Running Head: MOOD & ATTENTION

Emotional Valence and Arousal Interact in the Control of Attention

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Abstract

Olivers & Niewenhuis (2005) reported that observers were better able to identify targets in a rapid visual sequence when they simultaneously listened to happy music. Here we examine how the emotion-attention relationship is influenced by changes in both mood valence (negative vs positive) and arousal (low vs. high). We used a standard induction procedure to generate moods in participants that included calm, happy, sad, and anxious (Eich, Macaulay & Ryan, 1994). Results of an attentional blink (AB) task showed no differences in first-target accuracy, but second-target accuracy was highest for participants with low arousal and negative affect (sad), lowest for those who were strongly aroused with negative affect (anxious), and intermediate for positive affect regardless of arousal (calm, happy). We discuss implications of this valence-arousal interaction for the control of visual attention.

Abstract = 132 words

Recent reports emphasize that visual attention is influenced by the affective state and the general strategic approach of the participant. Attention-demanding tasks are improved when participants simultaneously listen to music (Olivers & Niewenhius, 2005), are in a positive mood (Derryberry & Tucker, 1994; Olivers & Niewenhius, 2006), follow instructions to engage in a relaxation strategy (Olivers & Niewenhius, 2006; Smilek et al, 2006), and when a task-irrelevant event diverts attention away from a central task (Arend, Johnston, & Shapiro, 2006; Thompson, Schellenberg, & Husain, 2001). Here we examine possible interactions of affective valence and arousal on participants' ability to control their focus of visual attention.

Our interest in this question began with Olivers and Nieuwenhuis (2005), who asked participants to identify targets in a rapid sequence under quiet testing conditions, while listening to music, or while ruminating on self-directed thoughts. The results showed a second-target deficit in the quiet condition, which is the expected result in two target identification tasks (Shapiro, Arnell & Raymond, 1997). The surprising result was that this deficit was substantially reduced in the music condition. In the rumination condition there was a smaller improvement in second-target accuracy. Olivers and Nieuwenhuis (2006) proposed the overinvestment hypothesis to account for role of both positive affect and distraction. On this account, participants normally devote unnecessary cognitive resources to items in a rapid stream, thereby allowing non-target items to inadvertently gain entry to a limited-capacity processing stage, where they interfere with the consolidation of target items for subsequent report. It is as though the two-target task is a cognitive "sting" operation, luring participants into focusing too much attention on non-target items. Thinking about positive experiences and being distracted both prevent this over-investment.

Here we explore the emotion-attention connection using a broader range of emotional states. There is general agreement among emotional theorists that core mood states can be organized using the dimensions of valence and arousal. Where theorists differ is in whether they label the dimensions "pleasure-misery" and "sleep-arousal" (Barrett & Russell, 1999) or "pleasant-unpleasant" and "activation" (Larsen

& Diener, 1992), and whether they label the cardinal axes or axes rotated by 45 degrees (Watson & Tellegen, 1985; Thayer, 1989). According to Yik, Russell & Barrett (1999), these models can be integrated using a common space that differentiates core states but in which assignment of axes is arbitrary. It is important to note that this framework does not imply that all states corresponding to the same pleasure-arousal coordinates produce the same experience. For example, anger, fear, jealousy, grief and contempt are all unpleasant high-arousal states, but this does not imply that they feel the same. Emotional experiences are differentiated by attribution processes individuals make to interpret the cause of a given mood state (Russell, 2003).

We note several hints in the literature that there are separable influences of valence and arousal on attention. Effects of arousal can be seen in impairments of immediate memory associated with traumatic stress (Nadel & Jacobs, 1998) and in distractions caused by task-irrelevant stimuli (Schimmack, 2005); influences of valence can be seen in the way threatening stimuli such as snakes and angry faces attract attention (Lang, Davis & Öhman, 2000), and in the greater efficiency of processing when stimuli are emotionally relevance to the participant (Shapiro, Caldwell, & Sorensen, 1997). But there are also indications that valence and arousal interact to produce unique outcomes. For example, individuals who are sad or depressed (low arousal with negative affect) tend to process the finer details of a scene at the expense of gist, while happy (high arousal with positive affect) individuals tend to focus on the gist at the expense of details (Gaspar & Clore, 2002; Huber, Beckmann, & Herrmann, 2004).

Our approach used a standard mood induction procedure involving music and guided rumination to induce short-term moods in participants that spanned a range of valence and arousal (Eich, Macaulay & Ryan, 1994). We then had participants perform an attentional blink or AB task (Shapiro et al., 1997), stopping every few minutes to reassess their mood. We used these ongoing self-assessments to categorize participants into four groups, corresponding to whether they were experiencing negative or positive emotions and whether their level of arousal was low or high. For convenience, we refer to these four groups of participants as sad (negative, low arousal), calm (positive, low arousal), anxious (negative, high arousal), and happy (positive, high arousal). Readers should note that these groups were defined solely by the ratings participants gave to their own emotional states while they performed the task.

Method

Participants

One hundred students at the University of British Columbia participated either for extra course credit or payment. All reported normal or corrected-to-normal vision and were naïve to our purpose. Participants were first screened with the Beck Depression Inventory (BDI). Anyone scoring above 15 overall or more than 0 on question 9 (suicidal tendencies) was excluded from participation. Participants were assigned to one of five induction groups: sad (negative, low arousal), calm (positive, low arousal), anxious (negative, high arousal), happy (positive, high arousal), and neutral (no induction procedure). Data from four students were not included because they were unable to either identify the first target with 75% accuracy, or to identify the second target at the longest lag with 75% accuracy. One participant was excused with a serious toothache.

Mood Induction and Maintenance

Participants were first given instructions and practice (20 trials) on the visual target task. They were then instructed how to rate their mood with a 9 x 9 grid, marking the square that best exemplified their affect (extremely unpleasant on the right to extremely pleasant on the left) and arousal (extremely high energy at the top to extremely low energy at the bottom).

After instruction on mood ratings, participants were seated in a reclining lounge chair with headsets for the duration of the experiment and instructed to develop a

particular mood by listening to music and by recalling in detail mood-appropriate events from their past. After these instructions, one of four music selections that have been validated to promote a particular mood was played through the headsets for 10 minutes before testing began. Details of the instructions and the musical selections can be found on the web:
<http://www.psych.ubc.ca/~ennslab/research/mood_induction.html>

Participant rated their mood at 5-minute intervals. After the second rating, they began the two-target task with the music continuing to play. Testing was divided into two sets of 80 trials. After the first set, participants took a 5-minute break and again used the music and their imagery to maintain the appropriate mood. Following this "top up," participants completed another mood rating and then finished the remaining set of trials. At the end of testing, participants again rated their mood and indicated how genuine their induced moods were on a 10-point scale.

Attentional Blink Task

The two-target task was presented on a computer screen viewed from 57 cm. A white fixation cross, 0.25˚ by 0.25˚, was displayed in the center of the screen to indicate the onset of a trial. Items were white distractor digits (0-9) or white letter targets (20 letters of the English alphabet, excluding I, O, Q, and Z), which each subtended 0.9˚ vertically. The luminance of all items was 90 cd/m2, and the luminance of the background was 2.3 cd/m2.

Participants initiated each trial by pressing the spacebar. A sequence of items, each displayed for 82 ms, was presented in the center of the screen. Items were permitted to repeat but not in immediate succession. Participants were instructed to ignore the digits and to identify all letters they saw, in any order, by pressing corresponding keys. The number of digits that appeared before the first letter varied randomly from 8 to 14. Each stream terminated with a single digit, which acted as a mask for the second target. The critical factor for measuring attention was that the two letters were separated by lags of 2, 4, or 8, with the expectation that second target accuracy would be most reduced at lags 2 and 4.

Results

Mood Assessment

Participants rated their mood six different times, with the first rating providing a pre-test baseline. These ratings showed that participants generally began in a positive mood (mean affect rating = 1.3, SE = .16), with a neutral level of arousal (mean affect rating = 0.2, SE = .19), and these ratings did not vary with the assigned induction procedure, affect: $F(4, 90) < 1$, arousal, $F(4, 90) < 1$.

Following mood induction, participants' moods changed significantly ($p < .01$) and remained different throughout the testing session, as shown in Table 1. Participants also rated their mood experiences as "genuine" at the end of the session (mean = 7.1, SE = 0.20) and these ratings did not differ significantly between induction groups, $F(3, 76) < 1.99$. There was a small tendency for participants with low initial arousal scores to report higher arousal as the session continued, $F(16, 376) = 2.06$, $p < .01$, MSe = 1.15, and for those with initially positive ratings to report less positive affect as the session continued, $F(16, 376) = 2.86$, $p < .01$, MSe = 0.61, suggesting that the two-target task itself increased arousal and reduce positive affect.

The distribution of the mean mood ratings for all participants can be seen in Figure 1. The ratings of most participants fell into the mood quadrants they had been assigned to (anxious14/19, happy18/19, sad 13/19, calm 12/19). These self ratings were the basis of our assignment to four combinations of valence (negative, positive) and arousal (low, high). Readers should note that we analyzed the data first excluding and then including participants near the neutral points of the mood and arousal scales (+/- 0.5 units around 0 on each scale). We also analyzed the data using z-scores of the mood ratings and with both regression and analysis of variance

(ANOVA) techniques. The findings we report were evident in all analyses; those presented were selected for their ease of communication.

Attentional Blink Task

Figure 2 shows the mean accuracy for the two targets in each of the four mood groups. The main finding was that the second target deficit was influenced by both self-reported arousal and affect. This is most evident in the difference in accuracy between first and second targets at lags 2 and 4, which averaged 31% for the anxious group and only 19% for the sad group. The average of the happy group was 24% and that for the calm group was 23%. This means that participants who were sad had the smallest AB, those who were joyful or calm had an intermediate AB, while those who were anxious suffered the largest AB.

This conclusion was supported by statistical analyses. First, all accuracy data were analyzed with a mixed-design ANOVA on the between-participant factors of group (anxious, happy, sad, calm) and the within-participant factors of target (first, second) and lag (2, 4, 8). Significant main effects included that first target accuracy was greater than second target accuracy, $F(1, 91) = 229.19$, $p < .001$, $MSe = 158.55$; and that accuracy increased with lag, $F(2, 182) = 64.81$, $p < .001$, $MSe = 65.09$. Significant interactions included a reduction of the second target deficit at the longest lag, $F(2, 182) = 84.83$, $p < .001$, $MSe = 85.71$, and a difference between first and second accuracy that varied with group, $F(3, 91) = 2.77$, $p < .05$, $MSe = 158.55$.

Second, the four groups were examined in terms of the factors of arousal (low, high) and affect (negative, positive), separately for first and second target accuracy. Analysis of first target accuracy showed only that accuracy decreased about 2% from the lags 2 and 4 to lag 8, $F(2, 182) = 6.47$, $p < .01$, $MSe = 35.34$. No other factors were significant, either as main effects or interactions (all $p > .10$). Analysis of second target accuracy was based on the difference between first and second target accuracy on lags 2 and 4. This analysis showed a significant main effect of arousal, $F(1, 91) = 5.92$, $p < .02$, $MSe = 144.58$, reflecting the reduced AB for sad and calm participants over anxious and happy ones, and a significant interaction of arousal x affect, $F(1, 91) = 4.05$, $p < .05$, $MSe = 144.58$, reflecting the large effect of arousal for the two negative affect conditions (anxious vs sad: $F(1, 91) = 11.08$, $p < .01$) and the lack of an arousal effect for the two positive affect conditions (happy vs calm: $F(1, 91) < 1$).

Discussion

This study examined the relationship between visual attention and the self-reported mood of participants. In contrast to previous studies comparing specific moods with neutral baseline conditions (Olivers & Niewenhuis, 2005; 2006; Isaak & Uthaiya, 2006; Rokke, Arnell, Koch, Andrews, 2002) here we compared moods that varied independently in valence (negative vs. positive) and arousal (low vs. high). Instead of finding separate influences of arousal or valence, the results indicated that it was specific combinations of these dimensions that best predicted performance. Namely, sadness (low arousal - negative affect) produced the highest levels of performance, anxiety (high arousal - negative affect) led to the lowest levels of performance, and calm and happy states (low and high arousal combined with positive affect) were associated with intermediate performance.

It is important to note at the outset that these findings were specific to a measure of attention - the reduction in second target accuracy- and did not generalize to overall performance. First target accuracy was essentially the same for all mood groups (and yet not at ceiling levels), suggesting that the effect of mood was not to generally improve or impair performance. This rules out any blanket effects of mood or motivation that might come about through slowing or speeding of cognitive operations. Instead, finding a mood-specific effect on second-target accuracy suggests that there is a direct link between mood and the prioritization of items for visual attention (Derryberry & Tucker, 1994).

The finding of a valence-arousal interaction highlights the possibility that the control of attention may not be linked directly to the "core" emotional dimensions of valence and arousal. Instead, emotion may be linked to attention through connections that are unique to specific "attributed" emotional states such as sadness, anxiety, happy, etc. This has been a position advocated by theorists studying the neural basis of various emotional attributions, including the so-called six primary emotions of anger, fear, sadness, disgust, joy and surprise (Ekman, 1999; LeDoux, 2000). In this view, anger may facilitate attentional circuits best suited for combat (Blanchard & Blanchard, 1988), fear may enable circuits best suited for the evaluation of danger and flight (Lang et al., 2000), disgust could be linked to circuits involved in expelling harmful bodily substances (Berridge, 2003), and joy and surprise may be linked to processing information in a global and fluent manner (Fredrickson, 2003).

How might sadness be linked to the improved control of visual attention? One hint can be found in previous research showing that sadness is associated with attention to the details of perceptual experience at the expense of gist (Derryberry & Tucker, 1994; Gaspar & Clore; Huber, Beckmann, & Herrmann, 2004). Applied to the present results, this account suggests that the overfocusing on detail does not only apply to spatial features, but also to temporal ones. A system with a finer temporal resolution should indeed assist in the discrimination of items that follow one another every 82 ms.

Another way to link sadness to improved control over visual attention is through the overinvestment hypothesis of Olivers & Nieuwenhuis (2006). On this view, sadness was more successful than other mood inductions in distracting participants from allowing non-target items to gain entry to the limited-capacity processes of target identification. Also consistent with this account, calm and happy participants did perform better than anxious ones. But there are also questions that remain. For example, why did effective mood induction not have any influence on first target accuracy, as should occur if some moods reduce normal "overfocusing?" Also, why did our sad induction occupy participants with their own thoughts more effectively than the procedures for other moods, especially when participants reported equal ratings of "genuineness" in the different moods (Eich et al, 2007). Future research will have to resolve this question by disentangling the effects of distraction from those of mood.

Caution should also be exercised against over-interpreting the "benefits of sadness," because a study using a similar task reported that college students diagnosed as chronically dysphoric had larger second-target deficits than nondysphoric students (Rokke et al, 2002). The emotion-attention links of short-term mood manipulation may not generalize to chronic states.

Finally, it is worth considering the implications of these results for theories currently offered for the attentional blink. Resource-depletion models claim that a limited cognitive resource (visual short term memory or consolidation) is busy with the first item, depriving the second target of the same resource (Chun & Potter, 1995; Shapiro et al, 1997). This implies that being in a sad state allows the first target to be processed more quickly, perhaps because of the increased temporal resolution associated with this mood. Anxiety, on the other hand, must slow down the transfer of information into a stable form. Attentional filtering theories propose that the conscious mind can only direct one high-level task at a time. Thus, when a target is found that fits the current task "filter", subsequent distractors reset the filter in their own image (Di Lollo, Kawahara, Ghorashi, & Enns, 2005) or are strongly inhibited (Olivers & Niewenhuis, 2006). Sad individuals, in this view, are either able to switch more efficiently between tasks or are resistant to having their filter be altered by extraneous events.

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Figure captions

Figure 1. Mean self-reported ratings of affective valence (x-axis) and arousal (y-axis) of 95 participants in the study. Groups identified by different symbols were formed by subdividing these ratings based on whether they were positive or negative on each dimension.

Figure 2. Mean identification accuracy for first target (white circle) and second target (black square). Second target accuracy was included only if the first target was identified correctly, to ensure focused attention.

Table 1

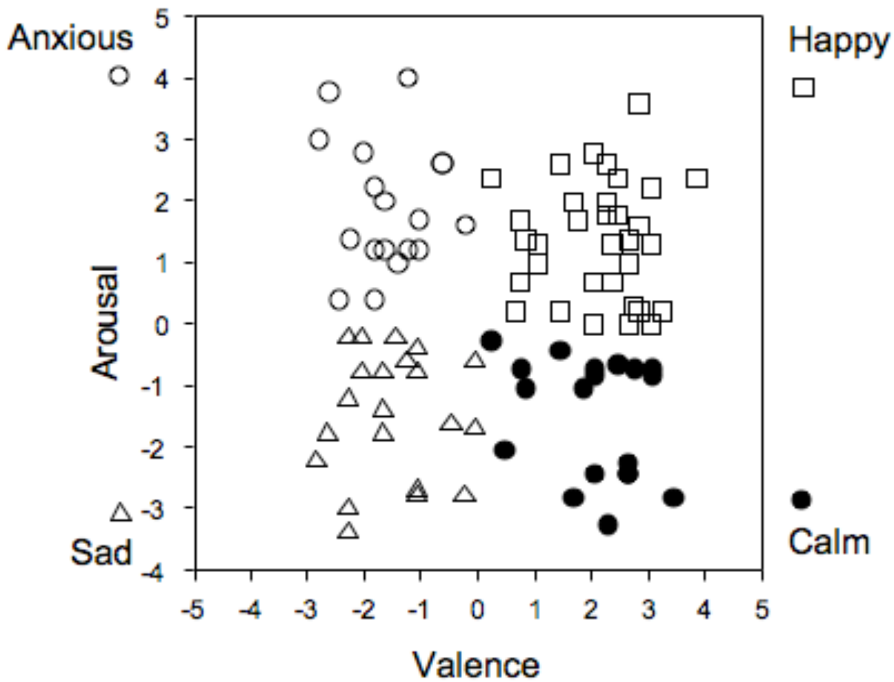
Mean mood scores (and standard errors) in each group for the five ratings made following the mood induction procedure.

Arousal Ratings

Group		Baseline	1	2	3	4	5
Sad	Mean	-0.15	-1.25	-1.60	-0.50	-0.85	-0.20
	SE	(.41)	(.36)	(.37)	(.36)	(.42)	(.44)
Anxious	Mean	0.60	1.05	1.15	2.20	1.05	1.40
	SE	(.41)	(.41)	(.44)	(.62)	(.47)	(.49)
Happy	Mean	0.10	1.30	1.10	1.45	1.50	1.35
	SE	(.54)	(.46)	(.44)	(.41)	(.38)	(.36)
Calm	Mean	0.00	-1.55	-1.55	-0.05	-1.05	-0.15
	SE	(.32)	(.37)	(.47)	(.43)	(.47)	(.40)
Neutral	Mean	.31	0.33	0.32	0.47	0.47	0.32
	SE	(.41)	(.32)	(.32)	(.33)	(.33)	(.33)

Affect Ratings

Sad	Mean	0.95	-1.45	-1.85	-1.40	-1.95	-1.50
	SE	(.32)	(.28)	(.32)	(.31)	(.36)	(.29)
Anxious	Mean	1.90	-.60	-1.65	-.80	-1.65	-1.10
	SE	(.30)	(.27)	(.29)	(.28)	(.29)	(.30)
Happy	Mean	1.20	2.45	2.50	1.85	2.40	2.00
	SE	(.40)	(.24)	(.22)	(.22)	(.30)	(.29)
Calm	Mean	0.80	1.90	2.20	1.95	1.90	1.70
	SE	(.29)	(.28)	(.25)	(.22)	(.29)	(.25)
Neutral	Mean	1.74	1.74	1.74	1.53	1.53	1.21
	SE	(.44)	(.28)	(.28)	(.29)	(.30)	(.28)


Anxious
Happy
Sad
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Valence
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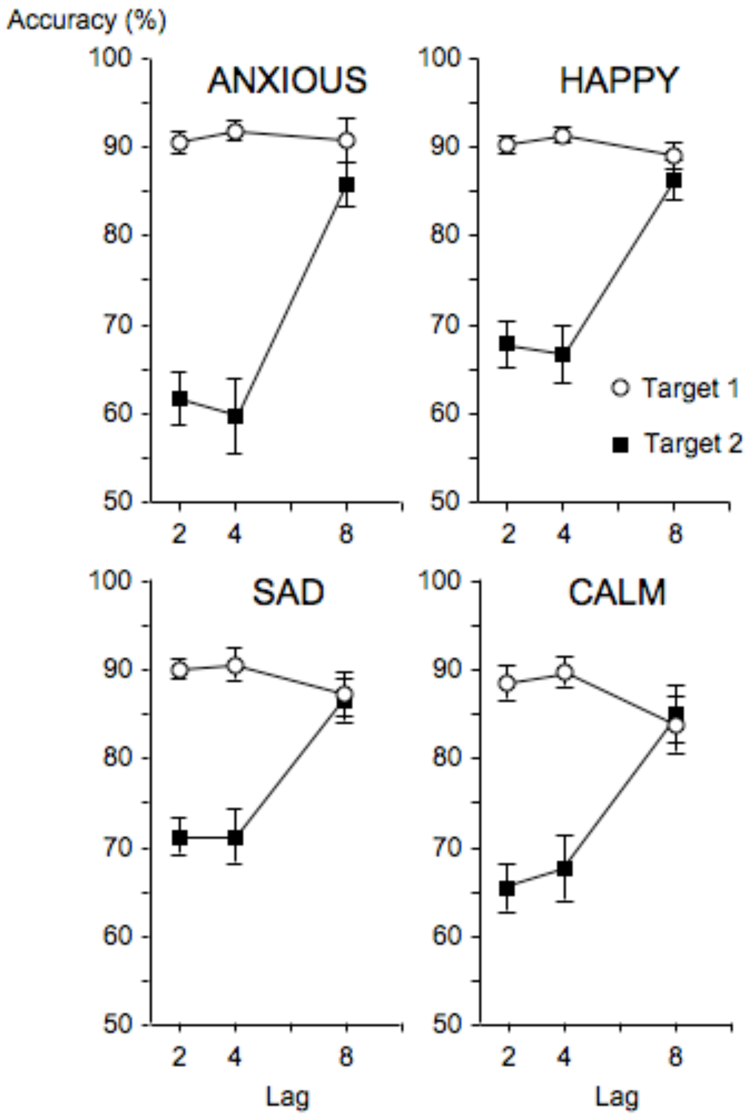
Accuracy (%)
ANXIOUS
HAPPY
SAD
CALM
100
90
80
70
60
50
2
4
8
Target 1
Target 2
Lag