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ORIGINAL ARTICLE

Gaze-contingent Attention Bias Modification Training and its Effect on Attention, Interpretations, Mood, and Aggressive Behavior

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Abstract
Cognitive theories propose that aggression is associated with specific patterns of attention to social cues, and suggest that cognitive biases in attention and interpretation are interrelated, The current study tested whether these attention patterns can be altered using a single session of a novel gaze-contingent cognitive bias modification paradigm (CBM-A) and assessed the impact of this on interpretation bias, aggressive behavior and mood. University students (18–31 years) were randomly assigned to either a single session of positive training ($n = 40$) aimed at increasing attention to pro-social cues, or negative training ($n = 40$) aimed at increasing attention to negative cues. Results showed that the positive training indeed resulted in an increase in pro-social attention bias, while the negative training seemed not to have an effect on attention to negative cues. Both groups did not differ on their interpretations, mood levels, self-reported aggression and behavioral aggression. Findings suggest that this novel gaze-contingent CBM-A paradigm can indeed alter biased gaze processes, but may not impact interpretations, aggression and mood. The current study was conducted in a non-clinical sample, further research with a clinical aggressive sample, such as forensic patients is necessary to further explore these issues.

Keywords Attention bias · Eye-tracking · Gaze-contingent · Interpretation bias · Aggression · Mood

Introduction

The Social information processing (SIP) model (Crick and Dodge 1994) is an influential cognitive theory concerning the development of aggressive behavior. This model asserts that aggressive behavior is associated with specific patterns of social information processing. Several studies that aimed to test this model found support for the existence of these associations suggesting that aggression is associated with biases in both selective attention (e.g., Dodge 2006) and interpretation of ambiguously hostile behaviors (e.g., de Castro et al. 2002 for a review). Moreover, different forms of information biases are associated rather than independent phenomena (Crick and Dodge 1994). Based on the SIP model, it can be hypothesized that reducing aggression-related cognitive biases in attention and interpretation may affect aggression, and furthermore that reductions in one type of bias may affect the other type of bias (c.f. Amir et al. 2010). The ultimate goal of the current study was to test a new attentional bias modification training and assess its effects on attention, interpretations, mood and aggressive behavior. A logical starting point of this endeavor is focusing on how aggressive individuals differ in their attentional deployment from non-aggressive individuals.

According to the SIP model (Crick and Dodge 1994), individuals first attend to the most relevant social cues in a social situation and encode it for further processing. Encoding functions in a bottom-up manner that affects the way the social situation is interpreted. Thus, encoding has to be selective and fast in order to efficiently identify all relevant cues in the environment. The traditional hypothesis of the SIP model suggests that aggressive individuals tend to show heightened attention for hostile versus non-hostile social cues, increasing the likelihood of a hostile interpretation of the situation, therefore increasing the chances of aggression (Crick and Dodge 1994). In support of this hypothesis a number of studies found that individuals who score high on

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measures of aggression or anger tend to show heightened attention for hostile stimuli on various reaction-based tasks, like the dot-probe (e.g., Smith and Waterman 2003, but see; Schippell et al. 2003), the emotional Stroop (e.g., Eckhardt and Cohen 1997; Smith and Waterman 2003; Van Honk et al. 2001a, b), and visual search (e.g., Cohen et al. 1998; Smith and Waterman 2004). However, almost all these studies used verbal stimuli (but see Van Honk et al. 2001a) that were presented without a context. As a result the patterns of attentional deployment captured by such paradigms may not be optimally informative of attentional processes during actual social interactions.

To overcome such issues, other studies have focused on attention deployment to visual stimuli depicting social situations, using eye-tracking (Wilkowski et al. 2007; Horsley et al. 2010; Troop-Gordon et al. 2018). Interestingly, these studies show a different pattern of results, supporting an alternative hypothesis described as the 'schema inconsistency hypothesis'. According to this hypothesis aggressive individuals' interpretations of social situations are based more on pre-existing hostile intent schemata than on available social cues in the current social situation. Importantly, even though some studies suggest that aggressive individuals focus their attention on schema inconsistent cues (i.e., non-hostile cues) (Wilkowski et al. 2007; Horsley et al. 2010), these cues are not well recalled (Horsley et al. 2010) suggesting that schema-inconsistent information is sub-optimally encoded (de Castro and van Dijk 2017). In order to test this idea, Troop-Gordon et al. (2018) presented children with video clips of child actors portraying scenes of ambiguous provocation, and assessed their peer beliefs. They found that aggressive children who hold negative peer beliefs take greater time before they first fixate on social cues from the actors in the scene, in particular the provocateur, while they do not dwell longer on the provocateur after the actual provocation has occurred. Such initial inattention to social cues, and the failure to compensate for this after a provocation, may be a result of overreliance on schema-based hostile beliefs in the context of ambiguous situations. Taken together, the findings from these studies suggest that aggressive individuals might benefit most from training programs that would train them to effectively attend to and encode relevant social cues that help disambiguate the situation. Therefore, the current study assessed the effect of an attention training program aimed at explicitly directing attention towards relevant social cues while trying to determine the intent of an actor in ambiguous social situations.

One way to train attention, is to use the CBM-A paradigm. CBM-A was originally developed to manipulate attention selectivity in the context of anxiety research where it is used to change participant's attention selectivity away from threatening cues to more non-threatening cues (MacLeod et al. 2002). Studies have shown that such manipulations of attentional bias influenced anxiety and stress reactivity (see Bar-Haim 2010 for review). However, the results have been mixed and the reported effect sizes are small to moderate (Van Bockstaele et al. 2013). This may have to do with the fact that CBM-A procedures that have been used so far inferred focus of attention on the basis of manual reaction times to visual cues on the screen. This makes it difficult to ascertain whether the training indeed affects visual direction of attention. A more powerful and direct manipulation would be to provide feedback based directly on the gaze direction using an eye tracker. Therefore, the current study used a novel gaze-contingent CBM-A procedure, which potentially has better effects in training attention in the context of aggression.

Recent studies in the context of depression and anxiety show that attention can indeed be trained successfully using gaze-contingencies (Price et al. 2016; Ferrari et al. 2016; Lazarov et al. 2017). Following this, in the present training, a gaze-contingent procedure in which the screen is updated based on the individual's eye position (Foulsham et al. 2013), was used to manipulate attention. More specifically, we provided positive feedback to participants if they fixed their gaze on the pro-social cues, and negative feedback if they fixed their gaze on the negative cues in ambiguous social provocation scenes. Such a setup might potentially increase the training effects as it ensures a fixation on and processing of the information in the desired areas of interest. Importantly, it provides an effective real time attention manipulation of the cues (Glaholt and Reingold 2011).

In the current study, the CBM-A training provided a first step toward the development of attention bias training program aimed at training more pro-social looking strategies for aggressive individuals. During the training participants were presented with pictures of ambiguous social situations in which something unfortunate happens (e.g., one person spilling a drink on someone else). Previously it has been shown that individuals scoring high on aggressive tendencies tend to pay less attention to the face of a potential harm-doer (i.e., provocateur) in scenes depicting ambiguous signs of hostility, and tend to look longer at angry body expressions, than do individuals scoring low on aggressive tendencies (Lin et al. 2016). Arguably, the face is the single most informative social cue regarding the intentions of one person towards another (Cadesky et al. 2000). Following this, directing individual's attention to facial expressions during social interactions may provide a viable target in CBM-A training. In addition, by combining the attention training with the explicit instruction to look at cues that can help disambiguate the situation, we hoped to ensure encoding of the attended information. In the current CBM-A two cues were identified on each picture; pro-social cues which includes the face of the harm-doer, which can indicate whether the incident happened by accident (or not); or to negative cues (e.g., the drink spilling on victim) which provides no useful information regarding the intent of the harm-doer and might only increase feelings of anger in the participant. Depending on the training condition, participants were either trained to attend more to the pro-social cues or to the negative cues.

The current study had four aims. First, we aimed to examine whether aggression-related attention mechanisms can be altered using this novel gaze-contingent CBM-A procedure. Second, we aimed to examine the effects of the altered aggression-related attention mechanisms on aggressive behavior using self-report and behavioral measures. We predicted that training individuals to attend to the negative cues would increase subsequent attention bias to negative cues and increase aggressive behavior. On the other hand, training them to attend to the pro-social cues would increase pro-social attention and reduce subsequent aggressive behavior. Third, this study aimed to test whether this procedure affects how subsequent ambiguous social information is interpreted, in order to investigate the interaction between attention and interpretation bias and how both of these biases contribute to aggressive behavior. This is relevant because it can show whether CBM procedures need to target only one or better target both biases to achieve the strongest effects. We expected that participants who were trained to attend to pro-social cues would make less hostile interpretations than participants who were trained to attend to negative cues. Finally, based on previous research in the context of anxiety (MacLeod et al. 2002) showing that manipulating attention bias may impact mood, we also assessed the impact of the attention modification training on mood in an explorative way.

Method

Participants

Forty male and forty female students from Erasmus University Rotterdam (48 Caucasians, 5 Asian, 7 Middle Eastern, 2 Hispanic, 1 African, and 17 others), aged between 18 and 31 ($M=20.61$, $SD=2.11$) participated in exchange for course credits. Participants were randomly selected from a list of students who had subscribed to participate in the experiment. The study was conducted according to the rules of the Helsinki Declaration on informed consent and confidentiality (World Medical Association 2001) and all procedures were carried out with adequate understanding and written consent of the participants.

Eye-Tracking Procedure

During the CBM-A training, eye movements were recorded using a SMI-RED 250 device (Sensomotoric Instruments GmbH, Teltow, Germany) with a sampling rate of 250 Hz.

The stimuli were presented on a 22-inch computer screen with a resolution of 1680×1050 pixels. The viewing distance was approximately 60 cm. The size of the picture was 1344×777 pixels. For each image, areas of interest (AOI) were defined around a 'negative' cue showing the negative outcome of the situation (e.g., coffee spilling on the victims clothes), and a 'pro-social' cue (the face of the harm-doer, see Fig. 2). Each AOI was defined as a square area and had a size of either 252×210 or 336×210 pixels to encompass the entire area of display of pro-social or negative cue in the picture.

To ensure accuracy of the gaze pattern, a nine-point calibration and 4-point validation was performed before starting with the first phase. Also, a chin-rest was used to maintain a constant head position and distance from the computer screen throughout the training.

CBM-A Training

The CBM-A task consisted of 52 trials that were presented using E-prime software. On each trial, the participants viewed an image of a social interaction during which something unfortunate happens, like one person spilling a drink over the other, while the intention of the harm-doer is unclear. These images were used to assess attention and interpretation biases and manipulate attention bias. Each image appeared only once, so 52 different pictures were used. The training task was completed within a single session and started with an eye-tracker calibration. The CBM-A training consisted of four phases: practice, baseline, training, and test. The practice phase was implemented to introduce participants to the experimental procedure and consisted of three trials. In order to examine the effects of the training on attention and interpretation bias, an assessment of attention and interpretation bias was administered during the baseline and test phases. The baseline and test phases were identical and consisted of six trials each. The manipulation of attention bias took place during the training phase, which consisted of forty trials. The whole CBM-A task took approximately 25 min to complete.

Phase 1 (Practice)

On each trial participants were presented with an image which is not related to the images used in the training. To get acquainted with the procedure, participants were instructed to fix their gaze on a certain AOI and received feedback on the their performance; "Correct" if they fixed their gaze on the correct part of the picture; "Incorrect" if they fixed their gaze on the incorrect part of the picture; or "Too slow" if they didn't fix their gaze on any AOI and were asked to try again.

Phase 2 (Baseline) and 4 (Test)

On each trial participants were presented on the computer screen with a single sentence describing a situation in which a mishap has occurred. For example, "There is water all over his clothes!" The description was presented on the screen until the mouse was clicked. Participants were then presented with an image of the described situation in which the intent of the harm-doer was ambiguous (see Fig. 1 for an example). While looking at the images, participant's eye movements were recorded automatically using the eye-tracking device. During these phases participants' total dwell-time to both areas of interest (i.e., pro-social and negative cues) was recorded, which we used as a measure of the attention bias.

To measure attention bias, participants were asked to look at the part of the picture that best indicates whether or not the incident happened on purpose (e.g., see Fig. 1). To assess participants' interpretation of the intent of the harm-doer they were asked "Why did this happen?", and presented with two possible interpretations, one hostile and one benign (cf. AlMoghrabi et al. 2018). For example, the picture presented in Fig. 1 was accompanied by the following two interpretations: (a) This happened on purpose because he wanted to tease him (hostile interpretation); (b) This happened by accident because he tripped (non-hostile interpretation). Participants indicated the likelihood that a specific interpretation is true by dragging an arrow on a 100-point visual analogue scale that was anchored with the labels "No, definitely not" (−50) on the left and "Yes, definitely" (+50) on the right ends of the scale. During this phase, no feedback was provided. The viewing time was fixed for 5000 ms for each image. Additionally, a minimum amount of eye gaze time of 80 ms at a certain AOI was qualified as a gaze fixation (e.g., Huijding et al. 2011; Gerdes et al. 2008).

Phase 3 (Training Phase)

For the training phase, the participants were randomly assigned to either the negative or positive training, each consisting of forty trials. Similar to phases 2 and 4, each trial presented participants with an image of a situation in which one person is harming another, but the intention of the harm-doer is unclear. The images were always preceded by a short description of the situation that was presented for 3000 ms. For example, the image presented in Fig. 2 was preceded by the description: "He got the ball hard on his head!" Subsequently, the image of the situation was presented on the screen for 5000 ms, along with the question "Why did this happen?" Participants were instructed to fixate on the part of the picture that best indicates whether the incident happened on purpose or by accident, until they received feedback. In this phase a gaze-contingent procedure was used to ensure participant's fixation on the specified areas of interest. Depending on the training condition either the negative or the pro-social cue was reinforced as the correct answer. In the positive training condition, fixations on the pro-social cues (the faces of the harm-doers) were reinforced as "correct" while in the negative training fixations on the negative cues (the negative outcomes) were reinforced as "correct". If participants fix their gaze for 1000 ms on the "correct" AOI, the word "CORRECT" was presented at the top of the screen in bold green font. If participants fix their gaze for 1000 ms on the "incorrect" AOI, the word "INCORRECT" was presented at the top of the screen in bold red font. This feedback remained on the screen for 2000 ms, after which the next trial began. If participants didn't fix their gaze on either AOI for 5000 ms "Too slow" was presented on top of the screen in bold blue font for 2000 ms, after which the same picture would be shown to allow the participant to try again.

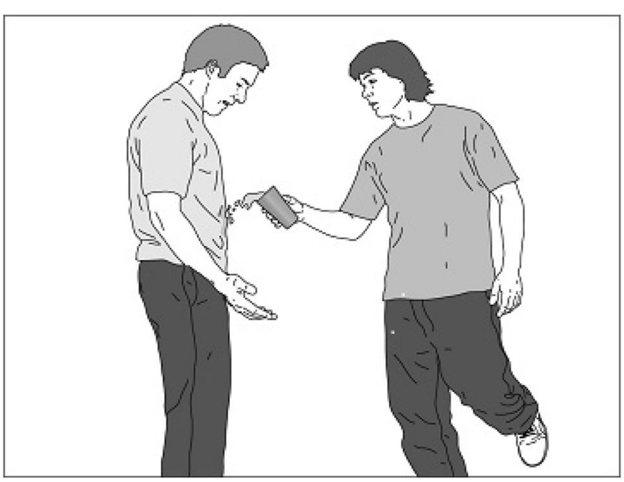

Fig. 1 Example image from the baseline phase

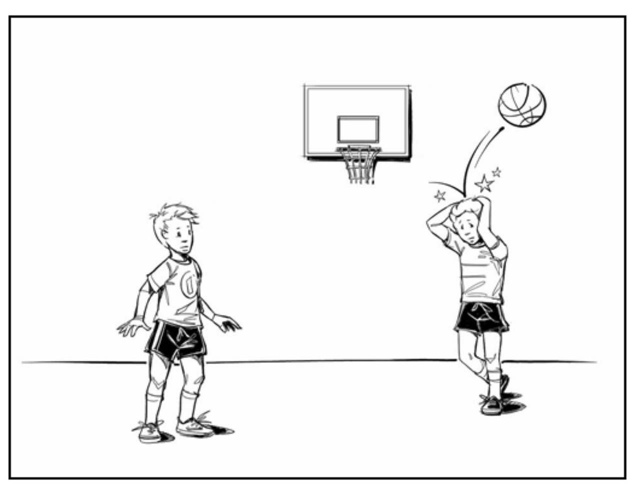

Fig. 2 Example image from the training phase

Stimulus Materials

A set of 52 pictures was used in the CBM-A training that each showed a situation in which one person harmed another, but was ambiguous regarding the intent of the harm-doer. For the baseline and test phases, we used the images from the study of Wilkowski et al. (2007) (see Fig. 1 for an example). For the training phase, we used the images from the study of Horsley et al. (2010) (see Fig. 2 for an example), supplemented by thirty images from stock image websites. Images were chosen that depicted a hypothetical real-life scenario, some including two males, some two females, and some a male and a female. The images depicted an interaction between those two characters, with one of the two characters (i.e., harm-doer) initiating a behavior that affects negatively the other character (i.e., victim).

To ensure the adequacy of the stimulus materials, in a pilot-study 40 university students were asked to rate the pictures on a number of characteristics, including the extent to which the depicted harm was intentional and how aggressive is the facial expression of the harm-doer. Participants rated intentionality on a 100 point visual analogue scale (VAS) that was anchored with the labels "Accidental" on the left and "Intentional" on the right end. Additionally, participants rated the facial expression of the harm-doer on a 100 point VAS that was anchored with the labels "Friendly" on the left and "Aggressive" on the right end. The results show that the pictures in the assessment phase were rated on average as very ambiguous regarding both the intent of the harm-doer [$M=51.3$, $SD=14.1$], and facial expression of the harm-doer [$M=50.8$, $SD=6.5$], and the pictures in the training phase were rated ambiguous regarding the intent of the harm-doer [$M=47.0$, $SD=11.6$], and quite ambiguous, but leaning a bit towards friendly, for the facial expressions of the harm-doer [$M=41.76$, $SD=4.8$].

Pre-measures

Prior to the CBM-A training, the present study sought to assess participants on a number of measures of state/trait aggression, anxiety, mood, and anger.

The Buss and Perry's (1992) trait Aggression Questionnaire (AQ) assesses trait aggression. Following the same method used by Farrar and Krcmar (2006), the present study reworded the AQ measure to assess state aggression (cf. AlMoghrabi et al. 2018). The modified questionnaire started with the following instruction: "Imagine that you just bought something to drink. When you walk outside, somebody bumps into you, spilling your drink over your favorite clothes. As you look at the mess, you hear this person swearing." In addition, the items comprised of items from the AQ that were rephrased. For example, the original AQ item "I have trouble controlling my temper" was rephrased to "I would have trouble controlling my temper with this person" to match state aggression. For each of the items, the participants were instructed to rate the extent (1 = extremely uncharacteristic of me; 7 = extremely characteristic of me). The questionnaire consists of 20-items on three subscales: physical aggression, verbal aggression, and anger. In the current sample, Cronbach's alpha was 0.87.

The Reactive-Proactive Aggression Questionnaire (RPQ; Raine et al. 2006) provides measures of both reactive (11 items; e.g., "damaged things because you felt mad") and proactive (12 items; e.g., "taken things from other students") aggression. For each item the participant provided a rating of 0 = Never, 1 = Sometimes, and 2 = Often. In the current sample, Cronbach's alpha was 0.77 for reactive and 0.75 for proactive aggression. Finally, anger was measured using part B of the Novaco Anger Scale (NAS; Novaco 1994). The measure consists of 25 potentially provoking situations (e.g., "Being joked about or teased"). The participant rated each provoking situation on a 5-point scale from 0 (little or no annoyance) to 4 (very angry). In the current sample, Cronbach's alpha was 0.88. Additionally, the participant's state mood was measured pre-training by asking participants to rate how happy, angry, sad, and afraid they felt at the moment. For each emotion they dragged an arrow on a 100-point visual analogue scale that was anchored with the labels "Not at all" (−50) on the left and "Very much" (+50) at the extreme ends of the scale.

For exploratory purposes beyond the scope of this manuscript the State-Trait Anxiety Inventory (STAI) was also included (Spielberger et al. 1983).

Post-measures

To test whether the training would influence self-reported aggression, the participants completed post-training again the reworded trait Aggression Questionnaire but with a different contextual story that read: "Imagine that you are at the Starbucks working on an assignment. Suddenly, someone bumps into your table, spilling coffee all over your notes. You see that the other person looks really annoyed." In our sample, Cronbach's alpha was 0.89.

The Positive Affect and Negative Affect Schedule (PANAS; Watson et al. 1988) was administered post-training to measure trait mood levels. Participants had to rate how much they generally feel (1 = Slightly; 5 = Extremely) about 10 positive emotional states (e.g., interested, inspired) and 15 negative states (5 items specifically covering anger were added to the original; e.g., upset, guilty). Cronbach's alpha for positive effects was 0.87, and for negative effects was 0.92. Additionally, the participant's state mood was measured again post-training by asking participants to rate how happy, angry, sad, and afraid they felt at the moment. For each emotion they dragged an arrow on a 100-point visual analogue scale that was anchored with the labels "Not at all" (− 50) on the left and "Very much" (+ 50) at the extreme ends of the scale.

Aggression Task

In addition to the self-reported measures, aggression was also measured post-training using the Taylor Aggression Paradigm (TAP; Taylor 1967) which is a behavioral measure of aggression. The task was introduced to the participants as a competitive reaction time game of 30 trials, and they were told that they would be competing against an opponent. Before starting with the actual task, the experimenter gave a brief introduction by telling each participant that this experiment was a collaboration between Erasmus University Rotterdam and Utrecht University and that their opponent was currently present at a lab in Utrecht and that the same instructions would be delivered to their opponent. After this, the experimenter would pretended to contact collaborators at Utrecht University to coordinate the start time of the experiment. This was done to ensure the credibility of the game. In fact, no experimental collaboration or opponent actually existed.

Each participant was seated at a desk with a mouse and a computer screen, and told that in order to beat their opponent in this reaction time game, they had to click the mouse as fast as possible when a rectangle turned from yellow to red. Participants were instructed that if they received the message "You Won" it would mean that they clicked faster than their opponent, while the message "You Lost" meant they were slower. Participants were informed that the winner would be allowed to administer a noise blast to their opponent. To make it more believable, the game started with the message "Connecting with opponent" on the screen. Also, in order to give the participant an idea of what kind of noise stimulus was used in the task in terms of intensity and duration, a noise testing procedure was administered before commencing the real task. Following that, on each trial participants first selected the duration (between 0 and 10 s) and the volume of the noise blast (between 0 and 100 dB) they would administer to the opponent should they win the trial. When they "lost" a trial, participants received a noise blast through the headphones and were given feedback regarding the level and duration of the noise they had received from their opponent. When participants "won" a trial, they could see on the screen what duration and level of noise their opponent's had set at the beginning of the trial. The opponent's noise selections, as well as the order of winning and losing trials, was pre-programmed (for the sequence of wins and losses; cf. Brugman et al. 2015).

Procedure

The participants were quasi-randomly assigned to one of two conditions: the positive condition ($n = 40$; 20 males and 20 females), which aimed to increase attention bias to pro-social cues or the negative condition ($n = 40$; 20 males and 20 females), which aimed to increase attention bias to negative cues. For either condition, the experimenter would start with a short introduction and a general explanation of the experimental tasks. Following this, participants started by completing the AQ, STAI, RPQ, and NAS questionnaires. Subsequently, they received specific instructions regarding the eye-tracking and the CBM-A training. After completing the CBM-A training the experimenter explained the TAP. After making sure that the participants understood the instructions of the TAP, they then proceeded with the task. Finally, the participants completed the AQ and PANAS. The entire experiment took approximately 60 min to complete.

Results

Data Reduction and Preliminary Analysis

First, based on the eye-tracking data, we calculated separate mean total viewing times in ms for the pre-defined AOIs for the pro-social and the negative cues at pre- and post-training. Next, pre- and post-training attention bias (AB) scores were calculated by subtracting the mean total viewing time at the negative cues from the mean total viewing time at the pro-social cues. Thus, a higher AB score indicates more attention allocation to pro-social (facial) than to negative (negative outcome) cues. Also, we calculated separate interpretation bias (IB) scores for each condition for the pre- and post-training assessments by subtracting the mean VAS likelihood rating for the hostile interpretation to be true from the mean VAS likelihood rating for the pro-social interpretation to be true. Thus, positive IB scores indicate that pro-social interpretations were rated as more likely to be true than hostile interpretations.

Next, in order to ascertain the appropriateness of our AB measure, we correlated the attention bias scores (AB-pre and AB-post) with the concurrently assessed aggression-related measures (i.e., AQ, NAS, RPQ, TAP and VAS state anger). The results indicated that there were no significant relations between pre- and post-training attention bias scores with respectively pre- and post-training aggression-related measures (see Table 1).

Baseline Measures

There were no significant differences between the participants in the positive and negative training conditions in their

Table 1 Correlations between attention bias scores pre/post-training and aggression-related measures pre/post-training

Measures	Attention bias
Aggression Questionnaire	−0.54/−0.06
Physical Aggression	−0.05/−0.12
Verbal Aggression	−0.02/0.06
Anger	−0.05/−0.08
Reactive-Proactive Aggression Questionnaire	0.01/n.a
NAS	−0.08/n.a
PANAS-positive	n.a./0.05
PANAS-negative	n.a./−0.13
Angry mood	0.06/−0.21
Afraid mood	−0.02/−0.13
Sad mood	−0.07/−0.09
Happy mood	0.01/−0.07
Taylor Aggression Paradigm	n.a./−0.08
Intensity	n.a./−0.08
Duration	n.a./−0.13

n.a. not assessed, *NAS* Novaco Anger Scale, *PANAS* Positive Affect and Negative Affect Schedule

All correlations: $p > 0.05$

baseline levels of self-reported aggressive behavior (AQ and RPQ), anger (NAS), trait anxiety (STAI-T), and mood ratings (happy, angry, sad, and afraid), for all $t(78) < -1.16$, $p > 0.201$. However, participants in the positive training condition reported a higher level of pre-training state anxiety (STAI-S) than participants in the negative training condition, $t(78) = 2.39$, $p = 0.019$. Descriptive statistics for the pre- and post-training measures are presented in Table 2. In addition, the analysis showed that participants in the negative groups scored higher on pro-social interpretation bias prior to the training ($M = 9.53$, $SD = 23.00$) than participants in the positive group ($M = -1.39$, $SD = 22.63$), $t(78) = -2.14$, $p = 0.035$. Both groups did not differ significantly on attention bias prior to the training $t(78) = 1.50$, $p = 0.137$, for the negative group ($M = -610.85$, $SD = 1458.02$) and for the positive group ($M = -167.70$, $SD = 1165.56$).

Reliability of the Attentional Process Measures

To assess the reliability of the attentional bias measure Cronbach's alpha's were calculated separately for baseline and test phase. First, we calculated separate total viewing times in ms for the pre-defined AOIs for the pro-social and the negative cues at pre- and post-training. Trials with less than 80 ms at either areas of interest were excluded. From the whole sample one participant looked less than 80 ms at either areas of interest on one trial. As a result we were unable to take this trial into account. Next, pre- and post-training attention bias scores for each image were calculated

Table 2 Descriptive statistics for pre/post-training measures

Measures	Positive training		Negative training	
Pre-training	*M*	*SD*	*M*	*SD*
Aggression Questionnaire	65.55	17.39	64.88	14.85
Physical Aggression	23.93	8.78	24.98	8.05
Verbal Aggression	18.33	4.86	17.70	4.16
Anger	23.30	6.78	22.20	5.91
Reactive-Proactive Aggression Questionnaire	32.18	5.06	32.33	6.10
NAS	71.85	13.58	70.85	12.52
Anxiety inventory-state	36.70	10.80	31.95	6.48
Anxiety inventory-trait	42.55	10.06	42.43	7.84
Angry mood	−40.98	16.78	−41.70	12.76
Afraid mood	−36.05	23.81	−41.53	12.47
Sad mood	−32.78	23.97	−36.73	16.70
Happy mood	13.35	19.51	18.20	18.00
Post-training				
Aggression questionnaire	64.45	18.98	63.15	15.81
Physical Aggression	24.55	8.81	24.68	8.08
Verbal Aggression	18.23	5.85	17.22	5.29
Anger	21.67	7.42	21.25	5.86
PANAS-positive	27.45	7.79	26.35	5.86
PANAS-negative	22.45	9.10	21.33	6.37
Angry mood	−35.28	22.41	−35.38	20.35
Afraid mood	−37.35	21.22	−42.83	13.67
Sad mood	−31.73	19.89	−35.23	18.39
Happy mood	12.03	22.04	16.55	19.84
Taylor Aggression Paradigm	16.78	12.20	19.62	15.64

NAS Novaco Anger Scale, *PANAS* Positive Affect and Negative Affect Schedule

separately by subtracting the total viewing time of the negative cues from the total viewing time of the pro-social cues. The Cronbach's alpha values for the pre- and post-training bias scores in the current sample were (baseline phase: $\alpha = 0.86$; test phase $\alpha = 0.84$).

Effects of Attention Training on Attention Bias

To determine training effects on attention bias, AB scores were subjected to a 2 Assessment (pre, post-treatment) × 2 Group (positive versus negative training) ANOVA with repeated measures.

The analysis revealed significant main effects of Group, $F(1, 78) = 21.43$, $p < 0.001$, $\eta_p^2 = 0.22$, and Assessment, $F(1, 78) = 8.58$, $p < 0.01$, $\eta_p^2 = 0.10$. More importantly, the crucial interaction between Group and Assessment was significant: $F(1, 78) = 15.04$, $p < 0.001$, $\eta_p^2 = 0.16$ (see Fig. 3). This interaction was decomposed using paired-samples *t*-tests of change over time. This showed that in the positive condition, attention bias

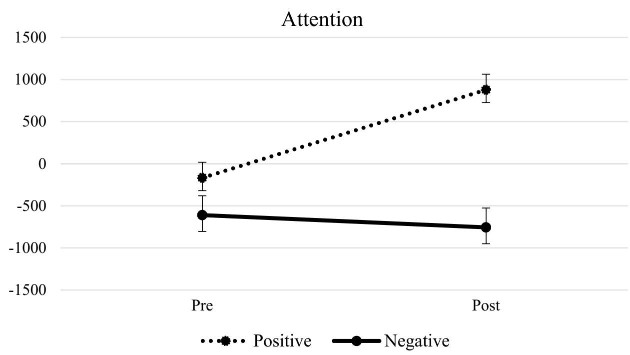

Fig. 3 Average attentional bias scores at pre- and post-training for each training condition. Error bars indicate standard error of the mean

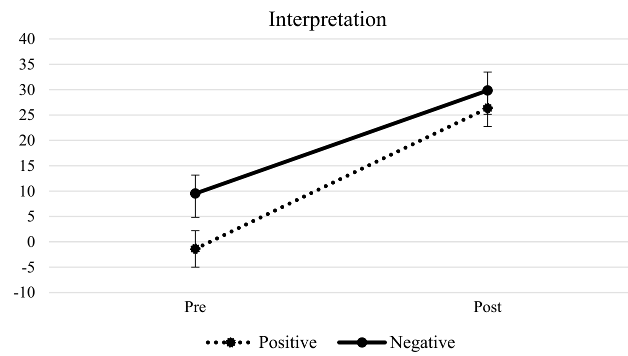

Fig. 4 Average interpretation bias scores at pre- and post-training for each training condition. Error bars indicate standard error of the mean

became significantly more positive, indicated relatively longer fixation durations on the pro-social cues (i.e., the face of the harm-doer) then on the negative cues: $t(39) = -5.43$ $p < 0.001$. In the negative condition, attention bias scores did not change significantly over time: $t(39) = 0.61$, $p = 0.546$.

Inspection of the participants' accuracy during the training phase (i.e., the extent to which they were doing what we wanted them to do during the training) showed that participants in the negative training condition made significantly fewer errors ($M = 17.56\%$, $SD = 11.26$) as compared to participants in the positive condition ($M = 24.94\%$, $SD = 20.06$, $t(78) = -2.03$, $p < 0.05$). This suggests that the observed difference in training effects between the two conditions cannot simply be attributed to differences in compliance to the training instructions. That is, compliance to the training instructions was significantly greater in the negative than in the positive condition, while the effects of the training on attention were greater in the positive than in the negative condition.

Effects of Attention Training on Interpretation Bias

To examine the effects of the attention training on interpretation bias, the IB scores were subjected to a 2 Assessment (pre versus post-treatment) × 2 Group (negative versus positive training) ANOVA with repeated measures. The analysis revealed that the crucial interaction between Group and Assessment was not significant: $F(1, 78) = 1.50$, $p = 0.224$, $\eta_p^2 = 0.02$. Moreover, no significant effects for Group emerged, $F(1, 78) = 2.43$, $p = 0.123$, $\eta_p^2 = 0.03$. However, the main effect of Assessment was significant, $F(1, 78) = 62.97$, $p < 0.001$, $\eta_p^2 = 0.45$. Surprisingly, it was found that in both conditions interpretation bias became significantly more pro-social post training (see Fig. 4).

Effects of Attention Training on Mood

VAS state mood ratings (happy, angry, sad, and afraid) were subjected to separate 2 Assessment (pre versus post-treatment) × 2 Group (positive versus negative training) ANOVAs with repeated measures. Only a significant main effect of Assessment emerged for self-reported anger, $F(1, 78) = 7.76$, $p < 0.01$, $\eta_p^2 = 0.09$, indicating that in both conditions self-reported state anger significantly increased from pre- to post-training. None of the other effects were significant, for all $F(1, 78) < 0.02$, $p > 0.885$, $\eta_p^2 = 0.00$.

In addition, independent-samples *t*-tests on the PANAS scores confirmed that the positive and the negative condition didn't differ significantly in terms of either their positive or negative trait affect scores, for both $t(78) < 0.64$, $p > 0.477$.

Effects of Attention Training on Aggression

Participants scores from the AQ were subjected to a 2 Assessment (pre- versus post-treatment) × 2 Group (positive versus negative training) ANOVA with repeated measures. The analysis revealed no main effects of Group or Assessment and no significant interaction between Group and Assessment: $F(1, 78) = 0.08$, $p = 0.774$, $\eta_p^2 = 0.00$ (see Fig. 5). Additionally, the analysis revealed that the training did not result in changes on the AQ subscales, all $F(1, 78) < 0.66$, $p > 0.421$, $\eta_p^2 > 0.003$.

Finally, participant's TAP scores were compared between the two conditions. An independent-samples *t*-test showed that the two training groups did not differ in terms of their TAP performance ($t(78) = -0.91$, $p = 0.367$), intensity ($t(78) = -0.20$, $p = 0.845$), and duration ($t(78) = -0.97$, $p = 0.337$).

Discussion

The current study examined whether a novel gaze-contingent cognitive bias modification of attention (CBM-A) procedure-designed to modify attention bias using pictorial

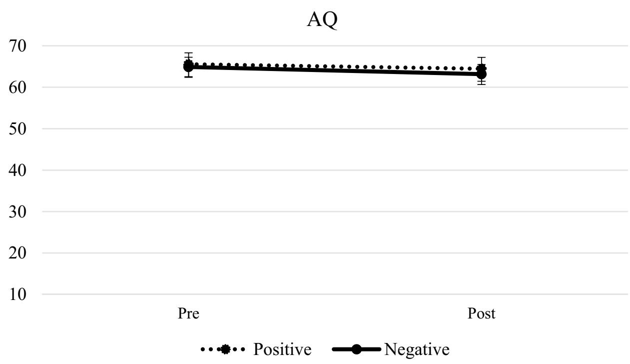

Fig. 5 Average Aggression Questionnaire (AQ) ratings at pre- and post-training for each training condition. Error bars indicate standard error of the mean

stimuli-influences attention, interpretations, mood and aggressive behavior. Results indicate that gaze-contingent attention training within the positive condition indeed resulted in an increase in attention to pro-social (facial) cues in images of ambiguous social situations. However, no change in attention to either pro-social or negative cues was found in the negative condition. Moreover, the attentional bias scores were unrelated to the concurrently assessed aggression related measures. Additionally, in both the positive and negative attention training conditions interpretations changed in a pro-social direction, and increased self-reported state anger was found.

The current finding that the positive training increased pro-social attention bias is well in line with previous findings that attention bias can be trained (Amir et al. 2009a, b; Van Bockstaele et al. 2013; Wadlinger and Isaacowitz 2008). Moreover, this finding underscores the feasibility of using a gaze-contingent approach to training attentional deployment (Price et al. 2016; Ferrari et al. 2016; Lazarov et al. 2017). The gaze-contingent approach was successful in training participants in the positive condition to pay more attention to pro-social cues (i.e., the face of the harm-doer) than to negative cues (i.e., the negative outcome) in a picture of an ambiguous social situation. The major advantage of this procedure is that the set-up enables direct assessment and training of gaze direction, rather than inferring this on the basis of task performance (i.e., reaction times) as is usually the case in attentional bias modification procedures. In addition, the current approach allows participants to experience the effect of their own eye-movements on altering the on-screen view presented to them, which creates interactive and responsive stimuli.

In contrast, although it appears that in the negative condition there was a slight increase in viewing negative cues from pre- to post-training, the attentional bias change score for this condition was not significant. This lack of training effect might be related to the fact that at pre-training, participants in both groups spent more time looking at the negative cues than the pro-social cues, suggesting that the negative cues were most salient in the depicted social situations. This is in line with a study of Wadlinger and Isaacowitz (2008) that found that participants looked longer at negative stimuli post neutral attention training, and argued that if participants were not trained to attend less to negative cues, these cues may be considered as "attention grabbing" in a social situation. Similarly, Ferrari et al. (2016), who also used a gaze-contingent attention bias modification procedures in a healthy sample, found that at pre-training participants took longer to disengage from negative stimuli than from positive stimuli. They argued that it takes more time to disengage from high arousing stimuli which in this case were the negative or threat-related stimuli. This might explain why our current sample in both conditions didn't show pro-social attentional bias pre-training which is supposed to be typical for healthy individuals. Additionally, the pre-existing negative attentional bias in the negative condition might also explain why participants in this condition have made very few errors in the training phase. That is, the training was reinforcing this pattern of selective attention toward negative cues, resulting in no further significant increase in negative attention bias pre- to post-training.

In general, the attention training did not have any effect on the aggression measures post-training. Additionally, the results showed that the attention training did not appear to have an effect on the TAP as a behavioral measure of aggression. Likewise, the attention bias scores did not correlate with the TAP scores and self-reported aggression scores both pre- and post-training. Consequently, the current study was not able to provide evidence for the association between attention bias and aggression. Furthermore, the CBM-A training did not result in the expected effects on interpretation bias. Earlier we argued that the face may be the single most informative social cue regarding the intentions of one person towards another (Cadesky et al. 2000). Therefore, it was suggested that high trait angry and aggressive individuals may have trouble mitigating their initial hostile interpretations, because they do not pay enough attention to and/or may not encode the right social cues. Following this line of reasoning, we hypothesized that aggressive individuals might benefit from training programs that would help them to effectively attend to relevant social cues that will help disambiguate the environment. Our current results suggest that this is not the case. That is, we did not find differential effects of training participants to attend to the pro-social (facial) cues or negative (outcome) cues on participants' interpretations of the ambiguous situations. In prior anxiety research, it has been indicated that cognitive biases influence and interact with one another in maintaining social anxiety (Amir et al. 2010; Hirsch and Clark 2004; Hirsch et al.

2006; White et al. 2011). For example, in the study of White et al. (2011) participants who were trained to attend to threat cues were more likely to interpret ambiguous stimuli as threat-related as compared to participants in a placebo-training group. Also, Amir et al. (2010) provided evidence that a single session of interpretation modification program modified interpretation bias in social anxiety participants, which in turn led to an increase in their ability to disengage attention from threat stimuli. Despite the hypothesis that modification of attention bias may influence interpretation bias, vice versa and thus enable changes on aggression, focusing on one cognitive bias may be insufficient to cause change in the context of aggression. In this case future work on CBM should target more biases at the same time, which may enable stronger training structure for it to become more malleable. In another line of argument, it could be that the current findings fit better with the reasoning of Wilkowski et al. 2007 and Horsley et al. 2010, that interventions targeting attention allocation should not only target attention allocation toward mitigating cues but to also target schemas that triggers a hostile interpretation of encoded cues in a social situation. In support of this idea, in a previous study using a similar training that was aimed at retraining hostile interpretations we did find some effect on aggressive outcomes (AlMoghrabi et al. 2018).

Additionally, the current CBM-A training did not result in expected effects on state mood, since self-reported angry mood state had increased in both conditions. This fits best with the findings of Ferrari et al. (2016) who found that negative mood increased in both negative and positive training groups post a gaze-contingent attention training. However, the negative group showed a stronger increase in negative mood than the positive group. This suggests that the increase in negative mood in the negative group might be due to sustained attentional processing of negative stimuli. In our case, the increase in self-reported angry mood from pre- to post-training in the negative condition could be related to the fact that participants had to continuously attend and process negative social cues during the training and were reinforced for a correct response. While in the positive condition the increase in self-reported angry mood from pre- to post-training might be the result of the high number of errors that participants made during the training compared to the participants in the negative condition. It is possible that participants in the positive training were inclined to fix their attention on negative cues when their attention should be fixed on prosocial cues, and became angry or annoyed by repeatedly receiving negative feedback. However, it is important to note that our sample did not include aggressive or high trait angry participants, making it more difficult to find aggression-related effects. Future research could apply this training to a clinically aggressive sample, before drawing firm conclusions about its therapeutic value.

The current results should be taken in light of several limitations. First, the current study included a sample of healthy university students. Therefore, it is not possible to make strong inferences about the potential use of the training in a clinical sample of aggressive individuals. In addition, it can be argued that it might be difficult to find effects on outcome measures of aggression in a relatively non aggressive sample such as we used here. Somewhat related to this, the current study didn't include measures of pre-existing hostile schemas of the participants. Considering previous findings that suggest that maladaptive attention allocation may only be related to aggression in individuals who hold hostile schema (e.g., Troop-Gordon et al. 2018), it is possible that the current training is only beneficial for individuals holding negative perceptions of others. Second, the measure of AB did not correlate significantly with the concurrently assessed aggression related measures, raising some questions about the validity of the currently adopted approach to assessing aggression related attention bias. Interestingly, a recent study did find a significant relation between a measure of aggression and a gaze pattern that somewhat similar to the one we used to operationalize AB in this study. That is, Laue et al. (2018) showed participants 3 image cartoon stories in which the first image illustrated the context, the second picture showed one character doing something that negatively affected another character, and a third picture showing the negative outcome and the facial expression of the harm-doer. The sequence of presentation was such that image 1 and 2 were subsequently presented alone, and then image 2 and 3 were presented on screen together. Results showed that when the final two pictures were presented together, individuals with higher aggression scores tended to look longer at the negative act in picture 2 than at the facial expression of the harm-doer in picture 3. Thus, higher aggression seemed to be related to more attention for the negative event than potentially mitigating information from the facial expression of the harm-doer. This is rather similar to our operationalization of attentional bias: more attention to the negative outcome of the incident than the facial expression of the harm-doer. However, one difference is that Laue et al. 2018 studied attention to the negative *act*, while in the current study we focused on the *outcome* of the act. Future work could explore whether this difference can explain why Laue et al. (2018) did and we did not find a relationship with a measure of aggression. Third, the lack of a control group means that we cannot completely preclude the possibility that the positive change in attention bias is due to some other factors. Future research needs to compare the positive training to a control group with a neutral training in order to more rigorously test its effectiveness on attentional processes. Fourth, although we have demonstrated the possibility that a single session of positive attentional training using gaze-contingencies could induce attention bias to pro-social cues, the training did not differentially affect aggression-related measures. Therefore, a possible related limitation might have to do with the number of sessions and trials of the training. In our study, participants completed a total number of 40 training trials during a single-session. Previous gaze-contingent studies showed a large variation in number of trials and sessions (e.g., Ferrari et al. 2016; Price et al. 2016; Sanchez et al. 2016; Lazarov et al. 2017). Despite those variations between studies, the results showed that the training was successful in changing gaze patterns in the intended direction. However those training effects differed in regards to symptom reductions. Single-session studies with a high number of trials (i.e., 270 trial), have found no changes in mood in response to a stressor (e.g., Ferrari et al. 2016). Single-session studies with a lower number of trials (i.e., 48 trials), were found to be successful in reducing negative emotions (e.g., Sanchez et al. 2016). On the other hand, previous gaze-contingent studies using even less trials (i.e., 30 trials) with a higher number of sessions (i.e., 8 sessions) found a great symptom reduction in socially anxious participants (e.g., Lazarov et al. 2017). This might suggest that future gaze-contingent attention training methodologies with limited number of trials might benefit from increasing the number of training sessions to produce higher impact on symptom reduction.

Additionally, because participants were explicitly instructed to attend to the information that indicated whether the incident happened on purpose or not, and because they received feedback on their response (the cue they payed attention to) during the training, we may not only have trained attention deployment, but also participants' interpretation of the cues in the social situations. At this point it is impossible to disentangle these possible effects. It is interesting to note, however, that participants' interpretations of the situations became significantly more pro-social after training in *both* training conditions. While this indicates that, as discussed above, the direction of attention did not have the expected effect in this study, the observed effects might be due to our instructions that were aimed at improving encoding of social cues. Perhaps making participants more aware of what they are looking at to decide whether something happened on purpose or not was sufficient to alter interpretations, regardless of the direction of attention. At this time, this is speculation, however, future research should include a neutral training condition to ensure that the observed changes were due to the training and not simply test–retest effects. Finally, in order to further the potential effectivity of the present CBM-A gaze-contingent training in modifying attention bias over other existing attention training methodologies such as dot-probe task, future research should directly compare the two methodologies.

To conclude, this is one of the first studies that developed and tested a novel gaze-contingent procedure targeting attention in the context of aggression bias. Importantly, our study shows that a single session of this novel gaze-contingent CBM-A was able to modify attention bias in a pro-social direction. However, we did not find evidence for effects of the training on interpretation bias, aggressive behavior and mood. That being said, the training is still in its early stages and as discussed above there are a number of aspects of the training that might be adjusted in order to get the desired effects on aggression. We hope that future research will further explore and improve the potential impact of this training on the attentional processes underlying aggression, and aggressive behavior.

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Compliance with Ethical Standards

Conflict of Interest Nouran AlMoghrabi, Jorg Huijding, Birgit Mayer, Ingmar H.A. Franken declare that they have no conflict of interest.

Informed Consent All procedures performed in the study involving human participants were in accordance with the ethical standards of the institutional research committee of the department of psychology of Erasmus University Rotterdam, Rotterdam, the Netherlands, and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

Animal Rights No animal studies were carried out by the authors for this article.

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