EFFECTS OF ANXIETY ON PERCEPTUAL BIASES FOR AMBIGUOUS BIOLOGICAL MOTION STIMULI

by

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A thesis submitted to the Department of Psychology in conformity with the requirements for the degree of Doctor of Philosophy

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Abstract

Biological motion stimuli, depicted as orthographically projected point-light or stick-figure walkers, do not contain any information about their orientation in depth. The projections of such stimuli, therefore, provide the same visual information when oriented towards the viewer as when oriented away. Even though this is the case, naïve observers display a bias to perceive the facing-towards percept more often. Some researchers have speculated that this facing-the-viewer bias may exist for sociobiological reasons. That is, mistaking another human as retreating when they are actually approaching could potentially have more severe consequences than the opposite error. This theory implies that the facing-towards percept of a biological motion stimulus is potentially more threatening. Measures of anxiety and the facing-the-viewer bias should therefore be related, as researchers have consistently found that anxious individuals display an attentional bias towards more threatening stimuli. In our first experiment, we demonstrated that individuals with greater anxiety do indeed have greater facing-the-viewer biases, and that this relationship is mediated by inhibitory ability (Chapter 2). As our first experiment was correlational in nature, we next used a between-subjects design. We showed that physical exercise, which is known to reduce anxiety, also reduces the facing-the-viewer bias for full stick figure walkers, but not for bottom- or top-half-only stimuli (Chapter 3). In our final experiment, we manipulated anxiety more directly using progressive muscle relaxation and an anxiety induction task (Chapter 4). In the latter experiment, we found that relaxation had the same effect on facing-the-viewer biases that physical exercise had, while our anxiety induction task did not affect biases significantly. In Chapter 6, we discuss the importance of these findings in the context of understanding how anxiety affects our perception of our external environment.
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Co-Authorship

I. Co-Authorship Declaration

In all cases, the data analysis, interpretation, and manuscript preparation were performed by the author. All experiments were conducted by both the author and research assistants. All experiments were designed by the author and the co-author (see Appendix A).

II. Declaration of Previous Publication

This manuscript includes three original papers, some of which have been published in peer-reviewed journals.

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Chapter 1

General Introduction

1.1 Perceiving biological motion perception

The human visual system is remarkably adept at detecting and processing the movement of other living things (Cutting & Kozlowski, 1977; Johansson, 1973). It does so quickly, and helps us extract a wealth of information with seemingly little effort. This ability, called biological motion perception, continues to be widely studied in the vision literature.

Gunnar Johansson (1973) was the first to study biological motion perception using stimuli specifically designed for this purpose. These stimuli, known as point-light displays, are three-dimensional figures comprised of dots (marking the major joints of the body) that are projected orthographically on a two-dimensional plane. Since their inception over 40 years ago, these stimuli have gone on to enjoy huge popularity in the vision literature because of the vast amount of information that can be extracted from so few points of light. For instance, naïve observers can accurately identify the gender of point-light stimuli (Kozlowski & Cutting, 1977; Pollick, Kay, Heim, & Stringer, 2005; Troje, 2002), make accurate estimates of an individual’s mood (Michalak et al., 2009), or accurately judge emotions like anger or joy (Atkinson, Dittrich, Gemmell, & Young, 2004; Dittrich, Troscianko, Lea, & Morgan, 1996).

1.2 Point-light displays and ambiguous visual perception

If an object’s two-dimensional projection does not provide cues about how its parts are arranged in depth (e.g., by means of occlusion or perspective), multiple interpretations are possible. Even if recognition of the object or the object’s properties excludes most of these interpretations, the naïve observer is still left to choose between two interpretations that are
identical except for a mirror flip about the image plane. Examples of these objects, known as ambiguous figures, belong to a class of stimuli known as multistable visual phenomena (Leopold & Logothetis, 1999). One classic example of such a figure is the Necker cube (see Figure 1.1), which has two possible interpretations (Kornmeier, Hein, & Bach, 2009; Orbach, Ehrlich, & Heath, 1963).

![Necker cube](image.png)

*Figure 1.1.* A Necker cube on the left, with both possible percepts displayed unambiguously on the right. Observers of the Necker cube may experience perceptual reversals between these two possible percepts, as both are equally plausible.

Similar to a Necker cube, many orthographically projected biological motion stimuli provide observers with more than one viable percept. Examples of such figures include point-light displays, stick-figure walkers (i.e., dynamic point-light displays presented walking), or silhouettes. Studying multistable visual phenomena can provide insight into how we perceive stable interpretations of the external world. The human visual system is tasked with continuously reorganizing and disambiguating the visual environment around us and it does this massive
undertaking with very few errors (Leopold & Logothetis, 1999). Both higher-order (e.g., anxiety; Meredith, 1967) and lower-order (e.g., viewing angle; Troje & McAdam, 2010) neural areas contribute to this process of disambiguation, ensuring that although multiple interpretations of the world are possible, we only experience one at any given time.

To date, the neural processes that underlie multistable perception remain unclear (Leopold & Logothetis, 1999). While some researchers argue that perceptual reversals occur as a result of competition between two (or more) central neural representations for a given ambiguous figure (Logothetis, 1998), others have speculated that interhemispheric switching may modulate reversals between percepts (Miller et al., 2000, 2003; Pettigrew & Miller, 1998). To date, there is still no consensus on what is occurring within the brain during multistable perception. Research on ambiguous figures is still needed in order to answer these questions.

Regardless of the neural substrate(s) responsible for perceptual alternations, observing the durations that individuals spend perceiving the different percepts of an ambiguous visual stimulus allows for the quantification of perceptual biases (e.g., Gray, Adams, & Garner, 2009; Vanrie, Dekeyser, & Verfaillie, 2004). Assessing perceptual biases can be invaluable in understanding the human visual system. For example, if a point-light display or silhouette is viewed from a camera angle that is above the horizontal plane, the percept that is observed is identical to the one that would be perceived had the figure been viewed from the same angle below the horizontal plane (Troje & McAdam, 2010). When Troje and McAdam asked participants to view depth-ambiguous biological motion stimuli from different viewing angles, however, they found that participants were biased to perceive these stimuli as if viewing them from above more often than below. This ‘viewing-from-above’ bias has been reported for other objects as well and is thought to exist because we are making assumptions based on our prior
experiences. That is, since we have been more likely to view objects from above than from below, we assume that is again the case when faced with visual ambiguity. For instance, it influences the perception of the Necker cube (Orbach et al., 1963), ambiguous line drawings (Mamassian & Landy, 1998), and curved surfaces (Reichel & Todd, 1990).

Orthographically projected point-light stimuli are thus interesting to investigate because they are both 1) socially relevant and 2) visually ambiguous (and thus can be used to measure perceptual biases).

1.3 The facing-the-viewer bias

With point-light stimuli, just as the image can flip about the horizontal viewing plane (i.e., viewing-from-above vs. viewing-from-below), the image can flip about the vertical viewing plane (i.e., facing-the-viewer vs. facing away). That is, the fronto-parallel projection of a depth-ambiguous biological motion stimulus displayed facing the viewer is the same as its projection when facing away (see Figure 1.2). Naïve observers, however, display a bias to perceive these stimuli as facing towards them more often than facing away, even though the information contained in these images supports both percepts equally. This ‘facing-the-viewer’ bias has been found repeatedly (Brooks et al., 2008; Schouten, Troje, Brooks, Van Der Zwan, & Verfaillie, 2010; Schouten, Troje, & Verfaillie, 2011; Schouten & Verfaillie, 2010; Vanrie et al., 2004; Vanrie & Verfaillie, 2006) and appears to be affected by both bottom-up (e.g., kinematic and structural motion; Schouten et al., 2011) and top-down processes (e.g., gender of point-light display; Vanrie et al., 2004).
Figure 1.2. 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.

The first researchers to identify the facing-the-viewer bias for biological motion stimuli were Vanrie et al. (2004). They found that when they asked participants to view a series of male point-light walkers and to report which direction they perceived each walker to be oriented in, participants were significantly more likely to perceive point-light walkers as facing towards them. In fact, this was true for both walkers displayed walking forwards and those displayed walking backwards. Based on this latter finding, Vanrie et al. argued that the facing-the-viewer bias is indeed sensitive to a figure’s facing orientation, not to whether its movement suggests that it is approaching or receding. In addition, however, Vanrie et al. found that inverted point-light displays, projected straight on, did not elicit significant facing-the-viewer biases. In previous
studies, it has been shown that participants do not easily identify inverted point-light walkers as “human”, as they readily do with typical walkers (Pavlova & Sokolov, 2000; Sumi, 1984; Troje & Westhoff, 2006). Similarly, researchers have found that the usual wealth of information that point-light displays can provide (e.g., ability to identify emotions portrayed by point-light display) is not processed as efficiently when these stimuli are inverted (Dittrich et al., 1996; Dittrich, 1993). Given that the facing-the-viewer bias appears to be elicited by human-like figures but not by inverted ones, Vanrie et al. (2004) speculated that the facing-the-viewer bias may have sociobiological relevance.

1.4 Testing the sociobiological theory of the facing-the-viewer bias

The sociobiological theory of the facing-the-viewer bias maintains that having this bias is advantageous in terms of survival. That is, misinterpreting an approaching person as receding could potentially result in more severe consequences than the opposite error. Brooks et al. (2008) examined the sociobiological theory of the facing-the-viewer bias by systematically altering the gender of point-light walkers in order to observe effects on perceived walker orientations. These researchers found that while male walkers elicited facing-the-viewer biases, observers tended to perceive female walkers more often as facing away. Walkers of neutral gender elicited facing-the-viewer biases, but the magnitude of these biases were not nearly as pronounced as those elicited by male walkers.

Schouten et al. (2010), however, found that the degree of effect that was found by Brooks et al. (2008) was not replicable with naïve participants. Note that the Brooks study was based upon observing five participants and all but one of which was experienced at performing psychophysical tasks. This is a potential confound, as Troje and Davis (2011) found that facing-the-viewer biases increased along with experience with biological motion tasks. They argued that
the facing-the-viewer bias might form upon initial stimulus viewing and then strengthen with repeated viewings in the absence of any external ‘reality’ check since both the facing-towards and facing-away percepts of a point-light display are equally valid.

Even though Schouten et al. (2010) did not find a gender effect that was as strong as reported previously (i.e., Brooks et al., 2008), they did confirm that male walkers tended to elicit stronger facing-the-viewer biases than female walkers, while female walkers tended to elicit a facing away interpretation. Additionally, Schouten et al. found a significant interaction between observer gender and stimulus gender, such that male observers tended to have stronger facing-the-viewer biases in response to male walkers compared to female observers. They argued that their findings provide further evidence in support of the sociobiological theory of the facing-the-viewer bias. That is, they reasoned that this misinterpreting an approaching female walker would be less dangerous than misinterpreting an approaching male and so it makes sense that facing-the-viewer biases would be stronger for male walkers. They also speculate that facing-the-viewer biases are stronger in men when viewing male walkers because, in terms of evolution, men would historically be more likely to fight an approaching man than a woman.

1.5 Top-down vs. bottom-up contributions to the facing-the-viewer bias

Researchers interested in the facing-the-viewer bias have attempted to examine how both top-down and bottom-up processes contribute to it. For instance, Vanrie and Verfaillie (2006) performed a series of experiments designed to assess whether point-light displays that depicted different actions would elicit facing-the-viewer biases of different magnitude. They found that point-light figures that were displayed either biking or rowing elicited significant facing-the-viewer biases, while those that were displayed either jumping on the spot or saluting did not. One explanation for this might be that facing-the-viewer biases were only elicited when dynamic
point-light displays are performing an action that would result in directional movement (i.e., as opposed to jumping or saluting in which the person would not be moving from where they stood). In support of this, Vanrie and Verfaillie (2008) found that point-light displays that were presented walking elicited significant facing-the-viewer biases, while those that were presented jumping on the spot did not.

Another explanation of Vanrie and Verfaillie's (2006) findings, however, might be that there were specific low-level features inherent in the biking and rowing stimuli that elicited strong facing-the-viewer biases. For example, Weech and Troje (2013) found that the convexity and concavity represented in the positioning of the lower or upper limbs can significantly affect the facing-the-viewer bias. They argued that the facing-the-viewer bias must be sensitive to lower level stimulus features such as convexity and concavity, which our visual system already has prior assumptions about (i.e., we are biased to perceive convexity rather than concavity when surface normals are ambiguous). According to Weech and Troje, the upper half of a human biological motion figure in fronto-parallel projection elicits a facing away bias because we assume that we look onto the bended elbows from their convex side. Likewise, the lower part elicits a facing-towards percept because we assume that we are looking at the knees from their convex side.

Besides the convexity/concavity of the limbs, there are additional bottom-up processes that have been shown to play a role in disambiguating ambiguous biological motion stimuli. For example, the facing-the-viewer bias is sensitive to the kinematics and structure of biological motion stimuli (Schouten, Troje, & Verfaillie, 2011). There is also evidence that pairing looming or receding walking sounds with ambiguous point-light walkers also affects the facing-the-viewer bias, with looming sounds eliciting stronger facing-the-viewer biases and receding sounds
being associated with perceiving walkers more often as facing away (Schouten, Troje, Vroomen, & Verfaillie, 2011).

Given the support found for both bottom-up and top-down processes, it is clear that top-down processes, like the social relevance of a given point-light figure, do not account for all of the variance in perceived orientation. Alternatively, it appears likely that the facing-the-viewer bias results from a complex interplay between both top-down and bottom-up processes. This dissertation, however, will be mainly concerned with the top-down processes related to higher-order stimulus features of point-light figures, and how these related to the facing-the-viewer bias.

Top-down influences act upon our perceptual system and can come in a variety of forms. As our brain retrieves sensory information, it generates hypotheses about objects in our external environment and this identification process is guided in part by interoceptive, affective information (Barrett & Bar, 2009). People’s perception of their environment is thus affected by their preferences, such that their own biases will affect how they categorize and represent their external world (Balcetis & Dunning, 2006, 2007; Dunning & Balcetis, 2013). For instance, researchers have found that people are biased to perceived desirable objects as physically closer (Balcetis & Dunning, 2010) or physically larger in size (van Koningsbruggen, Stroebe, & Aarts, 2011). It has also been shown that observers can be biased to perceive a given percept of an ambiguous figure by previously associating that percept with reward (Balcetis & Dunning, 2006; Beard & Amir, 2008).

Perceptual biases can also cause changes in behaviour. Balcetis and Dunning (2010), for example, found that not only did participants think that a $100 bill some distance away (that they could win) was closer than an identical bill located at the same distance (that they thought belonged to the experimenter), but they also acted as if the money was closer. These researchers
found that participants were significantly more likely to overshoot the $100 bill when asked to try to throw a small object at it than they were when throwing at the experimenter’s $100 bill. Dunning and Balcetis (2013) argue that this perceptual bias might exist in order to facilitate or increase approach behaviours towards desirable objects.

1.6 The threat bias in anxious individuals

There is a wealth of evidence that both highly anxious nonclinical populations, as well as 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 et al., 2009; Mogg, Bradley, de Bono, & Painter, 1997; Mogg & Bradley, 2005; Singer, Eapen, Grillon, Ungerleider, & Hendler, 2012). 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 (Gray et al., 2009; Singer et al., 2012).

This threat bias appears to be specific to anxiety itself, as it is not related to symptoms of depression (MacLeod et al., 1986) and has even been found to diminish after successful treatment of anxiety (El Khoury-Malhame Myriam et al., 2011). A meta-analysis of 112 studies
of the threat bias in anxious individuals reported an effect size of $d = 0.45$, with more anxious people consistently displaying an attentional bias towards threatening stimuli (Bar-Haim et al., 2007). They also did not find any difference in effect sizes between those with clinical anxiety disorders and those with high, but not pathological, levels of anxiety; nor were there any differences among different anxiety disorder populations (e.g., obsessive-compulsive disorder, generalized anxiety disorder). Moreover, this meta-analysis ruled out the effects of comorbid mood disorders as potential confounds.

Because more anxious individuals tend to perceive their world as more threatening, some have argued that this threat bias may contribute to and maintain anxiety disorders by biasing their attention towards stimuli that in turn evoke more anxiety in a form of feed-forward loop (Clark & Wells, 1995; Heeren, Peschar, & Philippot, 2011; MacLeod et al., 1986; Musa & Lépine, 2000). For example, it has been argued that individuals with social phobia, which is characterized by marked anxiety in response to social situations, are biased to perceive the actions of others more negatively during social situations (Clark & Wells, 1995; Rapee & Heimberg, 1997). This, in turn, causes people with social phobia to feel more anxious and more likely to avoid similar situations in the future. Furthermore, this process is exacerbated by the fact that social situations are full of ambiguity and thus provide many instances whereby the threat bias can be evoked.

1.7 Anxiety and the facing-the-viewer bias

Implicit in the sociobiological hypothesis of the facing-the-viewer bias is that the facing-towards percept of a biological motion stimulus is potentially more threatening than the facing-away percept. Indeed, there is some evidence that people perceive it as such, as observers tend to
perceive male point-light stimuli as facing towards them more often than female stimuli (Brooks et al., 2008; Schouten et al., 2010).

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. That is, since more anxious individuals tend to interpret ambiguous visual stimuli as more threatening (i.e., the threat bias), one would hypothesize that more anxious individuals would have greater facing-the-viewer biases. To date, however, there have been conflicting findings. For example, using the Experiences in Close Relationships Scale (Brennan, Clark, & Shaver, 1998), Heenan et al. (2012) found that greater attachment anxiety significantly correlated with greater facing-the-viewer biases. 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, using Liebowitz Social Anxiety Scale (LSAS; Liebowitz, 1987). The purpose of this dissertation will be to further assess the relationship between anxiety and the facing-the-viewer bias.

1.8 Understanding the link between the facing-the-viewer bias and anxiety

To date, there is evidence that perceptual biases function either by allocating attentional resources to processing a previously rewarded, desirable percept (Balcetis, Dunning, & Granot, 2012; Dunning & Balcetis, 2013) or by inhibiting a previously punished, aversive percept from conscious awareness (Voss, Rothermund, & Brandstädter, 2008). In Chapter 2, we examined whether inhibitory ability (as measured with a Go/No-Go task) would mediate the relationship between anxiety and the facing-the-viewer bias. Our findings in Chapter 2 replicated the previous observation made in our laboratory that anxiety and facing-the-viewer biases are
positively correlated (Heenan et al., 2012), and confirmed our hypothesis that inhibition mediates the relationship between anxiety and this perceptual bias.

The findings in Chapter 2 were important, but like our previous investigations of the facing-the-viewer bias (i.e., Heenan et al., 2012), they were correlational in nature. We thus set out to conduct a between-subjects experiment. In Chapter 3, we investigated the effects of physical exercise on the facing-the-viewer bias. Our motivation for this study was that physical exercise is known to indirectly reduce anxiety (Bahrke & Morgan, 1978; Salmon, 2001; Wipfli, Rethorst, & Landers, 2008), and we hypothesized that exercise would reduce the facing-the-viewer bias. We also had participants observe full stick figure walkers, bottom-half-only stimuli, and top-half-only stimuli. We argued that any effect of exercise on the facing-the-viewer bias should be present only for full stick figure walkers, which should hold more social relevance than either bottom- or top-half-only stimuli. As we hypothesized, physical exercise reduced the facing-the-viewer bias, and did so only for full stick figure walkers.

In Chapter 4, we replicated the study described in Chapter 3 exactly, except for the substitution of an anxiety induction/reduction task instead of physical exercise. We hypothesized that anxiety induction (via a stressful imagery writing task) would increase facing-the-viewer biases, while progressive muscle relaxation would reduce them. Again, we hypothesized that these effects would only hold true for full stick figure walkers, and not affect facing-the-viewer biases for bottom- or top-half-only stimuli. As we predicted, participants who performed progressive muscle relaxation had significantly lower facing-the-viewer biases for full stick figure walkers than those in a control group. The anxiety induction task, however, failed to significantly affect biases.
In Chapters 3 and 4, we provided evidence that both physical exercise and progressive muscle relaxation reduce the facing-the-viewer bias for stick figure walkers. We make the argument that greater facing-the-viewer biases are indicative of increased propensity to perceive threat in situations of visual ambiguity (i.e., the threat bias). Our findings suggest that both physical exercise and progressive muscle relaxation lead people to experience their external world as less threatening, thus providing another potential mechanism for their anxiolytic benefits.
Chapter 2

Anxiety, Inhibition, and the Facing-the-viewer Bias

2.1 Introduction

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 (Anderson et al., 2013; Li et al., 2000; Meldman, 1965; Meredith, 1967; Nagamine et al., 2007). 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 threatening 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, Santos, & Calvo, 2007; Eysenck & Derakshan, 2011), 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 task-irrelevant information (i.e.,
distractions), because they are less able to exert top-down attentional control to prevent bottom-up attentional resources from being used.

Attentional control theory might help make sense of the literature on anxiety and the perception of ambiguous visual stimuli, as it is possible that anxiety affects perceptual biases by making it more difficult to inhibit, or ‘suppress’ percepts. 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 and thus they 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 difficulty inhibiting the more threatening percept. This hypothesis is in line with the findings of Fox (1994) who reported that highly anxious people had more 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).

2.2 Experiment 1

No experiment, to date, has examined concurrent inhibitory ability in the context of the relationship between anxiety and the facing-the-viewer bias. While one previous study reported that facing-the-viewer biases correlated positively with anxiety (Heenan et al., 2012), another study reported a negative correlation (Van de Cruys et al., 2013). With this in mind, the goals of the present study were to investigate 1) whether anxiety and facing-the-viewer biases are correlated, and 2) whether this relationship is mediated by inhibition. We assessed three types of anxiety (state, trait, and social interaction), and predicted that the relationship between anxiety
and facing-the-viewer biases would be strongest for social interaction anxiety given the social relevance of biological motion stimuli. 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 had three main hypotheses: 1) greater 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 be a significant mediator between anxiety and facing-the-viewer biases.

2.3 Methods

2.3.1 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, $SD = 1.18$). 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 the 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 $> 3$). Therefore, all statistical analyses were conducted on the remaining 48 participants (35 women, 13 men), ranging in age from 17 – 22 ($M_{age} = 18.90$ years, $SD_{age} = 1.19$). There were no significant differences between men and women in terms of Go/No-Go task performance, perceptual bias measures, or anxiety scores.
2.3.2 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 State-Trait Anxiety Inventory (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 Social Interaction Anxiety Scale (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).

2.3.2 Stimuli and Apparatus

2.3.2.1 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.

2.3.2.2 Perceptual Task

Stick figure walkers were based on biological motion point-light walkers (Troje, 2002, 2008), consisting of 15 white dots (depicting the centre of major body landmarks) with connecting lines presented on a black background. Each walker was 9.5 cm high, subtending a visual angle of 6° for the observer, and was displayed walking on the spot. Each walker was displayed rotating counterclockwise at a speed of 25°/s. The veridical rotation direction of each walker was never changed, though participants could still perceive the stimulus to rotate either clockwise or counterclockwise because of the depth-ambiguous nature of these stimuli.

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 of 5 times per min (i.e., an average of every 12 s).

2.3.3 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. The walker remained until the end of the block. Participants completed 2 blocks, separated by a 1 min rest period, during which the screen was blanked.

2.3.4 Procedure

Upon arriving at the lab, each participant provided verbal and written informed consent before completing the STAI, SIAS, and demographic questionnaires (age, gender, and questions regarding exclusion criteria). 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., Go/No-Go task, perceptual task). For each task, the experimenter read standardized instructions, but was then permitted to paraphrase the instructions if additional information was requested.

We designed and ran the Go/No-Go task using MATLAB (The MathWorks Inc., US: Massachusetts) and the Psychophysics Toolbox (Brainard, 1997). 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. Targets (the letter ‘X’) and nontargets (all other letters) were presented individually for 375 ms with a 500 ms interstimulus interval. The experimenter instructed participants to respond to stimuli as fast as possible. The task took approximately 5 min to complete.
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). 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 (Jackson, Cummins, & Brady, 2008). 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 minutes. 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, and no participants failed to meet this requirement. 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 a stick figure walker rather than a 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.

2.3.5 Data Analyses

The main dependent variable for the Go/No-Task task was participants’ response bias [i.e., \(-0.5(\text{hit rate} + \text{false alarm rate})\)]. This variable will henceforth be referred to simply as
inhibition, with greater values representing better inhibition and lower values representing poorer inhibition.

For the perceptual task, participants’ responses were analyzed in order to assess how many times participants perceived the stick figure walker to be facing away and ‘flip’ towards them and how many times the stick figure walker was facing towards them and they perceived it to ‘flip’ away. From these data, we could compute participants’ ratio of flips away vs. flips towards (i.e., the number of flips towards, divided by the total number of flips). For the resulting ratio, greater values indicated a greater propensity to perceive the stick figure walker flip towards the observer, and thus a stronger facing-the-viewer bias. We then computed an average of these ratios across blocks and this average ratio will henceforth be referred to as participants’ FTV score.

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 & 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 $p_{\text{adjusted}} = \frac{c}{k}(p_{\text{unadjusted}})$, where $c$ represents the number of comparisons, and $k$ was determined by the rank after sorting original $p$ values by magnitude (see Benjamini & Hochberg). All significant correlations described below are thus significant after performing this correction unless otherwise specified. All $p_{\text{adjusted}}$ 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 the Sobel’s test (Sobel, 1982) or the mediation
analysis method outlined by (Baron & 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 the 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 non-parametric and thus avoid this problem as they do not require an underlying normal distribution to produce an accurate estimate of a mediation effect.

### 2.4 Results

#### 2.4.1 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.

#### 2.4.2 FTV Scores & Anxiety

As hypothesized, we found that anxiety and FTV scores were positively correlated (see Table 2.1). Specifically, although state and trait anxiety did not correlate significantly with greater FTV scores, greater SIAS scores did (see Figure 2.1). We performed an exploratory correlational analysis between SIAS scores and the number of perceptual reversals recorded during the stick figure task. Two additional participants (both male) were omitted from these analyses as they were considered statistical outliers (i.e., with the criterion of $z$-score > 3) in terms of their number of facing-towards reversals. After adjusting for multiple comparisons, we found that neither the number of facing-towards, $r(44) = -.27, p_{\text{adjusted}} = .145$, nor facing-away reversals, $r(44) = .24, p_{\text{adjusted}} = .186$, correlated significantly with SIAS scores.
Figure 2.1. 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 compared to $\alpha = .05$ to determine statistical significance. * indicates significant at $\alpha < .05$ level, ** indicates significant at $\alpha < .01$ level.
2.4.3 FTV Scores & Inhibition

As predicted, poorer inhibition was correlated with greater FTV scores (see Table 2.1). Specifically, we found that poorer inhibitory performance on the Go/No-Go task was associated with greater FTV scores (see Figure 2.2). We performed an exploratory correlational analysis between response inhibition and the number of perceptual flips recorded during the stick figure task. After adjusting for multiple comparisons, we found that inhibition did not correlate with facing-away reversal frequencies, $r(44) = -.08$, $p_{\text{adjusted}} = .649$, but that the correlation between inhibition and facing-towards reversals approached significance, $r(44) = .35$, $p_{\text{adjusted}} = .057$.

Table 2.1

>Pearson r correlation coefficients among FTV scores, inhibition as measured by the Go/No-Go task, and three measures of anxiety (state, trait, and social interaction).

<table>
<thead>
<tr>
<th></th>
<th>FTV Score</th>
<th>STAI-S</th>
<th>STAI-T</th>
<th>SIAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>STAI-S</td>
<td>.10</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>STAI-T</td>
<td>.17</td>
<td>.60**</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>SIAS</td>
<td>.33*</td>
<td>.55**</td>
<td>.54**</td>
<td>--</td>
</tr>
<tr>
<td>Inhibition</td>
<td>-.39**</td>
<td>.02</td>
<td>-.25</td>
<td>-.28</td>
</tr>
</tbody>
</table>

*indicates significant at $\alpha < .05$ level, **indicates significant at $\alpha < .01$ level.
Figure 2.2. Scatterplot displaying Pearson’s $r$ correlations between facing-the-viewer (FTV) scores and inhibition as measured by the Go/No-Go task. Greater FTV scores indicate greater facing-the-viewer biases, while greater inhibition values indicate better inhibitory performance on the Go/No-Go task. Participants who had 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 significant at $\alpha < .05$ level, ** indicates significant at $\alpha < .01$ level.
2.4.4 Inhibition & Anxiety

We analyzed correlations among inhibition and anxiety measures. After correcting for multiple comparisons, we found that inhibition did not significantly correlate with any measure of anxiety (see Table 2.1).

Table 2.2
Regression statistics for mediation analyses examining inhibition as a potential mediator between social interaction anxiety and the facing-the-viewer bias

<table>
<thead>
<tr>
<th>Model</th>
<th>Criterion Variable</th>
<th>$F$</th>
<th>$R^2$</th>
<th>$p$</th>
<th>Variables in Model</th>
<th>$\beta$</th>
<th>$t$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>FTV Scores</td>
<td>5.50</td>
<td>.11</td>
<td>.023*</td>
<td>SIAS</td>
<td>.33</td>
<td>2.34</td>
<td>.023*</td>
</tr>
<tr>
<td>2</td>
<td>Inhibition</td>
<td>4.04</td>
<td>.08</td>
<td>.050*</td>
<td>SIAS</td>
<td>-.28</td>
<td>-2.01</td>
<td>.050*</td>
</tr>
<tr>
<td>3</td>
<td>FTV Scores</td>
<td>5.80</td>
<td>.20</td>
<td>.006**</td>
<td>SIAS</td>
<td>.23</td>
<td>1.69</td>
<td>.099</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Inhibition</td>
<td>-.33</td>
<td>-2.36</td>
<td>.023*</td>
</tr>
</tbody>
</table>

Note: * indicates significant at $\alpha < .05$ level, ** indicates significant at $\alpha < .01$ level.

2.4.5 Mediation Analysis

We hypothesized that the relationship between anxiety and the facing-the-viewer bias might be mediated by inhibition. As inhibition and anxiety (SIAS scores) were both significantly correlated with FTV scores, we performed a mediation analysis to assess whether inhibition was a significant mediating variable between anxiety and FTV scores (see Table 2.2 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 Figure 2.3).

![Diagram](image)

**Figure 2.3.** 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 significant at $\alpha < .05$ level, ** indicates significant at $\alpha < .01$ level.
2.5 Discussion

The purpose of this study was to assess the relationship among anxiety, inhibition, and the facing-the-viewer bias. We had three main hypotheses: 1) greater 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 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 anxiety have greater facing-the-viewer biases (Heenan et al., 2012), which provides further support to the sociobiological theory of the facing-the-viewer bias (Brooks et al., 2008; Schouten et al., 2010; 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 ($r = .71$, 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, which is measured by the LSAS only. This possibility, however, will have to be explored by future experiments.

Second, we found support for our hypothesis that weaker inhibition would be associated with greater facing-the-viewer biases. Here, we reasoned that individuals with poorer inhibitory
control might have increased perceptual reversals rates because they find it more difficult to inhibit the competing percepts of an ambiguous visual stimulus from entering conscious perception. Furthermore, our finding that greater inhibitory ability significantly predicted greater social interaction anxiety (see Table 2.2) supports the previous findings that more anxious individuals display poorer inhibitory performance (Chamberlain et al., 2005; Enright & Beech, 1993; Swick et al., 2012) and are in line with the predictions of attentional control theory (Eysenck et al., 2007; Eysenck & Derakshan, 2011). Note, however, that despite this significant simple regression, we did not observe significant zero-order correlations between inhibitory ability and any measure of anxiety. 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 et al., 2007; Eysenck & Derakshan, 2011). Here, our rationale was that more 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 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.
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 et al., 2002; Fox, 1994). We found support for this model, as we found that inhibition was a significant mediator between 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 among 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, Troje, & Verfaillie, 2011). Other factors, such as the concavity and convexity of the angles of the limbs (Weech et al., n.d.; Weech & Troje, 2013) 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 both such 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).
Moreover, while we have discussed anxiety in general thus far, it must be pointed out that we only observed significant correlations between social interaction anxiety and the facing-the-viewer bias, and that both state and trait anxiety did not correlate significantly this bias. One possibility is that those who scored high on the SIAS felt considerably more anxious than other participants during the experiment because the study itself involved social interaction with a stranger (i.e., the experimenter). The subsequent positive correlation between SIAS scores and participants’ FTV scores may therefore reflect, at least in part, some of this heightened stress. Alternatively, it may be the case that the facing-the-viewer bias is exclusively related to social interaction anxiety (and also to attachment anxiety, as has been previously reported; Heenan et al., 2012). Thirdly, it may be that state and trait anxiety are indeed related to the facing-the-viewer bias, but that we were unable to verify this in the current experiment due to insufficient statistical power. We will address this issue in more detail in the following chapters.

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.
2.6 Conclusion

While bottom-up factors surely contribute (e.g., Schouten et al., 2011), 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 correlated with FTV scores, that inhibitory performance was negatively correlated with FTV scores, and that inhibitory performance mediated the observed relationship between social interaction anxiety and FTV scores. At least 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 among anxiety, inhibition, and the facing-the-viewer bias. To this end, future studies would ideally make use of between-subjects designs in which anxiety is manipulated (directly or otherwise) in order to examine the causal effects on facing-the-viewer biases.
Chapter 3

Physical Exercise Reduces the Facing-the-viewer Bias

3.1 Introduction

In Experiment 1, as we observed that social anxiety correlated positively with the facing-the-viewer bias. Prior to that experiment, we had observed in our laboratory that greater attachment anxiety correlated significantly with greater facing-the-viewer biases (Heenan et al., 2012). On the other hand, Van de Cruys et al., 2013 found that individuals who scored high on a measure of social anxiety (i.e., more anxious) had weaker facing-the-viewer biases than those who had low scores on the same measure. All of the aforementioned studies, however, were correlational. To date, there have been no studies in which anxiety has been manipulated (directly or otherwise) in order to examine causal effects on facing-the-viewer biases.

One method of indirectly reducing anxiety that has received much support is engaging in physical exercise (Bahrke & Morgan, 1978; Clark, 1986; Petruzzello, Landers, Hatfield, Kubitz, & Salazar, 1991; Salmon, 2001; Stephens, 1988; Wipfli et al., 2008). Even so, the exact mechanisms by which this occurs remain underspecified. One possibility is that exercise provides people with an explanation for their physiological arousal, thus preventing them from attributing heightened arousal as related to external stimulation (Clark, 1986; Salmon, 2001). Such a hypothesis would explain why physical exercise has proven a successful treatment for specific phobias (Driscoll, 1976; Salmon, 2001). Regardless of the underlying mechanism, physical exercise provides a tool by which we can experimentally reduce participants’ anxiety in order to assess any corresponding changes in facing-the-viewer biases.
3.2 Experiment 2

The purpose of Experiment 2 was to investigate the relationship between physical exercise and the facing-the-viewer bias. Participants completed anxiety questionnaires, exercised on a treadmill, and then immediately completed a perceptual task that allowed us to assess their facing-the-viewer bias. In order to reduce response bias, we presented rotating stick figure walkers and deduced perceived facing orientation of walkers in a manner that was similar to how we assessed facing-the-viewer biases in Experiment 1.

We randomly assigned participants to three physical exercise conditions on the treadmill: Standing (0 km/h), walking (4 km/h), or jogging (8 km/h). As anxiety has been found to correlate positively with the facing-the-viewer bias (Heenan et al., 2012) and the anxiolytic benefits of physical exercise have been consistently reported (Bahrke & Morgan, 1978; Clark, 1986; Petruzzello et al., 1991; Salmon, 2001; Stephens, 1988; Wipfli et al., 2008), we hypothesized that facing-the-viewer biases would be lower for participants who exercised (walking or jogging) than for participants who were merely standing. Furthermore, we hypothesized that anxiety assessed prior to participants physically exercising would positively correlate with the observed facing-the-viewer bias and that this would be particularly visible in the standing condition. In the walking or jogging conditions, we expected participants to experience reductions in anxiety relative to pre-exercise levels and that this would reduce or even eliminate correlations between anxiety and the facing-the-viewer bias. Lastly, we assessed facing-the-viewer biases for three types of biological motion stimuli: Full stick figure walkers, bottom-half-only, and top-half-only. We hypothesized that exercise would weaken the facing-the-viewer bias for full walkers, but that this would not happen (or would happen to a smaller degree) if we showed only parts of the body. Our justification for this was that full stick figure walkers have more sociobiological
relevance than either bottom-half-only or top-half-only stimuli. Top-half-only stimuli, for instance, contain no motion of the feet, which researchers have identified as a key feature in identifying a stimulus as human (Troje & Westhoff, 2006).

3.3 Methods

3.3.1 Participants

Sixty-six naïve undergraduate and graduate students participated in this experiment (42 women, 24 men). All participants had normal or corrected-to-normal vision and had never participated in any experiment that involved biological motion stimuli. Participants ranged from 17 to 26 years of age ($M = 19.82$ years, $SD = 2.29$ years). We recruited participants either through an undergraduate participant pool or a voluntary participant pool comprised of both undergraduate and graduate students. Participants recruited from the voluntary participant pool received $10.00$ (CAD) for participation. Participants recruited from the undergraduate participant pool received course credit (0.5%) towards the completion of a first year undergraduate psychology course. Of these 66 participants, 11 were excluded (10 women, 1 man) for either failing to respond correctly to enough control trials (minimum 75% accuracy required; $n = 10$; all women) or because they were a statistical outlier ($z$ score $> 3$) in terms of their facing-the-viewer bias scores ($n = 1$; a man). All statistical analyses were performed on the remaining 55 participants (32 women, 23 men), who ranged from 18 to 26 years of age ($M = 19.95$ years, $SD = 2.32$ years).

3.3.2 Stimuli and Apparatus

Stimuli consisted of depictions of solid cubes and stick figure walkers. The cubes were tilted 10° degrees with respect to the horizontal plane such that the camera looked at them slightly from above. They were opaque and thus unambiguous. The 3D cubes rotated at a speed...
of 45°/s about a vertical axis, half of them clockwise and the other half counterclockwise. Presentation time was 0.5 s. They were rendered with an orthographic camera and measured 5 cm on-screen, subtending a visual angle of 4.75° for the observer.

Stick figure walkers were based on 3D biological motion point-light walkers, consisting of 15 dots (depicting the center of major skeletal joints; Troje, 2002, 2008) to which we added connecting lines. We used three versions of this stimulus: Full stick figure walkers, bottom-half-only, and top-half-only (see Figure 3.1). The initial phase of each walker (i.e., the posture of the walker at stimulus onset) was varied at random. Stick figures were rendered using an orthographic camera with a horizontal optical axis and appeared white on a black background. The 3D stick figures rotated counterclockwise at a speed of 45°/s about their vertical axis. The initial camera azimuth (i.e., the horizontal viewpoint) covered the whole range from 0° (frontal view) to 360° in 30° increments. Full walkers were 7.5 cm high on the screen, subtending a visual angle of 7° for the observer. Bottom-half-only walkers were 4 cm high, subtending a visual angle of 3.75°, while top-half-only walkers were 3.5 cm high, subtending a visual angle of 3.25°.
Figure 3.1. Example stimuli from the perceptual task. Stimuli included three types: (A) Full stick figure walkers, (B) bottom-half-only stick figure walkers, and (C) top-half-only stick figure walkers. Stick figure walkers were based on 3D biological motion point-light walkers consisting of 15 dots (depicting the center of major skeletal joints) to which we added connecting lines.

The treadmill used in this experiment had a deck measuring 50 cm wide by 146 cm long and an electronic display that showed time and speed (Advanced Fitness Group, Cottage Grove, Wisconsin). Participants were not allowed to alter their speed while on the treadmill, but they were allowed to discontinue at any time should they experience discomfort (no participants discontinued).
3.3.3 Questionnaires

Participants completed both the State and Trait forms of the State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983), which consists of 40 items and is designed to assess how anxious an individual is currently feeling (i.e., state anxiety) and how anxious an individual typically tends to feel (i.e., trait anxiety). Participants also completed the Social Interaction Anxiety Scale (SIAS; Mattick & Clarke, 1998), which is a questionnaire that consists of 20 items designed to assess how anxious an individual feels in situations involving social interaction (e.g., at a dinner party, meeting new people). Participants also completed a simple demographic questionnaire (age, gender, and questions regarding exclusion criteria). We hypothesized that facing-the-viewer biases would correlate most strongly with SIAS scores, given that the facing-the-viewer bias is thought to be socially relevant and that the SIAS is specifically designed to measure social anxiety.

3.3.4 Design

We used a mixed factorial design with two factors, one between-subject factor (Exercise) and one within-subject factor (Stimulus). Each factor had three levels. For Exercise, we randomly assigned each participant to a treadmill speed: 0 km/h (standing/control condition), 4 km/h (walking condition), or 8 km/h (jogging condition). For Stimulus, we presented each participant with three different types of stimuli: Full stick figure walkers, bottom-half-only, and top-half-only.

In total, each participant observed 144 stick figure trials (12 initial camera azimuths x 3 stimulus types x 4 repetitions) and 12 solid cube trials (same cube presented from 12 camera azimuths). Note, that even though all 3D stick figures rotated counterclockwise, we still covered all possible 2D stimuli. For instance, a clockwise rotating stick figure with an initial camera
azimuth of 30° rendered with an orthographic camera would have resulted in exactly the same 2D stimulus as the projection of a stick figure rotating counterclockwise with an initial camera azimuth of 150°. Solid cubes were dispersed equally throughout the trials such that a cube would be presented every 12 trials. These unambiguous cubes were presented as a control to ensure participants understood the concepts of clockwise and counterclockwise rotation and were not responding randomly.

3.3.5 Procedure

At the time of booking appointments, the experimenter asked participants to wear attire that was appropriate for exercise and instructed them that wearing running shoes was mandatory. A reminder email was sent out the night before participants were scheduled to participate in order to emphasize the importance of appropriate attire.

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, the experimenter led the participant to the treadmill and obtained the participant’s heart rate by asking participants to count the number of beats (measured by placing a finger on the carotid artery in their neck) for 15 s. Subsequently, the experimenter informed participants of the condition that they had been randomly assigned to and set the speed of the treadmill to either 0 km/h (standing/control condition), 4 km/h (walking condition), or 8 km/h (jogging condition). Participants then remained on the treadmill for 10 min. During that time, they were not allowed to use their cell phones or perform any other tasks.

After completing the treadmill exercise, the experimenter measured the participant’s heart rate again and then participants immediately performed the perceptual task. Without informing participants of the ambiguous nature of the stimuli, the experimenter instructed the
participant to press the ‘S’ key if the stick figure or the cube rotated clockwise, or the ‘K’ key if they rotated counterclockwise. Participants first completed a 12-trial practice block to familiarize themselves with the task, and also to familiarize themselves with judging clockwise and counterclockwise. The experimenter asked the participant to complete the practice block again if the participant did not understand the task. The 156 trials of the main experiment were then presented.

Both walker and cube stimuli were shown for 0.5 s. Following each stimulus presentation, observers were given a 2 s window to respond as to whether they saw the figure rotating clockwise or counterclockwise. Then the next trial began. If observers had not responded within this window, the trial was discarded from the analysis.

The experiment took place in a dimly lit room. Participants sat at a desk with a desktop computer in front of them consisting of a mouse, keyboard, and a 17” cathode ray tube screen running at 100 fps. Observers sat approximately 60 cm from the screen and kept their eyes level with the screen by adjusting the chair once before starting the experiment.

Upon completing the task, participants were verbally debriefed and also given a debriefing form. Overall, testing lasted approximately 30 min.

3.3.6 Data Analyses

Our measure for the facing-the-viewer bias was based on modelling the collected observer responses in terms of a generalized linear model (GLM) described below in Figure 3.2:
\[ r(\alpha) = S \left[ a + b \cdot f(\alpha) \right] \]

*Figure 3.1.* Generalized linear model (GLM) for calculating facing-the-viewer scores. Here, \( r \) is the rate of counterclockwise responses. \( \alpha \) expresses camera azimuth in degrees. \( S \) is the logistic function: \( f \) is a rectangular function which adopts a value of 1 if \(-90^\circ < \alpha < 90^\circ\), -1 if \(90^\circ < \alpha < 270^\circ\), and 0.5 if \( \alpha \) is either \(-90^\circ \) or \(90^\circ\). \( S \) is the logistic function: \( S(x) = 1/(1+e^{-x}) \). The variables \( a \) and \( b \) are the predictors of the model. The first predictor, \( a \), accounts for a general rotation direction bias, that is, for a preference for responding “clockwise” (if \( a < 0 \)) or “counterclockwise” (if \( a > 0 \)). The second predictor, \( b \), accounts for the degree to which the dependency of participants’ responses on horizontal viewpoint (camera azimuth, \( \alpha \)) follows the expected influence of camera azimuth on perceived rotation direction, \( f(\alpha) \). The variable \( b \) is therefore a measure of the facing-the-viewer bias and constitutes our main dependent variable, which is henceforth referred to as “FTV score”.

Note that parameters \( a \) and \( b \) of the GLM do not have easily interpretable units. Without any modification by the other effect (i.e. if \( b = 0 \)), a rotation direction bias of \( a = 1 \) would correspond to a response rate of 73% “counterclockwise” responses, an effect of \( a = 0 \) would correspond to a response rate of 50%, and an effect of \( a = -1 \) would correspond to a response rate of 27% “counterclockwise”. Likewise, given that \( a = 0 \), a FTV score of \( b = 1 \) would indicate that participants perceived the walker facing towards them in 73% of the cases, whereas \( b = -1 \) would indicate that they would see the walker only in 27% of the cases facing towards them and facing away in the remaining 73%.

We used 3 (Exercise) x 3 (Stimulus) mixed design ANOVAs to analyze FTV scores and reaction times. For repeated-measures variables (i.e., Stimulus and the Exercise x Stimulus
interaction), Wilk’s λ was used whenever the assumption of sphericity was violated. For all post-hoc comparisons, inflation of family-wise error rate was controlled using a Bonferroni correction. We also performed correlations. For these, 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 $p_{\text{adjusted}} = (c/k)(p_{\text{unadjusted}})$, where $c$ represents the number of comparisons, and $k$ was determined by the rank after sorting original $p$ values by magnitude (see Benjamini & Hochberg). All significant correlations described below are significant after performing this correction unless otherwise specified and all $p_{\text{adjusted}}$ statistics are compared with $\alpha = .05$ to judge statistical significance.

3.4 Results

3.4.1 Sample Statistics

Participants’ mean state anxiety score from the STAI was 31.67 ($SD = 7.53$), mean trait anxiety score from the STAI was 35.85 ($SD = 8.46$), and mean social interaction anxiety score from the SIAS was 20.04 ($SD = 10.20$). All three outcomes are typical of nonclinical populations and indicate normal levels of anxiety symptoms. To examine whether there were any gender differences in our data, we used individual sample $t$ tests to compare men and women. Men and women did not differ significantly in terms of age, heart rate (before or after exercise), any anxiety measure, or FTV scores for any of the levels of factor Stimulus (all $p$’s $> .05$).

3.4.2 Number of Missed Responses

For the perceptual task data, a 3 (Exercise) x 3 (Stimulus) mixed design ANOVA on the number of missed trials (i.e., no response within 2 s of previous stimulus presentation) revealed
no effect of Exercise \((F < 1)\), no effect of Stimulus \((F(2, 104) = 1.35, p = .265, \eta^2_{\text{partial}} = .02)\), and no significant interaction \((F < 1)\). On average, participants missed 3.90\% (i.e., about 5 trials) of the walker stimuli \((SD = 4.75\%\).

3.4.3 Heart Rate

To examine heart rates, we performed a 3 (Condition: Standing, Walking, and Jogging) \times 2 (Heart Rate: Before vs. After) mixed ANOVA. Heart rates were measured in beats per minute (bpm). The interaction between Condition and Heart Rate was significant, \(F(2, 52) = 60.49, p < .001, \eta^2_{\text{partial}} = .70\), with participants having significantly greater heart rates (relative to pre-exercise baseline) in the jogging condition \((M = 56.10 \text{ bpm increase}, SE = 3.54)\) compared to in the standing (control) condition \((M = 3.47 \text{ bpm increase}, SE = 3.99, p < .001)\). Participants’ heart rates also increased significantly in the walking condition \((M = 12.00 \text{ bpm increase}, SE = 3.37, p = .001)\) compared to the control condition. Heart rates for those in the control condition did not increase or decrease significantly compared to baseline \((p = .389)\).

3.4.4 FTV Scores

We analyzed effects on FTV scores with a 3 (Exercise) \times 3 (Stimulus) mixed design ANOVA. We found a significant main effect of Stimulus, Wilk’s \(\lambda = .49, F(2, 104) = 26.16, p < .001, \eta^2_{\text{partial}} = .51\), as well as a significant Exercise \times Stimulus interaction, Wilk’s \(\lambda = .76, F(4, 104) = 3.83, p = .006, \eta^2_{\text{partial}} = .13\). The main effect of Exercise was not significant, \(F(2, 52) = 1.82, p = .172, \eta^2_{\text{partial}} = .07\).

For the significant main effect of Stimulus, post-hoc comparisons revealed that FTV scores for top-half-only walkers \((M = -0.38, SD = 0.11)\) were significantly lower than for either full \((M = 0.66, SD = 0.10, p < .001)\) or bottom-half-only stick figure walkers \((M = 0.64, SD = 0.08, p < .001)\). Full and bottom-half-only stick figure walkers, however, did not differ
significantly from each other. To further examine these biases, we performed one-sample $t$ tests on FTV scores separately for each level of Stimulus (collapsed across all levels of Exercise) against $b = 0$ (i.e., no bias). These $t$ tests revealed that both full and bottom-half-only stick figures elicited significant facing-the-viewer biases, while top-half-only stimuli elicited a significant facing away bias (i.e., a negative FTV score; all cases $p < .001$; see Figure 3.3).
Figure 3.2. Mean facing-the-viewer (FTV) scores for full stick figure walkers, bottom-half-only stick figure walkers, and top-half-only stick figure walkers (grouped on x-axis). Mean FTV scores are displayed separately for the standing, walking, and jogging exercise conditions (grouped as differently shaded bars). There was a significant interaction between Exercise condition and Stimulus type. Note that * indicates a significant simple main effect, whereby FTV scores in the standing condition were significantly greater than either the walking or jogging conditions for full stick figure walkers only. No other simple main effects were significant. Error bars represent standard error of the mean.

To analyze the significant interaction between Exercise and Stimulus, we performed a simple main effects analysis (see Figure 3.3). As hypothesized, participants in the walking (p =
.021) and jogging conditions \( (p = .005) \) had significantly lower FTV scores than in the standing condition for full stick figure walkers only. On the other hand, participants in the jogging condition did not differ significantly from those in the walking condition in terms of FTV scores for full walkers. Although it appears as if FTV scores for top-half-only stimuli might differ among Exercise conditions if we had more statistical power, differences in FTV scores among Exercise conditions for either bottom-half-only or top-half-only stimuli did not approach statistical significance.

We also analyzed the simple main effects of Stimulus separately for each level Exercise. For the standing condition, FTV scores for top-half-only stimuli were significantly lower than for either full \( (p < .001) \) or bottom-half-only stimuli \( (p < .001) \), but full and bottom-half-only walkers did not differ significantly from each other \( (p = .107; \) see Figure 3.3). For the walking condition, we observed the same pattern: FTV scores for top-half-only stimuli were significantly lower than for either full stick figure walkers \( (p < .001) \) or bottom-half-only stimuli \( (p < .001) \), but full and bottom-half-only stimuli did not differ significantly \( (p = .606) \). On the other hand, we observed no significant differences in FTV scores among Stimulus types for the jogging condition \( (\)all \( p\)’s > .05\).

We then performed nine separate one-sample \( t \) tests for each combination of our two factors in order to compare FTV scores with zero \( (\)i.e., no bias\()\). For the standing condition, we found that while the full and bottom-half-only stick figure walkers elicited significant facing-the-viewer biases \( (\)both \( p < .001\)\), FTV scores for top-half-only stimuli did not differ significantly from zero \( (p = .070; \) see Figure 3.3). For the walking condition, we found significant facing-the-viewer biases for both full \( (p = .019) \) and bottom-half-only \( (p < .001) \) Stimulus types, and a significant facing away bias for top-half-only stimuli \( (p = .016) \). For the jogging condition, we
once again observed significant facing-the-viewer biases for full \((p = .046)\) and bottom-half-only stimuli \((p = .001)\), while FTV scores for top-half-only stimuli did not differ significantly from zero \((p = .327)\).

**3.4.5 Reaction Time**

We examined differences in reaction times (s) on the perceptual task using a 3 (Exercise) x 3 (Stimulus) mixed design ANOVA. Neither the main effect of Stimulus, Wilk’s \(\lambda = .92, F(2, 104) = 2.10, p = .133, \eta^2_{\text{partial}} = .08\), or Exercise, \(F(2, 52) = 0.59, p = .558, \eta^2_{\text{partial}} = .02\), was significant, nor was there a significant Exercise x Stimulus interaction, Wilk’s \(\lambda = .91, F(4, 104) = 1.26, p = .290, \eta^2_{\text{partial}} = .05\). Reaction times, therefore, did not differ as a function of Exercise or Stimulus. The means and standard errors (in parentheses) were as follows: Full stick figure walkers, 0.72 s (0.04), bottom-half-only stimuli, 0.72 s (0.04), and top-half-only stimuli, 0.74 s (0.04).

**3.4.6 Correlations**

We analysed correlations between anxiety (3 measures: STAI-state, STAI-trait, and SIAS) and FTV scores for full stick figure walkers separately for each level of Exercise, for a total of 18 comparisons (i.e., 6 comparisons per level of Exercise). One participant was excluded from correlational analyses (a male in the walking condition) as his data was a clear bivariate outlier after visually analyzing scatterplots due to a very large FTV score \((\text{Cook’s distance} = .33, \text{critical value} = .07; \text{see Cook, 1977})\). Using the very conservative multiple comparison correction method described above, we found that anxiety measures did not significantly correlate with FTV scores in any of the three Exercise conditions \((\text{all } p_{\text{adjusted}} > .05)\). When we used a less conservative correction (i.e., corrected for multiple comparisons separately for each condition, or 6 comparisons), we found that SIAS scores and FTV scores for full stick figure
walkers in the standing condition were significantly correlated, \( r(13) = .58, p_{\text{adjusted}} = .050 \).

Specifically, individuals with greater social interaction anxiety had greater FTV scores in the standing condition (see Figure 3.4). This correlation was not significant, however, for either the walking, \( r(18) = .38, p_{\text{adjusted}} = .194 \), or jogging conditions, \( r(17) = .30, p_{\text{adjusted}} = .254 \). There were no other significant correlations among anxiety measures and FTV scores.

![Figure 3.4](image.jpg)

**Figure 3.4.** Scatterplots displaying Pearson’s \( r \) correlations between facing-the-viewer (FTV) scores (for full stick figure walkers) and participants’ scores on the social interaction anxiety scale (SIAS). Separate scatterplots are displayed for each level of Exercise condition, with the standing condition shown in the top figure, the walking condition shown in the middle, and the jogging condition shown on the bottom. Note that \( p \) values have been adjusted for the number of multiple comparisons within each condition.

In accordance with the significant results of the ANOVA described above for FTV scores, we found a significant negative correlation between participants’ FTV scores for full stick figure walkers and participants’ heart rate measured immediately after they completed the
treadmill task, $r(53) = -.30, p = .027$. Lower FTV scores for full stick figure walkers were associated with greater heart rates recorded after participants completed the exercise portion of the study.

Although the 3 (Exercise) x 3 (Stimulus) ANOVA on reaction times on the perceptual task indicated no significant differences, we examined the correlations between reaction times and FTV scores. For full stick figure walkers, there were no significant correlations among reaction times and FTV scores for any of the three levels of Stimulus. However, we did observe that reaction times correlated positively with FTV scores for bottom-half-only stimuli, and correlated negatively with FTV scores for top-half-only stimuli (see Table 3.1 for all correlation coefficients and inferential statistics). This means that biases (facing-towards for the bottom-half-only stimuli and facing-away for the top-half-only stimuli) became stronger the longer participants took to respond. Note that stimulus presentation time was always the same and that responses were only given after the stimulus had disappeared.

**Table 3.1**

<table>
<thead>
<tr>
<th></th>
<th>Reaction Time (Full Stick Figure Walkers)</th>
<th>Reaction Time (Bottom-Half-Only)</th>
<th>Reaction Time (Top-Half-Only)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FTV Scores (Full Stick Figure Walkers)</td>
<td>.12</td>
<td>.14</td>
<td>.14</td>
</tr>
<tr>
<td>FTV Scores (Bottom-Half-Only)</td>
<td>.43**</td>
<td>.42**</td>
<td>.41**</td>
</tr>
<tr>
<td>FTV Scores (Top-Half-Only)</td>
<td>-.35*</td>
<td>-.33*</td>
<td>-.30*</td>
</tr>
</tbody>
</table>

*Note: Values represent Pearson’s $r$ correlation coefficients. Though not shown, $p$ values were adjusted according to the multiple comparison method outlined by Benjamini and Hochberg (1995) for 9 comparisons and adjusted $p$ values were then compared with $\alpha = .05$. * indicates significant at $\alpha < .05$ level, ** indicates significant at $\alpha < .01$ level.
3.4.6 Anxiety by Condition Interaction Analyses

Given our findings that Condition and social interaction anxiety were related to FTV scores for full stick figure walkers, we performed a multiple regression in order to assess whether there was a significant Condition X SIAS interaction in predicting FTV scores. The regression that included Condition, SIAS scores, and the Condition X SIAS interaction term as predictors was significant in predicting FTV scores for full stick figure walkers, $R^2 = .20, F(3, 51) = 4.20, p = .010$. Although Condition significantly predicted FTV scores, $\beta = .40, t(53) = -3.16, p = .003$, neither SIAS scores, $\beta = .38, t(53) = 1.12, p = .269$, nor the interaction term were significant, $\beta = -.10, t(53) = -0.63, p = .530$.

Despite this lack of a significant interaction, we divided our sample into those with high ($n = 30$) or low ($n = 25$) social interaction anxiety according to those above or below the median score of 17 on the SIAS. We performed the same 3 (Condition) x 3 (Stimulus) mixed design ANOVA that we described above, and found that although the main effect of Stimulus was significant for both high and low social interaction anxiety groups, (both $p$s < .001), the interaction between Condition and Stimulus type was only significant for the high SIAS group, Wilk’s $\lambda = .65, F(2, 104) = 3.16, p = .021, \eta^2_{\text{partial}} = .20$ (although it approached significance for low SIAS group, Wilk’s $\lambda = .65, F(2, 54) = 2.52, p = .055, \eta^2_{\text{partial}} = .19$). Of note though, when we performed a simple main effects analysis for both groups, we found no significant differences, perhaps because of reduced power after dividing the sample in half.

To further examine differences between high and low SIAS groups, we performed a 3 (Exercise Condition) x 2 (SIAS group) between-subjects ANOVA on FTV scores for full stick figure walkers only. We found that although the ANOVA itself approached significance, $F(5,$
49) = 2.39, \( p = .051 \), \( \eta^2_{\text{partial}} = .20 \), neither the main effect of SIAS group \((F < 1, p = .715)\), nor the Condition x SIAS group interaction \((F < 1, p = .849)\) was significant (see Figure 3.5).

![Figure 3.5](Image)

*Figure 3.5.* Mean facing-the-viewer (FTV) scores for full stick figure walkers for those who scored Low and High in terms of their scores on the social interaction anxiety scale (SIAS; grouped on x-axis as differently shaded bars). Error bars represent standard error of the mean. Scores are shown for each level of Condition.

### 3.5 Discussion

The purpose of Experiment 2 was to investigate the relationship between physical exercise and the facing-the-viewer bias. To do this, we asked participants to complete anxiety questionnaires, exercise on a treadmill, and then immediately complete a perceptual task that allowed us to assess their facing-the-viewer bias.
As exercise reduces anxiety, we expected that participants would show weaker facing-the-viewer biases after walking or jogging on the treadmill compared to when not exercising (i.e., standing still on a motionless treadmill). Furthermore, as full stick figure walkers have more sociobiological relevance than either bottom-half-only or top-half-only stimuli, we predicted that exercise would only weaken facing-the-viewer biases for full stick figure walkers. As hypothesized, we found that facing-the-viewer biases for full stick figure walkers were significantly weaker in participants who either walked or jogged compared to those in the standing condition, but that physical exercise had no measurable effect on facing-the-viewer biases for either bottom-half-only or top-half-only stimuli.

Our hypothesis that exercise would reduce the facing-the-viewer bias was based on the premise that anxiety and the facing-the-viewer bias are positively correlated. The anxiolytic benefits of physical exercise have been shown repeatedly (Bahrke & Morgan, 1978; Clark, 1986; Petruzzello et al., 1991; Salmon, 2001; Stephens, 1988; Wipfli et al., 2008), and since we assessed anxiety before participants completed the treadmill task, we hypothesized that measures of anxiety and the facing-the-viewer bias would only correlate in the standing condition. Although we found no significant correlations when using a strict correction for multiple comparisons, we did observe a significant positive correlation between social interaction anxiety and FTV scores when applying this method less conservatively. This finding appears to replicate the previous finding of a positive correlation between anxiety and the facing-the-viewer bias both in Experiment 1, as well as in previous experiments in our laboratory (Heenan et al., 2012). We did not, however, find any interaction between Condition and social interaction anxiety when performing a multiple regression analysis. We also did not find any differences between high and low SIAS groups after dichotomizing our sample based on SIAS scores above and below the
median. Furthermore, as was the case in Experiment 1, we only observed significant correlations between facing-the-viewer biases and social interaction anxiety. In Chapter 5 of this dissertation, we address this issue further.

The significant effect of Stimulus on facing-the-viewer biases that we observed also replicates previous findings (Schouten, Troje, & Verfaillie, 2011). Specifically, we found that both full and bottom-half-only stick figure walkers elicited facing-the-viewer biases, while top-half-only stimuli elicited facing away biases. This may occur because local motion features in the lower half of point-light figures (i.e., most notably, the feet) are quickly identified and help to adequately detect biological motion (see Troje & Westhoff, 2006). Top-half-only stimuli, on the other hand, are less likely to be readily identified as representing human figures. Alternatively, these differences in facing-the-viewer biases might be related to the convexity and concavity represented in the positioning of the lower or upper limbs (Weech & Troje, unpublished manuscript). Weech and Troje argue that the facing the viewer bias is sensitive to lower level stimulus features such as convexity and concavity, which our visual system already has prior assumptions about (i.e., a bias to perceive convexity rather than concavity when surface normals are ambiguous; (Langer & Bülthoff, 2001). According to Weech and Troje, the upper half of a human biological motion figure in fronto-parallel projection elicits a facing away bias because we assume that we look onto the bended elbows from their convex side. Likewise, the lower part elicits a facing-towards percept because we assume that we look at the knees from their convex side. Weech and Troje’s findings highlight the importance of bottom-up processes in producing the facing the viewer bias. Top-down processes like the one we discuss in the present study clearly do not account for all of the variance in facing biases, nor do we argue such here.
While the results of this study were as we expected, our findings contradict some previous reports regarding the facing-the-viewer bias. For example, while we saw a decrease in facing-the-viewer biases following physical exercise on a treadmill, others have found that walking on a treadmill actually increased facing-the-viewer biases for some point-light figures if the stimuli were displayed performing the same action as the observer (Manera et al., 2012). In the latter study, however, perceptual biases were assessed while participants were actually engaged in walking on the treadmill; a key difference from the present study.

Our results also contradict a recent finding that individuals with high social anxiety had significantly weaker facing-the-viewer biases than individuals with low social anxiety (Van de Cruys et al., 2013). Future research is needed in order to discern why our results differ from this previous finding.

Of interest, we unexpectedly observed that greater reaction times were associated with greater facing-the-viewer biases for bottom-half-only stimuli and the opposite trend (i.e., stronger facing away biases) for top-half-only stimuli. On the other hand, we found that reaction times were not related to facing-the-viewer biases for full stick figure walkers. In one previous study, shorter reaction times were associated with greater facing-the-viewer biases for full walkers when no time limit was imposed (Schouten, Davila, & Verfaillie, 2013). The authors of that study argued that strong facing-the-viewer biases help to disambiguate a figure, thus allowing its facing direction to be resolved more quickly. We, on the other hand, found the opposite relationship for top-half- and bottom-half-only biological motion stimuli: Stronger biases were associated with slower reaction times. Future research on the facing-the-viewer bias will have to carefully consider the amount of time that is given for participants to respond.
Experiment 2, however, was not without limitations. For instance, we must note that we have no way of knowing whether the reduction in the facing-the-viewer bias observed after jogging was due to concomitant reductions in anxiety, or via the physiological effects of physical exercise (e.g., changes in oxygenation, physiological arousal). While the correlations that we observed appear to support our interpretation that it is exercise’s anxiolytic properties that link it with reductions in the facing-the-viewer bias, we are forced to speculate. Furthermore, there was a methodological error present in Experiment 2, as we did not include a manipulation check in the form of an anxiety measure directly after participants completed the physical exercise task. We address both of these methodological limitations in Experiment 3, described in the next chapter.

Despite these limitations, the fact that such a short period of physical exercise can significantly alter perceptual biases (at least in the short term) is an important finding itself. A number of studies have found evidence that anxiety affects attentional (Bar-Haim et al., 2007; MacLeod et al., 1986; Mathews & MacLeod, 1985) and perceptual biases (Bar-Haim et al., 2007; Fox et al., 2002; Gray et al., 2009; Singer et al., 2012) towards visual stimuli that are potentially threatening, making it more likely that anxious individuals will perceive threat in their environment. Researchers have argued that having a stronger threat bias towards the environment may exacerbate anxiety disorders, making such disorders more difficult to treat and thus helping to perpetuate them (Clark & Wells, 1995; Heeren et al., 2011; MacLeod et al., 1986; Rapee & Heimberg, 1997). Reductions in threat bias due to exercise would therefore be a very interesting finding for clinicians. Attempts at experimentally modifying perceptual threat biases in anxious individuals has been found to reduce both the threat bias as well as symptoms of anxiety (Beard & Amir, 2008). Although further research is required in order to equate the
facing-the-viewer bias with the threat bias, the findings of Experiments 1 and 2 appear to support this. To our knowledge then, our study is the first to demonstrate that physical exercise can reduce perceptual biases related to the perception of threat, thus providing further empirical evidence of the anxiolytic benefits of physical exercise, as well as offering another potential mechanism for how this occurs.

3.6 Conclusion

This study is the first to attempt to investigate the effects of physical exercise on the facing-the-viewer bias. Our method, exposing our participants to different levels of exercise, is indirect. We therefore cannot be sure that the relationship between the amount of exercise participants experienced and their degree of facing-the-viewer bias is really mediated by anxiety. In the future, researchers should manipulate anxiety directly (either via anxiety induction or relaxation techniques) in order to assess effects on the facing-the-viewer bias. Multiple studies have confirmed the importance of both high-level social factors and low-level perceptual features in contributing to this perceptual bias. Our study reaffirms the importance of high-level social cognition in contributing to it, and provides empirical evidence that anxiety is positively correlated with it.
Chapter 4

Progressive Muscle Relaxation Reduces the Facing-the-viewer Bias

4.1 Introduction

In Experiment 2, physical exercise reduced the facing-the-viewer bias for full stick figure walkers, and we attributed this reduction as possibly due to the anxiolytic effects of exercise. This argument, however, is indirect. That is, it is possible that facing-the-viewer biases decreased after engaging in physical exercise due to the physiological effects of exercise (e.g., differences in oxygenation, vascular functioning). A more direct method of assessing whether anxiety relates to the facing-the-viewer bias is to attempt to manipulate anxiety directly and then observe the subsequent effect on the facing-the-viewer bias.

Inducing anxiety by asking participants to read scripts and to imagine personal experiences during which they experienced stress has been successful in increasing subjective anxiety in laboratory experiments (Kilts et al., 2006; Kimbrell et al., 1999; Sinha, Catapano, & O’Malley, 1999). Kimbrell et al., (1999), for example, found that participants who recalled stressful life events while looking at human faces expressing anxiety experienced significant increases in self-reported anxiety, as well as concomitant differences in brain activation (compared to controls) as measured by positron emission tomography (PET). There has also been one experiment in which facing-the-viewer biases were significantly affected by imagery scripts, as Heenan et al. (2012) found that reading a loneliness induction script significantly affected the relationship between attachment anxiety and the facing-the-viewer bias. Given the success that such imagery scripts have had in both increasing anxiety and affecting facing-the-
viewer biases, we chose to adopt a similar imagery script in order to induce anxiety in Experiment 3.

We were also interested in experimentally reducing anxiety in Experiment 3. First described by Jacobsen (1929), progressive muscle relaxation is a method of reducing anxiety that involves flexing and releasing muscle groups throughout the body while focusing on the internal sensation of relaxation that this provides (Benson, 1975; Bourne, 2011). Progressive muscle relaxation has been found to be an effective treatment for individuals with panic disorder (Ost, 1988), and is often used in conjunction with cognitive behavioural therapy to treat other anxiety disorders as well, such as specific phobias or obsessive-compulsive disorder (Bourne, 2011). Furthermore, a clinical study involving patients with cancer found that this relaxation technique was as effective as Alprazolam (a benzodiazepine) at significantly reducing symptoms of anxiety (Holland et al., 1991). Progressive muscle relaxation is also effective at reducing anxiety in non-pathological populations, as it has been found to reduce state anxiety, heart rate, and salivary cortisol levels relative to baseline measures in healthy undergraduates (Pawlow & Jones, 2005).

4.2 Experiment 3

The purpose of Experiment 3 was to investigate the relationship between anxiety and the facing-the-viewer bias by assessing participants’ biases after they engaged in a task designed to manipulate their level of anxiety. For the most part, the methodology of Experiment 3 was exactly the same as that of Experiment 2, except for the substitution of the exercise task with an anxiety manipulation task. Participants completed anxiety questionnaires, performed the anxiety manipulation task, and then immediately completed a perceptual task that allowed us to assess their facing-the-viewer bias. In order to reduce response bias, we presented rotating stick figure
walkers and deduced the perceived facing orientation of walkers in the same way as we did in Experiment 2.

We randomly assigned participants to three conditions: A control condition that involved performing an innocuous word search task, an anxiety induction condition that consisted of a stressful imagery writing task, or a relaxation condition that consisted of performing progressive muscle relaxation. As we observed that anxiety correlated positively with the facing-the-viewer bias in both Experiments 1 and 2, and as this has also been previously reported in the literature (Heenan et al., 2012), we hypothesized that participants in the anxiety induction condition would have greater mean facing-the-viewer biases than those in the control condition, while those in the relaxation condition would have lower facing-the-viewer biases than those in the control condition. As we did in Experiment 2, we assessed facing-the-viewer biases for three types of biological motion stimuli: Full stick figure walkers, bottom-half-only, and top-half-only. We hypothesized that anxiety induction and relaxation would increase and decrease (respectively) the facing-the-viewer bias for full walkers, but that this would not happen (or would happen to a smaller degree) for bottom-half- and top-half-only stimuli. Lastly, we added an additional anxiety measure in response to a methodological error in Experiment 2, whereby we did not directly assess anxiety immediately after participants completed the exercise task (i.e., a manipulation check). In Experiment 3, we assessed anxiety both before and after the anxiety manipulation (using a visual analogue scale). We hypothesized that anxiety assessed just after participants completed the anxiety manipulation would positively correlate with the facing-the-viewer bias.
4.3 Methods

4.3.1 Participants

Sixty-four naïve undergraduate students participated in this experiment (48 women, 16 men). All participants had normal or corrected-to-normal vision and had never participated in any experiment that involved biological motion stimuli. Participants ranged from 17 to 21 years of age \( (M = 18.39 \text{ years}, SD = 0.79 \text{ years}) \). We recruited participants through an undergraduate participant pool. Participants received course credit (1%) towards the completion of a first year undergraduate psychology course. Of these 64 participants, 7 were excluded (6 women, 1 man) for failing to respond correctly to enough control trials (minimum 75% accuracy required). An additional two women were excluded because they were statistical outliers (z score > 3) in terms of their anxiety scores. All statistical analyses were performed on the remaining 55 participants (40 women, 15 men), who ranged from 17 to 21 years of age \( (M = 18.44 \text{ years}, SD = 0.83 \text{ years}) \).

4.3.2 Stimuli and Apparatus

All stimuli for the perceptual task were the same as those used in Experiment 2.

For the control condition, participants completed word searches. We downloaded word searches from a free website (http://www.puzzles.ca/wordsearch.html) and used the same 10 for each participant (no participant completed all 10 during the allotted time). These word searches were chosen because of their neutral word categories (e.g., song names, types of food). There were also written instructions describing how to complete the word searches.

For the relaxation condition, the experimenter guided the participant through a progressive muscle relaxation exercise. This task involves focusing one’s attention on different muscle groups of the body (e.g., feet, calves, shoulders) and then tensing and relaxing them. The experimenter was trained to perform this technique by a senior graduate student in clinical
psychology. The procedure followed the script outlined by Bourne (2011), which is based on the relaxation technique described first by Benson (1975).

For the anxiety induction condition, participants were given a script that we created with the following instructions: *Please recall and write down a time when you felt very stressed or anxious. You will have 10 minutes to complete this. Be sure to write down the story in as much detail as you need in order to vividly remember and imagine this time in your life.* Participants were also told that they were to keep their stories when they were finished and to take these with them when they left the laboratory. If participants finished within the allotted time, they were instructed to think of another time and write about that until the experimenter told them the task was finished.

All participants completed a positive mood induction task at the end of the experiment. This task was identical to the anxiety induction task except that participants were instructed to write about a time when they felt very good about themselves (as opposed to very stressed). This task was included in order to ensure that any lingering negative or anxious mood was alleviated before participants left the experiment.

4.3.3 Questionnaires

Participants completed the same questionnaires as they did in Experiment 2 (i.e., both the state and trait forms of the STAI, as well as the SIAS). Participants also completed a simple demographic questionnaire (age, gender, and questions regarding exclusion criteria), which was identical to that used in Experiment 2.

For the manipulation check, we assessed participants’ subjective anxiety using a visual analogue scale. Participants marked their responses by drawing a mark on a line that spanned
from No Anxiety (far left) to Most Anxiety You Have Ever Felt (far right). The length of the line was 9 cm.

4.3.4 Design

As in Experiment 2, we used a mixed factorial design with two factors, one between-subject factor (Condition) and one within-subject factor (Stimulus). Each factor had three levels. For Condition, we randomly assigned each participant to either the control condition (i.e., innocuous word searches), the anxiety induction condition (i.e., anxiety imagery script), or the relaxation condition (i.e., progressive muscle relaxation). For Stimulus, we presented each participant with three different types of stimuli: Full stick figure walkers, bottom-half-only, and top-half-only.

The design, with respect to the perceptual task, was exactly the same as it was in Experiment 2.

4.3.5 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, the experimenter measured the participant’s heart rate by asking them to count the number of beats (measured by placing a finger on the carotid artery in their neck) for 15 s. The experimenter then asked participants to complete the visual analogue anxiety measure, followed by the anxiety manipulation part of the experiment. During this time, they were not allowed to use their cell phones or perform any other tasks. Participants in the control condition completed word searches after receiving both written and verbal instructions. Participants in the anxiety induction task performed the anxiety imagery writing task after receiving both written and verbal instructions. Participants in the relaxation condition were guided through the
progressive muscle relaxation task by the experimenter. In all three conditions, participants completed these tasks for 10 minutes.

After completing the anxiety manipulation portion of the experiment, the experimenter measured the participant’s heart rate again and asked them to complete the visual analogue anxiety measure once more (participants were not allowed to see their previous response). Participants then immediately performed the perceptual task (see Experiment 2).

The experiment took place in the same dimly lit room as was used in Experiment 2. Participants sat at a desk with a desktop computer in front of them consisting of a mouse, keyboard, and a 17” cathode ray tube screen running at 100 fps. Observers sat approximately 60 cm from the screen and kept their eyes level with the screen by adjusting the chair once before starting the experiment.

Upon completing the task, participants completed the positive mood induction task for 3 minutes. Participants were then verbally debriefed and also given a debriefing form. Overall, testing lasted approximately 40 min.

4.3.6 Data Analyses

Our measure for the facing-the-viewer bias was based on modelling the collected observer responses in terms of the same generalized linear model (GLM) that was described in detail in Experiment 2. Using this model, we derived a measure of the facing-the-viewer bias. We will henceforth refer to this dependent variable as FTV scores.

We used 3 (Condition) x 3 (Stimulus) mixed design ANOVAs to analyze FTV scores and reaction times. All methods related to post-hoc comparisons, corrections for multiple comparisons, and use of Wilk’s λ were the same as in Experiment 2.
4.4 Results

4.4.1 Sample Statistics

Participants’ mean state anxiety score from the STAI was 29.56 ($SD = 5.64$), mean trait anxiety score from the STAI was 35.95 ($SD = 7.52$), and mean social interaction anxiety score from the SIAS was 18.73 ($SD = 8.82$). All three outcomes were nearly identical to those found in Experiment 2, and are typical of nonclinical populations, indicating normal levels of anxiety symptoms. To examine whether there were any gender differences in our data, we used individual sample $t$ tests to compare men and women. Men and women did not differ significantly in terms of age, heart rate (before or after the experimental manipulation), any anxiety measure, or FTV scores for any of the levels of factor Stimulus (all $p$’s > .05).

4.4.2 Number of Missed Responses

For the perceptual task data, a 3 (Condition) x 3 (Stimulus) mixed design ANOVA on the number of missed trials (i.e., no response within 2 s of previous stimulus presentation) revealed no effect of Condition ($F < 1$), no effect of Stimulus ($F < 1$), and no significant interaction ($F < 1$). On average, participants missed 2.51% (i.e., about 4 trials) of the walker stimuli ($SD = 2.40\%$).

4.4.3 Heart Rate

To examine heart rates, we performed a 3 (Condition: Control, Anxiety Induction, Relaxation) x 2 (Heart Rate: Before vs. After) mixed ANOVA. Heart rates were measured in beats per minute (bpm). One participant (a female in the relaxation condition) was not included in these analyses as her post-manipulation heart rate was not recorded. The interaction between Condition and Heart Rate was significant, $F(2, 51) = 6.50, p = .003, \eta^2_{\text{partial}} = .20$, with participants having significantly greater decreases in heart rates (relative to baseline) in the
relaxation condition ($M = -4.71$ bpm increase, $SE = 1.63$) compared to in the control condition ($M = 0.67$ bpm increase, $SE = 1.58$, $p = .006$). Participants’ heart rates in the anxiety induction condition, however, increased significantly ($M = 3.37$ bpm increase, $SE = 1.54$, $p = .033$) compared to the control condition. Heart rates for those in the control condition did not increase or decrease significantly compared to baseline ($p = .675$).

4.4.4 Visual Analogue Anxiety Measure

To examine visual analogue anxiety measure scores, we performed a 3 (Condition: Control, Anxiety Induction, Relaxation) x 2 (Anxiety: Before vs. After) mixed ANOVA. Anxiety was measured (in cm) from right to left (with greater values indicating greater anxiety). The interaction between Condition and Heart Rate was significant, $F(2, 52) = 11.00$, $p < .001$, $\eta^2_{\text{partial}} = .30$, with participants having significantly greater decreases in anxiety (relative to baseline) in the relaxation condition ($M = 0.60$ cm decrease, $SE = 0.18$) compared to in the control condition ($M = 0.26$ cm decrease, $SE = 0.15$, $p = .002$). Participants’ anxiety in the anxiety induction condition, however, increased significantly ($M = 0.55$ cm increase, $SE = 0.18$, $p = .003$) compared to the control condition. Visual analogue anxiety scores for those in the control condition did not increase or decrease significantly compared to baseline ($p = .154$).

4.4.5 FTV Scores

We analyzed effects on FTV scores with a 3 (Condition) x 3 (Stimulus) mixed design ANOVA. We found both a significant main effect of Stimulus, Wilk’s $\lambda = .36$, $F(2, 104) = 44.34$, $p < .001$, $\eta^2_{\text{partial}} = .64$, and Condition, $F(2, 52) = 2.14$, $p = .045$, $\eta^2_{\text{partial}} = .11$. The Condition x Stimulus interaction, however, was not significant, Wilk’s $\lambda = .92$, $F(4, 104) = 1.07$, $p = .374$, $\eta^2_{\text{partial}} = .04$. 

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For the significant main effect of Stimulus, post-hoc comparisons revealed that FTV scores for top-half-only walkers ($M = -0.27, SD = 0.09$) were significantly lower than for either full ($M = 0.69, SD = 0.09, p < .001$) or bottom-half-only stick figure walkers ($M = 0.73, SD = 0.08, p < .001$; see Figure 4.1). Full and bottom-half-only stick figure walkers, however, did not differ significantly from each other. To further examine these biases, we performed one-sample $t$ tests on FTV scores separately for each level of Stimulus (collapsed across all levels of Condition) against $b = 0$ (i.e., no bias). These $t$ tests revealed that both full and bottom-half-only stick figures elicited significant facing-the-viewer biases, while top-half-only stimuli elicited a significant facing away bias (i.e., a negative FTV score; all cases $p < .001$). This was the same pattern of results that we observed in Experiment 2.

For the significant main effect of Condition, post-hoc comparisons revealed that FTV scores were significantly lower (across all stimulus types) in the relaxation condition ($M = 0.19, SD = 0.11$) than in the control ($M = 0.59, SD = 0.11, p = .040$). There were no differences, however, between the relaxation condition and the anxiety induction condition ($M = 0.38, SD = 0.11, p = .714$), or the anxiety induction condition and the control ($p = .502$).
Figure 4.1. Mean facing-the-viewer (FTV) scores for full stick figure walkers, bottom-half-only stick figure walkers, and top-half-only stick figure walkers (grouped on x-axis). Mean FTV scores are displayed separately for the control, anxiety induction, and relaxation conditions (grouped as differently shaded bars). Note that * indicates a significant simple main effect, whereby FTV scores in the relaxation condition were significantly lower than either the anxiety induction or control conditions for full stick figure walkers only. No other simple main effects were significant. Error bars represent standard error of the mean. Scores are shown for each level of Condition.

Despite not finding a significant Condition x Stimulus interaction, we conducted a simple main effects analysis on the data (i.e., looking at all possible comparisons among each level of
Stimulus separately for each level of Condition) as this information was central to our a priori hypotheses. As hypothesized, we found that participants in the relaxation condition had significantly lower FTV scores than in the control condition ($p = .020$) for full stick figure walkers only (see Figure 4.1). No other simple main effects comparisons were significant. Although it appeared as if FTV scores in the relaxation condition might be lower than in the control condition for bottom-half-only stimuli as well (i.e., upon visual inspection of Figure 4.1), this difference only approached significance ($p = .054$).

We then performed nine separate one-sample $t$ tests for each combination of our two independent variables in order to compare FTV scores with zero (i.e., no bias). For the control condition, we found that while the full and bottom-half-only stick figure walkers elicited significant facing-the-viewer biases (both $p < .001$), FTV scores for top-half-only stimuli ($p = .277$) did not differ significantly from zero (see Figure 4.1). For the anxiety induction condition, however, we found significant facing-the-viewer biases for both full and bottom-half-only stimuli (both $p < .001$), and a significant facing away bias for top-half-only stimuli ($p = .023$). For the relaxation condition, we once again observed significant facing-the-viewer biases for full ($p = .013$) and bottom-half-only stimuli ($p = .002$), while FTV scores for top-half-only stimuli did not differ significantly from zero ($p = .120$).

4.4.6 Reaction Time

We examined differences in reaction times (s) on the perceptual task using a 3 (Condition) x 3 (Stimulus) mixed design ANOVA. Contrary to what we observed in Experiment 2, the main effect of Stimulus was significant, Wilk’s $\lambda = .60$, $F(2, 104) = 16.96$, $p < .001$, $\eta^2_{\text{partial}} = .40$, as reaction times for full walkers ($M = 0.66$ s, $SD = 0.03$) were significantly shorter than for either bottom-half-only ($M = 0.69$ s, $SD = 0.03$, $p = .007$) or top-half-only stimuli ($M = 0.72$
s, $SD = 0.03$, $p < .001$). Reaction times for bottom-half-only and top-half-only stimuli, however, did not differ significantly ($p = .075$). Neither the main effect of Condition, $F < 1$, nor the Condition x Stimulus interaction, Wilk’s $\lambda = .89$, $F(4, 104) = 1.55, p = .192$, $\eta^2_{\text{partial}} = .06$, were significant.

4.4.7 Correlations

We analysed correlations among anxiety (4 measures: STAI-state, STAI-trait, SIAS, and visual analogue anxiety pre-post difference) and FTV scores for full stick figure walkers separately for each level of Condition, for a total of 45 comparisons (i.e., 15 comparisons per level of Condition). We found no significant correlations in any of the three levels of Condition (all $p_{\text{adjusted}} > .05$).

In addition to anxiety, we examined correlations between heart rate measures and FTV scores for full stick figure walkers. We observed no significant correlations between these measures, either in general or separately for each level of Condition.

Lastly, we examined the correlations between reaction times and FTV scores collapsed across all levels of Condition. Unlike in Experiment 2, no correlations were significant.

4.4.8 Anxiety by Condition Interaction Analyses

Given our findings that relaxation reduced FTV scores for full stick figure walkers and that greater SIAS scores had previously been found (i.e., in Experiments 1 and 2) to be associated with greater FTV scores, we performed a multiple regression in order to assess whether there was a significantly Condition X SIAS interaction in predicting FTV scores. The regression that included Condition, SIAS scores, and the Condition X SIAS interaction term as predictors was significant in predicting FTV scores for full stick figure walkers, $R^2 = .17$, $F(3, 51) = 3.39, p = .025$. Although Condition significantly predicted FTV scores, $\beta = -.42$, $t(53) = -$
2.64, $p = .011$, neither SIAS scores, $\beta = .42$, $t(53) = 1.38$, $p = .175$, nor the interaction term were significant, $\beta = -.21$, $t(53) = -1.37$, $p = .176$.

Despite this lack of a significant interaction, we divided our sample into those with high ($n = 29$) or low ($n = 26$) social interaction anxiety according to those above or below the median score of 18 on the SIAS. We performed the same 3 (Condition) x 3 (Stimulus) mixed design ANOVA that we described above for each group separately, and found that although the main effect of Stimulus was significant for both high and low social interaction anxiety groups, (both $ps < .001$) no other main effects or interactions were significant. Of note though, when we performed a simple main effects analysis for both groups, we found that FTV scores for full stick figure walkers were significantly lower in the relaxation group compared to the control group for the high SIAS group only (see Figure 4.2). For the low SIAS group, there were no significant simple main effects (i.e., no differences among levels of Condition for each level of Stimulus).
Figure 4.2. Mean facing-the-viewer (FTV) scores for full stick figure walkers for those who scored Low and High in terms of their scores on the social interaction anxiety scale (SIAS; grouped on x-axis as differently shaded bars). Scores are shown for each level of Condition. Error bars represent standard error of the mean. Note that * indicates a significant simple main effect, whereby FTV scores in the relaxation condition were significantly lower than either the anxiety induction or control conditions for the high SIAS group only. No other simple main effects were significant for either group.

4.5 Discussion

The purpose of Experiment 3 was to further test the hypothesis that more anxious individuals demonstrate larger facing-the-viewer biases than less anxious individuals. To accomplish this, we assessed participants’ biases after they engaged in either an anxiety induction task, or an anxiety reduction (i.e., relaxation) task. The methodology of Experiment 3 was practically the same as that of Experiment 2, except that we substituted the exercise task
with an anxiety manipulation task. Participants completed anxiety questionnaires, performed the anxiety manipulation task, and then immediately completed a perceptual task that allowed us to assess their facing-the-viewer bias.

Based on our observations from Experiments 1 and 2, as well as the previous finding of a positive correlation between anxiety and facing-the-viewer biases (Heenan et al., 2012), we hypothesized that participants in the anxiety induction condition would have greater mean facing-the-viewer biases than those in the control condition. We also expected that those in the relaxation condition would have lower facing-the-viewer biases than those in the control condition. Similar to Experiment 2, we assessed facing-the-viewer biases for three types of biological motion stimuli: Full stick figure walkers, bottom-half-only, and top-half-only. We hypothesized that anxiety induction and relaxation would increase and decrease (respectively) the facing-the-viewer bias for full walkers, but that this would not happen (or would happen to a smaller degree) for bottom-half- and top-half-only stimuli.

Unexpectedly, we observed that the facing-the-viewer biases of those in in the anxiety induction condition did not differ significantly from those in the control condition. As hypothesized, however, we found that facing-the-viewer biases for full stick figure walkers were significantly lower for those in the progressive muscle relaxation condition, but that relaxation did not significantly affect biases for either bottom-half-only or top-half-only stimuli.

In this experiment, we sought to examine the link between anxiety and the facing-the-viewer bias more directly than we did in Experiment 2 by manipulating anxiety directly (as opposed to indirectly via physical exercise). We also accounted for a methodological problem present in Experiment 2, by adding an additional measure of anxiety directly after the anxiety manipulation (i.e., a manipulation check). While we found that participants in the progressive
muscle relaxation group had significantly decreases in anxiety (relative to baseline) as well as concomitant reductions in facing-the-viewer biases, we did not find any significant correlations between anxiety and facing-the-viewer biases in Experiment 3. Similar to Experiment 2, we also did not find any interaction between Condition and social interaction anxiety when performing a multiple regression analysis. We did find, however, that when the sample was divided into those who scored either high or low on the SIAS, we only observed the significant reduction in FTV scores after relaxing in those with high anxiety. This finding makes sense given that we hypothesized that relaxation would reduce the facing-the-viewer bias via reduced anxiety.

One finding that did not support our hypotheses was that the anxiety induction task did not significantly impact facing-the-viewer biases. We designed this imagery task based on similar tasks in the literature that had been successful in increasing subjective anxiety (Kilts et al., 2006; Kimbrell et al., 1999; Sinha et al., 1999). Although we observed that subjective anxiety (as measured with a visual analogue scale) increased significantly after partaking in the anxiety induction condition, we did not observe any concomitant changes in facing-the-viewer biases. Future research is needed in order to assess whether our findings are due to inadequate anxiety induction, or whether facing-the-viewer biases cannot be increased via anxiety inductions.

Similar to our findings in Experiment 2, the results of Experiment 3 contradict a recent finding that individuals with high social anxiety had significantly weaker facing-the-viewer biases than individuals with low social anxiety (Van de Cruys et al., 2013). In both Experiments 1 and 2, we observed that reductions in anxiety (both indirect and direct) caused significantly weaker facing-the-viewer biases. Future research is needed in order to discern why our results differ from the previous finding of a negative correlation between anxiety and the facing-the-viewer bias.
The findings of Experiment 3 also replicated the significant effect of Stimulus on facing-the-viewer biases that we observed in Experiment 2. This finding replicates previous findings in the literature (Schouten, Troje, & Verfaillie, 2011) and is discussed in detail in Experiment 2.

We did not replicate, however, our unexpected observation in Experiment 2 that slower reaction times were correlated with greater facing-the-viewer biases for bottom-half-only stimuli and the opposite trend (i.e., stronger facing away biases) for top-half-only stimuli. Furthermore, contrary to what we observed in Experiment 2, we found that reaction times for full walkers were significantly shorter than for either bottom-half-only or top-half-only stimuli in Experiment 3. Future research on the facing-the-viewer bias will have to carefully consider the amount of time that is given for participants to respond. Such studies will also have to recruit greater sample sizes that are more amenable to correlational statistics than those of Experiments 2 and 3.

4.6 Conclusion

This study is the first to attempt to manipulate anxiety directly in order to investigate its effect on the facing-the-viewer bias. Taken together with the results from Experiment 2, we have again reaffirmed the importance of high-level social cognition in contributing to the facing-the-viewer bias. We have demonstrated, for the first time that progressive muscle relaxation can significantly reduce the facing-the-viewer bias for biological motion stimuli. This may provide an additional theoretical explanation for the anxiolytic benefits of this relaxation method: A reduction in threat bias.
Chapter 5

Meta-analyses across Experiments

5.1 Introduction

The use of similar measures across all three experiments described in this dissertation allowed us to perform a series of meta-analyses across experiments. Although the sample sizes used in each experiment made correlational analyses difficult to interpret, combining all three studies allowed for more statistical power.

5.2 Meta-correlations among anxiety measures and facing-the-viewer biases

We found significant positive correlations between social interaction anxiety and facing the viewer biases in Experiments 1 and 2, but not in Experiment 3. To examine this relationship across all three experiments, all non-excluded participants from Experiment 1, and all non-excluded participants from the control conditions in Experiments 2 and 3 were combined in a database. Because facing-the-viewer biases were measured differently in Experiment 1 than they were in either Experiments 2 or 3, we converted each score to a z-score (relative to the other participants in that particular study) and then imported these data as well. This combined sample consisted of 23 men and 58 women (N = 81) who ranged from 17 to 25 years of age (M = 18.95 years, SD = 1.46). Men and women did not differ in terms of facing-the-viewer biases (p = .124).

The correlation between facing-the-viewer biases and SIAS was significant, r(79) = .34, p = .002 (see Figure 5.1). As an exploration of the data, we performed the same combined approach at examining both state and trait scores from the STAI. We found that although state anxiety was not significantly correlated with facing-the-viewer biases, r(79) = .19, p = .091, trait anxiety was, r(79) = .29, p = .008.
Figure 5.1. Scatterplot displaying the correlation between facing-the-viewer scores (for all three Experiments) in terms of z-scores (y-axis) and participants’ scores on the social interaction anxiety scale (SIAS; x-axis).

\[ r(79) = .34, \ p = .002 \]
Chapter 6

General Discussion

6.1 Anxiety and the facing-the-viewer bias

The purpose of this dissertation was to test a hypothesis that arises from the sociobiological theory of the facing-the-viewer bias for biological motion stimuli: That mistaking an approaching human as retreating when he/she is actually approaching is potentially more costly than making the opposite mistake. In line with the anxiety literature, we expected that anxious individuals would demonstrate larger facing-the-viewer biases than less anxious individuals.

While there is already evidence that anxious individuals display a bias towards perceiving more threatening percepts when faced with visual ambiguity (Fox et al., 2002; Gray et al., 2009; Singer et al., 2012), there has been limited investigation into whether anxiety is related to the facing-the-viewer bias. In fact, the few studies that have examined the relationship between anxiety and the facing-the-viewer bias have yielded conflicting results (e.g., Heenan et al., 2012; Van de Cruys et al., 2013).

We set out to study how anxiety relates to the facing-the-viewer bias using both correlational (Experiment 1) and between-subject study designs (Experiments 2 and 3). Taken together, our results support our overarching hypothesis: More anxious individuals have greater facing-the-viewer biases, and vice versa.

In Experiment 1, we found that social interaction anxiety was significantly correlated with facing-the-viewer biases that were measured using a continuously rotating walker. We then replicated this finding in the control condition of Experiment 2, using rotating walkers that were
displayed very briefly (0.5 s). We found no significant correlations, however, between measures of anxiety and facing-the-viewer biases in Experiment 3. This latter null finding may have been due to a lack of statistical power, and indeed, when we combined the data from all three Experiments, we observed a significant correlation between social interaction anxiety and facing-the-viewer biases overall.

The between-groups effects that we observed in Experiments 2 and 3 are in accordance with the positive correlations we saw between anxiety and the facing-the-viewer bias in Experiments 1 and 2. For instance, in Experiment 2, we found that performing physical exercise significantly reduced the facing-the-viewer bias. This finding, however, does not implicate anxiety per se. Concomitant differences in blood oxygenation or physiological arousal, for example, could have caused the significantly lower facing-the-viewer biases observed after physical exercise. Compounding this, we made the error of not including a manipulation check in Experiment 2 that would have allowed us to confirm that exercise truly did reduce anxiety.

While we could not be certain in Experiment 2 that exercise reduced facing-the-viewer biases because of exercise’s anxiolytic properties, the results of Experiment 3 support such an interpretation. In Experiment 3, we observed that progressive muscle relaxation reduced both social interaction anxiety and the facing-the-viewer bias for full stick figure walkers only. On the other hand, we found that the anxiety induction task had no significant effect on facing-the-viewer biases. Future research is therefore needed in order to ascertain whether facing-the-viewer biases can be increased via experimental increases in anxiety. Such studies should also make use of anxiety induction tasks that induce greater anxiety than the one we used in Experiment 3.
In Experiments 1 and 2, we only saw significant correlations between social interaction anxiety and the facing-the-viewer bias, and in Experiment 3, even this correlation was not statistically significant. In Chapter 5, however, we demonstrated that when participants were collapsed across studies, we had enough statistical power to show significant correlations between the facing-the-viewer bias and two types of anxiety: Trait anxiety and social interaction anxiety. This is an important finding in terms of the arguments made in this dissertation. Our assertion that anxiety and the facing-the-viewer bias are related is based on our equating the facing-the-viewer bias with the threat bias. That is, a main tenet of this dissertation is that more anxious people perceive the facing-towards percept of ambiguous biological stimuli more often because this percept is perceived as more threatening, and more anxious individuals are biased towards attending or perceiving threatening stimuli. If we only observed significant correlations between social interaction anxiety and the facing-the-viewer bias, one might argue that this perceptual bias is exclusively related to social interaction anxiety, not anxiety in general, which would seem to contradict our link between the facing-the-viewer bias and anxiety in general. Given the fact that we saw a positive relationship between trait anxiety and the facing-the-viewer bias when we had more statistical power, and also given the fact that we had previously observed a positive relationship between this bias and attachment anxiety (Heenan et al., 2012), it appears more likely that the facing-the-viewer bias is indeed related to anxiety more generally. Furthermore, as we mentioned in Chapter 2, individuals who scored higher in terms of social interaction anxiety would also have been more likely to experience anxiety during the actual experiment itself, as it involved interacting socially with a stranger (the experimenter) in a new environment. Thus, these people would have felt more anxious at the time of completing the
perceptual task than other participants, which might account for the significant correlations we observed between social interaction anxiety and the facing-the-viewer bias.

Taken together, the findings of all three experiments in this dissertation provide strong evidence that anxiety and the facing-the-viewer bias are positively correlated in naïve observers. This supports the sociobiological hypothesis of this perceptual bias, and provides additional evidence that the facing-the-viewer bias is indeed affected by higher-order factors like the social relevance of stimuli or the degree of anxiety experienced by the observer.

6.2 Anxiety and the threat bias

The arguments made in this dissertation are all predicated on the argument that the facing-the-viewer bias and the threat bias are related. We originally hypothesized that the sociobiological theory of the facing-the-viewer bias implies that the facing-towards percept of a biological motion stimulus is potentially more threatening. Indeed, researchers have argued this before (e.g., Vanrie et al., 2004), and the findings that the gender of the point-light walker (Brooks et al., 2008) and the gender of the observer (Schouten et al., 2010) significantly affect perceived facing orientation would also seem to support this.

The threat bias in the anxiety literature has received much more attention compared to research on the facing-the-viewer bias (e.g., Bar-Haim et al., 2007; Clark & Wells, 1995; Gray et al., 2009; Mogg et al., 1997; Mogg & Bradley, 2005; Pérez-Edgar et al., 2010; Singer et al., 2012), and appears to be present in both anxious nonclinical populations, as well as those with diagnosed anxiety disorders. The threat bias has been found with ambiguous visual stimuli as well, as more anxious individuals have been found to display a bias towards perceiving the more threatening percept of ambiguous figures (Fox et al., 2002; Gray et al., 2009; Singer et al., 2012). Given these previous findings, we hypothesized that the facing-the-viewer bias might represent a
form of the threat bias that is specific to biological motion stimuli: More anxious individuals should display a bias to perceive these figures as facing towards them. Indeed, the results of all three studies in this dissertation support this hypothesis.

Future studies, however, will be required in order to more clearly link the facing-the-viewer bias with the threat bias. For instance, studies that investigate both the facing-the-viewer bias and the threat bias (e.g., via an emotional Stroop task, etc.) would provide researchers with the ability to show whether manipulations such as exercise or relaxation result in concomitant reductions in both of these biases in the same sample.

6.3 Anxiolytic mechanisms of exercise and relaxation

In Experiments 2 and 3 of this dissertation, we significantly reduced the facing-the-viewer bias (for full stick figure walkers only) in participants by having them physically exercise or by guiding them through a progressive muscle relaxation task. Of note, there is evidence that experimentally modifying perceptual threat biases in anxious individuals reduces both the threat bias, as well as symptoms of anxiety (Beard & Amir, 2008; El Khoury-Malhame Myriam et al., 2011). Taken together, the results of this dissertation suggest that a reduction in threat bias may represent a mechanism by which both exercise and progressive muscle relaxation achieve their anxiolytic effects.

With respect to exercise, although the exact mechanisms for how physical activity leads to reductions in anxiety are still unknown, it is likely that there are many factors that play a role given the complex physical and psychological effects of engaging in exercise (Petruzzello et al., 1991). Salmon (2001), for instance, argued that exercise training must recruit psychological processes that improve resilience to stress, thus helping people reduce their symptoms of anxiety over time. It also appears likely that exercise provides individuals with an explanation for
heightened physiological arousal, which prevents them from attributing heightened arousal to feelings of anxiety (Clark, 1986; Salmon, 2001). Such an interpretation would explain why physical exercise has proven to be a successful treatment for specific phobias (Driscoll, 1976).

The underlying theory for why progressive muscle relaxation is effective in reducing anxiety is very similar to how researchers interpret exercise’s anxiolytic benefits (e.g., Salmon, 2001). That is, progressive muscle relaxation helps people to engage their relaxation response, helping them to reduce their physiological arousal, which then prevents that arousal from being interpreted (or misinterpreted) as due to anxiety (Benson, 1975; Bourne, 2011). Indeed, this general principle is common to the conceptualization of relaxation training techniques in general, not just progressive muscle relaxation.

To date, there is much evidence in the literature in support of the anxiolytic benefits of both physical exercise (Bahrke & Morgan, 1978; Petruzzello et al., 1991; Wipfli et al., 2008) and progressive muscle relaxation (Bahrke & Morgan, 1978; Benson, 1975; Holland et al., 1991; Ost, 1988), but few have examined the link between these activities and perceptual biases. Our findings in Experiments 2 and 3 provide the first evidence that these activities can actually decrease the threat bias in non-clinical populations.

A reduced threat bias would be useful in the treatment of anxiety disorders. As we observed positive correlations between social interaction anxiety and the facing-the-viewer bias in Experiments 1 and 2, it seems likely that physical exercise and progressive muscle relaxation would help in reducing the threat bias in social situations in particular. While further research is needed, the evidence put forth in this dissertation is potentially exciting for clinicians who recommend either of these activities to those they are treating, as it offers an additional mechanism for why these activities help reduce anxiety. In both these cases, reductions in threat
bias could ostensibly have a protective, preventative benefit for individuals, as it would help reduce the amount of threatening stimuli that they perceive or attend to. For example, individuals with social phobia are biased to perceive the actions of others more negatively during social situations, which is a serious problem because social situations are full of ambiguity and thus provide many instances whereby this threat bias can be evoked (Clark & Wells, 1995; Rapee & Heimberg, 1997). In this dissertation, we observed that social interaction anxiety was positively correlated with facing-the-viewer biases, but that both exercise and progressive muscle relaxation reduced these biases. While more research is required, our findings that both exercise and relaxation reduced the threat bias for socially relevant stimuli provide additional support for the use of these activities in anxiety treatment protocols.

6.4 Inhibition as a mediator between anxiety and perception

In Experiment 1, we found that inhibitory ability (as measured by a Go/No-Go task) was a significant mediator between social anxiety and the facing-the-viewer bias for a full stick figure walker. This finding provides us with a theoretical mechanism by which anxious individuals experience a threat bias when observing ambiguous visual stimuli: They have difficulty inhibiting the more threatening percept.

Much of the arguments made in this dissertation are based on the fact that we equate the facing-the-viewer bias and the threat bias. Given this assumption, we were interested in looking at whether inhibition might mediate the relationship between anxiety and the facing-the-viewer bias because of several findings in the literature. For example, some individuals with anxiety disorders have difficulty inhibiting distracting thoughts, including those with post-traumatic stress disorder (Swick et al., 2012) or obsessive-compulsive disorder (Chamberlain et al., 2005; Enright & Beech, 1993). Furthermore, there is evidence that non-clinically anxious individuals
have difficulty inhibiting threatening stimuli on attention tasks compared to less anxious people (Fox, Russo, & Georgiou, 2005; Fox, 1994). In fact, researchers have even found that adolescents who had a history of behavioural inhibition as children displayed greater threat biases than those who were less inhibited (Pérez-Edgar et al., 2010).

Our finding that inhibition was a significant mediator in Experiment 1 is also in accordance with attentional control theory (Eysenck et al., 2007; Eysenck & Derakshan, 2011). According to this theory, more anxious individuals are less able to exert top-down attentional control to prevent bottom-up attentional resources from being used to process distracting stimuli. We had hypothesized that anxiety might therefore affect perceptual biases by making it more difficult to inhibit, or ‘suppress’ percepts. Our findings in Experiment 1 supported this, as we observed that people with greater anxiety also had both poorer inhibitory ability and greater facing-the-viewer biases.

6.5 The facing the viewer bias as a measurement tool

Measuring the facing-the-viewer bias is a relatively easy way of assessing the threat bias in individuals without introducing biases that are known to affect self-reports. Furthermore, the methodology that we employed in this study ensured that we measured the threat bias implicitly. That is, participants in all three studies described in this dissertation were unaware (until given feedback during debriefing) that the stick figure walkers that we used could actually be perceived as either facing towards the observer or away. We were therefore able to assess facing-the-viewer biases in participants without their knowledge, which allowed us to avoid response bias.

The fact that we displayed stick figures rotating, rather than simply display them head-on, also helped us avoid biases (see Jackson et al., 2008). That is, to avoid confounding the variable of interest (i.e., perceived facing orientation) with a simple response bias (e.g., Is the walker...
facing towards you or facing away?), we presented rotating stick figure walkers and asked participants to indicate their spinning direction. This method allowed us to infer perceived facing direction from participants’ responses, as we know the veridical rotation of the walkers (i.e., we always presented them rotating counter-clockwise).

The fact that facing-the-viewer biases provide an implicit measure of threat makes it an interesting tool. For example, in our laboratory, we have recently used the facing-the-viewer bias as an implicit measure of perceived threat in order to assess stigma towards individuals with schizophrenia (Heenan et al., 2014). The ease of use regarding this measure is also a significant benefit of using this measure, as is the lack of need for any expensive and complicated equipment (e.g., electroencephalograph), which is typical of studies attempting to measure threat implicitly. The findings outlined in this dissertation lend support to our argument that the facing-the-viewer bias is indeed related to the perception of threat. While more research should be done in order to replicate and expand on these findings, the door is open for future researchers to exploit the implicit nature of measuring facing-the-viewer bias in order to study other topics.

6.6 Effects of stimulus type of facing-the-viewer biases

The significant effect of stimulus type on facing-the-viewer biases that we observed (in both Experiments 1 and 2) replicates previous findings (Schouten, Troje, & Verfaillie, 2011). While we found that both full and bottom-half-only stick figure walkers elicited facing-the-viewer biases, top-half-only stimuli elicited facing away biases. As mentioned in Chapter 3, this may occur because local motion features in the lower half of point-light figures (most notably, the feet) help to detect biological motion (see Troje & Westhoff, 2006), while top-half-only stimuli are less readily identified as representing human figures.
We also speculate that these stimulus-dependent differences in facing-the-viewer biases might be related to the convexity and concavity represented in the positioning of the lower or upper limbs (Weech et al., n.d.; Weech & Troje, 2013). Weech and Troje argued that the facing-the-viewer bias is sensitive to lower level stimulus features such as convexity and concavity, which our visual system already has prior assumptions about (i.e., a bias to perceive convexity rather than concavity when surface normals are ambiguous; Langer & Bülthoff, 2001). According to Weech and Troje, the upper half of point light figures elicits a facing away bias because we assume that we look onto the bended elbows from their convex side. Likewise, the lower part of such figures elicits the perception of seeing the figure facing towards the observer because we assume that we look at the knees from their convex side.

In our experiment though, we were most interested in the effects on facing-the-viewer biases for full stick figure walkers. As we argued that these full walkers would have the most social relevance, we hypothesized that the effects of both exercise (Experiment 2) and progressive muscle relaxation (Experiment 3) would decrease facing-the-viewer biases only for full walkers. This was indeed the case. While we cannot be sure from our data that full stick figure walkers truly were more socially relevant than either bottom- or top-half-only stimuli, our findings regarding the facing-the-viewer bias (and also its positive relationship with social interaction anxiety) support this interpretation.

6.7 The sociobiological theory of the facing-the-viewer bias

The purpose of this dissertation was to assess whether anxiety and the facing-the-viewer bias were related, and this was motivated by earlier proposals that this bias might exist for sociobiological reasons (e.g., Vanrie et al., 2004). Our findings in all three experiments support the sociobiological theory of the facing-the-viewer bias, as we found that more anxious people
had greater facing-the-viewer biases, and that attempts to decrease anxiety in participants also significantly decreased facing-the-viewer biases. In addition, we only observed significant decreases in facing-the-viewer biases for full stick figure walkers, which was as we hypothesized given the increased social relevance of these figures compared to either bottom- or top-half-only stimuli.

We conclude that the sociobiological theory of the facing-the-viewer bias appears to be valid. More anxious individuals show a greater tendency to perceive these figures as facing them, and this appears to be because they are less able to inhibit this more threatening percept. Future studies should look to expand on these findings, as there are surely other factors (e.g., concavity and convexity of limbs) that impact this perceptual bias.
Chapter 7

Summary and Conclusions

The findings described in this dissertation give further evidence that anxiety and the facing-the-viewer bias are positively correlated, which supports the sociobiological theory of this perceptual bias.

Furthermore, we found that the relationship between anxiety and the facing-the-viewer bias is significantly mediated by a person’s inhibitory ability. While such a mechanism has been suggested previously in the literature, to our knowledge, no studies have demonstrated significant mediation analyses. Although no studies have demonstrated such findings for biological motion stimuli, more research is needed to ensure that these results are replicable with typical stimuli used in threat bias paradigms (e.g., emotional words or faces).

This dissertation provides further evidence that more anxious individuals display a bias towards perceiving threat in their external environment. Our findings add to an already large body of work in support of this perceptual threat bias. On the other hand, we demonstrated, for the first time, that both physical exercise and progressive muscle relaxation significantly reduce the facing-the-viewer bias for full stick figure walkers only. These findings provide an additional theoretical mechanism for why both these methods reduce anxiety (i.e., a reduction in the threat bias), as well as further implicate that anxiety is related to this perceptual bias. Future research on this mechanism may prove fruitful for clinicians and researchers alike in understanding treatments for anxiety disorders.
References


Appendix A

Permission of Co-Authors

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