Attentional bias to negative emotions in anxious individuals: an eye tracking study

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ABSTRACT

(1) Background: While anxiety disorders are becoming more prevalent in our society, anxiety diagnosis still traditionally requires filling out assessments or requires professional consultation and evaluation, but now we could perform a simple and quick screening using electronic equipment based on distinct indicators of anxious individuals. It is known that individuals suffering from anxiety disorders and anxious states exhibit attentional biases, particularly when viewing emotional faces, a tendency to perceive negative expressions first, and prolonged gaze durations. Hence, this article would examine the gaze characteristics of anxious people toward various negative faces in detail and would develop preliminary indicators for quick screening. (2) Method: A hospital sample of 28 anxious patients and a community sample of 23 healthy individuals were shown pairs of happy-negative and neutral-negative faces. Negative emotions include five emotions: anger, disgust, fear, sadness, and surprise. Using eye tracker to collect data in free viewing task. Multi-factor ANOVA (Analysis of Variance) test and multiple pairwise comparison Tukey's HSD test were used to examine attention bias of anxious individuals toward negative emotions. (3) Results: anxious group would tend to pay more attention on figures with negative emotions compared with neutral and positive emotions, on the contrary healthy group would take longer time on neutral and positive ones. Meanwhile this bias effect between anxious and healthy group exhibits more evidently in the case when fear and positive emotion figures appearing in pair. (4) Conclusions: This study confirms the significant differences in attentional bias for negative facial emotions between anxious and healthy individuals and provides more clear and specific characteristics for both populations' attentional features, offering indicators for future development in the eHealthcare industry.

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CCS CONCEPTS

• **Applied computing** → Life and medical sciences; Health care information systems.

KEYWORDS

anxiety, eye tracking, attentional bias, eHealthcare

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1 INTRODUCTION

Anxiety disorders have surpassed depression as the most widespread mental health illness, particularly in the COVID-19 epidemic, where prevalence has climbed to 33.59% and has increased by 88% in women [1]. When confronted with such a large anxious population, e-health and smart technologies would bolster medical resources. The first thing that could be done is to quickly target individuals who may be experiencing an anxiety state or disorder.

Traditionally, anxiety disorders have been diagnosed through the use of questionnaires, such as the well-known self-measurement scale, the Self-Rating Anxiety Scale (SAS [2]), and the State-Trait Anxiety Inventory (STAI [3]). The second most common method is to visit a hospital whereby, after a conversation with psychological professionals and another scale that is administered by the professionals, called the Hamilton Anxiety Scale [4], professionals could give a diagnosis based on the circumstances of their experience. Both are reliable, but they have a number of flaws, including the fact that they are time-consuming, easily concealed, and rely heavily on specialists.

First, the scale contains multiple questions, and completing dozens or hundreds of them is time consuming and inefficient.

Second, when evaluating using scales, the results are easily "False Positives" [5]. Because the majority of the answers on the scale are more skewed, and it is simple for the responder to achieve the desired outcome. Moreover, each individual may have a unique response style [6]. Certain people prefer the extreme options "highly" and "very," while others pride themselves on being rational and objective, opting for the middle option "neutral," which is prone to delivering inaccurate results. Thirdly, there is a high level of reliance on professionals. Screening a potential anxious individual would involve a psychologist or a professional counselor. This is because both the evaluation of the self-measurement scale and the conclusions drawn as a result of the assessment require the knowledge and experience of a professional psychologist. As a result, the role of professionals in identifying anxiety states and disorders has become critical.

Such conventional and labor-intensive methods should be able to be overtaken by technology in the age of e-health. Attentional bias refers to the tendency for attention to be driven by negative stimuli initially, as well as difficulty in disengaging from negative stimuli and attentional avoidance [7]. Healthy groups would unconsciously pay more attention to positive stimuli than negative stimuli when confronted with both positive and negative stimuli. By contrast, anxious individuals tend to focus only on negative stimuli, particularly those associated with threats [8]. Based on the significant and divergent attentional biases between the two groups, we may hypothesize an index and norm, and collect eye movement data using eye tracking to swiftly screen and evaluate whether an individual is more inclined toward the healthy or anxious group. After the first screening, a second validation and any necessary intervention could be performed continuously.

2 PARTICIPANTS AND METHODS

2.1 Participants

Anxiety group: anxious patients in the outpatient clinic of the Department of Psychology, Wafangdian Fourth Hospital, Dalian, China. Enrollment criteria: ① Comply with the diagnosis of anxiety disorder in the Chinese Classification of Mental Disorders, Third Edition (CCMD-3 [9]); ② Score $\geq$ 14 on the Hamilton Anxiety Scale (HAMA); ③ Score $\geq$ 50 on the Self-Rating Anxiety Scale (SAS). 28 participants were recruited, 12 male, 16 female; HAMA score (19.50±5.60); SAS score (68.00±9.99).

Healthy group: advertisements in public places were used to recruit participants. Pairings based on age and gender with the anxiety group. 23 individuals were enrolled, including 8 males and 15 females. Healthy group did not exhibit any anxiety symptoms as measured by the HAMA or SAS measures.

Written informed consent is signed by both groups of participants before being subjected to the study. The study is approved by the Ethics Committee of the Institute of Psychology, Chinese Academy of Sciences.

2.2 Methods

2.2.1 Equipment. Using a Tobii T120 eye tracker and its associated software, collecting all eye tracking data throughout the display of stimulation photographs. To operate and run the software, the eye tracker was attached to a Lenovo laptop.

2.2.2 Materials. 100 photographs were used. Each photograph contained 2 different emotions, either positive-negative or neutral-negative, 50 of each. Negative photos included 5 emotions: anger, disgust, fear, sadness, and surprise, 10 of each. Chinese Facial Affective Picture System (CFAPS [10]) was used for all facial photographs. Photographs were taken at a standard identity rate and at a standard intensity point. They are representative materials for emotion [11].

2.2.3 Experiment Procedure. Experiment was taken place in a quiet and comfortable room. One experimenter, operateed eye tracker, and gave instructions and explained. Facial emotion photographs were displayed on a monitor, participants were required to free view the screen, and no additional action needed. Facial emotion photographs were displayed on the monitor, as shown below in Figure 1, each photo was a pair of two faces. Negative (5 different negative emotions) paired with positive, and negative (5 different negative emotions) paired with neutral. Both emotions were presented randomly on the left and right sides. Each photo was shown for 5 seconds, and a black screen with a white cross in the center (functioning as a gaze point) was shown for 1 second prior to each face photo being shown. Participants were not required to make any decisions or actions while viewing the photos. Experiment took around ten minutes.

2.2.4 Experiment Design. (7 facial emotion types) X (2 group types) mixed two-factor design was used, the between groups factor was anxious group and healthy group, whereas the within groups factors were positive, neutral, anger, disgust, fear, sadness, and surprise facial emotions. The dependent variable was Total Fixation Duration (TFD), Fixation Count (FC), and Time to First Fixation (TFF).

2.2.5 Statistical Indicator. Using Tobii software to draw areas of interest (AOI), categorized according to emotions. Each displayed image is a set of two facial emotions, as shown in Figure 2, which are either negative-positive, or negative-neutral. AOI is labelled by emotions' initial, which are positive as P, neutral as N, anger as A, disgust as D, fear as F, sadness as SA, and surprise as SU. And for detailed research purpose, the pair-up emotion is listed after. For example, there are 50 positive-negative photos, with 10 positive-anger, 10 positive-disgust, 10 positive-fear, 10 positive-sadness, and 10 positive-surprise. AOI of the positive face pairing with anger is labelled as P_A, to identify which exact group of positive faces. All of the AOI labels in this paper follow this rule, the number of each AOI labels used in following test is shown below in Table 1.

According to exist study [12], confirmed total fixation duration (TFD), fixation count (FC), and time to first fixation (TFF) as statistical indicators of this paper. TFD is the duration of all fixations within an AOI in second. FC is the number of times the participant fixates on an AOI. TFF is the time from the start of the stimulus display until the test participant fixates on the AOI for the first time in second.

2.2.6 Statistical Analysis. First of all, before conducting statistical analysis, the whole procedure started with data cleaning and preprocessing, by removing and switching null data and reshaping the data matrix into an appropriate formation for coding. Then divide the raw data into different frame by filtering with different statistical indicator that used afterwards. Use multi-factor ANOVA (Analysis

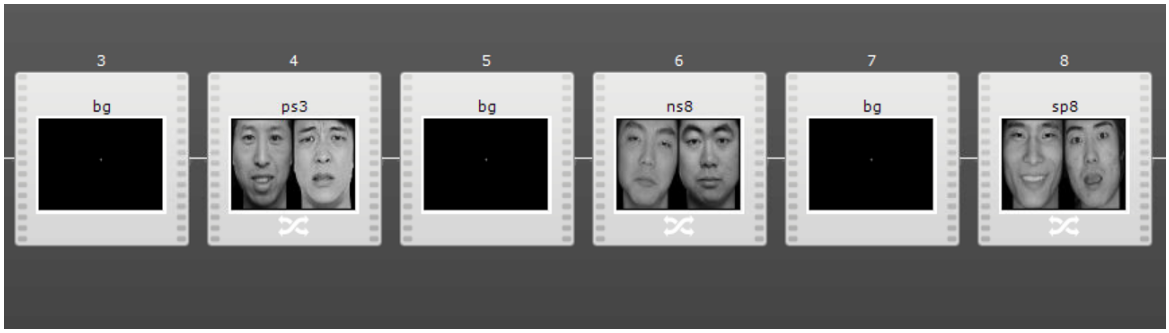

Figure 1: Trail sequence of the free viewing task.

Table 1: Facial emotion type number

A_N	D_N	F_N	SA_N	SU_N	A_P	D_P	F_P	SA_P	SU_P	N_A	N_D	N_F	N_SA	N_SU	P_A	P_D	P_F	P_SA	P_SU
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

Figure 2: Example of AOI, green part as angry, blue part as neutral.

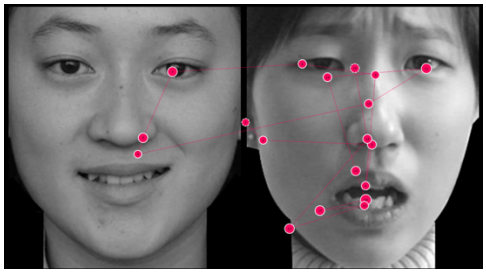

Figure 3: Eye track of an anxious participant on a positive-fear photo

of Variance) test to examine the main effect of facial emotion type and group type, and conduct multiple pairwise comparison test by using Tukey's HSD to test interaction effect within facial emotion and group type. All the data analysis and coding done in Python within VSCode.

3 RESULTS

The Figure 3 and Figure 4 shown below is an example of eye track of participants from anxious group and healthy group.

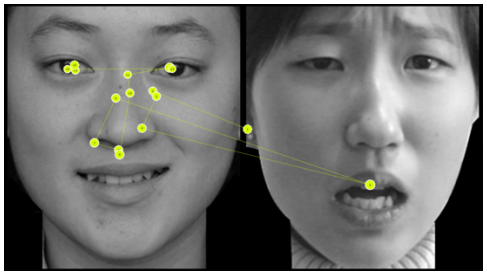

Figure 4: Eye track of a healthy participant on a positive-fear photo

The multi-factor ANOVA (Analysis of Variance) test shows that, in the aspect of Total Fixation Duration (TFD), the main effect of facial emotion type is statistically significant, F=2.60, MSE=34.91, P<0.05, η^2=0.41 and the main effect of group type is also statistically significant, F=34.41, MSE=462.1, P<0.05, η^2=0.28. In addition, based on the result of multiple pairwise comparison test by using Tukey's HSD method, the interaction effect between facial emotion type and group type is statistically significant, F=2.01, MSE=26.94, P<0.05, η^2=0.31. As shown in Table 5, the different interactive combinations which are statistically significant (P<0.05) are listed, where 3,6,13,18 represents facial emotion of F_N, A_P, N_F, and P_F respectively (see Table 1). The test result strongly supports that, the participants in anxious group have longer time of eye fixation at fear and anger figures, which companied with neutral and positive emotion figures beside. And participants in healthy group have longer time of eye fixation at neutral and positive emotion figures, which companied with also fear figures.

In the aspect of Fixation Count (FC), the ANOVA test shows that the main effect of facial emotion type is statistically significant, F=2.97, MSE=787.21, P<0.05, η^2=0.41, and the main effect of group type is statistically significant as well, F=44.30, MSE=11750.86,

Table 2: Total Fixation Duration (TFD)

Facial Emotion Type	Anxious Mean	Anxious SD	Healthy Mean	Healthy SD
A_N	6.02	2.40	6.07	2.79
A_P	5.39	4.33	5.82	5.00
D_N	5.70	2.87	5.81	2.86
D_P	5.94	2.77	5.41	2.72
F_N	5.52	2.84	5.37	2.82
F_P	5.82	4.63	5.43	4.29
N_A	6.24	2.83	7.39	3.61
N_D	6.00	3.28	8.00	3.47
N_F	5.84	2.79	8.26	4.11
N_SA	6.44	2.66	7.59	3.58
N_SU	6.00	2.52	6.99	3.09
P_A	5.91	4.72	7.86	6.61
P_D	5.73	2.40	8.11	3.82
P_F	6.36	4.98	8.21	6.21
P_SA	6.20	3.09	8.02	3.94
P_SU	6.06	2.85	7.87	3.77
SA_N	5.99	2.31	5.73	2.69
SA_P	6.07	3.18	5.37	2.84
SU_N	6.08	2.96	6.25	2.72
SU_P	5.88	2.80	5.81	3.12

Table 3: Fixation Count (FC)

Facial Emotion Type	Anxious Mean	Anxious SD	Healthy Mean	Healthy SD
A_N	32.62	9.17	32.67	12.10
A_P	29.32	21.70	31.11	22.83
D_N	30.26	11.73	31.29	13.09
D_P	31.36	9.80	29.73	11.70
F_N	29.38	11.54	30.22	12.85
F_P	31.26	22.85	28.44	21.40
N_A	32.98	11.20	37.76	13.02
N_D	32.45	12.38	40.60	15.16
N_F	30.45	11.99	41.20	14.70
N_SA	33.60	9.94	40.67	13.65
N_SU	31.72	10.28	36.44	11.26
P_A	31.92	23.35	39.60	29.38
P_D	32.11	11.41	42.11	13.76
P_F	34.55	24.12	43.09	29.72
P_SA	32.77	14.68	42.44	15.99
P_SU	31.25	11.87	41.56	14.43
SA_N	32.57	9.37	31.04	10.91
SA_P	31.72	13.78	29.78	13.88
SU_N	32.02	11.26	34.64	11.60
SU_P	30.51	12.62	32.00	13.67

P<0.05, η^2=0.32. Furthermore, the interaction effect between facial emotion and group type is also statistically significant, F=1.95, MSE=518.56, P<0.05, η^2=0.27. As shown in Table 6 are all the interactive combinations which P<0.05, the result reflects that the participants in anxious group have more eye fixation point at negative emotional face, such as anger, fear, and disgust (see Table 1), which companied with neutral and positive figures beside. And participants in healthy group have much more eye fixation point in positive figures, which companied with fear figures.

In the aspect of Time to First Fixation (TFF), the ANOVA test shows that the main effect of facial emotion type is not statistically

Table 4: Time to First Fixation (TFF)

Facial Emotion Type	Anxious Mean	Anxious SD	Healthy Mean	Healthy SD
A_N	0.59	0.80	0.70	0.66
A_P	0.90	2.20	0.65	1.59
D_N	0.74	0.80	0.63	0.83
D_P	0.69	0.86	0.57	1.05
F_N	0.91	2.02	0.54	0.69
F_P	0.85	1.16	0.65	1.06
N_A	0.92	1.13	0.47	0.56
N_D	0.94	1.45	1.00	1.05
N_F	1.13	1.54	0.95	1.08
N_SA	1.01	1.77	0.93	1.44
N_SU	0.83	1.46	0.62	0.92
P_A	0.98	2.28	1.03	1.50
P_D	1.66	2.46	0.91	0.72
P_F	0.98	1.72	0.72	0.67
P_SA	0.67	0.84	0.62	0.77
P_SU	0.61	0.91	0.85	0.86
SA_N	0.91	1.57	0.84	1.15
SA_P	0.81	1.45	1.17	2.00
SU_N	0.94	2.25	1.06	1.92
SU_P	1.00	1.51	0.50	0.91

Table 5: Interaction Effect in TFD

Anxious Group	Healthy Group	MeanDiff	Lower	Upper	p-value
(6, Anxious)	(13, Healthy)	2.990039	0.150539	5.829539	0.023613
(6, Anxious)	(18, Healthy)	2.961778	0.122278	5.801278	0.027339
(3, Anxious)	(13, Healthy)	2.873253	0.033753	5.712753	0.042669
(3, Anxious)	(18, Healthy)	2.844992	0.005492	5.684492	0.048751

Table 6: Interaction Effect in FC

Anxious Group	Healthy Group	MeanDiff	Lower	Upper	p-value
(6, Anxious)	(20, Healthy)	12.652174	0.033428	25.270920	0.048299
(6, Anxious)	(17, Healthy)	13.434783	0.816037	26.053528	0.019872
(6, Anxious)	(19, Healthy)	13.804348	1.185602	26.423093	0.012651
(6, Anxious)	(18, Healthy)	14.586957	1.968211	27.205702	0.004580
(3, Anxious)	(17, Healthy)	13.399068	0.780323	26.017814	0.020732
(3, Anxious)	(19, Healthy)	13.768634	1.149888	26.387379	0.013226
(3, Anxious)	(18, Healthy)	14.551242	1.932497	27.169988	0.004805
(2, Anxious)	(19, Healthy)	12.947205	0.328459	25.565951	0.035014
(2, Anxious)	(18, Healthy)	13.729814	1.111068	26.348559	0.013884
(10, Anxious)	(19, Healthy)	12.750776	0.132031	25.369522	0.043504
(10, Anxious)	(18, Healthy)	13.533385	0.914639	26.152131	0.017659
(13, Anxious)	(18, Healthy)	13.372671	0.753925	25.991416	0.021388
(8, Anxious)	(18, Healthy)	12.926242	0.307497	25.544988	0.035852

significant enough, however the main effect of group type is statistically significant, F=9.57, MSE=38.48, P<0.05, η^2=0.20, meanwhile the interaction effect is not statistically significant.

4 CONCLUSION

Applying eye tracker in eHealth industry was never new. Scientists have started to combine this equipment to assist understanding

metal illness for years [13]. The paper aims to develop an eye-movement indicator that can quickly and efficiently screening for anxiety states based on attentional bias features. It is predicated on the assumption that individuals experiencing anxiety states or anxiety disorders have an attentional bias toward negative emotions. Researchers found that anxiety patients have an attentional bias toward threatening feelings, but few have defined what constitutes "threatening emotions" [14]. Thus, additional experiment of attentional bias is necessary to pinpoint the bias's characteristics and to provide a more precise description and sharper markers.

Studying attentional bias more accurately could help transforming academic results to eHealthcare industry. With such a big anxious population, almost one in every three individuals is a potential population, and a quick and cost-effective screening method is critical for medical industry.

It is applicable in a variety of settings, including hospitals. For patients, a short eye movement screening can be performed to provide a reference report to the doctor prior to the standard measurement scale and doctor interview. Schools would also be good locations to put it; students face academic pressure. Meanwhile, the release of developing hormones tends to cause physical maladjustment, it is not an easy period for them, anxiety prevalence among children and adolescents is 6.5% [15], so maintaining a frequent and screening is essential. Special positions within the enterprise, such as portfolio managers in financial institutions, require the existence of quick screening by eye movement indicators in order to function in a very short period of time in the financial markets under pressure from massive amounts of money. Excessive anxiety may affect his performance at work, and if the state is found to be unfavorable, he can pause and conduct a short intervention before continuing.

A critical point that the unique advantage of using eye movement to screen for anxiety is that it is non-verbal and hence accessible to a wider group of people. The eye movement screening procedure does not require the use of words. Unlike the questions on the scale, the measurement cannot be performed effectively if the individual is illiterate. Second, whereas language varies by region and culture, eye movement screening can be conducted across cultures and even nations due to the physiological indications used.

To summarize, different mood disorders show different attentional biases, and a better understanding of these biases will allow us to assist a greater number of people. This would allow medical treatment to be more adaptable, since more accurate physiological signs and more efficient measures can be recognized using technology. Numerous experiments and research have examined the causal link between attentional bias and anxious states [16]. According to some, attentional bias is a result of anxiety states, while others believe it is the result of a generalized bias toward negative stimuli, which results in anxiety states. Regardless of the source, this provides inspiration for eHealth in that we may be able to intervene afterwards using eye-tracking equipment to enhance and reduce anxiety through the use of positive stimulus pictures.

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