli in these alternative ways. Immediately after this classification is made, the cue signaling the required behavioral response can then appear, and participants' relative speed to execute an avoidance or approach response then can be assessed in the usual manner. Because this measure of behavioral responding is taken only after the stimulus has been coded in the instructed manner, the index of behavioral avoidance now will reveal group differences in behavioral avoidance to stimuli that have been coded in a predetermined manner. By adopting this novel methodology, it becomes possible to test the differing predictions generated by the two hypotheses under scrutiny.

In the current experiment, we delivered this modified Stimulus-Coding AAT to groups of high and low socially anxious individuals. Participants were presented with images of faces, showing either emotional or non-emotional expressions, and were required to make two responses on each trial. First, the image appeared in a square format and the participant classified the face either in terms of its emotionality or its gender, in accordance with an auditory instruction, by pressing one of two buttons to convey their classification on the instructed dimension. The speed of this classification response was recorded, to index participants' relative readiness to code the face stimuli on each dimension. Immediately following their response, the image transitioned to either landscape or portrait format, which signaled whether they should immediately make a push or pull response to the image using the joystick. As in Heuer et al. (2007), the image decreased or increased in size, respectively, when each of these two responses were made to strengthen the sense of avoidance and approach. Participants' relative speed to execute the push vs. pull response revealed readiness to execute an avoidance vs. approach to images after having coded these in the instructed manner.

According to the *pre-behavior coding bias hypothesis*, we should find that the high socially anxious participants, compared to the low socially anxious, are disproportionately speeded to code faces in terms of whether or not they exhibit emotional expressions, rather than in terms of whether they are male or female. This hypothesis provides no basis for predicting that these social anxiety groups will differ in terms of their relative approach vs avoidance responses, as these are assessed after participants have all coded stimuli in the instructed manner. In contrast, according to the *post-coding behavioral bias hypothesis*, we should find the high socially anxious participants, compared to the low socially anxious, exhibit a disproportionate relative speeding to make a push (avoid) rather than pull (approach) to emotional faces alone, after having classified the faces in terms of their emotionality. This hypothesis provides no basis for predicting that these social anxiety groups will differ in terms of their relative speed to code faces in terms of emotionality vs gender. The pre-behavior coding bias hypothesis and the post-coding behavioral bias hypothesis are not mutually exclusive alternatives, and if both are valid then we should find both of the above described group differences.

1. Methods

1.1. Participants

As in Heuer et al. (2007), we sought to recruit high and low socially anxious participants to complete the experiment. Participants were 64 undergraduate psychology students at the University of Western Australia, recruited from a larger participant pool (N = 840) on the basis of responses on the Social Interaction Anxiety Scale (SIAS; Mattick & Clarke, 1998). This sample size enabled us to detect an effect size of $\eta_p^2 = 0.07$ (similar to that reported by Heuer et al., 2007) with a power of 0.8 for both planned repeated measures ANOVA analyses on classification latencies and joystick movement times. We sampled from the upper and lower thirds of the distribution of scores to create a High Social Anxiety (HSA) group ($N = 32$, $M_{SIAS} = 47.13$, $SD_{\mathrm{SIAS}} = 8.23$, Range_{SIAS} 36–67, $M_{Age} = 19.56$, $SD_{Age} = 3.99$) and a Low Social Anxiety (LSA) group (N = 32, $M_{SIAS} = 10.69$, $SD_{SIAS} = 6.07$, Range_{SIAS} 0–20, $M_{Age} = 21.47$, $SD_{Age} = 6.75$).[1] Age did not significantly differ between groups ($t(62) = 1.37$, $p = .17$) nor did gender ($\chi^2(1, N = 64) = 1.87$, $p = .17$).

2. Materials

Measures. Social Interaction Anxiety Scale (SIAS; Mattick & Clarke, 1998). Social anxiety was assessed with the SIAS. Scores can range from 0 to 80 with higher numbers reflecting higher levels of social anxiety. The SIAS has been shown to have good reliability and validity (Brown et al., 1997).

Face Stimuli. In order to replicate Heuer et al. (2007), we required a stimulus set consisting of images of faces displaying emotional and non-emotional expressions. The stimulus set was created such that each identity displayed both non-emotional and emotional expressions (the latter equally comprised of happy and angry expressions, as in Heuer et al.). Half of these faces were male and half female. We selected images from the NimStim set for this purpose (Tottenham et al., 2009). Three photos of 32 identities (16 male and 16 female) were drawn from this set. For each identity, two photos displayed an emotional expression (one happy and one angry) and one photo a non-emotional expression. As such, a total of 96 images were selected for the task, 64 displaying an emotional expression (32 happy, 32 angry) and 32 displaying a non-emotional expression. In each image, the face was shown on a grey background.[2]

Apparatus. The task was run on a Hewlett-Packard PC with a standard QWERTY keyboard and 22 inch widescreen color monitor, set at a resolution of 1920 × 1080 pixels with a 5 ms refresh rate. Sennheiser HD-201 headphones and a Logitech Attack 3 joystick were attached to the computer.

2.1. Stimulus-Coding Approach Avoidance Task

The design of the traditional AAT was extended by including an additional component that required coding of each stimulus image on a prescribed dimension, prior to delivery of the signal indicating whether to execute an approach or avoidance response. Specifically, on each trial in the Stimulus-Coding AAT employed here participants first classified the face stimuli either in terms of emotionality (i.e., whether or not it displayed an emotional expression), or in terms of gender (i.e., whether it was male or female). They registered the classification response by pressing either of two buttons with their non-dominant hand, which rested on these response keys during the task. Immediately following the participant's classification response, the signal indicating whether to make the AAT response of pushing or pulling the joystick appeared. Participants made this response using their dominant hand, which rested on the joystick during the task. Each of these trial components will be described in turn.

At the beginning of each trial, one of the face stimuli appeared on screen in a square format, accompanied by a single word question delivered through headphones.[3] On half the trials, this single word question was either “emotional?” or “neutral?", which required participants to categorize the emotionality of the face. On the other half of the trials, the single word question was either “male?” or “female?", which required participants to categorize the gender of the face. Each question required a ‘yes’ or ‘no’ response, which participants made using the right and left arrow keys on the keyboard, respectively. Classification latencies were recorded, yielding an index that could reveal the ease with which the images could be coded in terms of their emotionality, as opposed to in terms of the non-emotional dimension of gender.

Immediately following detection of this categorization response, the face image changed from the initial square format to either a portrait or landscape format. Participants were required to either push or pull the joystick dependent on the image format. For half the participants, portrait format signaled push and landscape format signaled pull and vice versa for the other half. The image on the screen increased in size when participants pulled the joystick and decreased in size when they pushed the joystick. The trial was complete once the participant had pushed or pulled the joystick to its limit. After the participant had fully extended the joystick, the image on the screen disappeared and the screen remained blank for an inter-trial interval of 1000 msec before the next trial began. Speed of the joystick response was recorded, operationalized as the time from initial movement of the joystick until the joystick was fully extended. These data were used to calculate Avoidance Bias Scores by subtracting the median RT to make a push response in each condition from the median RT to make a pull response in each condition (e.g. Initial Emotional Classification|Emotional Face Pull RT *minus* Initial Emotional Classification|Emotional Face Push RT, or Initial Gender Classification|Non-Emotional Face Pull RT *minus* Initial Gender Classification|Non-Emotional Face Push RT). This resulted in four bias scores that each reflected the relative tendency for participants to avoid a particular category of stimulus after it had been coded in the instructed manner with a higher number reflecting increased behavioral avoidance.

A total of 256 trials were delivered in the task. On half of these trials, participants were shown an image of a face displaying an emotional expression, and on half they were shown an image of a face displaying a non-emotional expression. Each unique identity was shown 8 times across the 256 trials, equally often showing emotional and non-emotional expressions, and equally often with the initial requirement to classify in terms of emotionality or gender, and equally often with the subsequent requirement to execute an approach (pull) or avoidance (push) response. Order of presentation of the images was randomized, and after every 64 trials participants were given a self-timed rest period.

2.2. Procedure

On arrival, participants were seated in a testing room and provided

[1] Though it is a widely used convention to contrast high and low anxious individuals by comparing the top and bottom thirds of the distribution of questionnaire scores (e.g. Helfinstein, White, Bar-Haim, & Fox, 2008; Holmes, Richards, & Green, 2006; Shilton, Laycock, & Crewther, 2019), it should be noted that Heuer et al.‘s study contrasted the top and bottom 10% of social anxiety scores.

[2] Each identity from the NimStim set was selected on the basis that across both the happy and angry expressions the face had an open or closed mouth.

[3] The sound files used for these single word questions were recorded and processed using Audacity software in order to ensure they were all of equal volume and length (500 msec).

with an information sheet and consent form. Upon giving their written consent, participants completed the SIAS. They were then verbally presented with instructions on how to complete the experimental task and given a short practice version of the task (employing 1 male and 1 female identity not used in the test task), before completing the test version of the task. At the conclusion of the experimental session, participants were debriefed and thanked for their participation. The experimental session lasted approximately 40 min.

3. Results

3.1. Overview of analytical approach

After conducting initial screening and cleaning of data we conducted two main analyses to test each of our hypotheses. The first analysis was a mixed design repeated measures ANOVA, conducted on classification decision latencies, to determine if high and low socially anxious participants differed in relative speed to classify faces in terms of their gender vs emotionality. The second analysis was a mixed design repeated measures ANOVA, conducted on joystick movement execution time, to determine if high and low socially anxious participants differed in relative speed to make an approach vs avoidance response to emotional faces, after participants had initially coded such faces in terms of emotionality. We sought to replicate the analytical approach employed by Heuer et al. (2007) and so, as was the case in their original study, we employed median RTs as our measures of response time, we indexed approach and avoidance responses using time to complete the pull and push joystick response, and we excluded from consideration all trials on which participants made errors.

3.2. Data screening

As reaction time data is meaningful only on trials where responses are accurate, classification latencies and joystick movement speeds were computed using trials on which participants made a correct response on both the initial coding component and the subsequent joystick movement component. Any participant who made errors on more than 20% of trials was excluded, and this resulted in the removal of three participants. The remaining participants demonstrated a high level of accuracy, exhibiting the correct classification and joystick response on 94.74% of trials. Low and high socially anxious participants did not differ in terms of accuracy, $t(59) = 0.886$, $p = .379$ (for low socially anxious, mean accuracy = 95.16%, $SD = 3.91$ and for high socially anxious mean accuracy = 94.33%, $SD = 3.37$). In order to test the differing predictions generated by the two accounts under scrutiny, both the classification latencies and the joystick movement speeds were subjected to analyses of variance, as described below.

3.3. Did anxiety groups differ in their relative speed to classify face emotionality and gender?

The average median classification latencies shown by the two groups of participants in each experimental condition are shown in Table 1. These data were subjected to a 3-way mixed model ANOVA with the within-subjects factors Classification Required (Emotionality Classification vs. Gender Classification) and Face Emotionality (Emotional Face vs. Non-Emotional Face), and the between-subjects factor of Social Anxiety Group (High Social Anxiety vs. Low Social Anxiety). The pre-behavior coding bias hypothesis, but not the post-coding behavioral bias hypothesis, predicts that we should find a significant Classification Required x Social Anxiety Group interaction, due to the high socially anxious being disproportionately fast to classify faces on the emotional dimension compared to the non-emotional dimension.

There was a large main effect of Classification Required, $F(1, 59) = 279.33$, $p < .001$, $\eta_p^2 = 0.826$, indicating that overall participants were generally slower to classify the faces in terms of their emotionality ($M = 1173$ $SD = 210$) compared to classifying them in terms of gender ($M = 971$, $SD = 169$). There was also a main effect of Face Emotionality, $F(1, 59) = 8.89$, $p = .004$, $\eta_p^2 = 0.131$, indicating that on average, participants were faster to make classification decisions concerning the emotional faces ($M = 1058$, $SD = 188$) than concerning the non-emotional faces ($M = 1087$, $SD = 191$). These two main effects were subsumed within a large significant two-way interaction of Face Emotionality and Classification Required, $F(1, 59) = 33.44$, $p < .001$, $\eta_p^2 = 0.362$, reflecting the fact that the above described main effect of Face Emotionality was disproportionately greater when participants were required to categorize faces in terms of their emotionality rather than in terms of their gender. No other significant effects were obtained. Of greatest relevance to the issue under consideration, the two-way interaction of Classification Required x Social Anxiety Group predicted by the pre-behavior coding bias hypothesis did not approach significance, $F(1, 59) = 1.33$, $p = .254$, $\eta_p^2 = 0.02$. A follow-up Bayesian analysis revealed that the Bayes factor associated with this interaction (BF10 = 0.442) indicated moderate support for H0 (van Doorn et al., 2019). Thus, the findings provide no support for the idea that high socially anxious individuals are characterized by an increased readiness to classify faces in terms of their emotionality.

3.4. Did anxiety groups differ in post-coding approach-avoidance responses to emotional and non-emotional faces?

The average median joystick movement times exhibited by the two groups of participants under each experimental condition and the resulting Avoidance Bias Scores are shown in Table 1. These bias scores were subjected to 3-way mixed model ANOVA with the within-subjects factors Initial Classification Required (Initial Emotionality Classification vs. Initial Gender Classification) and Face Emotionality (Emotional Face vs. Non-Emotional Face), and the between-subjects factor of Social Anxiety Group (High Social Anxiety vs. Low Social Anxiety). The post-coding behavioral bias hypothesis, but not the pre-behavior coding bias hypothesis, predicts that we should replicate the findings obtained by Heuer et al. (2007) and others by finding a significant two-way interaction between Social Anxiety Group and Face Emotionality, due to high socially anxious participants displaying increased Avoidance Bias Scores to emotional faces. Moreover, this hypothesis also predicts that this two way interaction should be strongest when the faces have been initially classified in terms of emotionality rather than gender, leading to its further moderation by Initial Classification Required, within a three-way interaction.

The ANOVA revealed no significant main effects (max $F = .698$). However, there was a significant two-way interaction between Face Emotionality and Social Anxiety Group, $F(1, 59) = 4.33$, $p = .042$, $\eta_p^2 = 0.07$. The nature of this effect was consistent with the anxiety-linked avoidance of emotional faces reported by Heuer et al. (2007). Specifically, for emotional faces the High Socially Anxious participants evidenced higher avoidance bias scores than did the Low Socially Anxious participants ($M = 54.64$, $SD = 70.24$ vs. $M = 29.59$, $SD = 71.76$), whereas this was not the case for non-emotional faces ($M = 39.73$, $SD = 58.79$ vs. $M = 41.02$ $SD = 73.82$). Furthermore, this two way interaction was indeed modified by Initial Classification Required, giving rise to a significant 3-way interaction of Face Emotionality x Social Anxiety Group x Initial Classification Required, $F(1, 59) = 5.69$, $p = .02$, $\eta_p^2 = 0.09$.

We examined the nature of this higher order interaction by computing the significance of the simple 2-way interaction of Face Emotionality x Social Anxiety Group at each level of the Initial Classification Required factor. When the initial classification had required participants to code faces in terms of gender, this simple 2-way interaction did not approach significance, $F(1, 59) = 0.05$, $p = .827$, $\eta_p^2 = 0.001$. In contrast, however, the interaction was strongly evident when the initial classification had required participants to code the

Table 1
Average medians and standard deviations of measures obtained from the Stimulus-Coding AAT by Social Anxiety Group, Face Emotionality and Classification Required.

Measure	Initial Emotionality Classification		Initial Gender Classification	
	Emotional Face	Non-Emotional Face	Emotional Face	Non-Emotional Face
High Socially Anxious				
Classification judgement	1145 (204)	1221 (264)	973 (185)	961 (176)
Push	781 (91)	808 (113)	778 (95)	777 (90)
Pull	843 (118)	840 (111)	826 (130)	825 (111)
Avoidance Bias Score	62.03 (64.4)	32.05 (62.35)	47 (76)	47.4 (55.24)
Low Socially Anxious				
Classification judgement	1129 (192)	1199 (181)	986 (172)	965 (142)
Push	785 (120)	772 (111)	778 (126)	769 (101)
Pull	810 (122)	823 (133)	813 (129)	800 (123)
Avoidance Bias Score	24.97 (64.95)	51.2 (79.95)	34.22 (78.57)	30.83 (67.68)

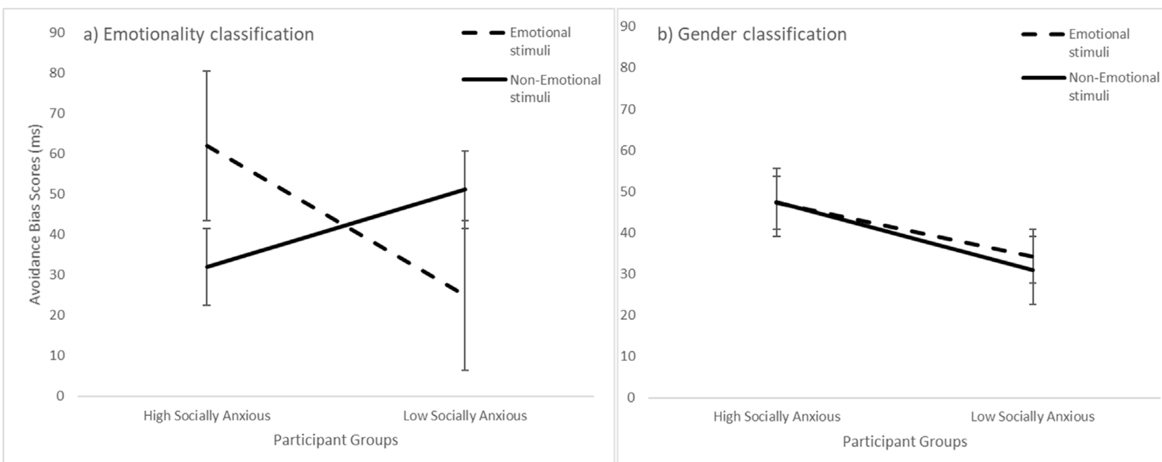

Fig. 1. Graphical representation of the 3-way interaction of Social Anxiety Group by Face Emotionality by Classification Required on avoidance bias scores. Error bars are standard errors.

faces in terms of emotionality, $F(1, 59) = 8.49$, $p = .005$, $\eta_p^2 = 0.126$. The nature of this simple 2-way interaction, illustrated in Fig. 1, remained consistent with anxiety-linked avoidance of emotional faces. For emotional faces, High Socially Anxious participants evidenced higher avoidance bias index scores than did the Low Socially Anxious participants ($M = 62.03$, $SD = 64.4$ vs. $M = 24.97$, $SD = 64.94$; $F(1, 59) = 5.01$, $p = .03$, $\eta_p^2 = 0.08$), but this was not the case for non-emotional faces ($M = 32.05$, $SD = 62.35$ vs. $M = 51.2$, $SD = 79.95$; $F(1, 59) = 0.43$, $p = .513$, $\eta_p^2 = 0.007$). Therefore, as predicted by the post-coding behavioral bias hypothesis, the obtained pattern of findings indicates that high socially anxious participants demonstrated greater behavioral avoidance of emotional faces than low socially anxious participants, when all participants had coded faces in terms of their emotionality.

4. Discussion

The present study tested two candidate explanations for the previously observed finding, obtained using the AAT, that individuals with elevated social anxiety exhibit heightened behavioral avoidance of emotional faces. Contradicting the prediction generated by the pre-behavior coding bias hypothesis, we found no evidence that high and low socially anxious participants differed in their relative speed to code faces in terms of their emotionality vs gender. However, consistent with the prediction generated by the post-coding behavioral bias hypothesis, we found that high socially anxious participants showed heightened behavioral avoidance of emotional faces, compared to non-emotional faces, after all participants had initially coded the faces in terms of their emotionality. Hence, our findings lend support to the post-coding behavioral bias hypothesis, without providing any evidence to support the pre-behavior coding bias hypothesis.

Given that the anxiety-linked difference on the behavioral task assessing approach and avoidance was observed only when participants performed the coding task by classifying the faces in terms of emotionality, it is possible to construe this effect as a very particular profile of anxiety-linked difference in the cost of switching from the coding task to the behavioral approach and avoidance task. Regardless of the expression displayed by stimulus faces, there was no evidence that the cost of switching from executing the gender coding task to executing either the approach or the avoidance response on the behavioral task differed between high and low socially anxious participants. However, when faces displayed emotional expressions, then for the high socially anxious individuals the cost of switching from executing the emotional coding task to executing the approach response on the behavioral task was greater than the cost of switching from this coding task to executing the avoid response on the behavioral task. This was not the case for low socially anxious participants. Conceptualizing the observed effects in terms of switching costs highlights the importance fact that, although the locus of anxiety-linked difference in behavioral avoidance of emotional faces was post stimulus coding, it was observed only when this coding task required participants to classify faces in terms of their emotionality.

Although there was no evidence from the present study that high and low socially anxious individuals were differentially efficient at coding stimuli in terms of emotionality or gender, this does not preclude the possibility that future extensions of the present methodology may yet serve to identify anxiety-linked coding differences, that contribute to subsequent patterns of avoidance behavior. Perhaps the present coding task was too easy to reveal anxiety-linked differences that would become apparent if participants were required to classify the stimuli in more complex ways, such as discriminating subtle differences in specific types of emotions. Alternatively, it may be that the present coding task was too difficult to reveal anxiety-linked differences, particularly given that participants were unpracticed at imposing the required classification in response to auditorily presented questions. Future research could investigate this possibility by providing participants with more practice at coding facial stimuli in these two ways, perhaps within coding practice blocks, preceding the blocks that deliver trials with the structure employed in the present study. Should future research identify conditions under which anxiety-linked differences in the readiness to code the emotionality of faces become evident, then appropriately designed extensions of the Stimulus-Coding AAT can be employed to determine whether or not such coding differences contribute to socially-anxious individuals' heightened tendency to exhibit behavioral avoidance of emotional faces.

As with many tasks, the precise parameters employed in the AAT can vary across studies, as can the manner in which the dependent measures are computed and analyzed. There are sometimes strong grounds for adopting a particular approach, for example to ensure that a study closely follows the protocol adopted in an earlier study yielding an effect that it is intended to replicate. This was the case in the present study, where our use of median response latencies to compute our dependent measures, our exclusion of incorrect trials, and the design of our analyses, served to match the approach adopted in Heuer et al.'s study. While future researchers who seek only to replicate the present finding could likewise choose to adopt the exact same approach, we appreciate that there could also be sound justification for departing from this template, by altering presentation parameters or by computing approach and avoidance measures in differing ways. While we encourage the appropriate refinement of measures and analytical approaches in future work, we also advocate the use of study pre-registration to protect against the potential perception that such variation is arbitrary or unplanned.

The findings obtained in the present study may have the capacity to inform development of intervention approaches. There has been much recent interest in the possibility of alleviating psychological dysfunction by using training procedures designed to directly modify the specific types of biases that characterize these conditions (e.g. Ferrari, Möbius, Becker, Spijker, & Rinck, 2018). The current findings suggest two candidate mechanisms that could be targeted to potentially reduce the anomalous pattern of avoidance behavior that Heuer et al. (2007) and others have found to characterize elevated social anxiety. First, and most obviously, the observation that this reflects a post-classification behavioral bias encourages the evaluation of training procedures designed to directly modify such avoidance behavior. These could involve the therapeutic application of previously developed training variants of the AAT. For example, several investigators have shown that training variants of the AAT in which participants are required to consistently make pull responses to smiling faces, with the aim of training approach responses to such social stimuli, can serve to reduce emotional reactivity to a subsequent social stressor (Rinck et al., 2013; Taylor & Amir, 2012). The present finding that the avoidance behavior that characterizes elevated social anxiety is evident only when participants initially classify faces in terms of emotionality, suggests that the beneficial impact of such AAT training may be increased by imposing this classification requirement at the beginning of each training trial. Moreover, it further suggests that a training procedure designed to reduce the emotional classification of facial stimuli may serve to also attenuate socially anxious individuals' heightened tendency to behaviorally avoid emotionally expressive social stimuli, given that they show such heightened avoidance only when they code such stimuli in terms of their emotionality.

In closing, it is appropriate to highlight the potential offered by the novel Stimulus-Coding AAT approach introduced in the present study, to advance understanding of other established patterns of dysfunctional approach or avoidance behavior, that have been demonstrated using the conventional AAT. These include, for example, not only the findings that spider fearful individuals exhibit heightened avoidance of spider images (Rinck & Becker, 2007), and contamination fearful individuals exhibit heightened avoidance of images depicting contamination (Najmi et al., 2010), but also the findings that heavy drinkers exhibit heightened behavioral approach to alcohol stimuli (Wiers, Rinck, Dictus, & Van den Wildenberg, 2009), or that restrained eaters demonstrate enhanced behavioral approach to food stimuli (Veenstra & de Jong, 2010), or that smokers display approach biases towards smoking-related cues relative to non-smokers (Wiers et al., 2013). In nearly every case, these aberrant patterns of approach or avoidance behavior, previously observed on the AAT, could be driven either by individual differences in the initial coding of the stimuli, or by individual differences in the behavioral response evoked by coding it in a particular manner. The Stimulus-Coding AAT approach enables the experimenter to determine which is the case, by controlling the manner in which stimuli are coded immediately before individual differences in behavioral approach or avoidance responses are measured, while also permitting assessment of individual differences in the ease with which stimuli can be coded in alternative ways. Hence we hope that this novel approach will prove to be of value to fellow researchers, working to advance understanding of the mechanisms that underpin the patterns of biased approach or avoidance behavior exhibited, on the conventional AAT, by people experiencing other types of clinically relevant symptomatology.

For the time being, we can conclude: i. That the elevated avoidance of emotional faces exhibited by high socially anxious individuals on the AAT, reported by Heuer et al. (2007), is a replicable effect; ii. The present study provided no evidence that this effect results from high socially anxious individual's heightened readiness to classify faces in terms of emotionality; and iii. Our findings instead suggest that the effect results from a behavioral bias that operates subsequent to having classified faces in terms of emotionality, reflecting heightened behavioral avoidance of emotional faces in high socially anxious relative to low socially anxious individuals, despite equivalent stimulus coding.

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CRediT authorship contribution statement

Daniel Rudaizky: Conceptualization, Methodology, Software, Formal analysis, Investigation, Data curation, Writing - original draft, Visualization, Project administration. **Mike Rinck:** Writing - review & editing. **Eni Becker:** Writing - review & editing. **Colin MacLeod:** Conceptualization, Methodology, Software, Resources, Writing - review & editing, Supervision, Funding acquisition.

Declaration of competing interest

The authors have no conflicts of interest to declare.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.brat.2020.103656.

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