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The relationship between social anxiety and the perception of depth-ambiguous biological motion stimuli is mediated by inhibitory ability

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ABSTRACT

Orthographically projected biological motion stimuli are depth-ambiguous. Consequently, their projection when oriented towards the viewer is the same as when oriented away. Despite this, observers tend to interpret such stimuli as facing the viewer more often. Some have speculated that this facing-the-viewer bias may exist for sociobiological reasons: Mistaking another human as retreating when they are actually approaching could have more severe consequences than the opposite error. An implication of this theory is that the facing-towards percept may be perceived as more threatening than the facing-away percept. Given this, as well as the finding that anxious individuals have been found to display an attentional bias towards threatening stimuli, we reasoned that more anxious individuals might have stronger facing-the-viewer biases. Furthermore, since anxious individuals have been found to perform poorer on inhibition tasks, we hypothesized that inhibitory ability would mediate the relationship between anxiety and the facing-the-viewer bias (i.e., difficulty inhibiting the threatening percept). Exploring individual differences, we asked participants to complete anxiety questionnaires, to perform a Go/No-Go task, and then to complete a perceptual task that allowed us to assess their facing-the-viewer biases. As hypothesized, we found that both greater anxiety and weaker inhibitory ability were associated with greater facing-the-viewer biases. In addition, we found that inhibitory ability significantly mediated the relationship between anxiety and facing-the-viewer biases. Our results provide further support that the facing-the-viewer bias is sensitive to the sociobiological relevance of biological motion stimuli, and that the threat bias for ambiguous visual stimuli is mediated by inhibitory ability.

1. Introduction

The human visual system is remarkably adept at deriving information from the movement of other living things (Johansson, 1973). This ability, referred to as biological motion perception, is often studied using point-light stimuli. These stimuli are comprised of relatively few dots representing the main joints of the body, yet naïve observers can accurately identify their gender (Pollick, Kay, Heim, & Stringer, 2005; Troje, 2002) and even make accurate estimates of a figure's mood or level of anxiety (Michalak et al., 2009). Another interesting property of point-light stimuli and related biological motion stimuli (e.g., silhouettes or stick figures) is their depth-ambiguity. Because such figures are depth-ambiguous when projected orthographically, they can elicit two equally plausible percepts with different facing orientations (see Fig. 1). Although the available visual information supports both percepts equally, naïve observers perceive these stimuli as facing towards them more often than facing away, a phenomenon that has been termed the facing-the-viewer bias (Brooks et al., 2008; Schouten, Troje, Brooks, Van Der Zwan, & Verfaillie, 2010; Schouten, Troje, & Verfaillie, 2011; Schouten & Verfaillie, 2010; Vanrie, Dekeyser, & Verfaillie, 2004; Vanrie & Verfaillie, 2006).

Some have argued that the facing-the-viewer bias may exist for sociobiological reasons (Brooks et al., 2008; Schouten et al., 2010; Vanrie et al., 2004). That is, mistaking an approaching person as retreating could potentially have more severe consequences than the opposite error. Implicit in this hypothesis is that the facing-towards percept of a biological motion stimulus is potentially more threatening than the facing-away percept, and in fact, there is some evidence that people perceive it as such. For instance, observers tend to perceive point-light displays depicting male walkers as facing towards them more often than female stimuli (Brooks et al., 2008; Schouten et al., 2010) and men are typically viewed as more threatening than women (see Cicone & Ruble, 1978). However, later studies (e.g., Schouten et al., 2011;

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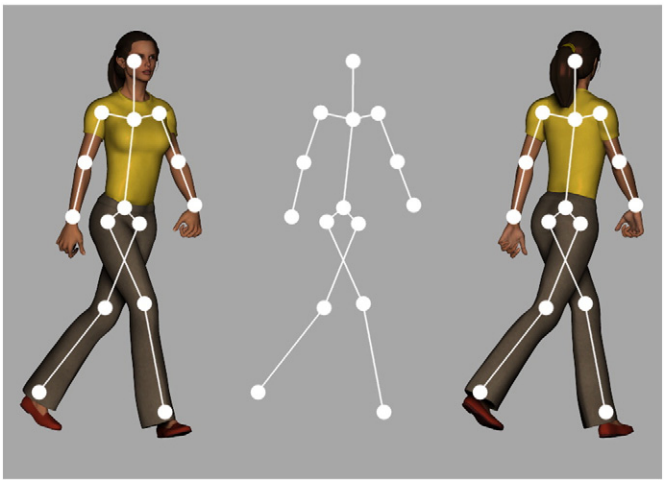

Fig. 1. An example of a static multistable stick figure walker (center), with both the front-facing (left) and rear-facing (right) orientations shown superimposed on the same stick figure walker in order to show the two possible perceptual interpretations of these stimuli. This figure is reprinted with permission from Weech et al. (2014).

Weech, McAdam, Kenny, & Troje, 2014) suggest that this gender effect might occur for reasons other than gender, and so further research on the relationship between the figure gender and the facing-the-viewer bias is needed.

Given this link between the facing-the-viewer bias and the perception of threat, one way to test the sociobiological theory would be to examine how this perceptual bias is affected by observers' level of anxiety. There is a wealth of evidence that both highly anxious nonclinical populations and those with diagnosed anxiety disorders display an attentional bias towards visual stimuli that are potentially threatening (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Gray, Adams, & Garner, 2009; Mogg & Bradley, 2005; Mogg, Bradley, de Bono, & Painter, 1997; Singer, Eapen, Grillon, Ungerleider, & Hendler, 2012). This predisposition towards threat has been found to occur at both the perceptual (unconscious) and attentional (conscious) levels (see Bar-Haim et al., 2007), though the distinction between these two is still unclear in the literature (for our purposes, we will refer to perceptual and attentional biases interchangeably). For example, MacLeod, Mathews, and Tata (1986) had people watch while two words (either threat words or innocuous ones) were displayed simultaneously on a computer screen. They found that more anxious individuals diverted more attention to processing the threatening words as evidenced by longer latencies to visual probes located near those words. The threat bias has also been confirmed with ambiguous visual stimuli, as more anxious individuals have been found to display a bias towards perceiving the more threatening percept of ambiguous figures (Fox, Russo, & Dutton, 2002; Gray et al., 2009; Singer et al., 2012). For instance, during binocular rivalry tasks (in which perceptual alternations are elicited by displaying different stimuli to each retina), researchers have found that more anxious individuals are more likely to perceive threatening images than neutral ones at stimulus onset (e.g., angry or fearful facial expressions; Gray et al., 2009; Singer et al., 2012). This threat bias does appear to be specific to anxiety itself, as it is not related to symptoms of depression (MacLeod et al., 1986) and has been found to diminish after successful treatment of anxiety (El Khoury-Malhame Myriam et al., 2011). In fact, some argue that this threat bias may contribute to and maintain some anxiety disorders by causing anxious individuals to attend to threatening stimuli or events in their environment that then evoke further anxiety in a self-perpetuating feed-forward loop (Heeren, Peschard, & Philippot, 2011; MacLeod et al., 1986).

Given the support for the threat bias and that the facing-the-viewer bias appears to be greater for more threatening stimuli, one would hypothesize that more anxious individuals would have greater facing-the-viewer biases. Indeed, there is evidence that this is the case, as Heenan and Troje (2014) found that participants who exercised on a treadmill or those who performed a progressive muscle relaxation task had significantly lower facing-the-viewer biases than controls. Since both these tasks are known to cause reductions in anxiety, Heenan and Troje argued that anxiety and the facing-the-viewer bias are related. In support of this, these authors found that social interaction anxiety and facing-the-viewer biases were positively correlated and, in an earlier study, Heenan, Refling, MacDonald, and Troje (2012) reported a similar positive correlation between facing-the-viewer biases and attachment anxiety. Furthermore, Heenan et al. (2014) found that participants had greater facing-the-viewer biases immediately after conversing with an individual who was portraying symptoms of schizophrenia, which they argued supports the use of this bias as an implicit measure of perceived threat. On the other hand, Van de Cruys, Schouten, and Wagemans (2013) found that individuals with high social anxiety had significantly *weaker* facing-the-viewer biases than individuals with low social anxiety, as indicated by the total scores from the Liebowitz Social Anxiety Scale (LSAS; Liebowitz, 1987).

While more research on the facing-the-viewer bias is required, a consistent finding regarding anxiety and ambiguous visual stimuli is that reversal rates (i.e., the rate at which one experiences reversals between percepts) increase as a function of anxiety. For example, there is evidence that more anxious participants have significantly faster perceptual reversal rates during binocular rivalry tasks than those who are less anxious (Anderson et al., 2013; Meredith, 1967; Nagamine et al., 2007) and also while viewing static ambiguous figures such as the Schroeder staircase (Li et al., 2000). Furthermore, individuals with clinically significant anxiety have been found to have faster reversal rates than healthy controls before receiving treatment but not afterwards (Meldman, 1965).

One reason why anxious individuals perceive more frequent reversals might be that they are less able to inhibit percepts. Some people with anxiety disorders have difficulty inhibiting distracting thoughts, such as individuals with post-traumatic stress disorder (Swick, Honzel, Larsen, Ashley, & Justus, 2012) or obsessive–compulsive disorder (Chamberlain, Blackwell, Fineberg, Robbins, & Sahakian, 2005; Enright & Beech, 1993). According to attentional control theory (Eysenck & Derakshan, 2011; Eysenck, Derakshan, Santos, & Calvo, 2007), anxiety disrupts the interaction between top-down, goal-directed attention (e.g., focusing on a task) and bottom-up, sensory-driven attention (e.g., noticing a potential threat). Highly anxious people, according to this theory, are less able to inhibit threatening, task-irrelevant information (e.g., distracting memories of trauma), because they are less able to exert top-down attentional control to prevent bottom-up attentional resources from being used to detect potential threats (i.e., threat bias). These theorists also argue that anxiety diminishes the efficiency of executive functioning *in general*, meaning that greater anxiety is correlated with poorer inhibitory performance for neutral, non-emotional stimuli. Of note here, inhibition can be described either as an attentional (i.e., conscious, deliberate) process or as an executive function that is more unconscious and automatic in nature. While differentiating between these two types of inhibition is beyond the scope of the current paper, researchers have demonstrated that bistable reversals can be both unconsciously and consciously controlled (e.g., reversal rates can increase with voluntary effort; for a review, see Leopold & Logothetis, 1999). For the purposes of this paper, we will not differentiate between conscious or unconscious inhibition.

Attentional control theory might be useful for interpreting the link between anxiety and the perception of ambiguous visual stimuli. That is, it is possible that anxiety affects perceptual biases by making it more difficult to inhibit, or 'suppress' percepts generally. For completely non-threatening visual stimuli, this hypothesis would also explain why more anxious individuals have faster perceptual reversal rates: They have difficulty inhibiting percepts in general and thus experience more rapid perceptual alternations. Conversely, for ambiguous visual

stimuli that have one percept that is more threatening than the other, this hypothesis would explain why anxious individuals are biased to perceive the more threatening percept over the less threatening one: They have particular difficulty inhibiting percepts that are threatening from awareness. This hypothesis is in line with the findings of Fox (1994) who found that highly anxious people had difficulty inhibiting threatening distractor words than less anxious people. It is also in agreement with the findings that attention-deficit hyperactivity disorder is characterized by both deficits in inhibitory processing (Barkley, 1997) and faster perceptual reversal rates (Gorenstein, Mammato, & Sandy, 1989). With this in mind, a goal of the present study was to assess whether inhibitory ability would mediate the proposed relationship between anxiety and facing-the-viewer biases.

No study, to date, has examined concurrent inhibitory ability in the context of the relationship between anxiety and the facing-the-viewer bias. Furthermore, the threat bias has typically been demonstrated with experimental paradigms like binocular rivalry where it can be difficult to differentiate between low- (e.g., contrast) and high-level (e.g., emotion) causes (Gray, Adams, Hedger, Newton, & Garner, 2013). Examining the threat bias using depth-ambiguous biological motion stimuli therefore gives the current study an advantage over previous experiments. The purposes of our study were to 1) confirm that social interaction anxiety and facing-the-viewer biases are positively correlated, and 2) to determine whether this relationship is mediated by inhibition. We assessed three types of anxiety (state, trait, and social interaction) using questionnaires that specifically measure these forms of anxiety. Participants completed anxiety questionnaires, a Go/No-Go task designed to measure inhibitory performance, and then a perceptual task that allowed us to assess their facing-the-viewer bias. We hypothesized that facing-the-viewer biases would correlate strongest with social interaction anxiety given the social relevance of biological motion stimuli and given the previous finding of a positive correlation between social interaction anxiety and facing-the-viewer biases (i.e., Heenan & Troje, 2014). More specifically, we had three main hypotheses: 1) greater social interaction anxiety would be associated with greater facing-the-viewer biases; 2) weaker inhibitory performance on the Go/No-Go task would be associated with greater facing-the-viewer biases; and 3) inhibitory performance would mediate the relationship between social interaction anxiety and facing-the-viewer biases.

2. Method

2.1. Participants

Fifty-five undergraduate and graduate students participated in this experiment (41 women, 14 men). Participants ranged from 17 to 22 years of age ($M = 18.91$ years, $SD = 1.18$ years). Participants were either recruited through an undergraduate participant pool or via a voluntary participant pool comprised of both undergraduate and graduate students. Participants recruited via an undergraduate participant pool received partial course credit and those recruited via the voluntary participant pool were compensated with $15.00 (CAD). All participants had normal or corrected-to-normal vision, were naïve to the purpose of the study, and had never before participated in any experiments that involved depth-ambiguous point-light walkers. Seven participants were excluded from statistical analyses because they had scores on anxiety (5 women, 1 man) or the Go/No-Go task (1 woman) that were considered statistical outliers (i.e., with the criterion of z-score > 3). Two additional participants (both male) were omitted from exploratory analyses as they were considered statistical outliers in terms of their number of facing-towards reversals. Therefore, all statistical analyses were conducted on the remaining 48 participants (35 women, 13 men), ranging in age from 17 to 22 ($M = 18.90$ years, $SD = 1.19$ years). We screened the data for significant differences between men and women in terms of Go/No-Go task performance, perceptual bias measures, or anxiety scores, but found none. Given this, we pooled men and women together for all statistical analyses.

2.2. Questionnaires

We measured three different types of anxiety: State anxiety, trait anxiety, and social interaction anxiety. Participants completed both the State and Trait forms of the STAI (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983). This questionnaire consists of 40 items and is designed to assess how anxious individuals are currently feeling (i.e., state anxiety) and how anxious individuals typically tend to feel (i.e., trait anxiety), and has been found to have good reliability (Cronbach's alpha = .93 and .87 for state and trait scales respectively; Knight, Waal-Manning, & Spears, 1983). In the past, individuals have been considered to have clinically relevant levels of state anxiety if they scored over 39 on the state scale of the STAI (Knight et al., 1983), and were considered to have clinically relevant levels of trait anxiety if they scored over 46 on the trait scale (Fisher & Durham, 1999).

Participants also completed the SIAS (Mattick & Clarke, 1998), which consists of 20 items designed to assess how anxious an individual feels in a variety of situations involving social interaction (e.g., at a dinner party, meeting new people). Like the STAI, the reliability of the SIAS is also strong, as Mattick and Clarke reported Cronbach's alphas ranging from .88 to .93 in both healthy controls and clinical populations. In the past, individuals have been considered to have clinically relevant levels of social interaction anxiety if their score on this measure was greater than 34 (Brown, Turovsky, Heimberg, Juster, et al., 1997).

2.3. Stimuli and apparatus

2.3.1. Go/No-Go task

Stimuli consisted of targets (the letter 'X') and nontargets (all other letters of the alphabet). The letters were presented in Arial font and were white on a black background. Each letter was 0.79 cm tall, subtending a visual angle of 0.5° for the observer. Targets and nontargets were presented individually for 375 ms with a 500 ms interstimulus interval. We designed and ran the Go/No-Go task using MATLAB (The MathWorks Inc., US: Massachusetts) and the Psychophysics Toolbox (Brainard, 1997).

2.3.2. Perceptual task

To avoid confounding the variable of interest (i.e., perceived facing direction) with a simple response bias (Is the walker facing towards or facing away?), we presented stick figure walkers rotating about a vertical axis and asked participants to indicate their spinning direction. Together with information about the "veridical" orientation of the 3D walker, we inferred perceived facing direction from participants' responses. Stick figure walkers were based on biological motion point-light walkers that consisted of 15 points that represented the center of major joints and a few other anatomical landmarks (Troje, 2002, 2008). Walkers were originally generated as 3D models walking stationary (as on a treadmill) but spinning counterclockwise about a vertical axis at a speed of 25°/s. They were then projected orthographically onto the screen and rendered with white dots and connecting white lines on a black background such that they appeared 9.5 cm high, subtending a visual angle of 6° for the observer.

Note that even though the veridical rotation direction of the 3D walker (counterclockwise) was never changed, the resulting stimulus does not contain any clue to reveal the veridical 3D rotation direction. The 2D projection shown to the participant is equally compatible with either of two interpretations which differ only by a mirror flip about the image plane. Specifically, participants can perceive the stimulus to rotate either clockwise or counterclockwise and indicated that at any point during the experiment by pressing one of two response keys on the computer's keyboard. Given that we knew both the veridical spinning direction and the veridical orientation of the walker at any time,

we can infer from the observer's response the currently perceived facing direction (see Troje & McAdam, 2010; Weech et al., 2014 for more details). Given that information, we also know whether any change in perceived spinning direction indicates a flip from a facing-away orientation to a facing-towards orientation, or whether it indicates a flip in the opposite direction.

A solid cube was displayed in the practice trial. It was 4 cm high, subtending a visual angle of 2.5° for the observer, and was opaque, thus having an unambiguous, rotation direction. The rotation direction of the cube changed at random at an average rate of 5 times per minute. Like the Go/No-Go task, we designed and ran the perceptual task using MATLAB (The MathWorks Inc., US: Massachusetts) and the Psychophysics Toolbox (Brainard, 1997).

2.4. Design

We used a correlational design with three main variables of interest: Anxiety, inhibition, and facing-the-viewer biases.

For the Go/No-Go task, a single block of trials consisted of 75% targets and 25% nontargets for a total of 64 stimuli. Block duration was 56 s, followed by a 20 s rest period during which the screen was blanked. Participants completed four blocks, the first of which was treated as a practice block. Data from the remaining three blocks were retained for statistical analyses (192 trials).

For the perceptual task, each block of the perceptual task was 4 min in duration. During each block, a stick figure walker was presented centrally on the screen and was displayed rotating for the entire duration of the block. Participants completed 2 blocks, separated by a 1 min rest period, during which the screen was blanked.

2.5. Procedure

Upon arriving at the lab, each participant provided verbal and written informed consent before completing the STAI, SIAS, and demographic questionnaires. After completing the questionnaires, participants sat comfortably in front of a desktop computer consisting of a mouse, keyboard, and a 22″ LCD screen (30 cm high by 48 cm wide). Observers sat 90 cm from the screen and kept their eyes level with the screen using a chinrest attached to the desk. The testing room was dimly lit and the window was covered.

All participants completed the computer tasks in the same order (i.e., first the Go/No-Go task, then the perceptual task). For each task, the experimenter read standardized instructions, but was then permitted to paraphrase the instructions if additional information was requested.

The experimenter instructed participants to press the space bar on the computer keyboard when they saw the target letter, but not to respond to nontargets. The experimenter instructed participants to respond to stimuli as fast as possible. The task took approximately 5 min to complete.

Participants first completed a practice task that consisted of viewing a rotating solid cube. They were instructed to respond by holding down the 'S' key on the computer keyboard when they saw the cube rotating clockwise and to hold down the 'K' key when they saw the cube rotating counter-clockwise. Participants observed the solid cube and responded for 2 min. At the end of the practice session, the experimenter compared the changes in rotation direction of the solid cube with the participant's responses. The task did not proceed unless the participants accurately reported at least 90% of the changes in rotation direction. After the practice trial, participants completed both blocks of the perceptual task (the instructions were the same as in the practice trial, only this time with the depth-ambiguous stick figure walker rather than the unambiguous, solid cube). Including the practice trial and instructions, the perceptual task took approximately 12 min to complete.

At the end of the experiment, the experimenter verbally debriefed participants and gave them a debriefing form before compensating them for their participation.

2.6. Data analyses

The main dependent variable for the Go/No-Go task was inhibition, which was defined as participants' response bias [i.e., $-0.5(z_{\text{hit rate}} + z_{\text{false alarm rate}})$], with greater values of that score indicating greater inhibition performance.

For the perceptual task, participants' responses were analyzed by classifying each reversal in perceived depth into either a reversal from a facing-away orientation into a facing-towards orientation (a "towards-reversal") or a reversal in the other direction (an "away-reversal"). Based on these data, we defined a FTV score in terms of the ratio of towards-reversals to the total number of reversals. Note, that a FTV score smaller than 0.5 would mean that the participant experienced more away-reversals than towards-reversals, while scores larger than 0.5 would indicate a true facing-the-viewer bias.

All statistical analyses were comprised of correlations and regressions. For correlations, we corrected for inflating false discovery rate by employing the correction method described first by Simes (1986), and then updated by Benjamini and Hochberg (1995). For this correction method, we set the chance of making a false discovery at $Q = .05$ and adjusted corresponding p values for correlation coefficients according to the formula $p_{\text{adjusted}} = p_{\text{unadjusted}}\, c / k$, where c represents the number of comparisons, and k was determined by the rank after sorting original p values by magnitude (see Benjamini & Hochberg, 1995). All significant correlations described below are thus significant after performing this correction unless otherwise specified. All p_{adjusted} statistics described below represent probability levels that have been adjusted, and these values are then compared with $\alpha = .05$. For regression analyses, we employed multiple regressions and mediation analyses using the bootstrapping method outlined by Preacher and Hayes (2008). This method of mediation analysis is preferred over Sobel's test (Sobel, 1982) or the mediation analysis method outlined by Baron and Kenny (1986) in cases of smaller sample sizes such as the current experiment (Fritz & Mackinnon, 2007; Hayes, 2009; MacKinnon, Fairchild, & Fritz, 2007). Furthermore, an assumption of Sobel's test is that the underlying mediation effect is normal, when in fact they are often skewed in reality (Hayes, 2009). Bootstrapping methods, on the other hand, are nonparametric and thus avoid this problem as they do not require an underlying normal distribution to produce an accurate estimate of a mediation effect.

3. Results

3.1. Descriptive statistics

Participants' mean STAI-state score was 28.81 ($SD = 6.51$), mean STAI-trait score was 36.46 ($SD = 7.49$), and mean SIAS score was 17.93 ($SD = 9.75$), which are typical of nonclinical populations and indicate normal levels of anxiety symptoms.

3.2. FTV scores & anxiety

In contrast to our hypothesis, we found that state and trait anxiety did not correlate significantly with greater FTV scores (see Table 1). As hypothesized, though, we found that greater SIAS scores significantly correlated with greater FTV scores (see Fig. 1).

3.3. FTV scores & inhibition

As predicted, poorer inhibition was correlated with greater FTV scores (see Table 1). Specifically, we found that poorer inhibitory performance on the Go/No-Go task was associated with greater FTV scores (see Fig. 2).

Table 1
Pearson r correlation coefficients between FTV scores, inhibition as measured with the Go/No-Go task, and three measures of anxiety (state [STAI-S], trait [STAI-T], and social interaction [SIAS]).

	FTV score	STAI-S	STAI-T	SIAS
STAI-S	.10	–	–	–
STAI-T	.17	.60**	–	–
SIAS	.33*	.55**	.54**	–
Inhibition	−.39**	.02	−.25	−.28

Note. p values have been adjusted for the number of multiple comparisons and then compared to $\alpha = .05$ to determine statistical significance. For all correlations, $df = 46$. STAI is an abbreviation for State-Trait Anxiety Inventory. SIAS is an abbreviation for Social Interaction Anxiety Scale.
* Indicates significance at $\alpha < .05$ level.
** Indicates significance at $\alpha < .01$ level.

3.4. Inhibition & anxiety

We analyzed correlations between inhibition (i.e., response biases from the Go/No-Go task) and anxiety measures. After correcting for multiple comparisons, we found that inhibition did not significantly correlate with any measure of anxiety (see Table 1). Note, however, that anxiety and inhibition were associated in the mediation analyses where multiple comparison corrections were not applied (see below).

3.5. Mediation analysis

We hypothesized that the relationship between anxiety and the facing-the-viewer bias would be mediated by inhibition. As inhibition and social interaction anxiety were both significantly correlated with FTV scores, we performed a mediation analysis to assess whether inhibition was a significant mediating variable between social interaction anxiety and FTV scores (see Table 2 for all regression model statistics). When both SIAS and inhibition were included as predictors in the same model, SIAS scores marginally (but not significantly) predicted FTV scores. Using a bootstrapping approach (i.e., Preacher & Hayes, 2008), we found that the indirect effect of SIAS scores on FTV scores through the mediator (inhibition) was not zero, as the 95% confidence interval based on 5000 bootstrap iterations ranged from 0.0001–0.0076. This finding is evidence of significant mediation (see Fig. 3). While there is much debate about how to determine effect sizes using this type of bootstrapping approach (see Preacher & Kelley, 2011), all techniques would agree that this is a relatively small but significant effect.

Table 2
Regression statistics for mediation analyses examining inhibition as a potential mediator between social interaction anxiety and the facing-the-viewer bias.

Model	Criterion variable	F	R^2	p	Variables inmodel	β	t	p
1	*FTV scores*	5.50	.11	.023*				
					SIAS	.33	2.34	.023*
2	*Inhibition*	4.04	.08	.050*				
					SIAS	−.28	−2.01	.050*
3	*FTV scores*	5.80	.20	.006**				
					SIAS	.23	1.69	.099
					Inhibition	−.33	−2.36	.023*

Note: FTV is abbreviated for facing-the-viewer. SIAS is an abbreviation for Social Interaction Anxiety Scale.
* Indicates significance at $\alpha < .05$ level.
** Indicates significance at $\alpha < .01$ level.

4. Discussion

The purpose of this study was to assess the relationship between social interaction anxiety, inhibition, and the facing-the-viewer bias. We had three main hypotheses: 1) greater social interaction anxiety would be associated with greater facing-the-viewer biases; 2) weaker inhibitory performance on the Go/No-Go task would be associated with greater facing-the-viewer biases; and 3) inhibitory performance would significantly mediate the relationship between social interaction anxiety and facing-the-viewer biases. We found support for all of these hypotheses.

First, our findings replicate the previous observation that individuals with greater social interaction anxiety have greater facing-the-viewer biases (Heenan & Troje, 2014; Heenan et al., 2012), and provides further support to the sociobiological theory of the facing-the-viewer bias as

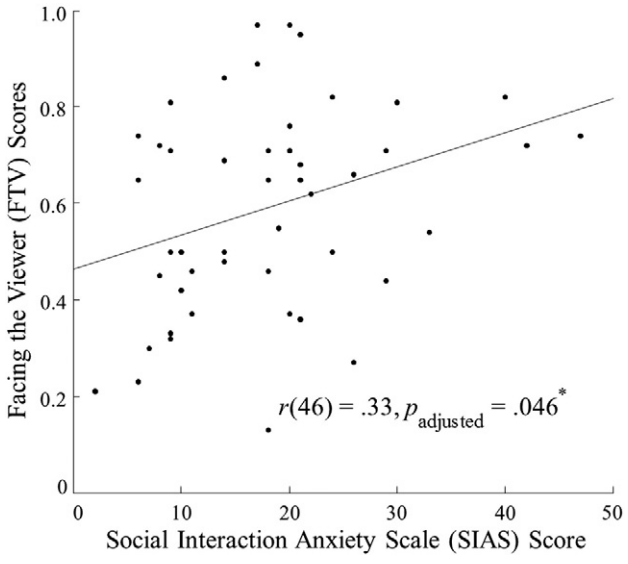

Fig. 2. Scatterplot displaying Pearson's r correlations between facing-the-viewer (FTV) scores and participants' scores on the Social Interaction Anxiety Scale (SIAS). Participants who had greater SIAS scores tended to also have greater FTV scores. Note that p values have been adjusted for the number of multiple comparisons and then compared to $\alpha = .05$ to determine statistical significance. *Indicates significance at $\alpha < .05$ level, ** indicates significance at $\alpha < .01$ level.

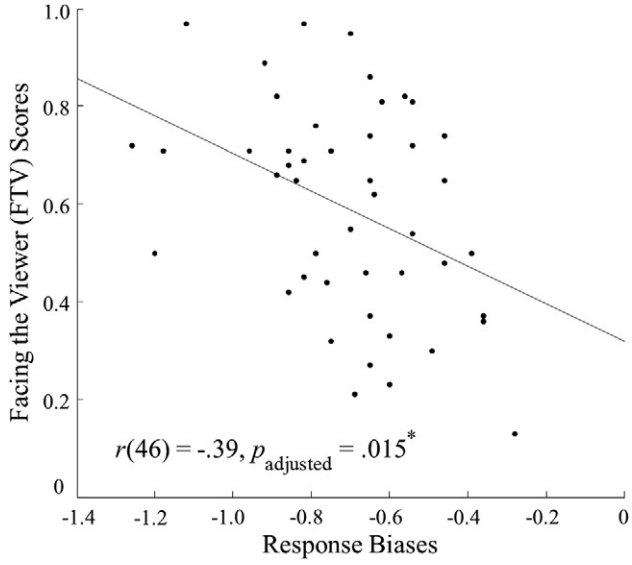

Fig. 3. Scatterplot displaying Pearson's r correlations between facing-the-viewer (FTV) scores and participants' response biases (i.e., inhibition) on the Go/No-Go task. Greater FTV scores indicate greater facing-the-viewer biases, while greater response biases indicate better inhibitory performance on the Go/No-Go task. Participants who had lower response biases (i.e., poorer inhibition) tended to also have greater FTV scores. Note that p values have been adjusted for the number of multiple comparisons and then compared to $\alpha = .05$ to determine statistical significance. *Indicates significance at $\alpha < .05$ level, ** indicates significance at $\alpha < .01$ level.

first suggested by Vanrie et al. (2004). Our findings are at odds, however, with the previous observation that a group of individuals with high social anxiety scores had weaker facing-the-viewer biases than those in a low social anxiety group (Van de Cruys et al., 2013). Note, however, that Van de Cruys et al. assessed social anxiety using the LSAS (Liebowitz, 1987), while we assessed social interaction anxiety using the SIAS. Although previous researchers have found that the LSAS is significantly correlated with the SIAS scale ($r = .72$, Fresco et al., 2001), the LSAS assesses a broader range of social anxiety facets (e.g., avoidance of social interaction) than the SIAS. One possibility, then, for why we found *greater* facing-the-viewer biases in socially anxious individuals but Van de Cruys et al. found *weaker* facing-the-viewer biases, is that the facing-the-viewer bias is sensitive to the facet of avoidance of social situations that is measured by the LSAS only. In addition though, we did not observe any relationship between state or trait anxiety and the facing-the-viewer bias. This finding is in line with previous observations (Heenan & Troje, 2014) but runs counter to our argument that the threat bias is associated with greater facing-the-viewer biases. The relationship between the facing-the-viewer bias, state anxiety, trait anxiety, and avoidance will have to be explored by future experiments using greater sample sizes.

Second, we found support for our hypothesis that weaker inhibition would be associated with greater facing-the-viewer biases. Here, we reasoned that more anxious individuals would have poorer inhibitory control in general and that this would be associated with a greater perceptual bias towards the facing-towards percept of the figure (i.e., the threat bias). Our finding that greater inhibitory ability significantly predicted greater social interaction anxiety in our regression analysis (Table 2) supports the previous findings that more anxious individuals display poorer inhibitory performance generally (Chamberlain et al., 2005; Enright & Beech, 1993; Swick et al., 2012) and is in line with the predictions of attentional control theory (Eysenck & Derakshan, 2011; Eysenck et al., 2007). Note that while we did not observe a significant zero-order correlation between inhibitory ability and social interaction anxiety (see Table 1), we did see a significant association between the two using simple regression (see Fig. 4). This discrepancy is accounted for by the conservative correction for multiple comparisons that we employed on all zero-order correlations.

Third, we found evidence that inhibition was indeed a significant mediator between social interaction anxiety and facing-the-viewer biases. We had originally hypothesized this based on the previous observations that more anxious individuals have greater perceptual reversal rates for ambiguous visual stimuli (Anderson et al., 2013; Li et al., 2000; Meldman, 1965; Meredith, 1967; Nagamine et al., 2007) and that more anxious people have difficulty with inhibitory control (Eysenck & Derakshan, 2011; Eysenck et al., 2007). Here, our rationale was that more socially anxious people would have difficulty inhibiting the more threatening (i.e., facing-towards) percept of depth-ambiguous biological stimuli. Fox (1994) found, for instance, that more anxious individuals have difficulty inhibiting threatening visual distractors. We found support for this hypothesis, as inhibitory ability was a significant, partial mediator between social interaction anxiety and the facing-the-viewer bias. To our knowledge, this is the first time that inhibitory ability has been found to be linked with the facing-the-viewer bias.

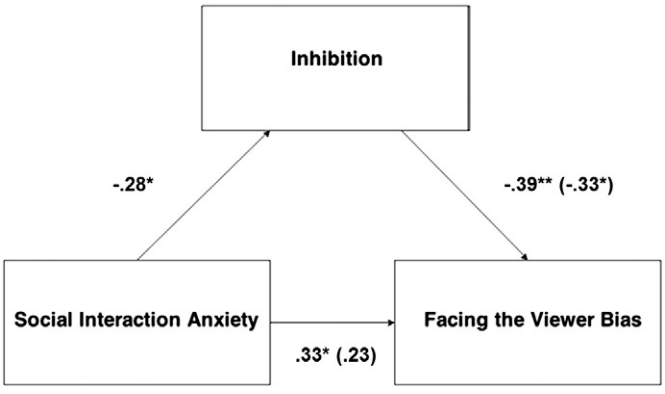

Fig. 4. Model and standardized regression coefficients for the relationship between social interaction anxiety (independent variable) and the facing-the-viewer bias (dependent variable) as mediated by inhibition (mediating variable). The standardized regression coefficient when controlling for either inhibition or social interaction anxiety is in parentheses. *Indicates significance at $\alpha < .05$ level, ** indicates significance at $\alpha < .01$ level.

The results of this study are important because they provide support for a key theoretical model in understanding the threat bias in anxious individuals. It has been argued that inhibition, as well as other executive functioning tasks that require attention (e.g., attentional switching), may play a key role in the threat bias (Fox, 1994; Fox et al., 2002). We found support for this model, as we found that inhibition was a significant mediator between social interaction anxiety and facing-the-viewer biases. It is important to note, however, that not all anxious individuals have problems with inhibition. For example, while individuals with greater anxiety do show poorer inhibitory ability at times, anxious individuals who also excel at attentional control tend to not display these impairments in inhibition (Derryberry & Reed, 2002). The relationship between anxiety, inhibition, and the perception of threatening stimuli is thus complicated by another variable, attentional control, which will have to be considered in future studies.

Despite the fact that our results support the sociobiological account of the facing-the-viewer bias, there are clearly other factors that affect it. For example, bottom-up factors such as the kinematics and structure of biological motion stimuli significantly contribute to the facing-the-viewer bias (Schouten et al., 2011). In fact, these findings shed doubt on the significance of previous findings that the gender of point-light figures affects the facing-the-viewer bias. Other factors, such as the concavity and convexity of the angles of the limbs (Weech et al., 2014) and familiarity with point-light stimuli (Troje & Davis, 2011) also surely play a role in this bias. Given the support found for both these bottom-up and top-down processes, it appears likely that the facing-the-viewer bias results from a complex interplay between several mechanisms. We do not seek to argue here that the sociobiological theory of the facing-the-viewer bias is the only driving force behind this bias. Instead, we reason that anxiety, inhibition, and the facing-the-viewer bias interact via a complex interplay of top-down (anxiety, previous experiences) and bottom-up processes (attentional resources available for inhibiting percepts, low-level perceptual biases).

More generally, the results of our study provide further evidence that anxious individuals perceive biological motion stimuli differently (Jung et al., 2009; Van de Cruys et al., 2013). For example, using fMRI, researchers have found that individuals with obsessive–compulsive disorder (an anxiety disorder characterized by serious anxiety and difficulty inhibiting thoughts) differ from healthy controls in terms of the brain areas they recruit while observing biological motion (Jung et al., 2009). Other researchers have found that individuals with obsessive–compulsive disorder perform poorer than healthy controls on biological motion perception tasks, but not on other non-biological motion perceptual tasks (Kim et al., 2008). Our study is the first to demonstrate that inhibitory ability may mediate the relationship between anxiety and the perception of biological motion stimuli, thus providing a rationale for the recruitment of other brain regions by more anxious populations.

5. Conclusion

While bottom-up factors surely contribute (e.g., Schouten et al., 2011; Weech et al., 2014) our findings support that top-down influences like the sociobiological relevance of biological motion stimuli affect the facing-the-viewer bias. We found support that social interaction anxiety was positively associated with FTV scores, inhibitory performance was negatively associated with FTV scores, and inhibitory

performance mediated the observed relationship between anxiety and FTV scores. For ambiguous visual stimuli, these findings support the theory that the threat bias in anxiety may be mediated by the fact that anxious individuals have difficulty inhibiting the more threatening percept. While the results of our study support our hypotheses, the correlational design we employed limits our ability to infer causality between social interaction anxiety, inhibition, and the facing-the-viewer bias. To this end, future studies would ideally make use of other research designs (e.g., within-subject, between-subject, or mixed designs) to better understand the nature of these relationships.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.actpsy.2015.02.012.

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