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Attention and interpretation processes and trait anger experience, expression, and control

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ABSTRACT

This study explored attention and interpretation biases in processing facial expressions as correlates of theoretically distinct self-reported anger experience, expression, and control. Non-selected undergraduate students (N = 101) completed cognitive tasks measuring attention bias, interpretation bias, and Spielberger’s State-Trait Anger Expression Inventory (STAXI-2). Attention bias toward angry faces was associated with higher trait anger and anger expression and with lower anger control-in and anger control-out. The propensity to quickly interpret ambiguous faces as angry was associated with greater anger expression and its subcomponent of anger expression-out and with lower anger control-out. Interactions between attention and interpretation biases did not contribute to the prediction of any anger component suggesting that attention and interpretation biases may function as distinct mechanisms. Theoretical and possible clinical implications are discussed.

Anger is a frequently experienced human emotion. However, the dispositional tendency to experience anger frequently and intensely is linked to a variety of deleterious outcomes. For example, high trait anger has been associated with elevated risk for cardiovascular problems (Chida & Steptoe, 2009; Smith, Glazer, Ruiz, & Gallo, 2004; Williams, 2010), as well as other physical illnesses (Suinn, 2001). Anger is correlated with health-risking behaviours, such as drinking, smoking, drug abuse, reckless driving, fighting, and unprotected sex (Adler, Brit, Castro, McGurk, & Bliese, 2011; Deffenbacher, Deffenbacher, Lynch, & Richards, 2003; Nichols, Mahadeo, Bryant, & Botvin, 2008; Sakusic et al., 2010), with risk for psychopathologies such as post-traumatic stress disorder (Feeny, Zoellner, & Foa, 2000; Meffert et al., 2008; Novaco, 2010), and with difficulties in spouse relationships (e.g. Baron et al., 2007), parent-to-child aggression (e.g. Mammen, Pilkonis, & Kolko, 2000), and workplace aggression (e.g. Hershcovis et al., 2007). However, the mechanisms underlying the tendency to experience anger and how that anger is regulated are not well-understood.

Theoretical models suggest that cognitive processes play a pivotal role in the aetiology and maintenance of anger and aggression (e.g. Crick & Dodge, 1994; Wilkowski & Robinson, 2010). The Integrative Cognitive Model (ICM) of trait anger and reactive aggression (Wilkowski & Robinson, 2008; Wilkowski & Robinson, 2010), as well as the Social Information Processing (SIP) model (Crick & Dodge, 1994), postulate that both attention and interpretation processes reflect initial stages of social and affective information processing and that biases in these two processes are cognitive precursors for trait anger and reactive aggression. Amplified attention toward hostile and threatening cues and a predisposition to interpret ambiguous information in a hostile manner have both been linked to greater anger and aggression (Owen, 2011; Schultz, Grodack, & Izard, 2010). Anger-related stimuli induce greater attentional interference in participants with high versus low trait anger (e.g.
Van Honk, Tuiten, De Haan, Van den Hout, & Stam, 2001). And, anger has been associated with negatively biased interpretation of ambiguous information, including attributions of anger, hostility, and negative intent toward others (e.g. Schultz, Izard, & Bear, 2004; Wenzel & Lystad, 2005). However, to date, attentional and interpretational components of cognitive bias in anger have not been examined within-persons, hence their additive and multiplicative role in anger and anger regulation remain unknown.

Besides the lack of information about how these processes may function together, there are also some methodological gaps in the extant literature on cognitive biases in anger. Research on attention biases in the context of anger is scarce. Most studies have examined anger-related differences by measuring interference in emotional Stroop tasks (Eckhardt & Cohen, 1997; Van Honk et al., 2001; Van Honk et al., 2001), or attention biases to anger or aggression-related words in dot-probe tasks (Quartana, Yoon, & Burns, 2007; Smith & Waterman, 2003). Interestingly, within the field of anxiety a meta-analysis revealed that a significant emotional Stroop effect emerged using words as stimuli whereas a non-significant effect was noted when using pictures of faces. In contrast, in the dot-probe task significant anxiety-related effects emerged both for verbal and face stimuli (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van Ijzendoorn, 2007). Considering the extensive research on anxiety-related attention biases using facial stimuli (Garner, Baldwin, Bradley, & Mogg, 2009; Jusyte & Schönemberg, 2014), but to our knowledge was applied only once in the context of anger (Penton-Voak et al., 2013).

Another limitation of the extant literature is related to the multifaceted nature of the construct of anger. That is, distinct cognitive biases might differentially relate to various components of how anger is expressed and experienced and these distinctions have rarely been clarified in research. A broad conceptualisation of anger and its management is illustrated in Spielberger’s conceptualisation reflected in his State-Trait Anger Expression Inventory (STAXI-2; Spielberger, 1999). The STAXI-2 assesses experience, expression, and control of anger. State anger reflects a current emotional state marked by subjective feelings varying from mild irritation to intense rage. Trait anger is construed as a dispositional tendency to perceive situations as annoying or frustrating and respond with elevated state anger. Within this framework, state and trait anger are conceptually distinguished from anger expression. Anger expression is broadly divided into two types: anger expression-out, reflecting the tendency to outwardly express anger, and anger expression-in, reflecting the tendency to suppress anger or direct it towards oneself. Two additional sub-components of anger expression reflect an individual’s ability to control and prevent anger expression toward the environment (anger control-out) and ability to control angry feelings by calming oneself down when angered (anger control-in) (Spielberger, 1999).
The current study builds on previous work by examining unique and common associations between components of anger and two putative cognitive processes, using measures of threat-related attention and interpretation biases. We assessed cognitive bias with two different tasks: (1) a dot-probe task that has been widely used to assess attention biases in anxiety disorders (Bar-Haim et al., 2007; MacLeod, Mathews, & Tata, 1998) but less frequently in the context of anger (e.g. Hommer et al., 2014); and (2) a task involving morphed faces designed to assess interpretation bias. We tested the associations between these bias assessments and self-reported trait anger, anger expression, and anger control. We predicted that both anger-related attention and interpretation biases would be associated with higher levels of trait anger and anger expression, and lower levels of anger control. We also hypothesised that anger will be most pronounced when individuals experience bias in both attention and in interpretation. It is not clear, however, whether attention and interpretation effects are additive or multiplicative; therefore, we also explored the contribution of potential interaction effects to anger beyond the separate effects of attention and interpretation biases alone.

Method

Participants

Undergraduate students from Tel Aviv University participated in the study (N = 101, mean age = 24.16 years, SD = 2.22; 65 females). The study was advertised across the campus, and students could enrol either on-line or via the phone. The only exclusion criterion was prior participation in other studies in our lab involving similar tasks. The study was approved by Tel Aviv University’s Institutional Review Board. Participants provided signed informed consent and received either course credit or monetary compensation ($5), to their preference.

Cognitive bias measures

Attention: the dot-probe task

The sequence of events on a dot-probe trial is described in Figure 1S (supplementary online material). Each trial began with the presentation of a fixation display (500 ms; white cross 1*1 cm), followed by a 500 ms presentation of an angry-neutral pair of chromatic faces of the same actor. Each face appeared on a grey square background subtending 50 mm in width and 37.5 mm in height. The faces were presented with equal distance from the top and bottom of the fixation cross and separated by 15 mm. The top photograph was positioned 30 mm from the top edge of the screen. Faces were of 10 actors (5 females), taken from the NimStim stimulus set (Tottenham et al., 2009; models 1, 2, 3, 6, 7, 20, 24, 27, 31, 33). Following the faces display, a target probe (“<” or “>”, 4*4 mm) appeared at the location previously occupied by one of the faces. Participants were required to determine which direction the arrow pointed via pressing a keyboard button (“<” or “>”) using their dominant hand as quickly as possible, while avoiding errors. The target remained on the screen until response. The task was run using e-prime software (Psychology Software Tools, Pittsburgh, PA) and was displayed on a 15.6” monitor.

The task comprised 80 trials, displayed in a random order. Each of the 10 face pairs was presented 8 times. Across the eight repetitions of each face pair, position of the angry and neutral faces (above or below the fixation), target position (above or below the fixation) and probe type (“<” or “>”) were fully counterbalanced. Thus, the probe appeared equally in the location of angry and neutral faces. Anger-related attention bias was calculated by subtracting mean reaction time (RT) in trials where the target appeared at the angry face location from mean RT in trials where the target appeared at the neutral face location. Positive scores reflect attentional vigilance toward the angry faces, whereas negative scores reflect attentional threat avoidance (Bradley, Mogg, Falla, & Hamilton, 1998). The task took approximately five minutes to complete.

Interpretation: the emotion-perception task

Each trial began with a fixation display (800–1200 ms; white cross 1*1 cm), followed by a 200 ms chromatic presentation of a morphed face (90 mm in height and 70 mm in width). Face presentation time was selected to be similar to that used in previous studies in the context of anxiety (Maoz et al., 2016), and anger (Penton-Voak et al., 2013). Each face was followed by a 200 ms scrambled face mask. A question mark then appeared and remained on the screen until the participant determined whether the face was “angry” or “happy” by pressing one of two pre-specified keyboard buttons. Participants were instructed to use one hand for each button. The location of the
buttons (happy/angry) was counterbalanced across participants. Morphed face sequences were generated from pictures of four actors (2 female), using Morpheus Photo Morpher v3.16. Each sequence consisted of 15 morphed faces ranging between the endpoints of happy and angry expressions of each actor. The endpoint faces were taken from the NimStim set (Tottenham et al., 2009; models 10, 18, 37, 41), and were different than the faces used in the dot-probe task. Each face was presented three times, for a total of 180 trials (4 sequences × 15 faces × 3 repetitions), displayed in random order. The task was run using e-prime software and was displayed on a 15.6" monitor. Figure 2S (supplementary online material) shows the sequence of events on a single trial and an example of one morphed sequence. The task took approximately eight minutes to complete.

Two measures were derived from this task, indexing two distinct aspects of interpretation bias: (a) percent of anger interpretations was used as an index of participants’ tendency to interpret the face stimuli as angry; and (b) interpretation RT bias was calculated to index a propensity to make negative interpretations more quickly than positive interpretations. The interpretation RT bias was calculated by subtracting mean RT in angry interpretation trials from mean RT in happy interpretation trials (Maoz et al., 2016). Positive interpretation RT bias scores reflect a tendency to make angry interpretations faster than happy interpretations. Negative scores reflect the opposite tendency.

**Self-reported anger**

Self-reported anger was evaluated using the STAXI-2 (Spielberger, 1999). The STAXI-2 was translated to Hebrew in cooperation with the copyright owners (PAR Inc.). All participants in the study were fluent in Hebrew.

The state anger index, referring to current, situational anger, was not analysed for two reasons: (a) the current theoretical focus was on stable anger-related characteristics; and (b) because no manipulation of anger occurred, only negligible variability in state anger was expected (and observed).

The trait anger score was derived from a 10-item scale denoting the participant’s disposition to perceive situations as annoying and react with anger elevations. The anger expression index combined responses to 32 items related to anger expression and control. Specifically, this scale has four sub-components: Anger Expression-Out (AX-O) reflecting a tendency to express anger toward the environment; Anger Expression-In (AX-I) reflecting anger directed inward; Anger Control-Out (AC-O) reflecting the ability to control and prevent anger expression toward the environment; and Anger Control-In (AC-I) relating to the ability to control angry feelings by calming oneself down when angered. Higher anger expression index scores represent more anger expression (AX-I and AX-O) and less control over anger experience and expression (AC-I and AC-O). Items were rated on a Likert-type scale (1 = “almost never” to 4 = “almost always”). In the present sample, Cronbach’s alphas for trait anger and for the anger expression index were 0.84 and 0.76, respectively. Cronbach’s alphas for the anger expression sub-components were 0.77, 0.73, 0.93, and 0.92 for AX-O, AX-I, AC-O, and AC-I, respectively.

**Procedure**

Participants were given an explanation about the study and provided signed informed consent. The tasks were then performed in the following order: emotion-perception task, dot-probe task, and STAXI-2. A two-minute break was allowed between tasks.

**Data analysis**

**Data cleaning**

**Dot-probe task.** Trials with RT longer than 2000 ms, or incorrect response were excluded. Then, trials with RT deviating by more than three SDs from the mean of each participant were also excluded. This resulted in an average exclusion of 3.0% of all trials per participant.

**Emotion-perception task.** To gauge compliance with task demands, a threshold of 70% accuracy in the identification of the two overtly angry and overtly happy facial expressions was determined (Stoddard et al., 2016). Since each face was presented three times during the task, accuracy estimation was based on a total of 48 trials (4 extreme faces × 4 sets × 3 repetitions). One participant had an accuracy score lower than the 70% threshold and was removed from further analysis. Average accuracy score for the remaining 100 participants was 97.25% (SD = 3.5%).

Trials with RTs longer than 2000 ms were excluded from the interpretation RT bias calculation. Then, trials with RTs deviating by more than three SDs from the
mean of each participant were also excluded from the interpretation RT bias calculation. This resulted in the removal of an average of 3.5% of all trials per participant.

**Regression analyses**

To determine the contributions of attention and interpretation biases to the participants’ trait anger and anger expression, we conducted two two-step hierarchical regression analyses. In the first step of each analysis, we entered attention bias, interpretation RT bias, and percent of anger interpretations as predictors. This allowed us to examine the relative contribution of the different cognitive biases to anger. In the second step, we added the two-way interactions (product terms) between the attention and interpretation biases. In the case of the anger expression index, which is composed of four theoretically distinguished sub-components, the significant overall model was followed-up by separate regressions for each of the sub-components. Analyses were conducted using IBM SPSS Statistics 22.

**Results**

Means, standard deviations, ranges, and correlations among the cognitive biases and self-reported anger variables are presented in **Table 1**. For scatter plots see Figure 3S in online supplementary materials. Mean trait anger and anger expression levels in the current sample were moderate (17.99 and 32.21, respectively) and similar to previously reported levels in normative adults samples (Spielberger, 1999). Since gender-based differences in some anger components have been previously reported (Fischer & Evers, 2010), we tested for gender-based differences on all the measures used in our study. No gender-related differences were noted in any of the cognitive or self-reported anger variables (ps > .10).

**Trait anger**

The results of the linear regression model are summarised in **Table 2**. The first step significantly explained 9% of the variance in trait anger ($R^2 = 0.091, F_{(3,96)} = 3.20, p < .05$). However, only threat-related attention bias significantly predicted trait anger ($β = 0.26, p < .05$). The interactions between the different cognitive measures added in step two did not account for additional variance.

**Anger expression index**

The results of the linear regression model are summarised in **Table 3**. The first step significantly explained 13% of the variance in the anger expression index ($R^2 = 0.13, F_{(3,96)} = 4.65, p < .005$). Attention bias and interpretation RT bias each contributed to the prediction of anger expression index ($β = 0.24, p < .05$ and $β = 0.28, p < .01$, respectively) and uniquely contributed to the variability in anger expression with 5.6% and 7.1%, respectively. Percent of anger interpretations did not contribute to the variability in anger expression index scores. Interactions between the different cognitive measures added in step two did not account for additional variance.

Follow-up regression analyses examining the sub-components of the anger expression index revealed:

![Table 1. Mean, SDs and range of the cognitive measures and self-report STAXI-2 scales, and Pearson correlations between the measures.](image-url)

<table>
<thead>
<tr>
<th>Measure</th>
<th>Mean</th>
<th>SD</th>
<th>Range</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>5a</th>
<th>5b</th>
<th>5c</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Attention bias (dot-probe task)</td>
<td>6 ms</td>
<td>22</td>
<td>−36–74</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Interpretation RT bias (emotion-perception task)</td>
<td>−3 ms</td>
<td>46</td>
<td>−121–135</td>
<td>0.06</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Percent of anger interpretations (emotion-perception task)</td>
<td>54.6%</td>
<td>5.6</td>
<td>37.2–68.3</td>
<td>0.17*</td>
<td>0.35**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Trait Anger (STAXI-2)</td>
<td>17.99</td>
<td>4.71</td>
<td>10–35</td>
<td>0.26**</td>
<td>0.16</td>
<td>0.08</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Anger Expression Index (STAXI-2)</td>
<td>32.21</td>
<td>13.45</td>
<td>5–69</td>
<td>0.23*</td>
<td>0.24*</td>
<td>−0.01</td>
<td>0.68**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5a. Anger expression - Out</td>
<td>14.50</td>
<td>3.48</td>
<td>8–28</td>
<td>0.16</td>
<td>0.20*</td>
<td>−0.02</td>
<td>0.62**</td>
<td>0.78*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5b. Anger expression - In</td>
<td>17.78</td>
<td>3.92</td>
<td>9–31</td>
<td>0.07</td>
<td>0.12</td>
<td>0.05</td>
<td>0.20*</td>
<td>0.39**</td>
<td>0.18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5c. Anger control - Out</td>
<td>25.65</td>
<td>5.43</td>
<td>11–32</td>
<td>−0.19*</td>
<td>−0.24*</td>
<td>0.05</td>
<td>−0.65**</td>
<td>−0.84**</td>
<td>−0.68**</td>
<td>−0.01</td>
<td></td>
</tr>
<tr>
<td>5d. Anger control - In</td>
<td>22.42</td>
<td>5.62</td>
<td>8–32</td>
<td>−0.22*</td>
<td>−0.14</td>
<td>0.01</td>
<td>−4.63**</td>
<td>−0.82**</td>
<td>−0.47**</td>
<td>−0.13</td>
<td>0.61**</td>
</tr>
</tbody>
</table>

*p < .08.

*p < .05.

**p < .01.
### Table 2. Estimated coefficients, standard errors, and 0.95 confidence intervals for predictors in the two steps of the regression model predicting trait anger.

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Coefficients</th>
<th>Multicollinearity</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>SE</td>
<td>Beta</td>
</tr>
<tr>
<td><strong>Step 1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attention bias</td>
<td>0.055</td>
<td>0.02</td>
<td>0.256</td>
</tr>
<tr>
<td>Interpretation RT bias</td>
<td>0.015</td>
<td>0.01</td>
<td>0.15</td>
</tr>
<tr>
<td>Percent of anger interpretations</td>
<td>−1.103</td>
<td>8.93</td>
<td>−0.01</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attention bias</td>
<td>0.064</td>
<td>0.02</td>
<td>0.295</td>
</tr>
<tr>
<td>Interpretation RT bias</td>
<td>0.016</td>
<td>0.01</td>
<td>0.152</td>
</tr>
<tr>
<td>Percent of anger interpretations</td>
<td>−0.765</td>
<td>9.310</td>
<td>−0.09</td>
</tr>
<tr>
<td>Attention bias × Interpretation RT bias</td>
<td>0.001</td>
<td>0.01</td>
<td>0.126</td>
</tr>
<tr>
<td>Interpretation RT bias × Percent of anger interpretations</td>
<td>−0.21</td>
<td>0.428</td>
<td>−0.05</td>
</tr>
</tbody>
</table>

Note: B = unstandardised estimated coefficient; SE = standard error; CI = confidence interval.
* p < .05
** p < .01.

### Table 3. Estimated coefficients, standard errors, and 0.95 confidence intervals for predictors in the two steps of the regression model predicting anger expression index.

<table>
<thead>
<tr>
<th>Predictor</th>
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<tbody>
<tr>
<td></td>
<td>B</td>
<td>SE</td>
<td>Beta</td>
</tr>
<tr>
<td><strong>Step 1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attention bias</td>
<td>0.148</td>
<td>0.060</td>
<td>0.240</td>
</tr>
<tr>
<td>Interpretation RT bias</td>
<td>0.083</td>
<td>0.030</td>
<td>0.284</td>
</tr>
<tr>
<td>Percent of anger interpretations</td>
<td>−37.51</td>
<td>24.97</td>
<td>−0.155</td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attention bias</td>
<td>0.168</td>
<td>0.062</td>
<td>0.273</td>
</tr>
<tr>
<td>Interpretation RT bias</td>
<td>0.089</td>
<td>0.031</td>
<td>0.304</td>
</tr>
<tr>
<td>Percent of anger interpretations</td>
<td>−29.321</td>
<td>25.857</td>
<td>−0.121</td>
</tr>
<tr>
<td>Attention bias × Interpretation RT bias</td>
<td>0.001</td>
<td>0.002</td>
<td>0.048</td>
</tr>
<tr>
<td>Interpretation RT bias × Percent of anger interpretations</td>
<td>−1.45</td>
<td>1.189</td>
<td>0.012</td>
</tr>
</tbody>
</table>

Note: B = unstandardised estimated coefficient; SE = standard error; CI = confidence interval.
* p < .05
** p < .01.
(a) anger suppression and anger expression toward oneself (AX-I) was not predicted by either attention or interpretation biases; (b) outward expression of anger (AX-O) was associated only with faster response to negative versus positive emotional interpretations (higher interpretation RT bias; \( \beta = 0.24, p < .05 \)); (c) greater control over experienced angry feelings (AC-I) was predicted by less allocation of attention toward threat (lower attention bias; \( \beta = -0.23, p < .05 \)); and (d) greater control over outward expression of anger (AC-O) was predicted by both lower attention bias toward threat (\( \beta = -0.21, p < .05 \)) and lower interpretation RT bias (\( \beta = -0.29, p < .01 \)).

Discussion

The current study explored the relations between cognitive processes (attention and interpretation biases) and self-reported anger measures reflecting theoretically distinguished aspects of anger experience, expression, and control. To our knowledge, this is the first study to examine the combined contributions of attention and interpretation biases on sub-components of self-reported anger expression and control. Results indicate a complex pattern of associations in which attention and interpretation biases each displayed unique associations with some anger components and overlapping contributions to other anger components. Unexpectedly, the interactions between the measured attention and interpretation biases did not contribute to the prediction of any anger component in the current sample.

Attention bias toward angry faces was associated with higher trait anger, whereas interpretation bias did not contribute to variability in trait anger. These findings suggest that the disposition to experience anger is related to a cognitive pattern of allocating more attention to threatening stimuli. This result converges with prior studies suggesting that individuals with high compared to low trait anger demonstrate greater attention bias toward negative stimuli (Van Honk, Tuiten, De Haan, et al., 2001). This finding is also consistent with the ICM framework (e.g. Wilkowski & Robinson, 2008, 2010), which suggests that high trait anger is associated with selective attention processes favouring hostile stimuli and specifically with difficulty in disengaging attention from such stimuli. These negatively biased attention patterns are thought to facilitate ruminative and hostile information processing that amplifies anger. In contrast, negative interpretation biases did not predict trait anger, a result inconsistent with our hypothesis and with the ICM notion that hostile interpretations are of primary importance in anger elicitation.

With respect to the anger expression index, reflecting the balance between anger reactivity and anger regulation (Spielberger, 1999), the current findings revealed effects associated with both attentional and interpretational biases. Participants with high anger expression index displayed greater attention to negative faces on the dot-probe task and faster negative interpretations on the emotion-perception task. These results correspond with the ICM and SIP models, which posit that biases in early stages of attention, encoding, and interpretation of social information are precursors for reactive aggression.

Although attention and interpretation processes may both contribute to individual differences in anger expression, an inspection of the association between attention bias, interpretation RT bias, and the different sub-components of the anger expression index revealed a more specific pattern. While faster negative interpretation plays a role in the tendency to express anger toward the environment (AX-O), biased attention to angry faces is implicated in difficulties calming down when angered (AC-I). Both attention allocation toward threats and faster negative interpretations were associated with diminished ability to control one’s outward anger expression (AC-O). Thus, while faster negative interpretation appears to be related to outward anger behaviour (i.e. aggression) and less control over such behaviour, biased threat-related attention is involved in regulation and control processes of both inner feelings and outward behaviour related to anger.

The finding that fast negative interpretation is associated with aggression-related anger components (AX-O, AC-O) is not surprising. Hostile attributional style has been identified as a precursor of aggressive behaviour development (Dodge, 2006), and aggressive individuals tend to demonstrate hostile attribution of intent (Oroboio de Castro et al., 2002). Most of this literature focused on interpretation of social situations and many studies specifically focused on the attribution of negative intent to others. The current study focused on interpretation of anger in ambiguous facial expressions, demonstrating that fast-occurring interpretations of ambiguous faces as angry are related to self-reported anger expression toward the environment.

The finding that negative attention bias was associated with lower anger control (AC-I, AC-O)
corresponds with emotion regulation theories that include attention processes as key component of the emotion regulation system (Gross & Thompson, 2007). According to such models, distraction from negative thoughts serves as an early filter for blocking emotional information and preventing further emotion intensification (Sheppes & Gross, 2011). Similarly, the ICM model (Wilkowski & Robinson, 2008, 2010) suggests that self-distraction can reduce anger by reducing ruminative attention to hostile information. Biased attention to negative information may be a precursor for difficulties in employing distraction as an emotion regulation strategy. Therefore attention bias to negative stimuli may be related to lower control over anger reactivity, as indicated in the current study by the association between negatively biased attention and lower anger control (AC-I, AC-O).

Contrary to our expectations, no association was found between percent of anger interpretations and any of the self-reported anger measures. It may be that percent of anger interpretations, which is derived from a forced-choice response, is less sensitive than the RT-based measures. Additionally, percent of anger interpretations is based on explicit judgments and may reflect a conscious decision process. The two RT-based measures we used potentially reflect more implicit cognitive processes that may be less affected by conscious awareness. It also may be the case that this specific bias is more prominent in individuals with more extreme levels of anger, not represented in our non-selected sample, or individuals who have been exposed to extreme aggression, and thus may become sensitive to even mild expressions of anger, as has been found among abused children (Pollak & Kistler, 2002).

The current study did not find an effect for the interaction between attention and interpretation biases on anger measures. Typically, SIP and emotion regulation theories model attention and interpretation processes as inter-related rather than independent. Some see attention processes as preceding interpretation processes (Gross & Thompson, 2007; Sheppes & Gross, 2011), others see interpretation processes as influencing attention patterns (Wilkowski & Robinson, 2008, 2010), and some see these processes as having bidirectional influences (Crick & Dodge, 1994). Data from cognitive bias modification studies in anxiety support the notion that these two processes are influenced by one another. For example, participants trained to allocate attention toward threat were later more likely to interpret ambiguous information in a threat-related manner (White, Suway, Pine, Bar-Haim, & Fox, 2011). Likewise, participants who completed interpretation training that encouraged benign, rather than negative, interpretations of ambiguous stimuli demonstrated greater ability to disengage attention from threat after training (Amir, Bomyea, & Beard, 2010). Our findings suggest that each of these processes has a distinct and independent contribution to anger (for similar findings in anxiety disorders see Pergamin-Hight, Bitton, Pine, Fox, & Bar-Haim, in press; Teachman, Smith-Janik, & Saporito, 2007) and have at least two implications. First, the findings suggest that individuals with biases in both attention and interpretation are not “more angry” beyond the effects of each component separately. That is, one might expect a “toxic” permutation in which (a) a propensity to quickly focus attention on anger-related stimuli combined with (b) a propensity to interpret ambiguous stimuli as anger-related leads to uncharacteristically high anger expression, but this did not appear to evident in the response patterns. The second implication associated with a lack of interactions is that one mechanism does not compensate or negate another. For instance, if an individual had the propensity to attend to anger-related stimuli, but was relatively unlikely to interpret ambiguous stimuli as anger-related, then one might expect to see an interaction suggesting suppressive effects. This type of pattern, however, was absent in the current study. We note that alternatively, this lack of interactive effect may be related to the moderate anger levels in the current sample. It may be the case that in participants with more extreme anger levels, not represented in the current sample, these two processes might interact and amplify the effect of each other.

The relative lack of anger-related research examining attention and interpretation biases in processing facial expressions opens up important and interesting areas for future research. First, we used only angry–happy morphed sequences in the emotion-perception task. By focusing on only one type of negative emotion, we were unable to ascertain whether anger was related to a specific tendency to interpret ambiguous faces as angry or, alternatively, a more general tendency to interpret ambiguous faces as negative. Future studies could explore this question by using stimuli consisting of various negative emotions (e.g. contempt, fear, and disgust), or ambiguous emotions (e.g. surprise), and tasks that include other negative
response options in addition to anger. Adding a neutral response option might also help differentiate whether the pattern of more negative interpretation was due to more anger interpretations, less happy interpretations, or both. Similarly, in the dot-probe task only angry-neutral face pairs were used and we were therefore unable to determine whether the bias was specifically related to angry faces, or alternatively related to a bias toward negative emotional faces or even to any emotional faces compared to neutral faces. To examine this, future studies may use stimuli sets consisting of various emotional expressions. Moreover, future research could elucidate whether anger is related to attention engagement by angry faces, difficulty disengaging attention from angry faces, or both (for similar examinations in anxiety see Grafton & MacLeod, 2014; Koster, Crombez, Verschuere, Van Damme, & Wiersema, 2006).

On a related note, we focused solely on anger thereby may have limited our ability to control for other traits that may be associated with the measured cognitive biases. For instance, similar attention and interpretation biases have been previously shown to be related to anxiety (e.g. Bradley et al., 1998; Maoz et al., 2016). Thus, an important and interesting direction for future research may be exploring concurrent and differential associations between cognitive biases, anger, and anxiety in the same sample. Some findings support associations between anxiety and anger (e.g. Kashdan & Collins, 2010) and it could be the case that similar cognitive biases in threat monitoring are related to both traits, reflecting two distinct emotional reactions to threat (anger-fight, fear-flight). Moreover, attention and interpretation biases in threat processing may be related to broader reactivity and regulation characteristics that are not only anger-related.

With respect to measurement-related future research, we note that although RT bias scores are commonly used in the cognitive bias literature, several studies have found the reliability of such subtraction-based scores in the dot-probe task to be low (Schmukle, 2005; Staugaard, 2009). Some alternative, more reliable measures for attention bias have recently been suggested, such as attention bias variability (Naim et al., 2015), ERP and fMRI signals (e.g. Kappenman, MacNamara, & Proudfit, 2015; White et al., 2016), and eye-tracking (e.g. Lazarov, Abend, & Bar-Haim, 2016; Shechner et al., 2013). Future studies may use these alternative measures to replicate the biases found in the current study.

Finally, future research should examine the generalizability of our findings. More specifically, anger levels in our sample were rather restricted and may have limited our ability to account for effects related to more extreme anger levels. Future studies could enrol individuals with elevated levels of anger, from samples of above-average self-reported anger, to samples of individuals who suffer from anger-related problems disrupting normative function (e.g. frequent anger outbursts, or repeated violent acts). Establishing causality between cognitive bias and anger, and establishing these cognitive biases among highly angry samples, could serve as preliminary steps for future cognitive bias modification protocols once stable targets for treatment emerge. Computerised cognitive modification protocols are increasingly studied in the context of treatment for anxiety disorders (for reviews see Bar-Haim, 2010; Beard, 2011; Hakamata et al., 2010; MacLeod & Mathews, 2012), yet the use of computerised cognitive modification protocols in the context of anger and aggression treatment is still scarce (cf. Hawkins & Cougle, 2013; Penton-Voak et al., 2013; Stoddard et al., 2016). Based on the findings of the current study, interventions focusing on attention and interpretation processes may potentially contribute to changes in different anger-related elements.

Targeting interpretation processes may help reduce expressions of anger. Indeed, interventions training toward benign rather than negative interpretation of social scenarios have been shown to reduce anger and aggressive behaviour (e.g. Hawkins & Cougle, 2013). To our knowledge, only one randomised controlled intervention study used computerised modification training to target interpretation of ambiguous faces (Penton-Voak et al., 2013). In this study, youth trained toward positive interpretation of ambiguous faces demonstrated less aggressive behaviour compared with a control group. Since the current study found anger expression to be associated with the more implicit aspect of negative interpretation RT bias rather than with the explicit percent of negative interpretations, cognitive modification effects on anger expression may potentially be enhanced by targeting interpretation response times in addition to interpretation judgments. Alternatively, targeting attention processes, and specifically reducing attention allocation to negative stimuli via attention bias modification may uniquely contribute to improvement in the capacity to control and relax anger feelings when experienced. To our knowledge,
no attention bias modification protocol has been used yet to target anger regulation. The current results suggest that both attention- and interpretation-based interventions could potentially contribute to better control over outward anger expression. This combined approach could be directly tested in future randomised controlled intervention studies.

The current study also had several limitations. First, the order of the two cognitive tasks was not counterbalanced across participants. This may have affected the findings by increasing emotional sensitivity during the morph task which might have had a carry-over effect during the dot-probe task. Future studies examining both cognitive biases should preferably use a design in which the two tasks are counterbalanced. Second, the current study is correlative, limiting inferences regarding causality. The current analyses tested a theory-driven model suggesting that cognitive biases cause variations in anger levels. Nonetheless, it is also possible that individual differences in trait or state anger levels influence differential cognitive patterns. Although previous studies have demonstrated effect of changes in hostile interpretation on change in anger (e.g. Hawkins & Cougle, 2013), supporting the hypothesised causal sequence, this causal relation has not yet been demonstrated for attention biases. Future studies may test for causality by manipulating attention toward or away from hostile information while monitoring subsequent change in anger. A similar approach has been used to establish causality between attention bias and anxiety (Eldar, Ricon, & Bar-Haim, 2008; MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002). The alternative possible direction may be examined by manipulating state anger and measuring subsequent changes in cognitive biases. Third, the current study relied on self-reported anger, whereas future research may include more direct and objective measures of anger experience and expression (e.g. psychophysiological measures, criminal records).

In sum, this is the first study to explore attention and interpretation biases as well as their interaction as predictors of different self-reported anger sub-components. The current findings provide preliminary evidence for differential patterns of associations between cognitive processes and the sub-components of anger experience, expression, and regulation. These findings could be followed up using controlled experimental designs involving groups with heightened levels of trait anger or clinical groups, as well as cognitive modification protocols targeting different cognitive mechanisms in order to further elucidate their specific causal contribution to anger and its regulation in anger-provoking conditions.

**Disclosure statement**

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