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Attention bias vs. attention control modification for social anxiety disorder: A randomized controlled trial

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1. Introduction

Social anxiety disorder (SAD) involves intense fear and avoidance of scrutiny causing significant distress and impairment (American Psychiatric Association, 2013). The disorder may arise from biased attention to social threats (Clark & Wells, 1995; Morrison & Heimberg, 2013; Rapee & Heimberg, 1997), which can manifest as a tendency to over dwell on disapproving faces (Armstrong & Olatunji, 2012; Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Lazarov, Abend, & Bar-Haim, 2016; Lazarov et al., 2021).

Attention bias modification (ABM; Bar-Haim, 2010; MacLeod & Clarke, 2015) is a treatment approach designed to target biased attention to threat in anxiety disorders through repetitive computerized training. This approach relies on ample evidence indicating an association between anxiety and heightened attention to threatening relative to neutral information (Armstrong & Olatunji, 2012; Azriel, Britton, Gober, Pine, & Bar-Haim, 2022; Bar-Haim et al., 2007; Clauss, Gorday, & Bardeen, 2022; Pergamin-Hight, Naim, Bakermans-Kranenburg, van IJzendoorn, & Bar-Haim, 2015). The most common ABM protocols utilize variants of the dot-probe task (MacLeod, Mathews, & Tata, 1986), in which implicit learning of attention allocation away from threat stimuli and towards neutral stimuli is facilitated. Meta-analyses examining the efficacy of dot-probe based ABM for anxiety disorders report a significant small-to-medium effect size (Hakamata et al., 2010; Heeren, Mogoase, Philippot, & McNally, 2015; Linetzky, Pergamin-Hight, Pine, & Bar-Haim, 2015). Yet, the dot-probe based ABM has some significant limitations. These include unclear underlying mechanisms and target engagement, mainly due to poor internal consistency and test-retest reliability of the dot-probe task (for a review, see: McNally, 2019). An additional drawback is that the repetitive performance of the dot probe task is often experienced as tedious by patients, potentially limiting their engagement with the task, and hindering clinical improvement.

Gaze-Contingent Music Reward Therapy (GC-MRT) is a newer ABM protocol for SAD (Lazarov, Pine, & Bar-Haim, 2017). In GC-MRT, patients freely view a series of matrices consisting of threat and neutral faces while their gaze is monitored. A music track individually selected by each patient plays when s/he fixates on neutral faces but not when fixating disapproving faces, supporting gaze-contingent operant conditioning. Thus, patients gradually learn to allocate their attention (i.e., dwell longer) to neutral over threat faces. Three open trials of GC-MRT

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in adults (Umemoto et al., 2021; Zhu et al., 2022) and children (Linetzky, Kahn, Lazarov, Pine, & Bar-Haim, 2019) with SAD showed favorable findings. One randomized controlled trial (RCT) indicated efficacy over a control condition in which music was played throughout the sessions regardless of patients' gaze behavior (Lazarov et al., 2017). A second RCT reported comparable clinical responses in GC-MRT and a selective serotonin reuptake inhibitor (SSRI) treatment relative to a waitlist control (Cohen's ds of 0.91 and 1.01, respectively) (Arad et al., 2023). These two studies also indicated reduced dwell time on threat faces following treatment among GC-MRT patients, suggesting effective cognitive target engagement.

Notwithstanding promising findings, mechanisms of therapeutic effects remain unclear. Specifically, non-contingency control conditions (Lazarov et al., 2017) differ from the active GC-MRT condition on many factors, including demands placed on general attention control and attention to threats. Prior research suggests that therapeutic effects of other ABM treatments could arise through two different processes: a) modification of valence-specific attentional selectivity (i.e., 'valence-specific' bias models; Beck & Clark, 1997; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Shechner & Bar-Haim, 2016); or b) non-specific attention control enhancement (i.e., 'attention control' models; Bishop, 2007; Derryberry & Reed, 2002; Eysenck & Derakshan, 2011; Eysenck, Derakshan, Santos, & Calvo, 2007). According to the latter, attention bias to threat may result from impaired attention control, which in turn leads to reduced regulation of threat reactivity (Bishop, 2009; Bishop, Duncan, Brett, & Lawrence, 2004; Eysenck et al., 2007; Posner & Petersen, 1990; Posner & Rothbart, 1998; Sonia, 2008; Yantis, 1998). The vast majority of ABM trials have focused on valence-based contingency protocols and targeted aberrant threat-related attentional patterns characterizing patients with anxiety disorders (Hakamata et al., 2010; Linetzky et al., 2015). However, some researchers have proposed that other factors may account for ABM's clinical efficacy, suggesting a key role for general attention control rather than valence-specific attentional patterns (see: Heeren, Mogoase et al., 2015; McNally, 2019).

Indeed, poor attention control relates to social-anxiety (Liang, 2018; Moriya & Tanno, 2008; Morrison & Heimberg, 2013; Schmid, Kleiman, & Amodio, 2015; Sluis, Boschen, Neumann, & Murphy, 2018; Wieser, Pauli, & Mühlberger, 2009) and may moderate relations between social anxiety and attention bias. One study found greater attention bias among anxious individuals with poor relative to intact attention control (Taylor, Cross, & Amir, 2016). Furthermore, comparable reductions in social anxiety occur in some ABM protocols with shared effects on attention control but discordant effects on threat monitoring (Heeren, Coussement, & McNally, 2016; Heeren, Mogoaşe, McNally, Schmitz, & Philippot, 2015; Klumpp & Amir, 2010; Linetzky, Pettit, Silverman, Pine, & Bar-Haim, 2020; McNally, Enock, Tsai, & Tousian, 2013). Thus, efficacious ABM protocols may improve attention control, regardless of their effects on valence-specific processes (for a review and further discussion see: Basanovic, Notebaert, Grafton, Hirsch, & Clarke, 2017; Heeren, De Raedt, Koster, & Philippot, 2013).

The above-reviewed theory and experimental data suggest a central role for general attention control in the clinical efficacy of ABM. Although valence-specific modification of attentional patterns is commonly perceived as the main therapeutic factor in ABM, a question may be raised regarding its relative and unique contribution to the documented clinical effects of ABM. Direct evidence for the differential contribution of valence-based attention modification vs. improvement in general attention control to clinical efficacy is scarce. Thus far relevant information comes from indirect inference in studies reporting similar clinical effects for different emotion-based training protocols (e.g., comparing training of attention toward-threat, away-from-threat, and non-contingency training protocols; Heeren, Mogoaşe et al., 2015; Klumpp & Amir, 2010; McNally et al., 2013). Such similarity in efficacy has been interpreted as suggestive of the importance of general attentional control elements. However, no direct comparison to a non-emotion training condition was tested, leaving the relative contribution of valence-based emotion training unclear. Heeren et al. (2016) reported indistinguishable clinical improvement following different variations of non-emotional training. Again, no direct comparison to valence-based training was included. Two studies (Linetzky et al., 2020; Yao, Yu, Qian, & Li, 2015) directly compared emotion-based and non-emotion dot-probe contingency training within a single experimental design. Both studies found no between-condition differences in clinical efficacy, suggesting a role for general attention control improvement – potentially without a unique contribution of valence-based attention modification. To our knowledge, no study has yet directly compared emotion-based and non-emotion contingency training in GC-MRT.

Here, in an RCT of patients with SAD, we contrasted the clinical efficacy and the behavioral training effects of two conditions, one that entailed valence-specific attention modification (faces), and one that entails non-emotional attention modification (shapes). In addition, attention control was evaluated using both behavioral and self-reported indices. In line with the common assumption in ABM research, that general attention control may improve following treatment, but that the modification of valence specific attentional patterns is the critical ingredient for clinical improvement, we predicted that: a) attention control would similarly increase in both groups; and b) a larger clinical improvement would be observed in the faces compared to the shapes condition, suggesting that GC-MRT effectiveness is hinged on valence-specific attention modification.

2. Method

2.1. Participants

Participants were 50 treatment-seeking patients with SAD (mean age=30.16 years, SD=7.64, 27 males) recruited through advertisement in social media. Inclusion criteria were: (1) SAD as the main source of distress and impairment; (2) age of 18–65 years; (3) Liebowitz Social Anxiety Scale (LSAS; Liebowitz, 1987) score ≥ 50 (see LSAS description below). Exclusion criteria were: (1) posttraumatic stress, psychotic, or bipolar disorders; (2) epilepsy or brain injury; (3) suicidal ideation or risk; (4) drugs abuse; (5) concurrent pharmacological treatment other than SSRIs or concurrent psychological treatment.

Sample size was determined using G*Power 3.1.9.7 (Erdfelder, Faul, Buchner, & Lang, 2009). The estimated sample size for the detection of a significant small effect of $f= 0.25$, at 0.90 power and $\alpha = .05$, in a repeated-measures (group-by-time) interaction F test with two groups and two repeated-measurements, was $N = 46$. For demographic and clinical characteristics of the sample see Table S1 in the Supplementary Material. The two groups did not significantly differ in these characteristics at pretreatment ($ps > .086$) All participants provided a written informed consent. The study was approved by the local institutional review board (IRB) (ClinicalTrials.gov Identifier: NCT05018260). The progress of the patients through the study stages is described in a CONSORT diagram (Fig. S1 in the Supplementary Material).

2.2. Treatment

Patients were randomly assigned to one of two treatment groups: GC-MRT faces or GC-MRT shapes. Group assignment relied on randomly permuted blocks controlling for age (under/over 40 years), created with a computer-generated random number sequence prior to recruitment. A coordinator with no other involvement in the study assigned enrolled patients to treatment group. All patients received eight twice-weekly training sessions over four weeks.

GC-MRT faces. In the beginning of each treatment session patients selected a music track they wanted to listen to, then underwent a 5-point calibration and validation procedure that was repeated until a visual deviation $< 0.5^{\circ}$ on the X and Y axis of all points was achieved. Then, patients viewed 30 matrices comprised of 16 faces each: eight disgusted faces and eight neutral faces, with the four inner faces always presenting two disgusted and two neutral faces, and each face appearing only once in a matrix. Faces were taken from the Karolinska Directed Emotional Faces database (KDEF; Lundqvist, Flykt, & Öhman, 1998) (Fig. 1A). Each matrix was presented for 24 s. Music was played only when patients fixated on neutral faces and stopped when fixating on threat faces. This gaze-contingent operant conditioning procedure induces attentional preference for neutral over threat faces (for a detailed description of the GC-MRT faces protocol see: Arad et al., 2023; Lazarov et al., 2017).

GC-MRT shapes. In this condition patients underwent the same training procedure as in the faces condition, but instead of neutral and disgust faces, matrices with pointed and rounded shapes were presented. Each shapes matrix consisted of eight pointed and eight rounded shapes, with the inner four shapes comprised of two pointed and two round ones; each shape appeared only once in a matrix (Fig. 1B). To test whether an unexpected shapes-related attention bias (i.e., preference for pointy over rounded shapes) existed in patients with SAD, we compared baseline shapes-related gaze behavior between our patients and a sample of non-anxious participants. This comparison indicated no difference between patients with SAD and non-anxious participants in shapes-related attentional preference ($F(1110)= 2.09$, $p = .151$). For a detailed description of the non-anxious sample and the relevant statistical analysis, see Supplementary Material.

2.3. Outcome measures

2.3.1. Symptom severity

The primary clinical outcome was the total score on the clinician-rated LSAS (Liebowitz, 1987). The LSAS describes 24 socially relevant situations; each situation is rated in relation to the passing week on two scales ranging 0–3 assessing the levels of fear and avoidance provoked by the described situation. The LSAS was administered by two clinical psychologists trained to 85% reliability with a senior clinician; each patient was assessed by the same clinician at pre- and post-treatment, and clinicians were blind to group assignment and to treatment procedures. Cronbach's alphas were.83 and.91 at pre- and post-treatment, respectively.

Additional clinical outcome measures were the self-reported Social Phobia Inventory (SPIN; Connor et al., 2000), the Patient Health Questionnaire depression scale (PHQ-9; Kroenke, Spitzer, & Williams, 2001), and the Clinical Global Impression – Improvement (CGI-I) rated by a clinician. Cronbach's alphas for the SPIN were.71 and.89 at pre- and post-treatment, respectively; Cronbach's alphas for the PHQ-9 were.78 and.84 at pre- and post-treatment, respectively.

2.3.2. Attention to threat faces and pointed shapes

Percent attentional dwell time (DT%) on threat faces was measured using a validated free viewing task (Lazarov et al., 2016) (Fig. 1A). In this task, 30 faces matrices, with the same characteristics of those used for the treatment task, were presented without music while gaze behavior was tracked. At the beginning of each trial a central fixation cross appeared and remained on the screen until a 1000 ms fixation was identified. Then the face matrix appeared for 6000 ms, followed by a 2000 ms inter-trial interval until the next fixation cross appeared. DT% on threat faces from the total dwell time on faces was calculated for each matrix and then averaged across matrices (for a detailed description of this calculation see: Lazarov et al., 2017). Cronbach's alphas were.92 and.95 at pre- and post-treatment, respectively.

Attention allocation to pointed shapes was assessed with the same task used to measure attention to threat, applying images of round and pointed shapes instead of threat and neutral faces (Fig. 1B). DT% on pointed shapes from the total dwell time on shapes was calculated for each matrix, then averaged across matrices. Cronbach's alphas were.63 and.97 at pre- and post-treatment, respectively.

2.3.3. Attention control

The Attentional Control Scale (ACS; Derryberry & Reed, 2002) and an adapted arrow version of the Flanker Continuous Performance Test (Eriksen & Eriksen, 1974; Troller-Renfree, Nelson, Zeanah, & Fox, 2016; pp. 4, 1260) were used as self-reported and behavioural measures of attention control, respectively. The ACS is a 20-items scale assessing general capacity to control attention, with items rated on a 4-point scale representing the extent to which each statement is characteristic of the participant. The total ACS score was used in the current study. Cronbach's alphas of ACS scores were.81 and.85 at pre- and post-treatment, respectively. In the arrow version of the Flanker test, participants were asked to indicate if a target arrow is pointing left or right; this arrow was presented alongside distractor arrows (flankers), pointing in the same (congruent: <<<<< or >>>>>) or opposite (incongruent: <<><< or >><>>) direction as the target arrow. In each trial participants were presented with a fixation cross (500 ms), then with a row of five arrows with the target arrow in the center (500 ms). The task included 120 trials presented in two blocks. Each block included equal numbers of randomly presented congruent and incongruent trials. Response-time (RT) and accuracy were recorded throughout the task. Trials with RTs faster than 150 ms or longer than 2000 ms, or RTs more than 3 SDs above or below the participant's mean RT, were removed. An

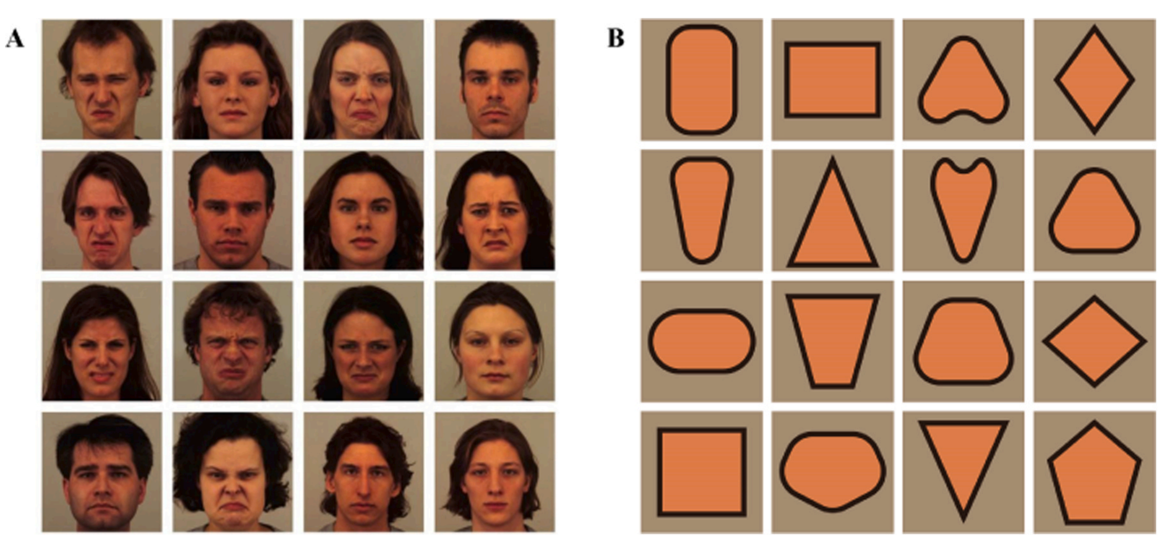

Fig. 1. Examples of a single matrix of disgusted and neutral faces (A) and a single matrix of pointed and round shapes (B).

interference bias score was computed as a subtraction of the mean RT on congruent trials from the mean RT on incongruent trials (Fan, Flombaum, McCandliss, Thomas, & Posner, 2003; Hillman et al., 2009; Mullane, Corkum, Klein, & Mclaughlin, 2009), so that higher values reflect greater interference (i.e., lower attention control). Split-half reliability of interference scores, calculated as a correlation between scores in even and odd trials, was.77 and.64 at pre- and post-treatment, respectively.

2.4. Apparatus

Eye-tracking was performed using a remote eye-tracker (Eye-Link Portable Duo, SR Research, Ltd., Ottawa, Ontario, Canada). Sampling rate was 1000 Hz. Participants were sitting 90 cm from a 24" ASUS VG248QE monitor with a screen resolution of 1920 × 1080 pixels.

2.5. Data analysis

A chi-squared test was first used to evaluate differences in training adherence rates (i.e., percent of patients who dropped out) between the GC-MRT and shapes control groups.

To assess training effects, two repeated-measures analyses of variance (ANOVAs) were conducted with DT% (on threat faces or pointed shapes) as a dependent variable; independent variables were session (1–8; within-subject variable), and treatment group (GC-MRT, shapes control; between-subjects variable). An independent samples t-test was used to compare the reduction in DT% on the target stimulus (threat or pointed shapes) from Session 1 to Session 8, between the two groups.

Treatment effects on symptoms severity and attention control were tested using generalized estimating equations (GEE), using an unstructured correlation matrix. A full factorial model including the effects of time (pre-treatment, post-treatment), group (GC-MRT, shapes control) and their interaction was first applied. Follow-up analyses of significant interaction effects compared the two time-points within each group separately. GEE was also applied to test pre- to post-treatment changes in attention allocation to faces and shapes. To this end, we used a full factorial model with time (pre-treatment, post-treatment), group (GC-MRT, shapes control), measurement-type (faces, shapes) and their interaction as predicting variables, and dwell time as a dependent variable.

A chi-squared test was applied to assess group differences in clinical improvement (CGI-I). We compared the number of patients rated 'much' or 'very much' improved at post-treatment to the number of patients who showed minimal or no improvement across groups (patients who dropped out were considered as not improved). Clinically Significant Change (CSC) cutoff was determined as a clinician-rated LSAS score of 46.29 at post-treatment. This cutoff was determined based on the test-retest reliability data from Baker et al. (2002) and pre-treatment LSAS scores from the authors' previous clinical trials data (N = 169). Group differences in CSC rates were evaluated using a chi-squared test, when patients who dropped-out were considered as not displaying CSC.

Finally, for each treatment group, we calculated Pearson's correlations between the change in attention to threat and the change in attention to pointed shapes. We also tested the correlations between these changes in dwell time, changes in clinician-rated SAD symptoms, and changes in attention control (ACS scores and Flanker interference bias score). To this end, relative change scores of each measure represented a subtraction of pre-treatment from post-treatment scores divided by pre-treatment scores.

3. Results

3.1. Treatment adherence

Among patients allocated to GC-MRT faces, three discontinued (two after two training sessions and one after three sessions). Among patients allocated to GC-MRT shapes, none discontinued. Completion rates did not differ between groups ($\chi2(1) = 3.19$, $p = .074$). In both groups, all completers attended all sessions, and no training session was cut short. All patients reported refraining from parallel treatments during the study.

3.2. Attention allocation during treatment

DT% on threat and pointed shapes by group and session is presented in Fig. 2. Analyses indicated a significant main effect of session ($F(7, 301)= 19.51$, $p < .001$, $\eta_p^2= .31$), and non-significant effects of group and session-by-group interaction ($ps > .558$). Comparable reductions in dwell time on the trained stimuli (threat faces or pointed shapes) from Session 1 to Session 8 were noted ($p = .868$).

3.3. Pre- to post-treatment clinical changes

There was a significant effect of time (Wald $\chi^2(1) = 102.52$, $p < .001$) on clinician-rated SAD symptoms, and non-significant group or time-by-group interaction effects ($ps > .401$). Regardless of treatment group, patients exhibited a decrease in LSAS scores from pre- to post-treatment ($p < .001$, $d=-0.93$ [95%CI −2.06 to –1.15]) (Table 1, Fig. 3A).

Similar change patterns were noted for the secondary clinical outcomes (Table 1). A significant main effect of time was found for self-reported SAD symptoms (SPIN; Wald $\chi^2(1) = 74.00$, $p < .001$; Fig. 3B), and depression (PHQ-9; Wald $\chi^2(1) = 44.58$, $p < .001$). Significant pre- to post-treatment reductions were noted for both measures (SPIN: $p < .001$, $d=-1.27$ [95%CI −1.73 to −0.82], PHQ-9: $p < .001$, $d=-1.17$ [95%CI −1.58 to −0.76]). Non-significant group or time-by-group interaction effects were noted ($ps > .174$).

Of the patients in the faces and shapes groups, 36% and 48% were rated 'much' or 'very much' improved on the CGI-I, respectively, with no difference between the groups ($\chi2(1) = 0.74, p = .390$). Finally, 32% of faces patients and 44% of shapes patients showed CSC; here too, with no significant difference between the groups ($\chi2(1) = 0.76$, $p = .382$).

3.4. Pre- to post-treatment changes in attention allocation

There was a significant time effect (Wald $\chi^2(1) = 26.76$, $p < .001$) and time-by-group-by-measurement-type interaction effect (Wald $\chi^2(1) = 18.63, p < .001$) on DT%. Shapes patients exhibited a significant reduction in dwell time on pointed shapes ($p < .001$, $d=-0.52$ [95%CI −0.99 to −0.04]), whereas faces patients did not show such change in shapes-related dwell time ($p = .178$) (Fig. 4A). In contrast, both faces and shapes patients showed significant reductions in dwell time on threat faces (GC-MRT: $p = .001$, $d=-1.10$ [95%CI −1.52 to −0.69]; Shapes control: $p = .011$, $d=-0.68$ [95%CI −1.08 to −0.27]), with no significant difference between the groups at post-treatment ($p = .188$) (Table 1, Fig. 4B). These results indicate that dwell time on threat faces decreased following both faces and shapes training, whereas dwell time on pointed shapes decreased only following shapes training.

3.5. Attention control

There was a significant main effect of time (Wald $\chi^2(1) = 26.30$, $p < .001$) on self-reported attention control (ACS), and the group and time-by-group interaction effects were not significant ($ps > .200$). Regardless of treatment type, patients showed an increase in ACS scores from pre- to -post treatment ($p < .001$, d=1.15 [95%CI 0.75–1.56]) (Table 1).

A significant time-by-group interaction effect on Flanker interference bias scores was found (Wald $\chi^2(1) = 4.14$, $p = .042$). Shapes patients showed a significant decrease in interference scores (indicating better attention control) from pre- to post-treatment ($p = .001$, $d=-0.65$ [95%

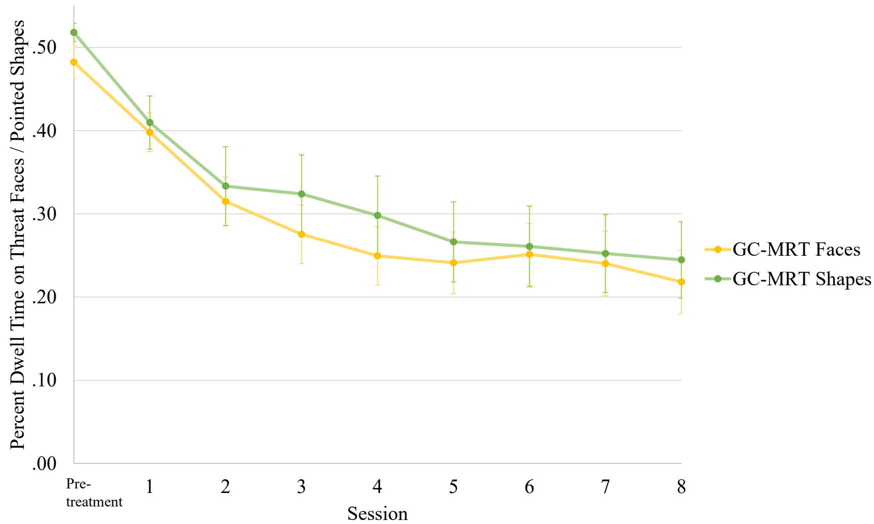

Fig. 2. Percentage of dwell time on threat faces (in GC-MRT Faces group) and pointed shapes (in GC-MRT Shapes group) across treatment sessions.

Table 1
Social anxiety and depression symptoms, attention allocation, self-reported and behaviorally measured attention control. GC-MRT, gaze contingent music reward therapy; LSAS, Liebowitz social anxiety scale; SPIN, social phobia inventory; PHQ-9, patient health questionnaire; ACS, attention control scale. Post-treatment scores are estimated marginal means.

		GC-MRT Faces		GC-MRT Shapes		Between-group comparison	
		Mean	SD	Mean	SD	Significane	Effect size
LSAS score	Pre-treatment	74.00	14.57	72.32	14.07	$p = .678$	$d = -0.12$ [95%CI – 0.67–0.44]
	Post-treatment	53.80	15.74	48.76	19.41	$p = .313$	$d = -0.28$ [95%CI – 0.86–0.29]
SPIN score	Pre-treatment	45.92	7.12	45.52	8.35	$p = .856$	$d = -0.05$ [95%CI – 0.61–0.50]
	Post-treatment	33.37	11.63	33.03	11.93	$p = .918$	$d = -0.28$ [95%CI – 0.61–0.55]
PHQ-9 score	Pre-treatment	11.00	4.97	12.36	5.25	$p = .347$	$d = 0.27$ [95%CI – 0.29–0.82]
	Post-treatment	6.77	4.86	8.87	4.66	$p = .120$	$d = 0.44$ [95%CI – 0.14–1.03]
% dwell time on threat faces	Pre-treatment	48.24	9.80	48.72	9.33	$p = .860$	$d = 0.05$ [95%CI – 0.50–0.60]
	Post-treatment	35.19	11.98	39.96	13.55	$p = .188$	$d = 0.37$ [95%CI – 0.22–0.97]
% dwell time on pointed shapes	Pre-treatment	48.69	4.97	51.82	5.30	$p < .05$	$d = 0.61$ [95%CI 0.04–1.18]
	Post-treatment	45.47	11.05	31.72	20.65	$p < .01$	$d = -0.82$ [95%CI – 1.43 to – 0.20]
ACS score	Pre-treatment	46.64	9.50	43.60	6.59	$p = .189$	$d = -0.37$ [95%CI – 0.93–0.19]
	Post-treatment	50.46	8.64	47.83	8.24	$p = .271$	$d = -0.31$ [95%CI – 0.89–0.27]
Flanker interference bias score	Pre-treatment	83.66	28.85	92.58	30.20	$p = .286$	$d = 0.30$ [95%CI – 0.27–0.87]
	Post-treatment	79.39	22.75	75.63	24.07	$p = .570$	$d = -0.16$ [95%CI – 0.73–0.41]

CI −1.05 to −0.25]), whereas faces patients did not show such change ($p = .271$) (Table 1).

3.6. Correlations between cognitive and clinical changes

A significant positive correlation was noted between change in dwell time on threat faces and change in dwell time on pointed shapes in the shapes group ($r = .66$, $p < .001$), but not in the faces group ($r = .18$, $p = .423$). The magnitude of these two correlations significantly differed between groups (Fisher's r-to-$Z = -1.86$, $p = 0.03$). Among shapes patients, the change in dwell time on pointed shapes was also negatively correlated with the change in ACS scores ($r = -.50$, $p = .017$) but not the change in LSAS scores ($r = .37$, $p = .078$). ACS and LSAS change scores were negatively correlated in this group ($r = -.57$, $p = .004$) but not in the faces group ($r = -.37$, $p = .085$), though the magnitude of the two correlations did not significantly differ (Fisher's r-to-$Z = 0.78$, $p = 0.217$). In both groups, the change in Flanker interference scores did not correlate with any measure of clinical change ($rs < .24$, $ps > .309$). For a complete correlation matrix and between-group comparisons in the magnitude of these correlations, see Table S2 in the Supplementary Material.

4. Discussion

In the current study we compared the effects of GC-MRT faces and GC-MRT shapes. Three main findings emerged: (1) the two training regimens induced comparable reductions in symptom measures; (2) shapes patients showed reduced attention to both pointed shapes and threat faces following treatment, whereas faces patients showed reduced attention only to threat faces; and (3) behaviorally measured attention control increased only among shapes patients whereas self-reported attention control increased in both groups and was positively correlated with clinical improvement.

As expected, GC-MRT with faces showed efficacy in reducing SAD symptoms. However, such efficacy was also observed in the shapes condition. These results resemble findings from previous reports on therapeutic effects induced by non-emotional contingency training in anxious participants (Heeren et al., 2016; Linetzky et al., 2020; Yao et al., 2015). Notably, the current study differs from these previous studies on several grounds thereby extending current knowledge about the role of non-emotional contingency training in ABM. First, the current study used an eye-tracking-based ABM protocol rather than a manual-response-based protocol. The use of GC-MRT's free-viewing task, shown to have better psychometric properties compared to manual-response-based ABM tasks (Arad et al., 2023; Lazarov et al., 2016, 2017; Linetzky et al., 2019; McNally, 2019), supports and

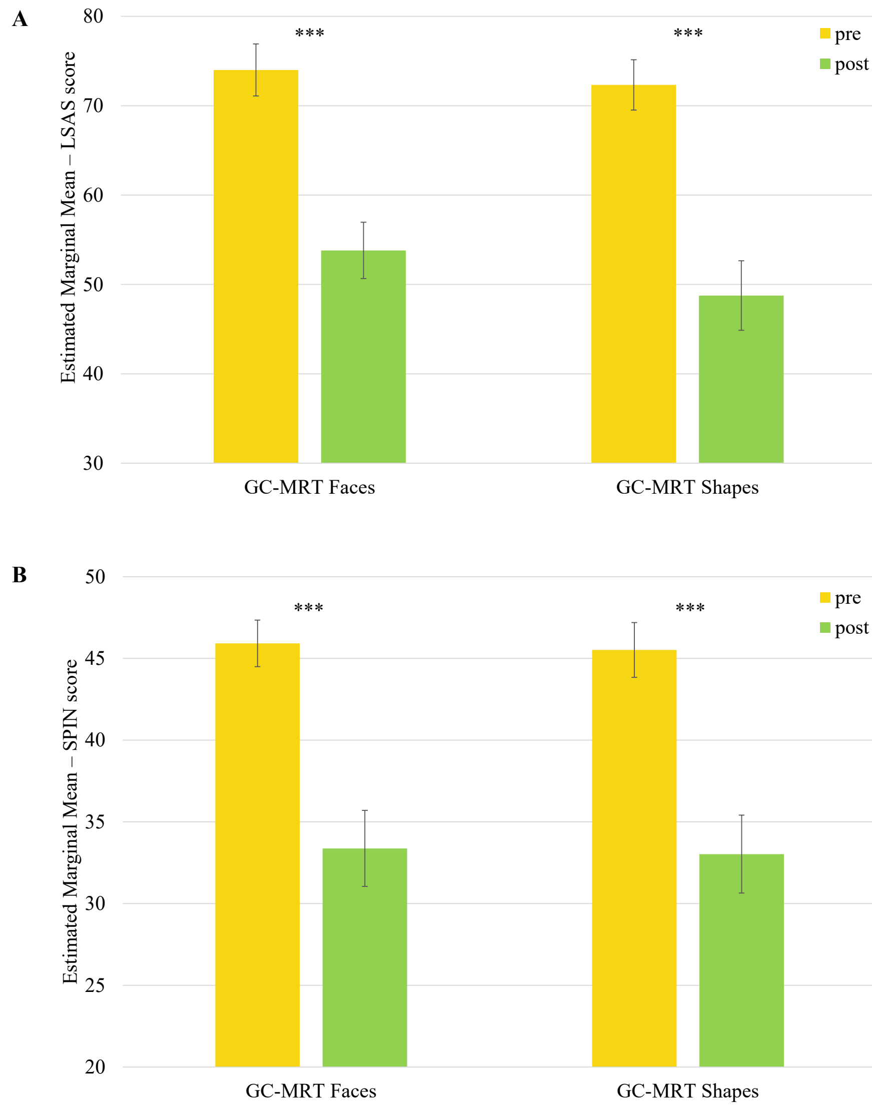

Fig. 3. Clinician rated (A) and self-reported (B) social anxiety symptoms, by group and time.

strengthen the reliability of previous findings. Second, the population tested here differed from Linetzky et al. (2020) who studies a pediatric sample with various anxiety disorders, and from Yao et al. (2015) who focused on sub-clinical socially anxious participants. Thus, the current study elaborates on past work on attention control in ABM efficacy, generalizing findings to a wider population. Third, whereas the current study included an eight-session protocol over four weeks, Heeren et al. (2016) applied a shorter, single-session intervention. Number of sessions and overall protocol length are important parameters in ABM, affecting learning consolidation and cumulative learning gains (Abend, Pine, Fox, & Bar-Haim, 2014).

The comparable clinical effect may be attributed to the reduction of attention bias to threat faces, which occurred in both faces and shapes groups. It is possible that in the faces group threat-related attention bias was targeted directly, whereas in the shapes group the enhancement of general attention control allowed a reduction in attention bias. Self-reported attention control increased in both conditions. This increase was expected, because both conditions utilized music reward encouraging participants to control their visuospatial attention based on a learned contingency. Of note, similar improvement in self-reported attention control was previously reported following dot-probe based ABM (e.g., Linetzky et al., 2020; Pettit et al., 2020, 2023). Importantly, in the shapes condition self-reported and behaviorally measured attention control increased and dwell time on threat faces decreased – even though these patients were not trained with faces. This change pattern is not trivial: a better ability to control visual attention could have supported the opposite pattern (i.e., increased dwell time on threat faces) or not be applied to faces at all. Instead, patients' improved attention control may have been potentially used by patients in the shape training condition to view the face matrices in a pattern resembling that of healthy individuals (Lazarov et al., 2016). This change in dwell time on threat faces – demonstrated in both conditions – suggests that better ability to voluntarily control attention may improve the down-regulation of threat reactivity and thus potentially minimize threat-related attention bias (Bishop, 2009; Bishop et al., 2004; Derryberry & Reed, 2002; Eysenck et al., 2007; Posner & Petersen, 1990; Posner & Rothbart, 1998; Sonia, 2008; Yantis, 1998). In turn, such improvements in attention control may improve anxiety symptoms. Alongside this possible pathway to clincial change, it is also possible that improving attention control alleviates SAD symptoms through other channels not related to biased threat attention. These other changes could include reduction in repetitive negative thinking and post-event processing (Sluis et al., 2018) or enhancement of emotional regulation and appropriate social responding (Simonds, Kieras, Rueda, & Rothbart, 2007). Fig. 5 illustrates potential relations between changes in attention control, threat-related attention bias, and social anxiety symptoms, as

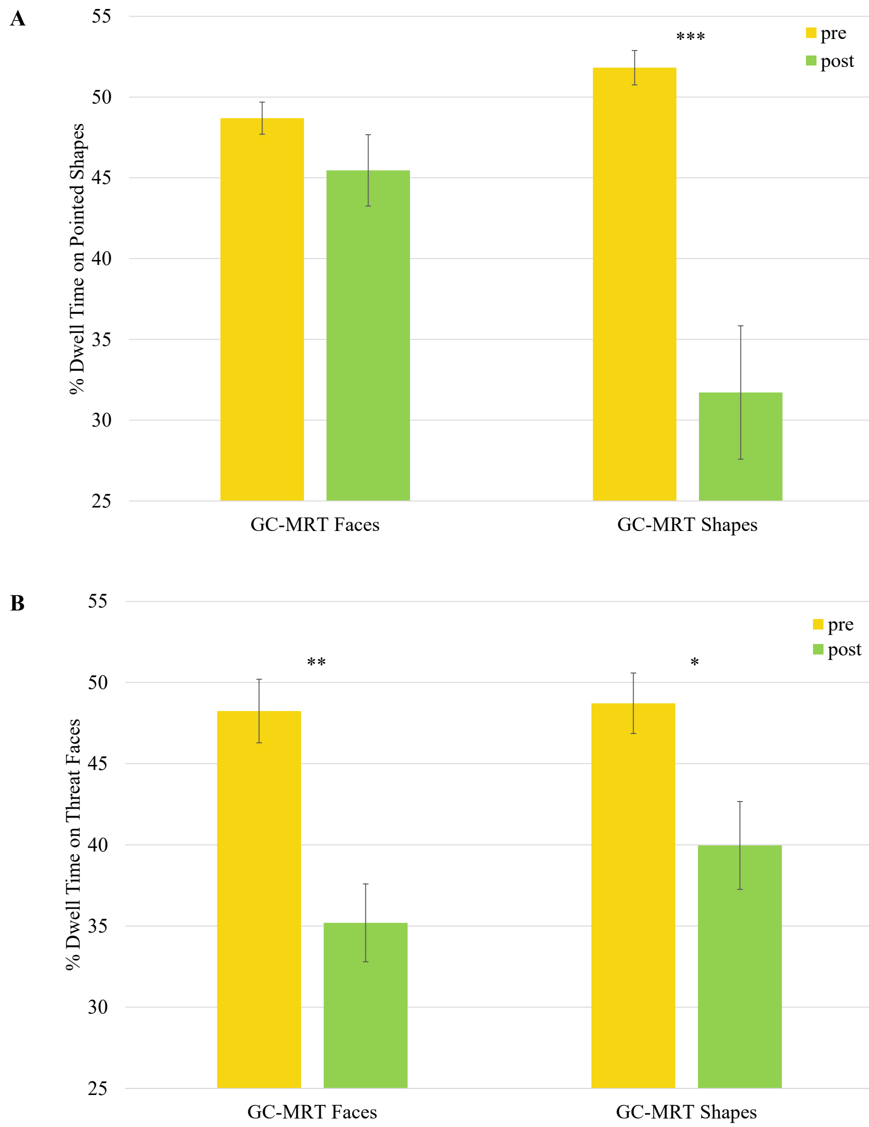

Fig. 4. Percent dwell time on pointed shapes (A) and threat faces (B), by group and time.

reflected in the current results. Future research in larger samples may further test the associations not reaching full significance here or apply experimental designs enabling evaluation of causal relations between these components.

Although it may appear logical to attribute the clinical effects of both treatment conditions to training induced enhancement of attention control, alternative explanations for the clinical findings should also be considered. First, it may be argued that the specifically induced change in attention to pointed shapes led to symptom reduction in the shapes group, and that attention bias toward pointed shapes – much like attention bias toward threat faces – may reflect a cognitive aberration in SAD. This possibility seems less likely considering that no baseline differences in attention allocation to pointed shapes were noted between patients with SAD and non-anxious control participants. Future studies could use alternative stimuli or contingencies (e.g., training towards round shapes) to further examine this possibility. Second, it is possible that the comparable clinical improvement noted in the faces and shapes groups, along with the similar noted changes in threat-bias and ACS scores, resulted from other non-specific treatment effects shared by both conditions. These may include time-based effects such as habituation to the training setting including the interpersonal interaction with the clinic staff. Another possibility is that the noted changes resulted from a placebo effect, associated with response-expectancy. It has been suggested that the halo of computerized fix to one's distress may promote positive expectations accounting for the clinical change (McNally et al., 2013). However, this possibility is less likely considering the findings of Lazarov et al. (2017), in which greater clinical efficacy with large effect sizes was noted for GC-MRT in comparison to a control condition in which no contingency existed between gaze behavior and music reward. It is also worth noting that ABM for SAD has been found clinically effective even when participants were not informed of any potential therapeutic benefits from it (e.g., Heeren, Reese, McNally, & Philippot, 2012; Klumpp & Amir, 2010). Finally, greater sense of self-efficacy stemming from better control over the played music may also have had a positive effect on SAD symptoms (Gaudiano & Herbert, 2003; Iancu, Bodner, & Ben-Zion, 2015; Thomasson & Psouni, 2010).

The current findings have potential clinical implications. First, the clinical results replicate previous reports indicating that GC-MRT is a potent treatment for SAD (Arad et al., 2023; Lazarov et al., 2017; Linetzky et al., 2019; Umemoto et al., 2021; Zhu et al., 2022). Second, the results suggest that alternative variations of GC-MRT applying non-emotional stimuli may be used with similar clinical potential. Such non-emotional variations may offer an advantage over threat stimuli for patients who experience the encounter with such images exceedingly

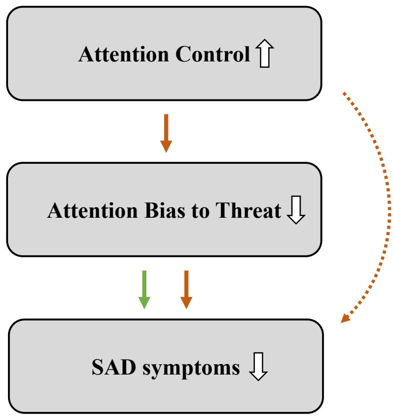

Fig. 5. Potential relations between changes in attention control, attention bias to threat faces, and SAD symptoms in the current study. In the GC-MRT faces condition (green), symptom relief may be accounted for by a reduction in attention bias towards threat faces. In the GC-MRT shapes condition (brown), improvement in attention control may have been translated into a decrease in attention bias, which in turn reduced symptoms. The enhancement of attention control could also have affected symptoms through other channels not related to attention bias to threat faces (dashed arrow).

distressing (Amir, Najmi, Bomyea, & Burns, 2010; Staugaard, 2010). Further research is needed to determine the most effective stimuli parameters for GC-MRT, especially in terms of long-term effects not tested in the current design. Third, a critical role has been suggested for general attention control in the maintenance of anxiety (Bishop, 2007; Derryberry & Reed, 2002; Eysenck & Derakshan, 2011; Eysenck et al., 2007; Morrison & Heimberg, 2013; Reinholdt-Dunne, Mogg, & Bradley, 2009; Taylor et al., 2016), and deficient attention control has been reported among socially anxious individuals (Liang, 2018; Moriya & Tanno, 2008; Morrison & Heimberg, 2013; Schmid et al., 2015; Wieser et al., 2009). Therefore, enhancing attention control in patients with SAD warrants clinical attention. The current findings indicate that such enhancement could be achieved using GC-MRT, but potentially could also be achieved through other attention control focused interventions (e.g., Wells, 1990, 2002; Wells, White, & Carter, PP. 129, 1997).

A few limitations of the current study should be noted. First, we only actively controlled for emotional valence. We did not directly compare a condition that requires the recruitment of attention control with a condition that does not. Therefore, several interpretations regarding the role of attention control enhancement may be possible for the current findings. Future studies may use a three-arm design including a no-contingency-training condition to address this limitation. Second, we did not counterbalance the type of shapes the patients in the shapes control group were trained to attend. This experimental decision was taken to equate the shapes condition with the faces condition in which only one category (threat faces) is trained. This decision, however, does not allow us to completely rule out the possibility that training patients to allocate their attention away from pointed shapes specifically, rather than a more general attention control training, led to symptomatic relief. Importantly, this concern is further relived by the lack of baseline difference between our patients and healthy comparisons in attention to pointed shapes. Third, due to the lack of long-term follow-up assessment in the current design, we could not test whether long-term clinical effects differed between conditions. As the clinical effect of faces GC-MRT have been maintained in a 3-months follow-up (Lazarov et at., 2017), it is of particular importance to determine the long-term effects of non-threat training on clinical outcome.

In conclusion, the current study expands the knowledge about potential underlying mechanisms of clinical change in GC-MRT for SAD, suggesting that attention control may play an important role in the observed clinical effects. Enhancement of attention control, without direct modification of valence-specific attentional preference, may facilitate symptom reduction in patients with SAD.

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Declaration of Competing Interest

The authors have no conflicts of interest to declare.

Data availability

Data will be made available on request.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.janxdis.2023.102800.

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