Attentional bias for emotional faces in depressed and non-depressed individuals: an eye-tracking study

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Abstract— **Current assessment tools for clinicians in mental health evaluation relies mostly on patient self-report and clinician's judgement. Recent studies suggest that affective disorders are correlated to attentional bias for visual information. This study used eye-tracking technology to measure attentional bias for faces in depressed and non-depressed individuals. The experiment was based on a free-viewing task of pair of faces including 4 types of expressions: neutral, sad, happy and angry. 69 individuals took part in this study. All the participants completed the Beck Depression Inventory II (BDI-II) to evaluate the severity of depressive symptoms. The attention indexes were total time for eye events, total fixation duration, ratio of total fixation and eye events, and fixation duration on each face. The results showed that depressed individuals have a significant (p = 0.005) difference in the total time of eye events (302.4±41.2) compared to non-depressed individuals (331.5±39.3) and revealed a tendency to disengage from emotional stimuli with differences in the total fixation in pair of faces. The study demonstrated that the use of eye-tracking is a valuable tool to asses attentional bias and important technology that could be used to improve diagnosis technics.**

I. Introduction

Traditional mental health measurements are based on psychological questionnaires, self-report written tests, interviews and direct observation of behavior [1]. Despite advances in neuroimaging, knowledge about the physiology of mental disorders and understandings about human genomics, individual and environmental factors associated with mental illness, the clinical approach for psychodiagnosis remains unchanged, risking a range of subjective biases [2].

On the other hand, great efforts have been made to find more objective methods to provide precise data of psychopathologies. Emerging studies have shown a correlation between attentional bias and mental disorders [3][4][5]. The early studies of attentional bias used a variety of visual tasks and reaction time (RT) as a measure of attention [6]. Emotional Stroop task and dot-probe task are common research paradigm in the literature [7][8]. The emotional Stroop effect refers to findings that an individual is slower to name color in a word that has negative connotation compared to neutral [9]. And according to cognitive theories, attentional bias is associated with the development and maintenance of mental disorder [10].

Building upon these findings, studies have experimentally used eye tracker devices to track eye movements and fixations during visual browsing tasks [11]. Important studies that used eye-tracking, asked participants to freely observe images containing distinct emotional facial expressions [12], [13]. During these experiments, attentional bias was calculated by the differences between fixation times to different emotional expression faces. The study of Duque et al. [14] assumed that depressed individuals would display negative bias with bigger fixation times to sad facial expressions than neutral and happy faces. And in accordance with these studies, the severity of depression is linked to the acuteness of attentional biases to sad faces.

This evidence shows the use of eye-tracking to attentional bias experiments. An advantage in the use of eye-tracking is the continuous and real-time measure of attention, collected via eye movements and fixations. The systems collect eye data at rates between 60 and 2000 Hz [15]. Eye-tracking technology provides more precise data compared to RT and seems promising for a better understanding of psychopathologies [1].

There is growing evidence that depressive symptoms are related to eyes fixations preferences to emotional stimuli. But the orientation of the bias remains uncertain. Some research has shown attentional avoidance of sad stimuli in depressed individuals, and other findings indicated increased attention to negative stimuli [10].

The present study used the eye-tracking technology to measure attentional bias for faces in depressed and non-depressed individuals by the comparison between fixations durations for different facial expressions. The experiment was based on a free-viewing task. The preference for using facial expression (angry, sadness, happy and neutral) and visual tasks (free-viewing task) is because they contain more interpersonal information, similar to social context.

II. Methods

A. Participants

There were 69 participants, including depressed and non-depressed individuals from a city localized in the south of Brazil (Ponta Grossa, Paraná). This study was approved by the ethics and research committee through "Plataforma Brasil" under the protocol no. 62432616.3.0000.5547.

B. Eye Tracking device

The data was recorded using the RED 500 infrared eye tracking system (SMI) with a sampling frequency of 500 Hz. The eye tracker was equipped by tree software: BeGaze,

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iViewX and Experiment Center, that allowed for calculating gazes based on the corneal reflex and pupil position. The direction of gazes was measured with x and y coordinates. The system was composed of a DELL Notebook Precision M4800 and a DELL 22” monitor. Device’s accuracy was 0.4º of visual angle and latency <4ms. The head of the participants was localized at 60cm from the monitor and eye tracker device. Participants were instructed to maintain stables head position. In another study that used a head positioning stabilizer [1], participants reported discomfort. The experiment was performed in a silent room with neutralized light in order to reduce the external influence on the experiment.

C. Self-report measure of depressive symptoms

After signing written informed consent, participants completed the Beck Depression Inventory-II (BDI-II) [16]. BDI-II is a clinical assessment tool that contains 21 items. The items correspond to subgroups of depressive symptoms, rated on a 4-point Likert scale, ranging from 0 to 3. In each item, the participant selects one of the four phrases (0 to 3 points), corresponding to his “state” in the recent period to the application. The total score of BDI-II ranges from 0 to 63 and; the severity of depressive symptoms is classified as follows: 0-13 (minimal), 14-19 (mild), 20-28 (moderate), 29-63 (severe). After that, the calibration procedure of the eye tracking device started.

D. Procedure and Stimuli

After calibration, the experiment started with the participants sitting centrally in front of the eye tracker device. The instructions were to maintain the position of the head stable, observe the images freely and, when a number appeared, the participant had to say it aloud.

The experiment stimuli consisted of four types of screen views: a black screen, a black screen with a fixation cross in the center, a black screen with a 1-digit number (ranging from 1 to 9) in the same position of the fixation cross, and a screen with a pair faces (neutral and emotional) made by the same actor. Faces were selected from the Brazilian Facial Expressions Database [17]. Following previous procedures [12], [18], all the images were modified in order to have faces with no neck and no hair placed on a black background. Faces were outlined with an oval shape, left and right to the central point of the stimulus (Fig. 1).

Fig. 1. Example of a pair of faces used in the eye tracking screen views: the pair of faces consisted of neutral-sad, neutral-happy, neutral-angry, placed equally on the left and right side of the screen during the experiment.

Participants viewed sets of pictures giving a total of 72 trials. Trials began with a black screen for 500 ms, followed by the display of a white fixation cross in the central position of the screen for another 500 ms. Promptly after, the cross was replaced by a random white 1-digit number (1-9) for a duration of 1000 ms. Participants were instructed before, to verbalize this number. This instruction was to ensure that the central fixation was being performed [12], [14]. Afterward, a pair of faces (like Fig. 1) was displayed on the screen for 3500 ms. Fig. 2 give a representation of a trial sequence of screen views.

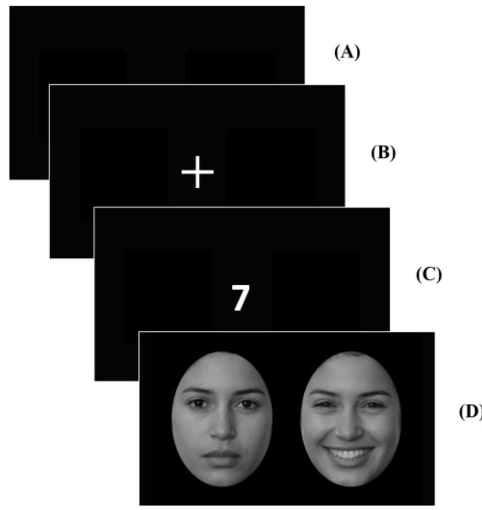

Fig. 2. Representation of screen views in a trial sequence. (A) a black screen for 500 ms. (B) a white cross for 500 ms. (C) a 1-digit number for 1000 ms. (D) pair of faces for 3500 ms. After that, a new trial started.

E. Attentional indexes

To estimate indices of attentional bias during the presentation of a pair of faces, which lasted 3500 ms (each), and throughout the experiment, we used fixation data recorded with the eye tracker. This variable was extracted and analyzed by the total fixation duration on each type of facial expression in each screen view of pair of faces. Fixation was considered as periods above 100 ms where the eyes gaze direction remained on a single location with a standard deviation of less than 0.5º of visual angle [19].

The total time of eye events (fixations, saccades, blinks) for all 72 trials from each participant was summed up to evaluate statistical equanimity for eye events and to characterize variations in the collected data. After that, fixations durations during the screen views of pair of faces (neutral and emotional) was summed up to establish percentage values of proportional duration for each participant. Then, fixations durations on each face for all the screen views of pair of faces for each participant was summed up and considered as the total fixation duration for pair of faces. These values were converted to bias measure based on percentage. Values above 50% correspond to a bias for the emotional face (sad, angry or happy) and values lower than 50% corresponded to a bias for the neutral face. These indexes were based on previous research [16][18][24].

F. Data Preparation

To examine the fixations and gaze directions, two areas of interest (AOI) were drawn around each location where the oval forms in which the faces were inserted. Fixations inside the AOI were classified as emotional or neutral. Fixations outside the AOI were considered as null fixation events.

For statistical analysis, the sample was characterized using position (median) and dispersion measurements (interquartile range) measurements. Shapiro-Wilk test was used to verify the normality of data. Differences between groups were calculated by the application of two independent samples t-test. Statistical Package for the Social Sciences (SPSS), version 17.0 (SPSS Inc. Chicago, IL) was used in all procedures. The p-value above 0.05 ($p<0.05$) was adopted as statistical significance.

III. Results

In total, 69 individuals were enrolled in the study. As shown in Table 1, participants in the study group reported significantly greater symptoms of depression (p = 0.000) than those in the control group. BDI-II scores in the study group were 33.3±12.3 (severe-moderate) and in the control group were 13.3±9.3 (minimal-mild). Eye events also have a difference between the two groups. Control group presented more eye events duration than study group.

TABLE I. DESCRIPTIVE ANALYSIS FOR AGE, BDI-II SCORE AND EYE EVENTS IN CONTROL AND STUDY GROUP

	Control	Study	p
N	44	25	
Age (years)	27.3±8.7	29.4±11.0	0.383
BDI-II (score)	13.3±9.3	33.3±12.3	0.000
Total Test (s)	331.5±39.3	302.4±41.2	0.005
Fixation faces events (s)	157.0±44.2	130.1±54.3	0.029

[a] Total test in this table means the total time of eye events collected by the eye tracker device. Fixation faces events were the sum of fixations on facial expressions for all the participants

Comparison between control and study group fixations for emotional faces ratio is demonstrated in Fig 4. The study group has demonstrated lower values of fixations in facial expression than the control group. Control group spent significantly more time looking to happy faces compared to the study group.

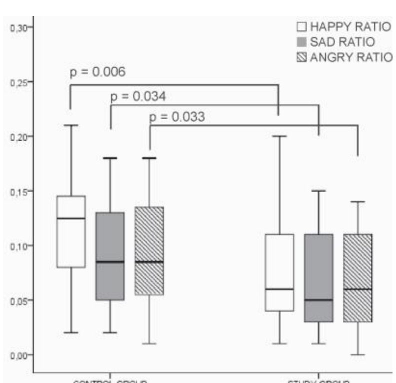

Fig. 3. Comparison between control and study group in emotional faces ratio (happy/total faces events, sad/total faces events and angry/total faces events).

In order to clarify these differences of fixation durations for faces between control and study group, an evaluation of the ratio related to emotional and neutral faces and the ratio related to null events (gaze directions outside of the AOI) and saccades was made (Table 2).

TABLE II. RATIO RELATED TO EMOTIONAL AND NEUTRAL FACES; NULL EVENTS AND SACCADES

	Control	Study	p
N	44	25	
Emotion Fixation/Total Faces	0.28±0.13	0.20±0.14	0.014
Neutral Fixation/Total Faces	0.25±0.11	0.18±0.12	0.013
Null / Total Faces	0.15±0.13	0.20±0.16	0.111
Saccades / Total Faces	0.28±0.15	0.36±0.20	0.083

Control group spent approximately 8% more time with fixations to emotional stimuli than the study group and approximately 7% to neutral facial expression more than the study group. And when compared the null events and saccades, study group showed a tendency to have bigger time results, but with no statistical significance. Study group presented bigger duration times for null events, saccades, and no significative difference between the spent time for different emotional expressions.

IV. Discussion

The current study purposed to explore attentional bias for emotional facial stimuli in depressed and non-depressed individuals using an eye tracker device. It was possible by using fixation duration and gaze direction during the experiment, assumed as bias. This is the first experiment that used eye-tracking technology to evaluate attentional bias for faces using a Brazilian database. Our research also included the evaluation of all eye events total time to verify how the eye tracker device collect data in this type of experiment. This enabled us to split our analyzes of precise data on the uptake of eye events.

The main differences observed in our experiment between the two groups of participants collected data, were that healthy group presented fixation duration time to happy faces higher than depressed group; and that the depressed group spent less time fixating in the AOI areas, and less fixation and eye events duration times compared to control group.

These findings could be related to the hypothesis that depressed individuals have facilities on disengagement from obsolete or unknown cognitive tasks [21]. Most related works presented results that indicate that individuals with severe depressive symptoms have a negative attentional bias. But in affective disorders, disengagement of a stimulus, that can acquire aversive properties, should be expected. The study of Elzen and MacLeod [22] showed predictions derived from the hypothesis that depression may adaptatively facilitate disengagement from unattainable goals. And in the moment of the application of the experiment, anxious factors like the duration of the experiment, the presence of one experimenter and the room design could influence the participant's behavior.

One advantage of eye tracking in this research is that it is a non-invasive method to collect gaze positions and a precise method to measure attention. And the short duration of the experiment and the environment with neutral characteristics provided an experimental design to avoid external influence on the participant's mood. Our study provided another factor's analysis contribution: the total time of eye events that occurred and collected by the eye tracker. Few works show these indices, focusing only on bias scores and failing to present the ratio between exposure times and eye events captured. With our analysis, it was possible to asses that the total time of the experiment is different from the total time of events captured by the device. Total time of the experiment was the sum of all the trials duration: black screen (500 ms), centered cross (500 ms), 1-digit number (1000 ms) and pair of faces (3500 ms). So, one trial duration was 5500 ms, and the total time of the experiment was 5500 ms x 72 trials, totaling 396000 ms. But the total time of events captured by the eye tracker device was different, as shown in the third line of Table I.

Our study has some limitations. It is important to know better about frames in collecting data, that could be related to the differences between total time of the experiment and the total time of eye events captured data. The current findings demonstrate that it is important to have a larger sample size and analyze factors that could influence the participant's mood at the moment of the application of the experiment. Another important factor is the possibility to design an experiment with a shorter duration, but with the same effectiveness of this. For future studies, more attentional indexes could be included in the data analysis; first fixation point, pupil dilatation during faces and patterns of fixation during the experiment.

Results presented differences in attentional bias for faces between control and study group. It confirmed the premise that depressive symptoms are related to attentional bias for emotional stimuli. This is a significant step in the analysis of attentional components in mental health evaluation, because depressive symptoms are present in most mental disorders and are predictive from Major Depressive Disorder [1].

V. CONCLUSION

This study used an eye tracker device to evaluate attentional bias for faces. The results showed that depressive symptoms affect how individuals spend attention on different stimuli. Depressed individuals showed lower values of eyes events total sum (302.4±41.2) than non-depressed (331.5±39.3), and a tendency to disengage from emotional stimuli with a difference of 8% of the fixation durations. Findings of this study promise to increase the understanding of attentional bias in correlation with mental disorders and psychopathologies. Eye tracker enables many ways to study and design one experiment to collect data and to provide the correct stimulation related to it.

The use of eye tracker and the use of free viewing task and other kinds of tasks, with emotional stimuli, are valuable tools to access attentional biases. This technology is a great opportunity to improve psychodiagnosis technics and clinicians work. In addition, improve knowledge about human behavior and the patient's treatment.

REFERENCES

[1] G. R. Figueiredo, D. Campos, W. L. Ripka, and L. Ulbricht, "Attentional bias for faces in relation to severity of depressive symptoms : an Eye-Tracking study," *XXVI Brazilian Congr. Biomed. Eng.*, vol. 1, pp. 1–10, 2018.

[2] R. D. Gibbons, D. J. Weiss, E. Frank, and D. Kupfer, "Computerized Adaptive Diagnosis and Testing of Mental Health Disorders," *Annu. Rev. Clin. Psychol.*, vol. 12, no. 1, pp. 83–104, 2016.

[3] I. S. Penton-Voak, M. R. Munafò, and C. Y. Looi, "Biased Facial-Emotion Perception in Mental Health Disorders: A Possible Target for Psychological Intervention?," *Curr. Dir. Psychol. Sci.*, vol. 26, no. 3, pp. 294–301, 2017.

[4] C. M. Sylvester, J. J. Hudziak, M. S. Gaffrey, D. M. Barch, and J. L. Luby, "Stimulus-Driven Attention, Threat Bias, and Sad Bias in Youth with a History of an Anxiety Disorder or Depression," *J. Abnorm. Child Psychol.*, vol. 44, no. 2, pp. 219–231, 2016.

[5] X. Li, T. Cao, S. Sun, B. Hu, and M. Ratcliffe, "Classification study on eye movement data: Towards a new approach in depression detection," *2016 IEEE Congr. Evol. Comput. CEC 2016*, pp. 1227–1232, 2016.

[6] M. I. Posner, "Orienting of attention: Then and now.," *Q. J. Exp. Psychol. (Hove).*, no. August, pp. 1–12, 2014.

[7] V. Günther, U. Dannlowski, A. Kersting, and T. Suslow, "Associations between childhood maltreatment and emotion processing biases in major depression: Results from a dot-probe task," *BMC Psychiatry*, vol. 15, no. 1, pp. 1–9, 2015.

[8] E. Pool, T. Brosch, S. Delplanque, and D. Sander, "Attentional Bias for Positive Emotional Stimuli : A Meta-Analytic Investigation Attentional Bias for Positive Emotional Stimuli : A Meta-Analytic Investigation," *Psychol. Bull.*, vol. 142, no. SEPTEMBER, pp. 79–106, 2015.

[9] S. J. Bujarski, E. Mischel, C. Dutton, J. S. Steele, and J. Cisler, *The Elicitation and Assessment of Emotional Responding*. Elsevier Inc., 2015.

[10] K. J. Hsu *et al.*, "Attentional bias modification treatment for depression: Study protocol for a randomized controlled trial," *Contemp. Clin. Trials*, vol. 75, no. June, pp. 59–66, 2018.

[11] A. J. Harrison and B. E. Gibb, "Attentional Biases in Currently Depressed Children: An Eye-Tracking Study of Biases in Sustained Attention to Emotional Stimuli," *J. Clin. Child Adolesc. Psychol.*, vol. 44, no. 6, pp. 1008–1014, 2015.

[12] A. Sanchez and C. Vazquez, "Looking at the eyes of happiness: Positive emotions mediate the influence of life satisfaction on attention to happy faces," *J. Posit. Psychol.*, vol. 9, no. 5, pp. 435–448, 2014.

[13] M. E. Kret, K. Roelofs, J. J. Stekelenburg, and B. de Gelder, "Emotional signals from faces, bodies and scenes influence observers' face expressions, fixations and pupil-size," *Front. Hum. Neurosci.*, vol. 7, 2013.

[14] A. Duque and C. Vázquez, "Double attention bias for positive and negative emotional faces in clinical depression: Evidence from an eye-tracking study," *J. Behav. Ther. Exp. Psychiatry*, vol. 46, pp. 107–114, 2015.

[15] T. Armstrong and B. O. Olatunji, "Eye tracking of attention in the affective disorders: A meta-analytic review and synthesis," *Clin. Psychol. Rev.*, vol. 32, no. 8, pp. 704–723, 2012.

[16] A. T. Beck, R. A. Steer, and G. K. Brown, "BDI-II. Beck Depression Inventory Second Edition. Manual.," *Psychol. Corp. Bower*, 1996.

[17] M. R. Rodrigues, "'Composição de um banco de expressões faciai brasileiro: um estudo de validação e comparação transcultural,'" Universidade Federal da Paraíba, 2015.

[18] A. Sanchez, C. Vazquez, D. Gomez, and J. Joormann, "Gaze-fixation to happy faces predicts mood repair after a negative mood induction," *Emotion*, vol. 14, no. 1, pp. 85–94, 2014.

[19] K. R. Marks, W. Roberts, W. W. Stoops, E. Pike, M. T. Fillmore, and C. R. Rush, "Fixation time is a sensitive measure of cocaine cue attentional bias," *Addiction*, vol. 109, no. 9, pp. 1501–1508, 2014.

[20] S. Lu *et al.*, "Attentional bias scores in patients with depression and effects of age: a controlled, eye-tracking study," *J. Int. Med. Res.*, vol. 45, no. 5, pp. 1518–1527, 2017.

[21] K. Koppe and K. Rothermund, "Let it go: Depression facilitates disengagement from unattainable goals," *J. Behav. Ther. Exp. Psychiatry*, vol. 54, pp. 278–284, 2017.

[22] J. van den Elzen and C. MacLeod, "Facilitated Cognitive Disengagement in Depression," *Behav. Ther.*, vol. 37, no. 3, pp. 304–313, 2006.