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Research paper

Free viewing of sad and happy faces in depression: A potential target for attention bias modification

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ABSTRACT

Background: Identification of reliable targets for therapeutic interventions is essential for developing evidence-based therapies. Attention biases toward negative-valenced information and lack of protective positive bias toward positive-valenced stimuli have been implicated in depression. However, extant research has typically used tasks with narrow stimuli arrays and unknown or poor psychometric properties. Here, we recorded eye-tracking data of depressed and non-depressed participants during a free viewing task to address these limitations.

Methods: Patients with major depressive disorder (MDD; $n = 20$) and undergraduate students with high ($n = 23$) and low ($n = 20$) levels of depression freely viewed 60 different face-based matrices for six seconds each. Each matrix included eight sad and eight happy facial expressions. Gaze patterns on sad and happy areas of interest (AOIs) were explored. Internal consistency for the entire sample and one-week test-retest reliability in the student sub-sample were assessed.

Results: Compared to undergraduates with low levels of depression, patients with MDD and students with high levels of depression dwelled significantly longer on sad faces. Results also showed a significantly longer dwell time on the happy AOI relative to the sad AOI only in the low depression group. The two depressed groups dwelled equally on the two AOIs. The task demonstrated high internal consistency and acceptable one-week test-retest reliability.

Limitations: Only sad and happy facial expressions were used. Relative small sample size.

Conclusion: Relative to non-depressed participants, depressed participants showed prolonged dwelling on sad faces and lack of bias toward happy faces. These biases present viable targets for gaze-contingent attention bias modification therapy.

1. Introduction

Cognitive models relate attention biases to depression (Beck, 1967, 1976; Clark et al., 1999; Teasdale, 1988), whereby the attention system of depressed individuals, unlike in non-depressed individuals, prioritizes negative-valence over positive and neutral information (Dalgleish and Watts, 1990; De Raedt and Koster, 2010; Koster et al., 2011; Peckham et al., 2010). In addition, some models suggest that depressed individuals also fail to demonstrate a positivity bias observed in non-depressed individuals (Alloy and Abramson, 1979, 1988; Matthews and Antes, 1992).

Research using reaction-time (RT) to quantify attention processes in MDD finds some evidence of attention bias toward negative information (Gotlib and Joormann, 2010; Peckham et al., 2010), with such biases, when revealed, typically emerging only when employing long (>1,000 ms) stimulus exposure durations (De Raedt and Koster, 2010; Gotlib and Joormann, 2010; Peckham et al., 2010). Some RT-based attentional research has also demonstrated a lack of a "protective bias" in depression. That is, depressed individuals typically lack an attentional preference for positive over negative information, which characterizes non-depressed individuals (Gotlib et al., 1988; Matthews and Antes, 1992; Mccabe and Gotlib, 1995; Peckham et al., 2010; Shane and Peterson, 2007). However, concerns about poor psychometric properties (i.e., internal consistency and test-retest reliability) of RT-based

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attention bias indices have lead research to employ alternative eye-tracking measures of attention, which were shown to be more reliable compared with RT measures (Skinner et al., 2017; Waechter et al., 2014). A meta-analysis of free-viewing eye-tracking studies concluded that depression involves reduced gaze maintenance on positive stimuli and increased gaze maintenance on negative-valence stimuli (Armstrong and Olatunji, 2012), with two more recent studies showing similar results in clinically diagnosed MDD patients (Duque and Vazquez, 2015; Lu et al., 2017). Other eye-tracking-based paradigms have reported similar results. For example, research using the attentional engagement-disengagement task, designed specifically to examine volitional disengagement of attention, has showed that depressed participants take longer to disengage sad faces and shift gaze towards neutral faces when explicitly prompted to do so (Sanchez et al., 2017; Sanchez et al., 2013).

Despite these coherent and promising findings, extant eye-tracking research has two main limitations. First, research has exclusively used stimulus sets with four or fewer items, limiting generalizability. Stronger, more generalizable results may arise via studies using more complex visual displays, thus extending extant findings in the field (Ferrari et al., 2016; Lazarov et al., 2016; Mogoase et al., 2014; Price et al., 2016; Richards et al., 2014). Second, no eye-tracking study to date has examined the test-retest reliability of attention bias indices in depression, with only one previous study reporting on acceptable internal consistency (Sanchez et al., 2017). In research on anxiety, Lazarov et al. (2016) addressed these two limitations, using a free viewing eye-tracking task, serving also as unique targets for a novel treatment (Lazarov et al., 2017). Given the high co-morbidity between anxiety and depression, the current study extends work on biased gaze patterns in anxiety to quantify a reliable indicator of attention biases in major depressive disorder (MDD). We recorded eye-tracking data while participants freely viewed visual displays comprised of happy and sad faces (16 faces per display), presented for 6 s each. We measured the gaze patterns of three groups of participants: undergraduate students with high or low levels of depressive symptoms, and a group of clinically diagnosed treatment-seeking patients with MDD. Internal consistency and one-week test-retest reliability were evaluated. Based on previous findings, we expected that relative to non-depressed participants, depressed participants would dwell longer on sad faces and shorter on happy faces.

2. Methods

2.1. Participants

Participants in this study belonged to three groups: undergraduate students with high levels of depressive symptoms, undergraduate students with low levels of depressive symptoms, and treatment-seeking patients with clinically diagnosed MDD. The clinical group consisted of 20 treatment-seeking patients diagnosed with MDD (7 females, mean age = 40.28 years, *SD* = 10.40, range = 23–58). Primary and co-morbid diagnoses were ascertained using the Mini-International Neuropsychiatric Interview (see below, M.I.N.I; Sheehan et al., 1998) administered by a clinical psychologist trained to 85% reliability criterion with a senior experienced psychologist. MDD diagnosis was further ascertained using the clinician-rated Montgomery–Asberg Depression Rating Scale (MADRS; (Montgomery and Asberg, 1979)). A cutoff score of 18 or higher was used as an inclusion criterion, reflecting moderate to severe depression (Mittmann et al., 1997; Snaith et al., 1986). Exclusion criteria for the MDD group were: a) age not between 18 and 60 years; b) present or past psychotic episode; c) co-morbid Tic disorder or Tourette's syndrome; d) any neurologic condition (e.g., epilepsy, brain injury); e) being in psychotherapy of any kind; and f) any change in medication occurring in the three months prior to participation in the study. Of the 20 participants with MDD included in the study, two also met criteria for dysthymia, 11 for generalized anxiety disorder (GAD), two for panic disorder (PD), one for obsessive-compulsive disorder (OCD), and five for social anxiety disorder (SAD). While not an exclusionary criterion, none of the patients were on any medication.

Two hundred and forty-two undergraduate students were screened for depressive symptoms using the Patient Health Questionnaire-9 (PHQ-9; (Kroenke et al., 2001)). Students with PHQ-9 score ≥ 10 constituted the high depression (HD) group (n = 23, 18 females, mean age = 23.87 years, *SD* = 1.98, range = 21–28). A PHQ-9 score of 10 is considered the clinical cutoff for a diagnostic status of moderate depression (Kroenke et al., 2001). Using this cutoff score enabled the enrollment of participants that most closely resemble the clinical population of interest. The low depression (LD) group consisted of students with PHQ-9 score ≤ 4 (n = 20, 15 females, Mean age = 23.60 years, *SD* = 1.67, range = 20–27), reflecting minimal depression using this scale. All student participants received course credit for participation.

The local Institutional Review Board approved the study and participants provided written informed consent. To avoid eye-tracking calibration difficulties we only invited participants who had normal or corrected-to-normal vision, also excluding use of multi-focal eyewear. None of the participants had prior experience with eye-tracking procedures.

2.2. Measures

2.2.1. Depression

Self-reported levels of depression were assessed using the PHQ-9 (Kroenke et al., 2001). The PHQ-9 is a 9-item self-report questionnaire evaluating symptoms of major depressive disorder according to the criteria of the fourth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV; (American Psychiatric Association, 1994)). Each PHQ-9 item corresponds to one of the nine DSM-IV symptoms of depression, rated in relation to the previous two weeks. The PHQ-9 has good validity, test-retest reliability, and internal consistency (Kroenke et al., 2001). Cronbach's α in the current sample was 0.88.

Clinician evaluated levels of depression were measured using the Structured Interview Guide for the MADRS (SIGMA (Williams and Kobak, 2008). The MADRS consists of 10-items assessing levels of depression symptoms during the past week, with each item rated on a scale of 0 (no evidence of symptom) to 6 (pervasive evidence). The MADRS has high inter-rater reliability and convergent validity (Montgomery and Asberg, 1979). Cronbach's α in the current sample was 0.70.

2.2.2. Primary and co-morbid diagnoses

Primary and co-morbid diagnoses in the clinical MDD group were assessed in individual clinical interviews using the MINI (Sheehan et al., 1998), a structured diagnostic interview for DSM-IV and ICD-10 psychiatric disorders (Lecrubier et al., 1997; Sheehan et al., 1997).

2.3. The eye-tracking task

Gaze patterns were assessed using an established eye-tracking task (Lazarov et al., 2016; Lazarov et al., 2017) adapted for depression, using a remote high-speed eye-tracker (SensoMotoric Instruments (SMI), Inc., Teltow, Germany). The task was designed and executed using the innate Experiment Center software provided by SMI.

Color photographs of 16 males and 16 female actors, each contributing a sad and a happy facial expression, were taken from the NimStim Stimulus Set (Tottenham et al., 2009). We assembled 60 different 4-by-4 matrices, each containing eight sad and eight happy facial expressions. Each individual face extended 225-by-225 pixels, including a 10-pixel white margin on every edge, for an overall size of 900-by-900 pixels (Fig. 1). Each single face appeared randomly at any position on the matrix while ensuring the following: a) each actor

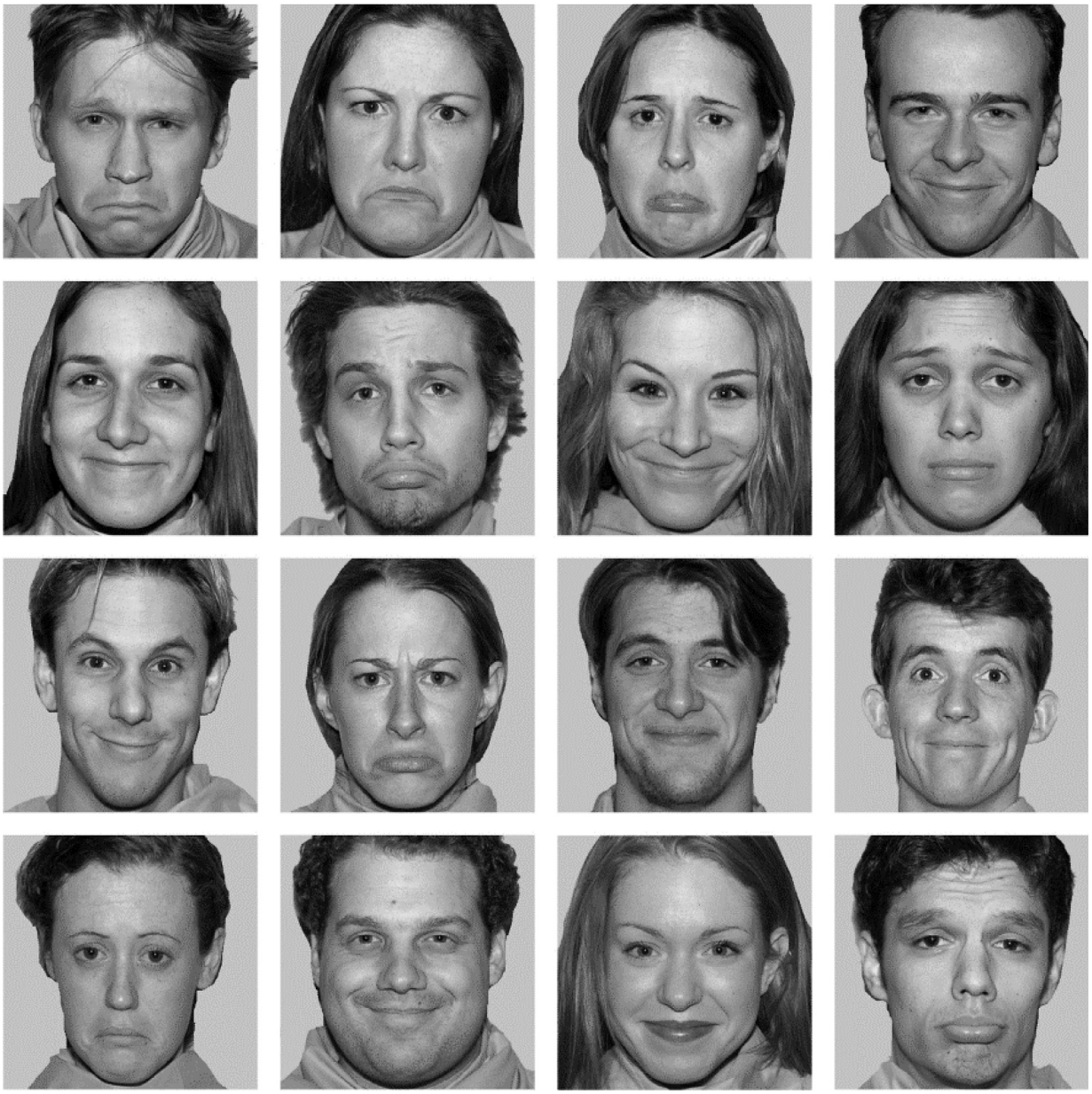

Fig. 1. An example of a single matrix. The eight sad faces comprise the sad area of interest (AOI) and the eight happy faces comprise the happy AOI.

appeared only once in a matrix; b) each matrix contained eight male and eight female faces; c) half the faces were sad and half were happy; and d) the four inner faces were always two sad and two happy.

Each trial of the task began with a fixation-cross, shown until a fixation of 1000 ms was recorded, verifying that each trial began only when participants' gaze was fixated at the matrix's center. Then the matrix was presented for 6000 ms, followed by an inter-trial interval of 2000 ms. Participants were instructed to look freely at each matrix in any way they chose until it disappeared. Each participant observed 60 different matrices, presented in two blocks of 30 matrices each. A 1-min break was introduced between blocks. Each single face picture appeared exactly 15 times per block. Each block was preceded by a 5-point eye-tracking calibration followed by a 4-point validation. The calibration procedure was repeated if visual deviation was above 0.5° on the *X* or *Y* axis. The task did not ensue until such calibration parameters were achieved. All participants were able to achieve this criterion.

2.4. Eye tracking measures

Eye tracking data was processed using SMI BeGaze native software (SensoMotoric Instruments, Inc., Teltow, Germany). Fixations were defined as at least 100 ms of stable fixation within 1-degree visual angle. For each of the 60 matrices we defined two Areas of Interest (AOIs), one including the eight sad facial expressions (i.e., the sad AOI) and one including the eight happy facial expressions (i.e., the happy AOI). Total dwell time per defined AOI (sad/happy) was calculated as the total dwell time on each AOI for each matrix averaged across the 60 matrices.

For completeness, we also analyzed first-fixation variables. However, in line with previous eye-tracking research indicating poor reliability of first fixation measures (Lazarov et al., 2016; Waechter et al., 2014; Wermes et al., 2017) we expected no group differences. Thus, several first fixation measures were computed: a) first fixation latency was calculated by averaging the latency to first fixations, in milliseconds, for each of the AOIs; b) first fixation location was measured by counting the number of times the first fixation was in each

AOI; and c) first fixation dwell time was computed by averaging first fixation duration, in milliseconds, for each of the AOIs.

2.5. Apparatus

Eye movements and gaze data were recorded using a remote high-speed eye-tracker (RED 500, SensoMotoric Instruments, Inc., Teltow, Germany), with a sampling rate of 500 Hz. Operating distance to the eye-tracking monitor was 70 cm. The stimuli were presented on a 22-inch Dell P2213 monitor with a screen resolution of 1680 × 1050 pixels.

2.6. Procedure

Participants were tested individually in a small and quiet room at the university. They were told that they are going to participate in a study examining gaze patterns using an eye-tracking apparatus. After providing a signed informed consent, participants were seated in front of the eye-tracking monitor and were told that during the experiment they would be presented with different matrices of faces, appearing one after the other. They were also informed that before the appearance of each matrix a fixation cross will appear at the center of the screen, on which they should fixate their gaze to make the matrix itself appear, and then were presented with a demonstration of this contingency. Participants were instructed to look freely at each matrix in any way they chose until it disappeared.

Following the completion of the eye-tracking task, HD and LD participants were invited to take part in a second eye-tracking session, held exactly one week later, while participants with clinical MDD were referred to the clinic to begin therapy. Two participants from the undergraduate HD group did not complete Session 2. The procedure for Session 2 in the student samples followed the same protocol as for Session 1, using new matrices from the same set of actors.

2.7. Data analysis

One-way analyses of variance (ANOVA) compared between-groups descriptive characteristics, with a chi-square test used to compare groups on gender distribution. Follow-up analyses for significant group differences included independent sample *t*-tests and chi-square tests for gender ration. To examine group differences on the eye tracking measures, we performed separate mixed-model ANOVAs with group (HD, LD, MDD) as a between-subjects factor and AOI (sad, happy) as a within subject factor. Follow-up analyses for significant interactions included separate one-way ANOVAs for the sad and happy AOIs, with follow-up Bonferroni corrected contrasts between the MDD and LD and HD and LD groups to further explicate group differences. Because our analyses indicate between group differences in age and gender distribution, we performed analysis of covariance (ANCOVA) for significant findings entering age and gender distribution as covariates to the above described main analyses. Follow-up analyses also included separate Bonferroni corrected paired-samples *t*-tests comparing the sad and happy AOIs within each group. All statistical tests were 2-sided, using α of 0.05. Effect sizes are reported using η_p^2 values for conducted ANOVAs. For significant findings, a 95% confidence interval (CI) is also reported.

3. Results

3.1. Demographic and clinical characteristics

Demographic and clinical characteristics of the three groups are described in Table 1. As expected, significant group differences were noted for depression scores on the PHQ-9, $F(2, 60) = 187.91$, $p < .001$, $\eta_p^2 = .86$. Follow-up analyses revealed a higher score for the MDD group compared with both the HD group, $t(41) = 4.44$, $p < .001$, Cohen's $d = 1.35$, and the LD group, $t(38) = 19.01$, $p < .001$, Cohen's $d = 6.01$. In addition, by definition, the HD group had a higher score compared with the LD group, $t(41) = -17.80$, $p < .001$, Cohen's $d = 5.60$. Significant differences between groups were also noted for age, $F(2, 60) = 51.39$, $p < .001$, $\eta_p^2 = .63$, with a higher age average in the MDD group compared with both the HD and the LD groups, which did not differ from each other. Groups differences were also noted for gender distribution, $\chi^2(2) = 10.31$, $p = .006$. Both the HD group and the LD group differed from the MDD group, with no significant differences between these groups. Finally, no group differences were noted for years of education, $F(2, 60) = 0.99$, $p = .37$.

3.2. Eye-tracking data

3.2.1. Continuous gaze allocation - total dwell time

Total mean dwell times, in milliseconds, by group and AOI are presented in Fig. 2. A main effect of AOI, $F(1, 60) = 12.20$, $p < .001$, $\eta_p^2 = .17$, indicated that participants spent less time dwelling on the sad faces ($M = 2003$ ms, $SD = 396$) compared with the happy faces ($M = 2222$ ms, $SD = 333$). However, this main effect was qualified by a significant group-by-AOI interaction, $F(2, 60) = 3.73$, $p = .03$, $\eta_p^2 = .11$, indicating differential dwell time patterns for the three groups with regard to the sad and happy AOIs. Separate follow-up one-way ANOVAs on total dwell time for the sad and happy AOIs revealed a significant difference between the groups on the sad AOI, $F(2, 60) = 3.39$, $p = .04$, $\eta_p^2 = .10$, but not on the happy AOI, $F(2, 60) = 0.70$, $p = .50$, $\eta_p^2 = .02$. Follow-up contrasts of total dwell time on the sad AOI comparing the LD group and the two depression groups revealed that the MDD group and the HD group spent significantly more time dwelling on the sad faces compared with the LD group, $F(1, 60) = 5.03$, $p = .04$, $\eta_p^2 = .08$, and $F(1, 60) = 5.26$, $p = .04$, $\eta_p^2 = .08$, respectively.[2]

Because groups differed on age and gender ratio, we repeated the above-mentioned analyses introducing age and gender as covariates. The group-by-AOI interaction effect remained significant, $F(2, 58) = 4.07$, $p = .02$, $\eta_p^2 = .12$, as did the one-way ANOVA on total dwell time for the sad AOI, $F(2, 58) = 4.59$, $p = .01$, $\eta_p^2 = .14$. The follow-up contrasts of total dwell time on the sad AOI also remained significant for the difference between the HD and the LD groups, $F(1, 58) = 5.42$, $p = .04$, $\eta_p^2 = .09$, and for the MDD vs. LD group, $F(1, 58) = 6.77$, $p = .02$, $\eta_p^2 = .10$.

Comparing dwell time on each AOI within each group revealed a significant difference between the sad and the happy AOIs for the LD group, with participants dwelling significantly longer on the happy AOI, $t(19) = 2.80$, $p = .03$, Cohen's $d = 1.05$. No differences were found between dwell times on the two AOIs for the HD and MDD groups, $t(22) = 1.75$, $p = .09$, and $t(19) = 1.05$, $p = .31$, respectively.

Internal consistency for total dwell time on sad and happy faces for the 60 matrices presented in Session 1 was high, with Cronbach's alphas of 0.92, 0.93, respectively. Within group internal consistency for total dwell time on sad and happy faces was 0.92, 0.88 in the MDD group, 0.88, 0.86 in the HD group, and 0.85, 0.96 in the LD group, respectively. One week test-retest reliability was significant for total dwell time on sad and happy faces, $rs(41) = 0.74$ and 0.72, respectively, $ps < 0.001$.

3.2.2. First fixation measures

As expected, non-significant group-by-AOI interaction effects were noted for all the first fixation measures. Namely, first fixation latency, $F(2, 60) = 0.23$, $p = .80$, $\eta_p^2 = .007$, first fixation location, $F(2, 60) = 2.29$, $p = .11$, $\eta_p^2 = .07$, or first fixation dwell time, $F(2,$

[2] As 11 out of the 20 MDD pateints were also diagnosed with GAD, we conducted an additional mixed-model ANOVA within the MDD group for total dwell time, with group (MDD + GAD, MDD) as a between-subjects factor and AOI (sad, happy) as a within subject factor. However, this group-by-AOI interaction effect was not significant, $F(1, 18) = .45$, $p = 0.51$.

Table 1
Demographic and clinical characteristics of the three groups.

	LD group (n = 20)		HD group (n = 23)		MDD group (n = 20)	
Measure	*M*	*SD*	*M*	*SD*	*M*	*SD*
PHQ-9	1.50[a]	1.00	14.13[b]	2.47	18.45[c]	3.86
Age	23.60[a]	1.67	23.87[a]	1.98	40.28[b]	10.40
Gender ratio (M:W)	5:15[a]	–	5:18[a]	–	13:7[b]	–
Years of education	12.40[a]	1.10	12.70[a]	1.36	13.20[a]	2.68

PHQ-9, Patient Health Questionnaire-9.Different superscripts signify differences between groups at $p < .01$.Same superscripts signify differences between groups at $p > .80$.

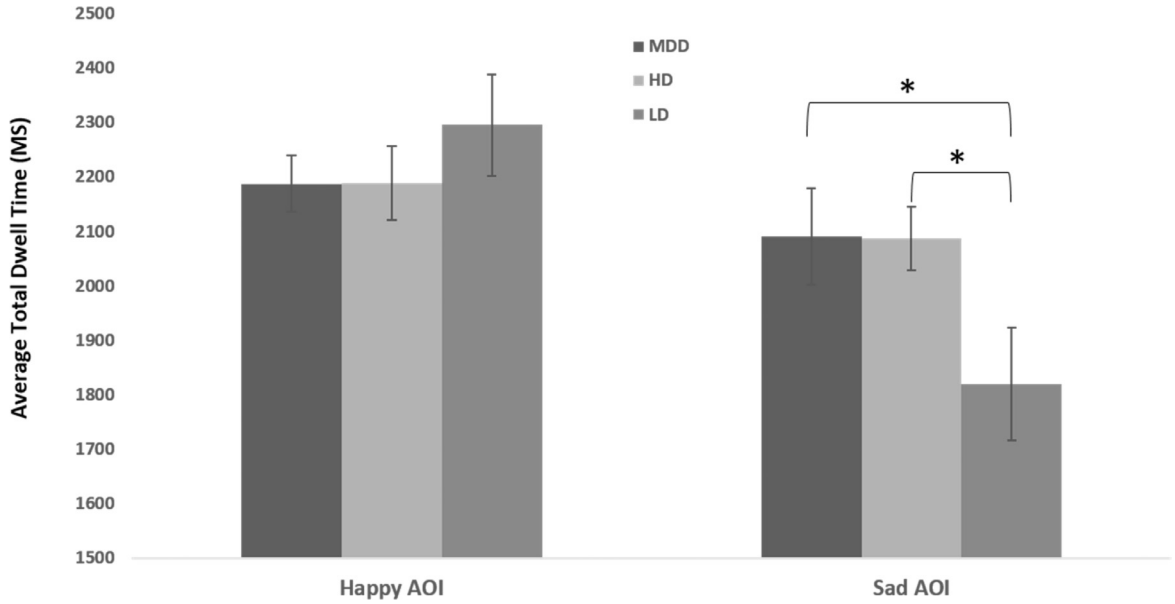

Fig. 2. Mean averaged total dwell time by AOI and Group. Higher values indicate higher mean average dwell time in milliseconds. Error bars denote standard error of the mean. Results indicate that compared with the low depression (LD) group, the high depression (HD) and the major depressive disorder (MDD) groups spent significantly more time fixating on the sad AOI. There were no significant differences in dwell time between the HD and MDD groups.

60) = 1.14, p = .33, η_p^2 = .04, indicating no depression-related gaze-pattern differences between the three groups with regard to the happy and sad AOIs on any of the first fixation measures. Indeed, test-retest reliabilities for these measures were found to be non-significant, rs (41) = 0.09, −0.15, and −0.07, respectively, all ps > 0.34. While test-retest reliability of first fixation measures were low, we still calculated internal consistency for these measures across participants. Internal consistency for sad and happy faces was 0.59, 0.55 for first fixation dwell time, 0.67, 0.74 for latency to first fixation, and 0.37, 0.51 for first fixation location, respectively.

4. Discussion

The present study compared gaze patterns during passive viewing of emotional faces among healthy and depressed participants. Two main results emerged. First, as compared to non-depressed students, both depressed students and patients with MDD dwelled longer on sad faces and equally divided viewing times between happy and sad faces. This contrasted with non-depressed students, who dwelled significantly longer on happy faces. Second, as in previous studies using distinct face emotions (Lazarov et al., 2016, 2017), the task in the current study also exhibited good psychometric features.

The current findings are consistent with previous research demonstrating attention bias to negative information in depressed relative to non-depressed individuals. In both RT-based research (Donaldson et al., 2007; Gotlib and Joormann, 2010; Gotlib et al., 2004; Gotlib et al., 2004; Peckham et al., 2010), and free-viewing eye-tracking research (Armstrong and Olatunji, 2012; Caseras et al., 2007; Duque and Vazquez, 2015; Kellough et al., 2008; Sears et al., 2010), negative bias in depression is primarily evident when stimuli are presented for long durations. In accordance with previous research, here, depression-related differences emerged for prolonged dwell time measures as opposed to the immediate measure of attention orienting, as reflected by first-fixation indices. However, such specificity could also reflect the poor reliability of first fixation measures (Lazarov et al., 2016; Waechter et al., 2014; Wermes et al., 2017).

Akin to previous findings (Gotlib et al., 1988; Mccabe and Gotlib, 1995; McCabe et al., 2000), non-depressed participants dwelled considerably longer on happy relative to sad faces, whereas depressed participants dwelled equally on both. In the current study, each faces display comprised the same number of sad and happy faces. Thus, the gaze pattern of the depressed participants appears to mirror the division of negative and positive information in the environment. This pattern echoes theories of so-called “depressive realism”, which suggest that depression involves particularly accurate appraisal of environmental stimuli, unlike in healthy individuals, who can display positive distortions in information processing (Alloy and Abramson, 1979, 1988; Matthews and Antes, 1992). Relatedly, research on emotional and cognitive aspects of subjective well-being among healthy participants indicates that these are associated with a general bias to attend happy faces over sad faces (Sanchez and Vazquez, 2014), again implicating a positivity bias among healthy individuals.

While the present results tightly correspond with previous findings, they also extend prior research in three important ways. First, the free-

viewing task employed here has good psychometric properties, with high internal consistency and acceptable one-week test-retest reliability. While a previous attentional eye-tracking study using an attentional engagement-disengagement task has shown satisfactory internal consistency (Sanchez et al., 2017), the current study is the first to also examine test-retest reliability in a free-viewing task designed to measure attention biases in depression. Current results extend previous data on a comparable measure used to assess biased attention in anxiety (Lazarov et al., 2016). Second, the current free-viewing task displays a large array of competing emotional faces at once, thereby increasing complexity and generalizability of obtained results. Array size in previous studies was restricted to a maximum of four stimuli. Indeed, researchers acknowledge the need to use more complex visual displays in attentional research to expand extant knowledge (Ferrari et al., 2016; Lazarov et al., 2016; Mogoase et al., 2014; Price et al., 2016; Richards et al., 2014). Third, unlike many attention tasks that require active response, the free viewing task used here has no explicit requirements from participants except for looking at the face matrices in any way they wish. Therefore, more naturalistic information processing and scanning patterns are encouraged and measured (Lazarov et al., 2016).

The current results should be considered in light of potential limitations. First, although significant group differences were observed in dwell time on sad faces, the current study has a small sample size that potentially limited power to detect between-groups differences in some of the first fixation gaze indices or for happy faces. Second, as previous research has implicated both an attentional bias toward sad faces and away from happy faces in depression (Duque and Vazquez, 2015; Lu et al., 2017) we chose to use both within single matrices to try and maximize biased attentional processes hoping to find an efficient and parsimonious target for therapeutic intervention. However, this decision limits our ability to differentiate the specific independent effects of sad and happy faces. Further research could extend the present results by using matrices comprised of sad and neutral faces and happy and neutral faces to elucidate the specific influence of each bias type (Lu et al., 2017). Future research could also incorporate other emotional expressions (e.g., anger, disgust) to further elucidate the specificity of the present results to sad and happy stimuli in the context of depression, or use the task in its current version to examine other psychopathologies to determine the specificity of the observed findings to depression. Finally, we did not use an MDD matched control-comparison group which limits our ability to draw more definite conclusions regarding this group, as reflected for example by age and gender differences across samples. However, attention differences manifested also between the low and high depressive symptom groups, where no demographic differences exist, with findings being unaffected by including age and gender as covariates in analyses. Still future studies may wish to include such a matched control to further clarify this aspect.

The present findings may have clinical implications for the development of novel gaze-contingent therapy for depression. Specifically, if patients with MDD dwell longer on dysphoric faces as shown here, this biased gaze pattern could serve as a viable target for therapeutic intervention. Applying a modified version of the current free viewing assessment task, we have recently demonstrated the clinical efficacy of a gaze-contingent feedback procedure in reducing social anxiety in patients with SAD (Lazarov et al., 2017). In this study the targeted mechanism was elevated dwell time on disgusted faces among patients with SAD (Lazarov et al., 2016). A randomized controlled trial in patents with MDD could now determine the therapeutic value of reducing dwell time on dysphoric faces in patients with MDD using a similar gaze-contingent music reward therapy (Lazarov et al., 2017).

Authors declaration

We declare that this manuscript is original and that it has not been published before or has been posted on a web site and that it is not currently being considered for publication elsewhere.

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Institutional Board Review

The authors assert that all procedures contributing to this work comply with APA ethical standards and with the Helsinki Declaration of 1975, as revised in 2008. All procedure were approved by the committees on human experimentation in Tel Aviv University.

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