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Research paper

Biased attention allocation in major depressive disorder: A replication and exploration of the potential effects of depression history

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ABSTRACT

Background: Increased attention allocation to negative-valenced information and decreased attention allocation to positive-valenced information have been implicated in the etiology and maintenance of depression. The Matrix task, a free-viewing eye-tracking attention assessment task, has shown corroborating results, coupled with adequate reliability. Yet, replication efforts are still needed. Therefore, we replicated a previously published study in depression, using the same task and attention measures. We also explored the potential added effect of depression history on attention allocation.

Methods: Participants diagnosed with major depressive disorder ($n = 65$) and a matched control group of healthy participants ($n = 37$) freely viewed 60 different face matrices, each presented for six seconds and comprised of eight sad and eight happy faces. Attention allocation to corresponding areas of interest (AOIs) was compared, and the internal consistency of attention allocation measures was assessed. We then compared the attention allocation of participants amidst their first episode ($n = 33$) to that of participants with a recurrent depressive episode ($n = 32$).

Results: A significant group-by-stimulus type (happy vs. sad faces) interaction emerged for total dwell time, replicating the findings of the original study. Groups differed on attention allocation to both the sad and happy faces. No findings emerged for first fixation measures. Internal consistency of the total dwell time measure was high. Depression history had no effect on attention allocation.

Limitations: Due to ethical constraints (delay of treatment), test-retest reliability was not assessed.

Conclusions: The Matrix task provides a reliable and replicable measure of attention allocation in MDD, showing no effects for depression history.

1. Introduction

Cognitive models of major depressive disorder (MDD) implicate several cognitive biases across different aspects of information processing (e.g., attention, interpretation, memory) in the onset, maintenance, and recurrence of the disorder (for reviews see Gotlib and Joormann, 2010; LeMoult and Gotlib, 2019; Mathews and MacLeod, 2005). In the realm of attention, it has been suggested that the attention system of depressed individuals is biased toward negatively-valenced (i.e., dysphoric) information over positive/neutral information, also showing a reduced "protective" bias toward positive information characteristic of non-depressed individuals (for reviews see Peckham et al., 2010; Winer and Salem, 2016). As these two biases are not mutually exclusive, they may operate conjointly to yield a potent bias toward dysphoric and away from positive information in depression (Basel et al., 2021; Duque and Vazquez, 2015; Imbert et al., 2024; Lazarov et al., 2018; Quigley et al., 2024), which has been specifically implicated as a potential target for therapeutic interventions (Beevers et al., 2021; Hsu et al., 2021; Jonassen et al., 2019; Shamai-Leshem et al., 2021). Research has consistently corroborated both of these biases in depression with eye-tracking research further elucidating their specific nature, showing them to manifest mainly in attention processes occurring after cue detection, namely, difficulty to disengage attention from dysphoric cues, once detected, and sustained attention (i.e., attentional maintenance) on these cues (for reviews and meta-analytic studies see Armstrong and Olatunji, 2012; Shamai-Leshem et al., 2023; Suslow et al., 2020).

Although extant research has considerably advanced the

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0165-0327/© 2025 Elsevier B.V. All rights are reserved, including those for text and data mining, AI training, and similar technologies.

understanding of attention allocation in depression, further establishing the field and moving it forward necessitates additional research efforts. Specifically, in adhering to the scientific method (Moonesinghe et al., 2007), research across all disciplines must demonstrate several key attributes in order to substantiate theoretical claims and facilitate confidence in relying on and implementing ensuing conclusions (Lilienfeld and Strother, 2020; Parsons et al., 2019). One such pivotal attribute is *replicability* – the ability to reproduce previous findings and statistically confirm the same hypothesis (Moonesinghe et al., 2007). Replicability in psychological sciences has received much traction over the last several years, being the subject of considerable scrutiny in light of the well-known 'replication crisis' which has cast serious doubts on the reliability of previous research and its clinical implications (Fabrigar and Wegener, 2016; Lilienfeld and Strother, 2020; Maxwell et al., 2015; Wiggins and Christopherson, 2019), including research on the association between attention biases and depression (Lazarov et al., 2021).

A critical underlying factor of adequate replicability is sound measurement, specifically, the *reliability* of measurement practices (Flake et al., 2017; Lilienfeld and Strother, 2020; McNally, 2019). If measures have questionable reliability, it should come as no surprise that emergent findings differ widely across measurements (e.g., time points, studies, and samples; Lilienfeld and Strother, 2020), leading to poor replicability, making their interpretation inconclusive at best (Flake et al., 2017). In psychological sciences, it has been explicitly suggested that researchers might not devote the required attention to the reliability of measures used in their studies, neglecting them, or taking them for granted (Lazarov et al., 2021; Lilienfeld and Strother, 2020; McNally, 2019; Parsons et al., 2019). Indeed, early attentional research using reaction-time (RT)-based measures such as the dot-probe task or the emotional Stroop task had ignored the poor internal consistency and reliability of the attention bias measures derived from these tasks, leading to a reevaluation of nearly three decades of research (McNally, 2019; Rodebaugh et al., 2016; Schmukle, 2005; Waechter et al., 2014). Trying to overcome this crisis, attentional research has turned to using advanced eye-tracking technology as an alternative assessment approach of attention, as it enables a more fine-grained exploration of attention processes as these unfold and change over time (Lazarov et al., 2021; Skinner et al., 2018; Suslow et al., 2020). Most importantly, eye-tracking-based attentional research has shown acceptable reliability, especially for attention indices measured over extended presentation durations (Armstrong and Olatunji, 2012; Lazarov et al., 2016; Lazarov et al., 2018; Lazarov et al., 2019; Shamai-Leshem et al., 2023; Skinner et al., 2018; Waechter et al., 2014).

One widely-used eye-tracking-based attention allocation task showing adequate reliability is the Matrix task, first described by Lazarov et al. (2016) when studying attention allocation processes in social anxiety. Briefly, during the task participants freely view 4-by-4 matrices comprised of 16 photographs of two types: eight neutral or positive stimuli and eight disorder-related stimuli (e.g. happy vs. sad faces in depression, neutral vs. disgust faces in social anxiety, pictures of low vs. high caloric food items in eating disorders). Attention allocation is indexed via the total time spent (i.e., total fixation duration) on each stimulus type (neutral vs. disorder-relevant content), with biased attention allocation reflected in increased dwell time on the disorder-specific content relative to the alternative stimulus type. Implementing the task in depression (using sad vs happy face matrices), a recent study (Lazarov et al., 2018) compared the performance of three groups of participants – participants with clinically-diagnosed MDD, and two analogue samples of undergraduate students scoring high and low on a self-report measure of depression. Results showed that both MDD patients and student participants with high levels of self-reported depression dwelled longer on sad faces compared with student participants with low levels of self-reported depression (comprising the non-depressed control group). Finally, and most relevant in the present context, the attentional measure (i.e., total dwell time) showed good psychometric properties, with high internal consistency and acceptable one-week test-retest reliability (Lazarov et al., 2018). Further addressing the reliability of the Matrix task at large, a recent multisite international study has shown it to have acceptable reliability in adults across various stimuli contrasts and psychopathologies, establishing it as a reliable measure of attention allocation (Shamai-Leshem et al., 2023).

The above-described study (Lazarov et al., 2018) lends preliminary support for the reliability of the Matrix task and the dwell time measure in depression. However, one study is surely not enough. Moreover, while sound reliability is essential for replicability, as stated above, direct replicability of key findings is critical for confidence in the task and its measures. This constitutes the aim of the present study, which is the first attempt to replicate the original Lazarov et al. (2018) study using exactly the same task and primary outcome measure (i.e., total dwell time) in depression. Specifically, participants with clinically-diagnosed MDD and non-depressed control participants completed the depression version of the Matrix task and were compared on the same attention allocation measures (Lazarov et al., 2018).

Aiming to further substantiate and extend previous findings, a few modifications were introduced. First, a larger sample of treatment-seeking participants with clinically-diagnosed MDD were recruited ($n = 65$ vs $n = 20$ in the original study) thereby increasing statistical power. Second, to specifically focus on clinical MDD, we did not recruit an analogue sample of undergraduate students scoring high on a self-report measure of depression as was done in the original study. While research in depression does show continuity between subthreshold and clinical depression (Enns et al., 2001), justifying the usage of analogue samples for initial exploration and insights of depression-related phenomena, clinical samples still differ from analogue ones on depression severity, well-being, and quality of life, as well as on cognitive and behaviorally functioning (Cuijpers and Smit, 2008; Hill et al., 1987). Relatedly, rather than using an analogue control group (i.e., undergraduate students scoring low on a self-report measure of depression), which differed from the MDD group on age as well as gender ratio, in the present study we recruited a matched control group (on age, years of education, gender) comprised of non-depressed healthy participants that also underwent a full clinical evaluation similar to that of the MDD group. We also assessed self-reported depression using two measures rather than just one to more comprehensively verify participants' subjective depression severity. Finally, we also explored the potential effects of depression history on attention allocation in the MDD group, which could not be explored in the original study due to the small sample size of the MDD group (n = 20). Interestingly, extant research in depression has shown number of depressive episodes to be related to depression severity (Hoertel et al., 2017), prognosis (Gorwood et al., 2010), and most relevant for the present study, the presence of various cognitive deficits (e.g. Basso and Bornstein, 1999; Elgamal et al., 2010; Vanderhasselt and De Raedt, 2009). Hence, number of depressive episodes was treated as another grouping variable in our exploratory analysis.

We expected to replicate the results of Lazarov et al. (2018), namely, that while both groups will dwell longer on happy faces relative to sad faces (i.e., a main effect of face type), this preference would be less prominent in the MDD group (i.e., group-by-face type interaction). We also expected to replicate the adequate psychometrics of the dwell time measure. While in the original study no group differences emerged for first fixation measures (i.e., latency, location, or dwell time), we still decided to incorporate these indices in the current study to be as consistent as possible with the original one.

2. Method

2.1. Participants

Participants were 65 treatment-seeking individuals with a clinical diagnosis of MDD (i.e., the MDD group) and 37 individuals without a past or current diagnosis of any psychiatric disorder (i.e., the healthy control group; HC). The two groups were matched on age, years of

education, and gender distribution. Demographic and psychopathological characteristics (see Measures below) by group are presented in Table 1.

Participants were recruited via online advertisements (e.g. social media platforms, the lab's website), local media, and community postings. Interested participants were invited for a full in-person clinical assessment using the Mini-International Neuropsychiatric Interview (MINI; (Sheehan et al., 1997)) – a well validated structured interview for a DSM-based psychiatric diagnosis (Lecrubier et al., 1997; Sheehan et al., 1998). These interviews were conducted by a PhD level clinical psychologist trained to an 85 % reliability criterion with a senior psychologist. Depression levels were further assessed using the clinician-rated Montgomery-Asberg Depression Rating Scale (MADRS; (Montgomery and Åsberg, 1979)).

Inclusion criteria for the MDD group were: a) primary DSM-5 diagnosis of MDD; b) MADRS total score $\geq$ 19, reflecting moderate depression (Müller et al., 2003); c) 18–65 years of age; and d) normal or corrected-to-normal vision. Exclusion criteria were: a) history or current psychosis, bipolar disorder, manic or hypomanic episode; b) epilepsy or brain injury; c) clinically significant suicidal ideation or behavior; d) severe alcohol or cannabis use disorder, and/or any severity of other substance use disorder (except nicotine use disorder); e) eye-tracking calibration difficulties; and f) pharmacological treatment if not stabilized for at least three months or concurrent psychotherapy at the time of the study, as this has been shown to affect attention allocation patterns in depression (Guy et al., 2024).

Inclusion criteria for the HC group were: a) 18–65 years of age; and b) MADRS score $\leq$ 6, reflecting normal or absence of depressive symptoms (Montgomery and Åsberg, 1979). Exclusion criteria were: a) any DSM-5 psychiatric disorder; past or present, b) clinically significant suicidal ideation or behavior; c) current unstable or untreated medical illness; d) current or past organic mental disorder, seizure or brain injury; and e) eye-tracking calibration difficulties.

Of the included 65 MDD participants, 31 also met the criteria for generalized anxiety disorder (GAD), 22 for social anxiety disorder (SAD), six for panic disorder (PD), two for obsessive compulsive disorder (OCD), and one for agoraphobia. Thirty-three MDD participants were amid their first depressive episode. Thirteen participants were treated with psychiatric medication at the time of their participation.

The study was conducted in accordance with ethical guidelines of the Declaration of Helsinki and was approved by the Institutional Review Board of the university (protocol 0000079-1). All participants provided written informed consent prior to participation. Participants received a small monetary compensation (amounting to approximately $15) for completing the study and were debriefed following the completion of all study procedures.

Table 1
Demographic and clinical characteristics per group.

Measure	MDD group (n = 65)		HC group (n = 37)		t	p	*Cohen's d*
	M	*SD*	*M*	*SD*			
Age	41.16	11.8	42.16	9.2	0.23	0.816	0.04
Years of Education	14.09	2.55	15.25	2.58	2.18	0.031	0.44
Gender ratio (M:W)	35:30	–	22:15	–	–	–	–
MADRS	29.7	5.09	0.57	1.48	33.99	<0.001	7.00
PHQ-9	18.1	3.64	1.46	1.48	28.76	<0.001	5.92
BDI-II	30.9	9.05	0.73	1.52	20.05	<0.001	4.13
GAD-7	11.6	4.94	0.30	1.02	13.75	<0.001	2.83

Note. MDD, major depressive disorder; HC, healthy control; MADRS, Montgomery-Asberg Depression Rating Scale; PHQ-9, Patient Health Questionnaire-9; BDI-II, Beck Depression Inventory – II; GAD-7, Generalized Anxiety Disorder-7.

2.2. Measures

Depression levels were assessed using the clinician-rated MADRS (Montgomery and Åsberg, 1979) and two self-report questionnaires – the Patient Health Questionnaire-9 (PHQ-9; Kroenke et al., 2001) and the Beck Depression Inventory-II (BDI-II; Beck et al., 1996). General anxiety was measured via the Generalized Anxiety Disorder (GAD-7) questionnaire (Spitzer et al., 2006). Primary and co-morbid diagnoses were determined using the MINI (Sheehan et al., 1997). See Supplementary Material for a detailed description of each measure.

2.3. The Matrix task

2.3.1. Task description

The eye-tracking Matrix task was identical to the one used in Lazarov et al. (2018). Color photographs of 16 males and 16 female actors, each appearing once with a sad and once with a happy facial expression, were taken from the NimStim Stimulus Set (Tottenham et al., 2009). Sixty different 4-by-4 matrices were assembled, 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 (see Fig. 1 for an example of a single matrix). The faces appeared randomly at any position on the matrix while ensuring the following: a) in each matrix each actor appeared only once; b) each matrix contained eight male and eight female faces; c) half the faces had a sad facial expression and half had a happy one; and d) the four inner faces always included two sad and two happy faces.

To verify that each trial began only when participants' gaze was fixated at the matrix's center, each trial of the task began with a fixation-cross shown until a fixation of 1000 ms was recorded. Then the matrix was then 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-minute break was introduced between blocks to reduce fatigue. Each single face/picture appeared exactly 15 times per block.

See Supplementary Materials for information about the eye-tracker apparatus and parameters, including measures taken to ensure data quality.

2.3.2. Eye tracking measures

Following the original study of Lazarov et al. (2018), for each of the 60 matrices two Areas of Interest (AOIs) were defined based on the type of facial expression (i.e., sad or happy), such that one AOI included the eight sad facial expressions (the sad AOI) and one included the eight happy facial expressions (the happy AOI). As in previous studies using the Matrix task (Lazarov et al., 2018; Shamai-Leshem et al., 2023), *sustained attention* was assessed by averaging the total duration of all fixations per AOI (in seconds) across the 60 presented matrices; *vigilance* was indexed by both first fixation latency, calculated by averaging the latency to first fixations in milliseconds for each of the AOIs, and first fixation location, measured by counting the number of first fixations on each AOI; and first fixation dwell time was used to reflect *initial difficulty to disengage* a cue once detected, and was computed by averaging first fixation duration, in milliseconds, per AOI.

2.4. Procedure

Participants were tested individually in a quiet room at the university. Following the signing of informed consent, they were seated in front of the eye-tracking monitor and told that they are going to participate in a study examining gaze patterns using eye-tracking technology. They were also told that during the experiment they would be presented with different matrices of faces, appearing one after the other, and were instructed to look freely at each matrix in any way they chose until it disappeared. They were then informed that a fixation cross will

Fig. 1. An example of a single matrix.

appear at the center of the screen before the appearance of each matrix, on which they need to fixate their gaze in order for the matrix itself to appear and were presented with a demonstration of this contingency. Following these basic instructions, the Matrix task commenced.

2.5. Data analysis

A power analysis was performed using G*Power 3.1.9.4 (Faul et al., 2007), using the group-by-AOI interaction effect size reported in the replicated study using the same task in depression ($\eta_p^2 = 0.11$; (Lazarov et al., 2018)). Results indicated that a sample of 90 has a power of 90 % to detect this interaction at an alpha level of 0.05.

All reported statistical analyses were conducted using SPSS (IBM; version 27.0) and were 2-sided, using an α of 0.05. Effect sizes are reported using η_p^2 for ANOVAs and *Cohen's d* for mean comparisons.

2.5.1. Demographic and clinical characteristics

Independent sample *t*-tests were used to compare groups on demographic and clinical measures (i.e., age, years of education, and scores on the various questionnaires; see Measures above). A Chi-square test compared groups on gender ratio.

2.5.2. Eye-tracking measures

2.5.2.1. Main analysis. Our main analysis plan followed the same analytic approach taken by Lazarov et al. (2018). Accordingly, group differences in total dwell time were examined using a mixed-model Repeated Measure ANOVA with group (HC and MDD) as a between-subjects factor and AOI (i.e., face-type; sad, happy) as a within-subject factor.

The same analysis was used for first fixation measures – latency to first fixation, first fixation location, and first fixation dwell time.

2.5.2.2. Exploratory analysis. Number of depressive episodes of each MDD participant was assessed using the MINI-5 interview, and was then used to divide the MDD group into two sub-groups – a first depressive episode group and multiple episodes group. Next, we repeated the above-stated analysis entering depressive episodes history (i.e., no episode, first episode, recurrent episode) as the grouping variable. Specifically, group differences were examined using a 3-by-2 mixed-model repeated measure ANOVA with group (HC, first-episode vs. multiple episodes) as a between-subjects factor and AOI (sad, happy) as a within-subject factor.

2.5.3. Reliability

Reliability was assessed for three variants of the total dwell time measure, namely, dwell time on sad faces, dwell time on happy faces, and the percentage of dwell time on sad faces out of total dwell time (% dwell time = dwell time on sad stimuli/dwell time on sad + happy stimuli; (Shamai-Leshem et al., 2023)). Internal consistency was

examined for the overall sample ($N = 102$) and separately by group (MDD, HC), using Cronbach's alpha and treating each trial (i.e., each matrix) as a single item.

3. Results

Data of this study are openly available in Open Science Foundation (OSF) at https://osf.io/gmyfe/?view_only=78a052ad2e20447a9308595343bf3e10

3.1. Demographics and clinical characteristics

Demographic and clinical characteristics of the two groups are described in Table 1. Not surprisingly, the MDD group scored significantly higher than the HC group on the MADRS, the PHQ-9, and the BDI-II, as well as on the GAD-7. No group differences emerged for age, years of education, and gender, $\chi^2 = 0.3$, $p = .58$.

3.2. Eye-tracking data and reliability

3.2.1. Main analysis

3.2.1.1. Mean total dwell time. Mean total dwell time, in seconds, by group and AOI (sad, happy) is presented in Fig. 2 and Table 2. Results indicated a main effect of AOI, $F(1,100) = 46.63$, $p < .001$, $\eta_p^2 = 0.32$ – across groups, participants dwelled longer on the happy AOI than on the sad AOI. Yet, as expected, this main effect of AOI was qualified by a significant group-by-AOI interaction, $F(1, 100) = 14.92$, $p < .001$, $\eta_p^2 = 0.13$, reflecting differential attention allocation patterns of the two groups with regard to the two AOIs.

Follow-up simple effects analysis per AOI revealed significant group differences on both AOIs. Considering the sad AOI, MDD participants dwelled significantly longer on the sad faces compared with HC participants, $t(100) = 2.01$, $p = .047$, *Cohen's d* = 0.41. The opposite pattern emerged for the happy AOI, with HC participants dwelling significantly longer on the happy faces compared with MDD participants, $t(100) = 4.91$, $p < .001$, *Cohen's d* = 1.01. Follow-up within-group simple effect analysis showed that while both groups dwelled significantly longer on the happy AOI than on the sad AOI (HC group: $t(36) = 4.99$, $p < .001$, *Cohen's d* = 0.80; MDD group: $t(64) = 3.31$, $p < .001$, *Cohen's d* = 0.41), this difference was more prominent in the HC group than in the MDD group.

Internal consistency for total dwell time on happy and sad faces for all 60 matrices across participants was high, with Cronbach's α of 0.96, 0.94, respectively. Within groups internal consistency for total dwell time on sad and happy faces was 0.91, 0.91 in the MDD group, and 0.96, 0.96 in the HC group, respectively. Internal consistency for percentage of dwell time on sad faces was also high, with Cronbach's α of 0.94, 0.96, and 0.89, for all participants, the HC group, and the MDD group, respectively.

3.2.1.2. First fixation measures. No significant group-by-AOI interaction effects emerged for any of the first fixation indices – first fixation latency, $F(1, 100) = 0.03$, $p = .85$, first fixation location, $F(1, 100) = 2.77$, $p = .09$, or first fixation dwell time, $F(1, 100) = 1.51$, $p = .22$.

Internal consistency for first fixation measures were low, yielding Cronbach's α of 0.50, 0.66 for latency to first fixation on sad and happy faces, respectively. This was also the case for first fixation location (−0.18, −0.95)[1] and for first fixation dwell time (0.46, 0.69).

3.2.2. Exploratory analysis

Demographic and clinical characteristics of the two depression subgroups (first, multiple episodes) are described in Table 3. No significant group differences emerged in any of the measures.

Total dwell time, in seconds, by depressive episode group (HC, first, multiple) and AOI (sad, happy) is presented in Fig. 3. A significant main effect of AOI emerged, $F(1,99) = 32.95$, $p < .001$, $\eta_p^2 = 0.25$, which was qualified by a significant group-by-AOI interaction, $F(2,99) = 7.59$, $p < .001$, $\eta_p^2 = 0.13$.

Follow-up analysis revealed significant interaction effects between the HC group and the first depressive episode group, $F(1,68) = 10.43$, $p = .002$, $\eta_p^2 = 0.13$, as well as the multiple episodes group, $F(1,67) = 7.58$, $p = .008$, $\eta_p^2 = 0.10$. No significant interaction effect emerged when comparing the first episode group and the multiple episodes group, $F(1,63) = 0.66$, $p = .42$.

4. Discussion

The current study aimed to replicate a previous attention allocation eye-tracking study in depression, using the same attention allocation task and outcome measures (Lazarov et al., 2018). Participants freely viewed 60 different matrices, each comprised of eight happy and eight sad faces. Total dwell time on the sad and happy AOIs as well as first fixation measures (i.e., latency, location, and dwell time) per AOI were assessed, as was the task's internal consistency.

A significant group-by-AOI interaction for total dwell time emerged. Both groups dwelled longer on happy than on sad faces, but this pattern was significantly more prominent among control participants. This result replicates that of Lazarov et al. (2018) and is also in accordance with extant eye-tracking research on attention allocation in depression (Armstrong and Olatunji, 2012; Rudich-Strassler et al., 2022; Shamai-Leshem et al., 2022; Suslow et al., 2020). Also akin to Lazarov et al. (2018), excellent internal consistency was noted for total dwell time. Yet, the present study also extends and elaborates the original one in several important ways: a larger sample size of participants with clinically-diagnosed MDD was recruited, thereby increasing statistical power; the MDD group was compared to a matched control group of healthy non-depressed participants, rather than to an analogue sample; both samples (participants with MDD and healthy control participants) underwent a full clinical evaluation using the clinician-administered MINI; and we also explored the potential effects of depression history on attention allocation patterns. Taken together, current findings suggest that the dwell time measure of the Matrix task is not only a reliable index of attention allocation in depression, but also a replicable one.

While the group-by-AOI interaction was similar to that of the original study (Lazarov et al., 2018), follow-up simple effects analyses yielded a slightly different results pattern. Aligning with the original study (Lazarov et al., 2018), here, too, participants with MDD showed increased dwell time relative to HC participants on sad AOI. This echoes existing theories and research in the field that implicate an attentional bias toward negative information in MDD (for reviews see Armstrong and Olatunji, 2012; Gotlib and Joormann, 2010; LeMoult and Gotlib, 2019; Suslow et al., 2020). As for the happy AOI, participants with MDD dwelled significantly less, relative to HC participants, on happy faces, an attention pattern that was also observed in the original study, but without reaching statistical significance. This divergence is probably due to increased power and the more suitable control group used in the present study. The reduced positivity bias in MDD may reflect the absence of a "sufficient" protective attention allocation pattern in favor of positive information characterizing non-depressed individuals (De Raedt and Koster, 2010; Duque and Vazquez, 2015; Imbert et al., 2024; Peckham et al., 2010; Quigley et al., 2024; Sanchez and Vazquez, 2014; Winer and Salem, 2016). Indeed, as noted above, while both groups were biased toward the positive AOI, this was significantly greater among HC participants. Interestingly, exploring the effect sizes of the between-groups simple effects per AOI showed that the effect size of

[1] Negative Cronbach's α indicates greater within-subject variability than between-subject variability.

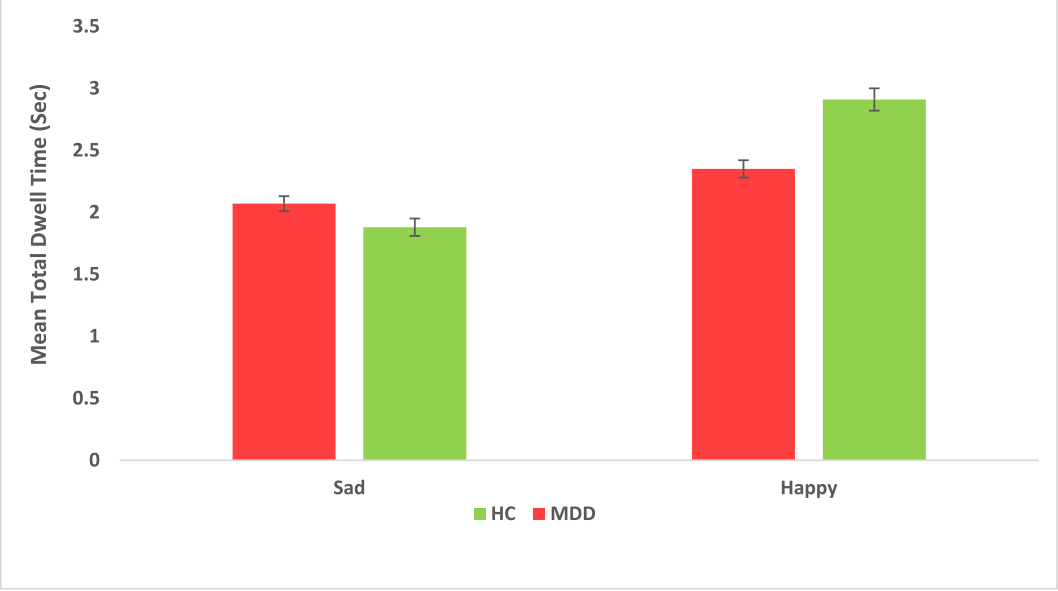

Fig. 2. Mean total dwell time (in seconds) on sad and happy faces by Group. Error bars denote standard error of the mean.
Note. MDD, major depressive disorder; HC, healthy control.

Table 2
Mean total dwell time per group and area of interest (AOI).

AOI	MDD group (n = 65)		HC group (n = 37)		Total	
	M	*SD*	*M*	*SD*	*M*	*SD*
Happy	2.35	0.40	2.91	0.74	2.55	0.61
Sad	2.07	0.40	1.88	0.53	2.00	0.46

Note. MDD, major depressive disorder; HC, healthy control.

Table 3
Demographic and clinical characteristics by depression history.

Measure	First Depressive Episode (n = 33)		Multiple Depressive Episodes (n = 32)		*t*	*p*
	M	*SD*	*M*	*SD*		
Age	42.21	10.88	41.05	12.83	0.39	0.69
Years of Education	14.33	2.47	13.84	0.88	0.77	0.44
Gender ratio (M:W)	17:18	–	18:14	–	–	–
MADRS	29.18	5.07	30.28	5.11	0.87	0.39
PHQ-9	17.91	3.18	18.53	3.57	0.75	0.46
BDI-II	31.33	9.47	30.34	8.73	0.41	0.68
GAD-7	11.81	4.71	11.45	5.25	0.29	0.77

Note. MADRS, Montgomery-Asberg Depression Rating Scale; PHQ-9, Patient Health Questionnaire-9; BDI-II, Beck Depression Inventory – II; GAD-7, Generalized Anxiety Disorder-7.

group differences in attention allocation toward happy faces (Cohen's d = 1.01) was larger than that of sad faces (d = 0.41). This results pattern echoes past research in the field (for a review see Armstrong and Olatunji, 2012), suggesting that the reduced positive bias among depressed individuals is the more pronounced bias in depression. Yet, some studies found similar effect sizes for both biases, while others reported no effect for the happy AOI (Klawohn et al., 2020). These mixed findings across studies may be related to the severity of depression across samples (Armstrong and Olatunji, 2012; Imbert et al., 2024) and/or to specific methodological factors, such as the type of stimuli used (e.g., emotional faces, naturalistic images) or the complexity of the stimulus array presented during the task (Klawohn et al., 2020). These diverse findings once again emphasize the importance of replication efforts aiming to clarify and determine the circumstances under which each attentional

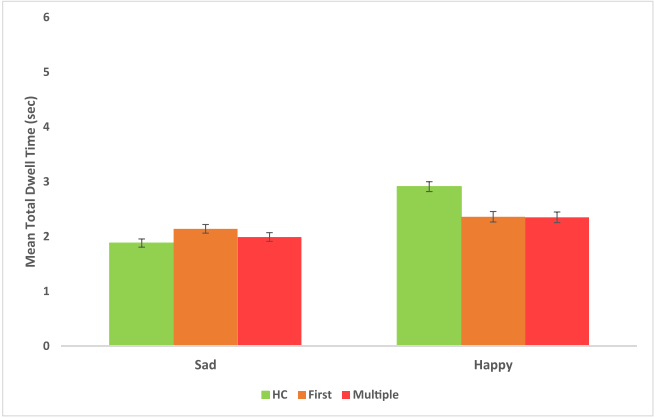

Fig. 3. Mean total dwell time (in seconds) on sad and happy faces by Depressive Episodes. Error bars denote standard error of the mean.
Note. HC, healthy control.

bias, both negative and positive, emerge.

The above-noted pattern of between-groups simple effects suggests a double bias in depression – toward dysphoric and away from positive stimuli (Basel et al., 2021; Duque and Vazquez, 2015; Lazarov et al., 2018). Yet, as the present study used sad vs. happy face matrices (as did the original study), one cannot know with certainty which specific bias (i.e., toward sad faces, away from happy faces, or both) "drives" the observed results. An initial insight into this question comes from a recent study which used the matrix task to compare the attention allocation of depressed and healthy participants using separate sad vs. neutral and happy vs. neutral face matrices (30 matrices each in two separate blocks). While both groups dwelled longer on the happy than on the neutral faces, an attention allocation pattern favoring sad over neutral faces appeared only in the MDD group (Klawohn et al., 2020). Considering these findings in light of current results suggest that the sad faces may be 'responsible' for the observed pattern of attention allocation. Alternatively, however, one may question the importance of this 'responsibility' question – does a single cue have any 'real' relevance in determining attention allocation without taking into account which additional cues are presented alongside it (i.e., competing for one's

attention; (Bacon and Egeth, 1994; Failing and Theeuwes, 2018; Folk et al., 1992; Leber and Egeth, 2006))? Put differently, could we really determine the "pure" effect of a single stimulus type in isolation from co-presented cues when interpreting attentional patterns (e.g., "it is the sad faces that did it…"). Indeed, prior research on attention allocation has shown depression to be associated with a lack of a general attention bias toward *relatively* positive over *relatively* negative information (Basel et al., 2021). This relativity notion is also supported by classic theories of emotion perception asserting that the valence of a specific facial expression is determined not only by its physical features, but also by the context in which it is presented (Brosch et al., 2010; Russell and Fehr, 1987). This suggests that rather than trying to 'pinpoint' specific emotions as responsible for observed biases, future research should focus on the dynamic interaction between co-presented competing stimuli.

To explore other factors that may influence attention allocation among depressed individuals, beyond that of the valence/emotion of presented information, we also examined the possible impact of one's depression history, namely, whether one is amid a first or a recurrent depressive episode. Results showed that while both depression groups (i.e., first episode, recurrent episode) differed significantly from never depressed healthy participants on attention allocation patterns, no differences were noted when comparing the two depression groups. This lack of group differences on the attentional indices may suggest that the recurrence of a depressive episode does not further influence one's attention allocation beyond the effect of the first one, which possibly plays a pivotal role in altering one's attentional system. The fact that no significant group differences emerged for any of the demographic or clinical characteristics strengthens this postulation. This suggestion is also in line with a recent meta-analysis that showed that relative to never depressed participants, both previously depressed and currently depressed individuals displayed greater attention bias toward dysphoric information coupled with reduced attention toward positive stimuli, with the latter two groups not differing in attention allocation to either type of information (Shamai-Leshem et al., 2022). The authors postulated that dysphoric and positive attention biases are stable underlying factors in depression, which may represent either a stable pre-existing tendency (i.e., a risk factor for depression; (Gibb et al., 2009; Joormann et al., 2007; Kujawa et al., 2011; Montagner et al., 2016; Pérez-Edgar et al., 2006; Silk et al., 2006) or a cognitive "scar" left by the first depressive episode (Knight et al., 2018; McIntyre et al., 2013). In the present context, both options would suggest that recurrent depressive episodes do not "add" to an already existing biased attention allocation. However, as the present study was cross-sectional, better exploring the added effect of recurrent depressive episodes on attention allocation would necessitate a longitudinal research design tracking participants' attention allocation across several depressive episodes.

Several limitations should be acknowledged, instigating future research endeavors. First, the present study did not include a re-test session that would have enabled us to explore test-retest reliability. As depressed participants were waiting for treatment, ethical considerations precluded a delay of treatment. While previous research using the Matrix task did show it to have adequate test-retest reliability, including when using sad-happy matrices (Lazarov et al., 2018; Shamai-Leshem et al., 2023), this contrast was only assessed among healthy non-depressed participants. Hence, establishing the task's test-retest reliability using a clinical sample is still warranted. However, and as stated above, test-retest reliability is a prerequisite for replicability. Thus, current findings may provide the sought after confidence in the psychometric properties of the Matrix task in depression. Second, as we aimed to replicate the original study of Lazarov et al. (2018), we used the same sad-happy matrices. Yet, additional research using other emotional expressions/contrasts (e.g., fear vs neutral; anger vs happy) is now needed to further establish the task's reliability in depression beyond this basic emotional contrast. Notwithstanding the utility of face stimuli in research on attention allocation in depression (e.g., given their role in depression-related negative interpretation of social cues and impairments in social skills; Gotlib et al., 2004), faces are unique stimuli in terms of their processing (e.g., speed and ease; for a review see Posamentier and Abdi, 2003). Hence, while faces are well suited for the Matrix task which displays 16 stimuli at once (Shamai-Leshem et al., 2023), other stimulus types (e.g., naturalistic scenes) may be less suited for presentation within the Matrix task. This, in turn, limits the suitability of the Matrix task for other types of stimuli relevant for depression, and curbs the generalizability of current findings to face stimuli. Future research could try and present different stimulus types using a modified version of Matrix task in which 2-by-2, rather than 4-by-4, grids are used (for examples see Basel and Lazarov, 2024; Basel et al., 2023). Finally, while present findings established the psychometric properties of the current task (e.g., sad-happy contrast) in depression, additional research in other psychopathologies characterized by depressive features (e.g. post-traumatic stress disorder) is also needed to establish its suitability as a depression-related attentional task (Alon et al., 2023; Lazarov et al., 2019).

Taken together with past research (Lazarov et al., 2018; Shamai-Leshem et al., 2022), present findings suggest the dwell time measure of the Matrix task (with sad-happy matrices) to be a reliable index of attention allocation in depression, which could also serve as a reliable target for intervention via attention bias modification (ABM) procedures (Rooney et al., 2024). Indeed, a previous study has used the current Matrix task (sad vs happy matrices) coupled with gaze-contingent music reward to train participants' attention away from the sad and toward the happy faces hoping to alleviate symptoms (Shamai-Leshem et al., 2021). Unfortunately, there were no differences in symptom reduction between the active and a placebo group that received non-contingent music throughout training (see also Möbius et al., 2018; Woolridge et al., 2021 for similar null findings). Interestingly, and most relevant in the present context, the two groups also did not differ on pre-to-post changes in attention allocation. Put differently, the gaze-contingent procedure did not change the attentional target, and hence, not surprisingly, no symptom reduction followed (Hertz-Palmor et al., 2023). Future research should therefor explore more potent attention modification procedures that would better target attention allocation in depression (i.e., the dwell time on sad vs. happy faces), which would hopefully lead to corresponding reductions in depressive symptoms (Hertz-Palmor et al., 2023).

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.

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.

CRediT authorship contribution statement

Shani Lavi: Writing – original draft, Project administration, Investigation, Formal analysis, Data curation, Conceptualization. **Dana Shamai-Leshem:** Writing – review & editing, Project administration, Investigation, Data curation. **Yair Bar-Haim:** Writing – review & editing, Supervision, Resources, Investigation, Funding acquisition. **Amit Lazarov:** Writing – review & editing, Supervision, Resources, Investigation, Funding acquisition, Conceptualization.

Role of the funding source

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Declaration of competing interest

The other authors have no financial disclosures. We wish to confirm that there are no known potential conflicts of interest associated with this publication.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jad.2025.01.058.

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