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A naturalistic visual scanning approach to assess selective attention in major depressive disorder

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Abstract

Cognitive biases in information processing play an important role in the etiology and maintenance of emotional disorders. A new methodology to measure attentional biases is presented; this approach encourages subjects to scan and re-scan images with different thematic content, while the pattern of their attentional deployment is continuously monitored by an eye-tracking system. Measures of attentional bias are the total fixation time and the average glance duration on images belonging to a particular theme. Results showed that subjects with depressive disorder ($n=8$; Beck Depression Inventory Score $\geqslant 16$) spent significantly more time looking at images with dysphoric themes than subjects in the control group ($n=9$). Correlation analysis revealed that the differences between the fixation times of the two groups are significantly correlated with the valence ratings, but not with the arousal ratings of the images. The average glance duration on images with social, neutral and threatening themes were similar for both groups, while the average glance duration on images with dysphoric themes was significantly larger for subjects with depressive disorder. The above results suggest that subjects with depressive disorder selectively attend to mood-congruent material and that depression appears to influence the elaborative stages of processing when dysphoric images are viewed.

Keywords: Cognitive biases; Eye tracking; Eye movements; Major depression; Pathophysiology; Cognition

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1. Introduction

Understanding the vulnerability factors that promote mood disorders over the life span is a high priority for psychiatric research. One area of growing interest is the relationship between selective attention and mood-related psychopathology (Mogg and Bradley, 1998; McNally, 1998). With selective attention, some stimuli are given priority and amplified, while others are inhibited (Posner and Dehaene, 1994; Hillyard et al., 1999). Selective attention to negatively valenced information supports and sustains the maladaptive patterns of information processing that are characteristic of depressive states (Dalgleish and Watts, 1990; Mogg and Bradley, 1998). Further, recent evidence suggests that attentional biases causally alter emotional reactivity to stress (MacLeod et al., 2002). In this way, individual differences in selective attention may constitute an important vulnerability factor for depressed individuals.

Attentional biases in clinical populations have been observed primarily in cognitive reaction-time tasks (such as modified Stroop and probe-detection tasks) that measure selective attention indirectly. The modified Stroop task requires participants to name the ink colors of emotionally toned and neutral words. An increase in the response latency to the emotional words relative to neutral words is thought to indicate greater attentional allocation to the emotional content of the word (MacLeod, 1991). The probe-detection task presents pairs of emotionally toned and neutral words for a brief period of time. Participants are asked to respond as quickly as possible to a dot probe that appears in one of the two locations that the words formerly occupied. Shorter response latencies indicate that the dot probe appears in the attended region of the visual field (Posner et al., 1980). A modified visual dot probe task that features pictures instead of words has been used in several studies of attentional bias in anxiety (Mansell et al., 1999; Bradley et al., 2000; Mogg et al., 2000). In the modified test, following a brief (500 ms) presentation of a pair of pictures, a probe is presented for approximately 1 s in the location that one of the pictures formerly occupied. Participants are asked to press one of two response buttons as quickly as possible to indicate where the probe appears. Reaction times for correct responses are used as a measure of attentional bias. Bradley et al. (2000) further modified the visual dot probe test by using the initial direction of eye movements to emotional faces to determine attentional bias in anxiety.

Using the response latency tasks, however, it is difficult to distinguish attentional effects from other non-attentional factors such as deficits in motor response and response selection, both of which are common in depressed individuals. In addition, the dot probe task does not provide complete information about the pattern of attentional deployment before or after the moment of measurement. It only provides a snapshot of the state of affairs some 500 ms after the onset of the word or image pair. To rectify this problem, Hermans et al. (1999) suggested a new paradigm in which eye movements provide a continuous index of attentional deployment. In this paradigm, the proportion of viewing time spent on pictures relating to the emotional concerns of the experimental group is used as a measure of attentional bias.

Using the methods described above, attentional biases for threatening information have been found in various clinical anxiety disorders (MacLeod, 1986; Mogg et al., 2000). In contrast, evidence of attentional biases for negatively valenced information in depressive disorders is inconclusive. Mathews et al. (1996) and Mogg et al. (1995) found supportive evidence for attentional biases in subjects with clinical depressive disorders, while McCabe and Gotlib (1995) and Bradley et al. (1995) did not find such biases. This inconsistency may be partially due to limitations in the experimental techniques used to measure selective attention.

The current study set out to *directly* examine visual selective attention in normal and depressed subjects using an eye-tracking technology specifically adapted to allow continuous monitoring of the point-of-gaze. The paradigm suggested by Hermans et al. (1999) is extended by displaying multiple (more than two) complex visual stimuli that compete for the subject's attention. In addition, the visual stimuli are presented for a relatively long period of time, so that the participant has the

Table 1
Clinical characteristics of subjects with major depression

Subject	Sex	Age	Secondary diagnoses	Current medication	BDI	BAI
1	F	45	Social phobia	n/a	32	16
2	F	23	Dysthymia, panic with agoraphobia, social phobia	Zoloft (100 mg)	43	39
3	F	49	n/a	n/a	24	18
4	F	28	Dysthymia	n/a	38	25
5	F	26	Dysthymia, social phobia	n/a	22	15
6	M	40	n/a	n/a	26	27
7	F	42	Social phobia, OCD	Citalopram (20 mg)	21	9
8	M	42	Panic with agoraphobia, GAD	Clonazepam (3 mg)	26	10

n/a, Not applicable; OCD, obsessive-compulsive disorder; GAD, generalized anxiety disorder.

opportunity to scan and re-scan the different images. By monitoring both fixation time and fixation frequency on each of the competing images, attentional bias can be characterized by the amount of time that each image is fixated on and by the subject's visual scanning pattern.

Point-of-gaze tracking technologies are ideally suited for measuring selective attention to complex visual stimuli, since under normal viewing conditions, eye movements are automatic in that individuals commonly look at stimuli that attract their attention (Jonides, 1981). Indeed, shifts in gaze position closely follow and are guided by shifts in attentional focus (Moray, 1993; Kowler, 1995). The primary hypothesis of this study was that relative to normal control subjects, individuals with major depressive disorder would selectively attend to visual images with dysphoric themes. The secondary hypothesis was that individuals with major depressive disorder would not be able to shift their attention away from dysphoric stimuli as readily as normal controls.

2. Methods

2.1. Subjects

All subjects were recruited through newspaper advertisements and information posters at the University of Toronto and the Center for Addiction and Mental Health (CAMH). All prospective participants underwent a brief screening interview to obtain a general psychiatric history and to identify likely cases of major depression. Individuals reporting current major depression and those with no lifetime psychiatric history were then administered the mood and anxiety disorder modules of the Structured Clinical Interview for DSM-IV-TR (SCID; First et al., 1998) by a trained research assistant. All study subjects later completed the Beck Depression Inventory (BDI; Beck et al., 1961) and the Beck Anxiety Inventory (BAI; Beck et al., 1988) on the day the visual tracking protocol was administered.

The depressed group for the current study consisted of individuals who met SCID criteria for current major depression and scored 16 or greater on the BDI, the recommended cutoff for depressed subjects (Kendall et al., 1987). The normal control group consisted of individuals who reported no psychiatric history and scored 5 or less on both the BDI and the BAI. Individuals with significant eye pathology, visual acuity problems or neurological disorders were excluded. Depressed individuals who were on medication were not excluded. All subjects were between the ages of 18 and 50. All participants provided informed consent approved by the CAMH human ethics committee.

There were six females and two males in the depressed group ($n = 8$) and seven females and two males in the control group ($n = 9$). The mean ages of the depressed and control groups were 36.9 ± 9.7 years and 27.0 ± 5.7 years, respectively, $t(15) = 2.60$, $P = 0.03$. The mean BDI scores (standard deviation in parentheses) were 29.0 (7.4) and 1.9 (1.7) for the depressed and control groups, respectively. The mean BAI scores were 19.9 (9.4) and 1.3 (0.7) for the depressed and control groups,

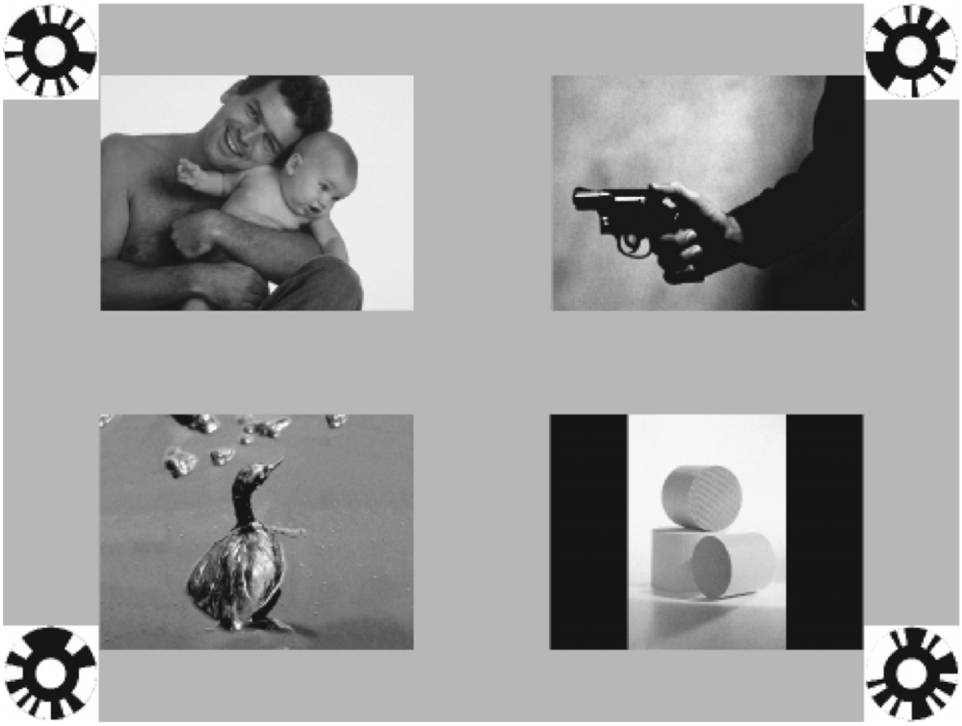

Fig. 1. Example of a study slide (top left: social theme; top right: threatening theme; bottom left: dysphoric theme; bottom right: neutral theme).

respectively. The clinical characteristics of each subject in the depressed group are presented in Table 1.

2.2. Visual stimuli

The visual stimuli consisted of a series of slides back-projected onto a screen, with each slide containing four images. The images on each slide fell into four main categories: neutral stimuli, stimuli related to themes of loss and sadness, stimuli related to themes of threat and anxiety, and stimuli relating to themes of interpersonal attachment and social contact. Henceforth, these categories are referred to as the neutral, dysphoric, threatening, and social themes, respectively. The images were chosen from the International Affective Picture System (IAPS), a standardized and validated set of images with affective ratings (Center for the Study of Emotion and Attention [CSEA-NIMH], 1999). The IAPS ranks the valence (feeling of pleasure vs. displeasure), arousal (feeling of excitement vs. calm), and dominance (feeling of control in the situation) of the images on a numerical scale based on tests conducted in normal populations (Lang et al., 1999). In the present study, the images were chosen based on the valence ratings as well as the thematic content. Neutral images were selected to have valences of approximately 5. Images relating to threatening and dysphoric themes generally had lower valences ranging from 2 to 4, while images relating to social themes generally had higher valences ranging from 6 to 8. Images on each slide were selected to have similar arousal levels with a maximum difference of less than 2 between the arousal ratings of the dysphoric, threatening, and social images.

A total of 15 slides, eight *study slides* and seven *neutral slides*, were shown to each subject. Each of the four images on a study slide was selected from each of the four themes previously listed (Fig. 1). The spatial position of an image pertaining to a particular theme was altered randomly between slides. The images on each neutral slide had closely matched valence and arousal ratings. The neutral slides served as practice and filler slides; the latter were included so that dysphoric images did not appear on every slide. The four reference targets that provide data for the estimation of the point-of-gaze (discussed in the next section) were integrated into each slide.

2.3. Point-of-gaze estimation methodology

For robust and accurate point-of-gaze determination, head-mounted eye-tracking systems are usually preferred, as they permit relatively free and natural head movements. In order to estimate point-of-gaze with head-mounted eye-tracking systems, the angular rotation of the eye relative to the head and the head position relative to the scene are required. The angular rotation of the eye relative to the head is obtained from the VISION 2000 (EL-MAR Inc., Toronto, Canada) portable eye-tracking system (Wetzel et al., 1996). The system consists of a small scene camera, an eye tracker assembly, and an electronic control and processing unit. The scene camera is mounted on a headband, and captures the field of view of the subject. The eye tracker assembly, which is mounted on the same headband, consists of three primary components: a small infrared (IR) video camera, two IR light-emitting diodes (LEDs), and a hot mirror that reflects IR light, but is transparent to visible light. IR light from the LEDs illuminates the eye, and images of the eye are reflected off the hot mirror to the IR camera. These images are processed at a rate of 120 Hz to obtain estimates of eye position with a resolution of $\pm 0.1°$, and a linear horizontal and vertical tracking range of $\pm 40°$ and $\pm 30°$, respectively. An eye position marker is electronically superimposed onto the video from the scene camera. Using images from the scene camera, the distinctive reference targets that are placed in the scene (shown in Fig. 1) are tracked and estimates of the head position relative to the scene are obtained. Using the head and eye position information, the point-of-gaze in the plane defined by the reference targets is calculated (Yu and Eizenman, in press). By defining the boundaries of each image on a slide relative to the reference targets (this is done on a single video frame from the scene camera), the boundaries of each image can be reconstructed in all subsequent video frames by computing the appropriate planar homography (Criminisi et al., 1999). Visual scanning parameters such as fixation time and fixation frequency are obtained by determining whether the point-of-gaze falls within these defined boundaries.

2.4. Procedure

On the day of administration of the visual scanning protocol, all subjects first completed the BDI and BAI rating scales. Subjects were then escorted to the testing room, fitted with the head-mounted eye tracking system, and seated 140 cm in front of a portable projection screen where visual stimuli were back-projected. The system was then calibrated by asking the subject to fixate sequentially on a predefined set of 10 calibration points projected onto the screen. After calibration, the 15 slides were shown sequentially for 10.5 s each and the subjects were instructed to view the slides. The display size of each slide was 102.0×76.5 cm^2, while the display size of each IAPS image within each slide was 33.0×24.8 cm^2, representing visual angles of 13.3° horizontally and 10.0° vertically. In order to allow the subjects to get accustomed to the procedure, the first three slides presented to each subject were not analyzed.

Automated fixation analysis algorithms were used to generate the following key dependent variables for each slide from the raw data gathered by the eye tracking system:

- Fixation time—the total time that each subject fixates on a particular image (in order to be included in the fixation time, each fixation interval must be greater than 200 ms in duration)
- Fixation frequency[1]—the number of times that

[1] The term *frequency* is used in the sense of absolute frequency, i.e. the number of occurrences in a specified time interval (10.5 s for a single slide).

each subject directs (and re-directs) attention to a particular image
- Glance duration—the average amount of time that each subject's gaze stays within the boundaries of a particular image (calculated by dividing fixation time by fixation frequency)

For each subject, fixation times and fixation frequencies on images with the same theme are summed up to generate the total fixation time and total fixation frequency for each theme. Glance durations on images with the same theme are averaged over the eight study slides to generate the average glance duration for each theme.

2.5. Statistical analysis

Total fixation time, total fixation frequency and average glance duration were analyzed in a 2 (Group: control, depressed)×4 (Theme: dysphoric, social, threatening, neutral) analysis of variance (ANOVA) with repeated measures for the four different themes. Following the primary hypothesis (i.e. longer fixation time on images with dysphoric themes for individuals with depressive disorder), there should be a significant Group×Theme interaction in the total fixation time data. Following the secondary hypothesis (i.e. longer glance duration on images with dysphoric themes for individuals with depressive disorder), there should be a significant Group×Theme interaction in the average glance duration data. When significant Group×Theme interactions were found, two-tailed *t*-tests were used to determine the significance of the differences in total fixation times, total fixation frequencies and average glance durations between the control and depressed groups. Levene's test of equality of variances was used to verify that the variances of the two population means were homogeneous. Whenever the equal variance assumption was not satisfied, Welch's *t*-test was applied; otherwise, the standard *t*-test was used. Pearson correlation tests were also used to assess the correlation between various study parameters. Significance levels for all statistical tests were set to $P=0.05$.

Table 2
Total fixation time and frequency data for 8 study slides

Theme	Group	Fixation time (s)		Fixation frequency	
		Mean	S.D.	Mean	S.D.
Dysphoric	Control	19.35	3.30	17.11	4.51
	Depressed	25.32	3.89	16.38	5.24
Neutral	Control	15.31	3.42	15.67	4.18
	Depressed	12.21	2.48	14.75	5.25
Social	Control	26.80	4.07	18.22	3.11
	Depressed	23.70	5.75	16.00	3.78
Threatening	Control	17.45	3.07	17.00	5.17
	Depressed	17.76	3.84	15.50	4.93

3. Results

3.1. Fixation times, fixation frequencies, and glance durations

Total fixation time and frequency data for each theme and subject group are presented in Table 2. There was a significant Group×Theme interaction for the total fixation time, $F(3.13)=7.38$, $P=0.004$. More detailed analysis showed that the total fixation time on dysphoric images was significantly larger for subjects in the depressed group as compared to that of subjects in the control group, $t(15)=3.42$, $P=0.004$. There was no significant Group×Theme interaction for the total fixation frequency, although the mean fixation frequency of the control group was higher than that of the depressed group for all themes (Table 2). For individual slides, the fixation frequency on each image ranged from 0 to 5 for both the control and depressed groups.

Average glance duration for each theme and subject group are presented in Table 3. There was a significant Group×Theme interaction for the average glance duration data, $F(3.13)=3.60$, $P=0.043$. More detailed analysis showed that the average glance duration on images with dysphoric themes was significantly larger for subjects in the depressed group as compared to that of subjects in the control group, $t(15)=2.53$, $P=0.023$. The average glance duration on social, neutral and threatening stimuli did not differ significantly between the two groups, $t(15)<1.08$, $P>0.297$.

Table 3
Average glance duration data for 8 study slides

Theme	Group	Glance duration (s/glance)	
		Mean	S.D.
Dysphoric	Control	1.33	0.34
	Depressed	1.82	0.45
Neutral	Control	1.07	0.41
	Depressed	0.95	0.36
Social	Control	1.60	0.24
	Depressed	1.62	0.40
Threatening	Control	1.13	0.24
	Depressed	1.32	0.47

For the dysphoric images on each of the test slides, the mean fixation times and the average glance durations were consistently greater for the depressed group (Table 4). The consistency of the data in Table 4 confirms the robustness of the differences in visual scanning behavior between the control and depressed groups.

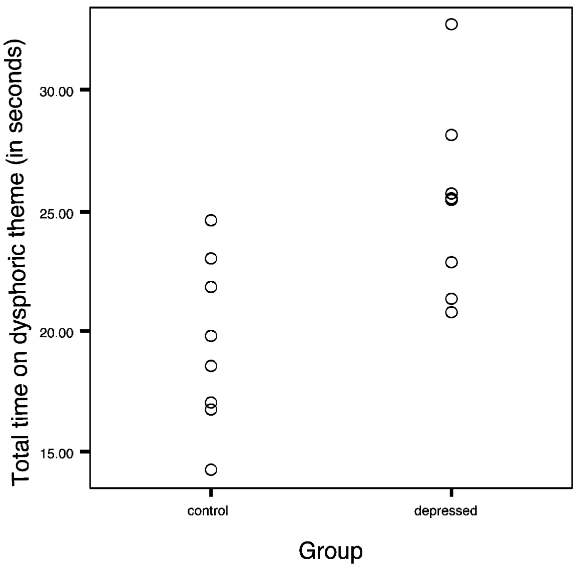

Fig. 2. Total fixation time on dysphoric theme by subject group.

Table 4
Fixation time and glance duration for each dysphoric image

Slide number	Group	Fixation time on dysphoric theme (s)		Average glance duration on dysphoric theme (s/glance)	
		Mean	S.D.	Mean	S.D.
1	Control	1.96	0.64	1.09	0.52
	Depressed	3.02	1.46	1.76	0.93
2	Control	2.36	0.75	1.44	0.99
	Depressed	3.12	1.13	1.81	1.30
3	Control	2.42	0.73	1.31	0.81
	Depressed	2.72	1.10	1.76	1.16
4	Control	2.36	0.86	1.24	1.19
	Depressed	3.36	1.63	1.73	1.08
5	Control	2.21	0.70	1.03	0.35
	Depressed	3.28	1.57	1.29	0.58
6	Control	2.94	1.43	1.94	0.65
	Depressed	3.23	0.87	2.00	1.13
7	Control	2.43	0.91	1.10	0.44
	Depressed	3.05	0.89	1.79	1.05
8	Control	2.67	1.63	1.51	0.78
	Depressed	3.55	1.64	2.45	2.03

Fig. 2 shows the total fixation time on dysphoric images for each subject in the control and depressed groups. For the depressed group, BDI scores and total fixation time on dysphoric images were not significantly correlated, nor were BAI scores correlated with the total fixation time on either threatening or dysphoric stimuli. As the depressed group was statistically older than the control group, a univariate ANOVA using total dysphoric fixation time as the dependent variable and age as a co-variate was performed. This analysis was done to ensure that the difference in total fixation time on dysphoric images among the groups was not simply due to an age effect. With age co-varied out, dysphoric fixation time continued to be significantly different between groups, $F(1.14)=8.29$, $P=0.01$. Further analysis revealed no significant correlation between age and dysphoric fixation time across all 17 subjects ($r=0.33$, $N=17$, $P=0.19$), or within each group considered separately.

To further demonstrate that the observed attentional bias is associated only with dysphoric imag-

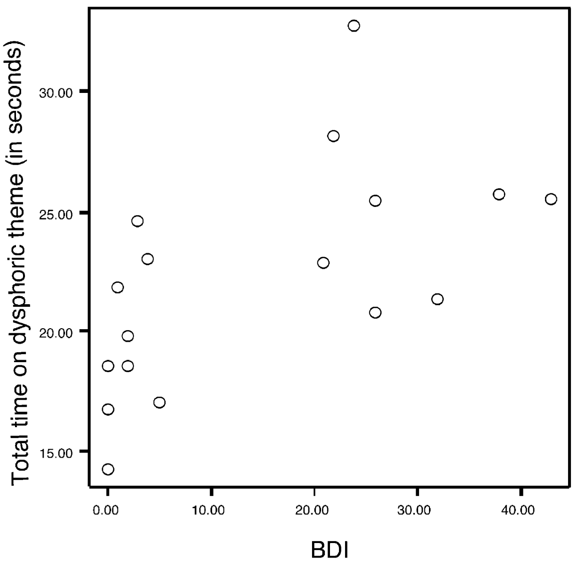

Fig. 3. Total fixation time on dysphoric theme vs. BDI.

es on study slides, similar statistical tests were performed on subsets of eight random images from the neutral slides (neutral slides have images with similar valences). In all 10 cases tested, the total fixation time on each set of images did not differ significantly between the depressed and control groups, $t(15)<1.0$, $P>0.3$. No significant differences were found in the viewing patterns of the control and depressed groups due to the relative positions of the images on the screen, i.e. the mean of the total fixation times on the left, right, top, and bottom portions of the slides did not differ significantly, $0.40>t(15)>0.14$, $0.694<P<0.892$.

In order to investigate the relationship between attentional bias and depression levels at both the individual and group levels, the total fixation times on the dysphoric theme were plotted against the BDI score (Fig. 3). Note that as a group, subjects with a greater BDI score generally spent more time on dysphoric images, but as individuals, subjects with similar BDI scores exhibited large variability in their fixation times. Hence, the correlation between BDI score and fixation time on the dysphoric theme is low. Pearson correlation tests were performed to better understand how the image characteristics (as quantified by the IAPS affective ratings) affect the differences in the fixation times of the control and depressed groups. The tests assessed the correlation between the differences in fixation time, and the IAPS affective ratings: valence, arousal and dominance.

Correlation analysis revealed that the valence of an image and the difference between the total fixation times of the control and depressed groups on the image are significantly correlated, $r=0.563$, $N=32$, $P=0.001$. No significant correlation was found between the difference in fixation times and the arousal rating of the image, $r=0.018$, $N=32$, $P=0.924$. The differences in total fixation times on each image as a function of valence and arousal ratings are shown in Fig. 4a and b, respectively. Since the dominance rating of a picture is highly correlated with its valence rating ($r=0.804$, $N=32$, $P<0.001$), the correlation results confirm that image selection with valence as the main criterion is appropriate.

4. Discussion

This study introduces a novel protocol that encourages the participant to scan and re-scan multiple images with different competing themes. By monitoring the subject's visual scanning patterns, attentional bias can be characterized by both the amount of time that each image is fixated on and by the participant's ability to transfer attention from image to image.

The primary hypothesis for the study was that, given competing visual stimuli with different themes, depressed individuals would selectively attend to dysphoric images more so than controls. Despite the small sample size, the results were highly consistent with this hypothesis. The depressed participants fixated on dysphoric themes for a significantly longer duration, which suggests that depressed participants selectively attend to stimuli with themes of loss or sadness. As shown in Table 2, the total fixation time of the depressed group on images with dysphoric themes was 30.8% greater than that of the control group.

The secondary hypothesis for the study was that depressed individuals would not be able to shift their attention away from dysphoric stimuli as

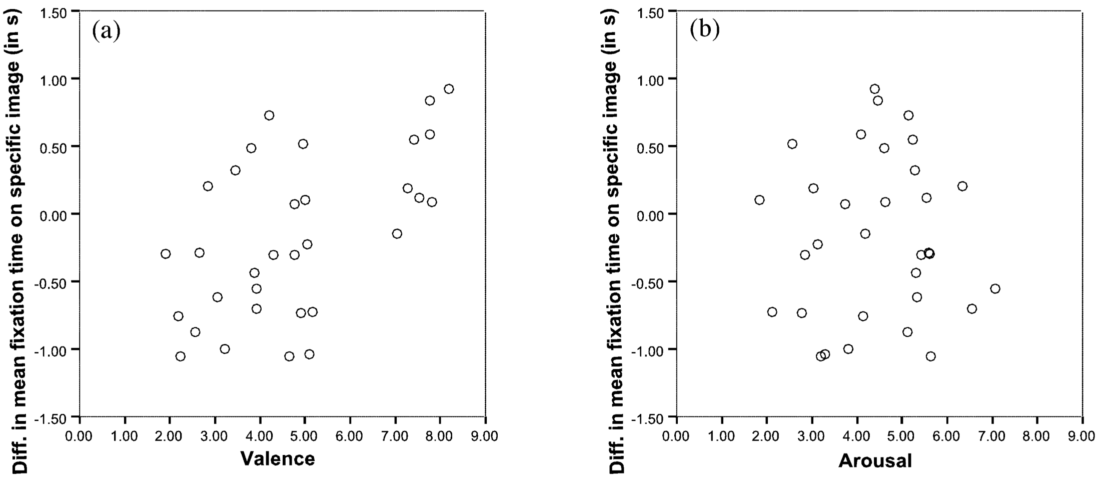

Fig. 4. Differences in mean fixation times (between the control and depressed groups) on each image, as a function of (a) valence and (b) arousal ratings.

readily as normal controls. For the depressed participants, the average glance duration on dysphoric stimuli was significantly longer than that of control subjects while the average glance durations on social, neutral or threatening stimuli were not significantly different. As shown in Table 3, the average glance duration of depressed individuals on dysphoric stimuli was 36.8% larger than that of control subjects. These findings are consistent with recent cognitive models of depression (Williams et al., 1997) that suggest that depression appears primarily to influence later elaborative stages of processing rather than early attentional processes. Subjects with depression do not scan dysphoric stimuli more often than normal controls (Table 2), but rather tend to elaborate on the dysphoric stimuli for longer time periods. The data in Table 3 also suggest that depressed individuals are able to shift their attention away from social and neutral stimuli as readily as normal controls.

To confirm the validity of using the valence rating of an image as the main criterion for image selection, the effect of the arousal rating of an image on fixation time was examined in greater detail. Fig. 5 shows that, for all subjects, the relationship between fixation time and the arousal properties of an image can be described by an inverted U-shaped function, which is consistent with the Yerkes–Dodson Law. Although the fit of the quadratic regression model is rather poor ($R^2_{adj}=0.34$), the overall relationship is significant, $F(2.29)=8.95$, $P=0.001$. However, as shown in Fig. 4b, the *differences* in the fixation times of the control and depressed groups are not correlated with the arousal properties of the images. Since the differences in the fixation times of the two groups are correlated with the valence of the images (Fig. 4a) but not with the arousal, it implies that the two groups can be better differentiated on the basis of the valence ratings rather than the arousal ratings of the images.

The overall validity of the protocol in measuring visual selective attention to emotionally salient themes was demonstrated, despite the fact that large differences exist among the scanning patterns of individuals. No attentional biases were observed when subjects viewed neutral slides, and no biases were evident due to the relative position of the image within each slide. In addition, the consistency of the differences in fixation times and glance durations on the dysphoric images in each slide, between the depressed and control groups, indicates that the valence rating is a useful criterion in the image-selection process and that the thematic content categories are appropriately defined.

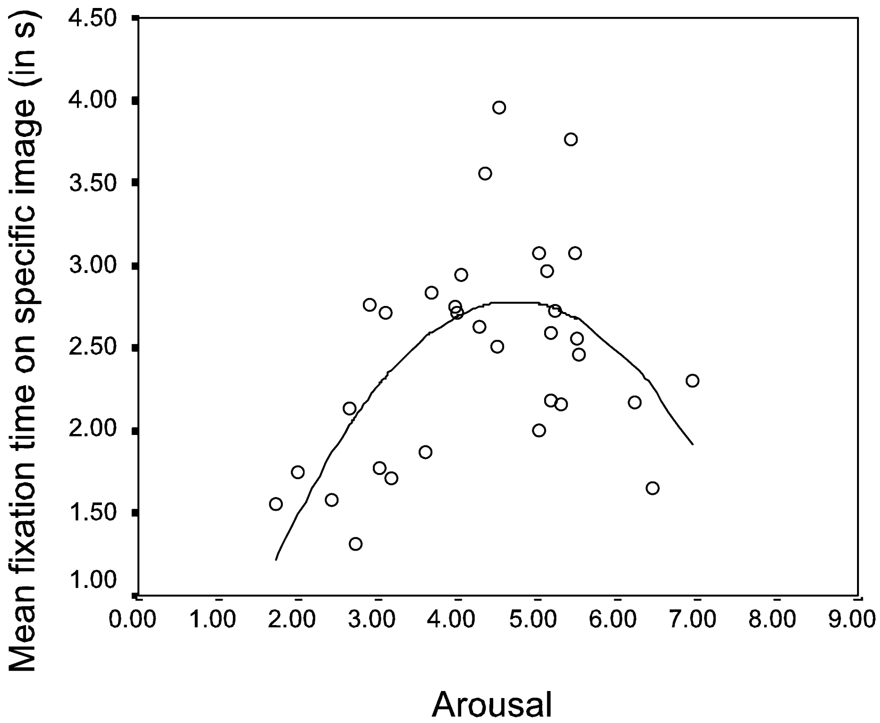

Fig. 5. Fixation time as a function of arousal rating. Each point indicates the mean fixation time of all subjects on a specific image. The functional relationship can be described by a parabola $y=b_2x^2+b_1x+b_0$ with the following parameters: $b_2=-0.176$, $b_1=1.654$, $b_0=-1.111$.

A large body of work suggests that selective attention to negatively valenced information supports and sustains the maladaptive patterns of information processing that trigger and maintain both anxious and depressed states (Dalgleish and Watts, 1990; Mathews and MacLeod, 1994; Mogg and Bradley, 1998). In general, selective attention to threatening stimuli in anxious individuals has been easier to demonstrate than selective attention to themes of loss and sadness amongst depressed patients. This has been due in part to the confounding effects of anxiety in depressed patients. However, it has been proposed that anxiety affects automatic unconscious processes involved in focusing attention (increasing the salience of threatening stimuli), while depression affects strategic cognitive processes involved in the selective recall of negative self-referent information (Watkins et al., 2000). The current results suggest that with the appropriate methodology, selective attention to dysphoric stimuli can in fact be demonstrated in depressed individuals with concurrent anxiety.

It cannot be concluded from the current study that depressed subjects with concurrent anxiety have a strong attentional bias towards threatening stimuli. This contradicts prior work suggesting that anxious individuals selectively process threatening information (Mogg et al., 2000). Interestingly, a consideration of individual subjects did indicate that the subject with the highest BDI and BAI ratings had unusually low fixation times on threatening themes, well outside 3 S.D. of the means of both the control and depressed groups. In contrast to other depressed subjects, this individual appears to have adopted an avoidance strategy to stimuli pertaining to threat and anxiety. This suggests that there are marked individual differences in attentional biases to anxiety-provoking stimuli in this population. Larger samples are needed to determine whether these 'opposing' attentional biases are associated with particular clinical characteristics including co-morbidity, personality traits, course of illness and/or treatment response. Future studies of sub-populations with depression only or anxiety only, as well as the co-morbid condition, will be needed to distinguish the relative importance of depression vs. anxiety in explaining the current results.

More work is needed to determine whether visual attentional biases in depression are predictive of and/or responsive to anti-depressant treatment, and whether they may constitute a marker of vulnerability to recurrent episodes. It will also be interesting to determine whether novel therapies based on visual selective attention patterns may be developed for depressed individuals. In summary, the novel visual scanning methodology presented in this article can be a powerful tool for the naturalistic assessment of intentional, fully conscious processing biases in depressed individuals.

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References

Beck, A., Brown, G., Epstein, N., Steer, R., 1988. An inventory for measuring clinical anxiety: psychometric properties. Journal of Consulting and Clinical Psychology 56, 893–897.

Beck, A., Ward, C.H., Mendelson, M., Mock, J., Erbaugh, J., 1961. An inventory for measuring depression. Archives of General Psychiatry 4, 561–571.

Bradley, B.P., Mogg, K., Millar, N., White, J., 1995. Selective processing of negative information: effects of clinical anxiety, concurrent depression, and awareness. Journal of Abnormal Psychology 104, 532–536.

Bradley, B.P., Mogg, K., Millar, N.H., 2000. Covert and overt orienting of attention to emotional faces in anxiety. Cognition and Emotion 14 (6), 789–808.

Center for the Study of Emotion and Attention [CSEA-NIMH], 1999. International Affective Picture System: Digitized Photographs. The Center for Research in Psychophysiology, University of Florida, Gainesville, FL, 32610.

Criminisi, A., Reid, I., Zisserman, A., 1999. A plane measuring device. Image and Vision Computing 17 (8), 625–634.

Dalgleish, T., Watts, F.N., 1990. Biases of attention and memory in disorders of anxiety and depression. Clinical Psychology Review 10, 589–604.

First, M.B., Spitzer, R.L., Gibbon, M., Williams, J.B.W., 1998. Structured Clinical Interview for DSM-IV-TR Axis I Disorders, Research Version, Patient Edition (SCID-I/P), Biometrics Research, New York State Psychiatric Institute, New York.

Hermans, D., Vansteenwegen, D., Eelen, P., 1999. Eye movement registration as a continuous index of attention deployment: data from a group of spider anxious students. Cognition and Emotion 13 (4), 419–434.

Hillyard, S.A., Vogel, E.K., Luck, S.J., 1999. Sensory gain control (amplification) as a mechanism of selective attention: electrophysiological and neuroimaging evidence. In: Humphreys, G.W., Duncan, J., Treisman, A. (Eds.), Attention, Space and Action: Studies in Cognitive Neuroscience. Oxford University Press, New York, pp. 31–53.

Jonides, J., 1981. Voluntary versus automatic control over the mind's eye's movements. In: Long, J., Baddeley, A. (Eds.), Attention and Performance IX. Erlbaum, Hillsdale, NJ, pp. 187–203.

Kendall, P.C., Hollon, S.D., Beck, A., Hammen, C.L., Ingram, R.E., 1987. Issues and recommendations regarding the use of the Beck Depression Inventory. Cognitive Therapy and Research 11, 289–299.

Kowler, E., 1995. Eye movements. In: Kosslyn, S.M., Osheron, D. (Eds.), Visual Cognition. MIT Press, Cambridge, MA, pp. 215–265.

Lang, P.J., Bradley, M.M., Cuthbert, B.N., 1999. International Affective Picture System: Instruction Manual and Affective Ratings. Technical Report A-4, University of Florida—The Center for Research in Psychophysiology, Gaineville, FL.

MacLeod, C., Rutherford, E., Campbell, L., Ebsworthy, G., Holker, L., 2002. Selective attention and emotional vulnerability: assessing the causal basis of their association through the experimental manipulation of attentional bias. Journal of Abnormal Psychology 111, 107–123.

MacLeod, C.M., 1986. Attentional bias in emotional disorders. Journal of Abnormal Psychology 95, 15–20.

MacLeod, C.M., 1991. Half a century of research on the Stroop effect: an integrative review. Psychological Bulletin 109, 163–203.

Mansell, W., Clark, D.M., Ehlers, A., Chen, Y.-P., 1999. Social anxiety and attention away from emotional faces. Cognition and Emotion 13 (6), 673–690.

Mathews, A., MacLeod, C., 1994. Cognitive approaches to emotion and emotional disorders. Annual Review of Psychology 45, 25–50.

Mathews, A., Ridgeway, V., Williamson, D.A., 1996. Evidence for attention to threatening stimuli in depression. Behaviour Research and Therapy 34, 695–705.

McCabe, S.B., Gotlib, I.H., 1995. Selective attention and clinical depression: performance on a deployment of attention task. Journal of Abnormal Psychology 104, 241–245.

McNally, R.J., 1998. Information-processing abnormalities in anxiety disorders: implications for cognitive neuroscience. Cognition and Emotion 12, 479–495.

Mogg, K., Bradley, B.P., 1998. A cognitive-motivational analysis of anxiety. Behaviour Research and Therapy 36, 809–848.

Mogg, K., Bradley, B.P., Williams, R., 1995. Attentional bias in anxiety and depression: the role of awareness. British Journal of Clinical Psychology 34, 17–36.

Mogg, K., Millar, N., Bradley, B.P., 2000. Biases in eye movements to threatening facial expressions in generalized anxiety disorder and depressive disorder. Journal of Abnormal Psychology 109 (4), 695–704.

Moray, N., 1993. Designing for attention. In: Baddeley, A., Weiskrantz, L. (Eds.), Attention Selection, Awareness, and Control. Clarendon Press, Oxford, pp. 111–134.

Posner, M.I., Dehaene, S., 1994. Attentional networks. Trends in Neuroscience 17, 75–79.

Posner, M.I., Snyder, C.R., Davidson, B.J., 1980. Attention and the detection of signals. Journal of Experimental Psychology: General 109, 160–174.

Watkins, P.C., Martin, C.K., Stern, L.D., 2000. Unconscious memory bias in depression: perceptual and conceptual processes. Journal of Abnormal Psychology 109, 282–289.

Wetzel, P.A., Krueger-Anderson, G., Poprik, C., Bascom, P., 1996. An eye tracking system for analysis of pilots' scan paths. Proceedings of the 18th Industry Training Systems and Education Conference, pp. 1–16.

Williams, J.M.G., Watts, F.N., MacLeod, C., Mathews, A., 1997. Cognitive Psychology and Emotional Disorders. Wiley, Chichester, England.

Yu, L.H., Eizenman, M. A new methodology for determining point-of-gaze in head-mounted eye tracking systems. IEEE Transactions on Biomedical Engineering, in press.