Research Article

Emotional Valence and Arousal Interact in Attentional Control

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ABSTRACT—*A recent study demonstrated that observers' ability to identify targets in a rapid visual sequence was enhanced when they simultaneously listened to happy music. In the study reported here, we examined 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 calm, happy, sad, and anxious moods in participants. Results for an attentional blink 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 with strong arousal and negative affect (anxious), and intermediate for those with positive affect regardless of their arousal (calm, happy). We discuss implications of this valence-arousal interaction for the control of visual attention.*

Recent reports have emphasized that visual attention is influenced by the observer's affective state and general strategic approach. Performance on attention-demanding tasks improves when participants simultaneously listen to music (Olivers & Nieuwenhuis, 2005), are in a positive mood (Derryberry & Tucker, 1994; Olivers & Nieuwenhuis, 2006), or follow instructions to engage in a relaxation strategy (Olivers & Nieuwenhuis, 2006; Smilek, Enns, Eastwood, & Merickle, 2006), as well as when a task-irrelevant event diverts attention away from the attention-demanding 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 a study by Olivers and Nieuwenhuis (2005), who asked participants to identify two targets in a rapid sequence under quiet testing conditions, while listening to music, or while ruminating on self-directed thoughts. The results showed a deficit in identification of the second target in the quiet condition, which is the expected result in tasks requiring identification of two targets in rapid succession (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 the roles of positive affect and distraction in producing this pattern of results. According to this account, participants normally devote unnecessary cognitive resources to items in a rapid stream, thereby allowing nontarget 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 rapid serial visual presentation task is a cognitive "sting" operation, luring participants into focusing too much attention on nontarget items. Thinking about positive experiences and being distracted both prevent this overinvestment.

In the experiment reported here, we explored the emotion-attention connection using a broader range of emotional states. There is general agreement among emotion 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° (Thayer, 1989; Watson & Tellegen, 1985). According to Yik, Russell, and Barrett (1999), these models can be integrated using a common space in which core states are differentiated but 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 attributions individuals make to interpret the cause of a given mood state (Russell, 2003).

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The literature contains several hints that valence and arousal have separable influences 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 the emotional valence of the stimuli is relevant to the participant (Shapiro, Caldwell, & Sorensen, 1997). But it is also possible 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, whereas individuals who are happy (high arousal with positive affect) tend to focus on the gist at the expense of details (Gasper & Clore, 2002; Huber, Beckmann, & Herrmann, 2004). The unique roles of valence and arousal have not yet been disentangled in this research, however.

We used a standard mood-induction procedure involving music and guided rumination to induce in participants short-term moods that spanned a range of valence and arousal (Eich, Macaulay, & Ryan, 1994). A control group of participants was given no mood induction. We then had all participants perform an attentional blink (AB) task with two targets (Shapiro, Arnell, & Raymond, 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 affect, low arousal), calm (positive affect, low arousal), anxious (negative affect, high arousal), and happy (positive affect, high arousal). Readers should note that these groups were defined solely by the ratings participants gave to their own emotional states during the experimental session.

METHOD

Participants

One hundred students at the University of British Columbia participated either for extra course credit or for payment. All reported normal or corrected-to-normal vision and were naive to our purpose. Participants were first screened with the Beck Depression Inventory (Beck, Ward, Mendelson, Mock, & Erbaugh, 1961). Anyone scoring above 15 overall or greater than 0 on Question 9 (suicidal tendencies) was excluded from participation. Participants were assigned to one of five induction groups: sad (negative affect, low arousal), calm (positive affect, low arousal), anxious (negative affect, high arousal), happy (positive affect, high arousal), or neutral (no induction procedure). Data from 4 students were not included because they were unable to identify the first target with 75% accuracy or to identify the second target at the longest lag with 75% accuracy. One participant with a serious toothache was excused.

Mood Induction and Maintenance

Participants were first given instructions and practice (20 trials) on the AB task. They were then instructed how to rate their mood with a 9 × 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). They were told that they would do this six times during the experimental session.

After this instruction, participants were seated in a reclining lounge chair and given headsets to wear for the duration of the experiment. Except in the neutral induction condition, participants were instructed to develop a particular mood by listening to music and by recalling in detail mood-appropriate events from their past. One of four musical selections validated as promoting a particular mood was played through the headsets for 10 min before testing began. Details of the instructions and the musical selections can be found on the Web at www.psych.ubc.ca/~ennslab/research/mood_induction.html.

Participants in the sad, calm, anxious, and happy mood-induction conditions made their first mood ratings before beginning the mood-induction procedure, and their second ratings following the initial mood-induction instructions and before beginning the AB task. Participants in the neutral condition made their first two ratings at the same times, but instead of receiving mood-induction instructions were simply asked to rest during that period. After the second rating, all participants began the AB task, with the music continuing to play (except in the neutral condition). Testing was divided into two sets of 80 trials. All participants made their third ratings approximately 5 min into the first set of trials. Following the first set, participants took a 5-min break and (except in the neutral condition) again were instructed to use the music and their imagery to maintain the appropriate mood. All participants made their fourth set of ratings after this break. Approximately 5 min into the second set of trials in the AB task, participants rated their mood for a fifth time. Following all AB testing, participants rated their mood for a sixth time, and also rated how genuinely they had experienced their mood overall, using a 10-point scale.

AB Task

The AB task was presented on a computer screen viewed from a distance of 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 (22 letters of the English alphabet, excluding *I*, *O*, *Q*, and *Z*), each of which subtended 0.9° vertically. The luminance of all items was 90 cd/m^2, and the luminance of the background was 2.3 cd/m^2.

Participants initiated each trial by pressing the space bar. A sequence of items, each displayed for 82 ms, was presented in the center of the screen. Items could be repeated within a sequence, 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, which was in the immediately prior position. For purposes of measuring attention, the critical factor was that the two letters were separated by lags of 2, 4, or 8; we expected 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 pretest baseline. Participants generally began in a positive mood (mean rating = 1.3, SE = 0.16), with a neutral level of arousal (mean rating = 0.2, SE = 0.19), and these baseline ratings did not vary with the assigned induction procedure, $F(4, 90)$s < 1 for both affect and arousal.

Following the mood induction, participants' moods changed significantly (ps $< .01$), and ratings of the five different mood-induction groups remained different throughout the testing session, as Table 1 shows. Also, at the end of the session, participants rated their mood experiences as "genuine" ($M = 7.1$, $SE = 0.20$), and these ratings did not differ significantly among the induction conditions, $F(3, 76) < 1.99$. 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 affect ratings to report less positive affect as the session continued, $F(16, 376) = 2.86$, $p < .01$, $MSE = 0.61$; these results suggest that the AB task itself increased arousal and reduced positive affect.

Figure 1 presents the distribution of the mean mood ratings for all participants, including those in the neutral condition. The ratings of most participants fell into the mood quadrants they had been assigned to (anxious: 14/19, happy: 18/19, sad: 13/19, calm: 12/19); the 19 neutral-condition participants fell into the happy (12), calm (4), sad (2), and anxious (1) quadrants. 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 with ratings 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.

AB Task

Figure 2 shows the mean accuracy in reporting the two targets for each of the four mood groups. The main finding was that the deficit in second-target accuracy was influenced by both self-reported arousal and self-reported affect. This was 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%. Thus, participants who were sad had the smallest AB, those who were joyful or calm had an intermediate AB, and those who were anxious had the largest AB.

TABLE 1
Mean Mood Scores in Each Induction Condition

	Rating					
Group	Baseline	1	2	3	4	5
			Arousal			
Sad	−0.15 (0.41)	−1.25 (0.36)	−1.60 (0.37)	−0.50 (0.36)	−0.85 (0.42)	−0.20 (0.44)
Anxious	0.60 (0.41)	1.05 (0.41)	1.15 (0.44)	2.20 (0.62)	1.05 (0.47)	1.40 (0.49)
Happy	0.10 (0.54)	1.30 (0.46)	1.10 (0.44)	1.45 (0.41)	1.50 (0.38)	1.35 (0.36)
Calm	0.00 (0.32)	−1.55 (0.37)	−1.55 (0.47)	−0.05 (0.43)	−1.05 (0.47)	−0.15 (0.40)
Neutral	0.31 (0.41)	0.33 (0.32)	0.32 (0.32)	0.47 (0.33)	0.47 (0.33)	0.32 (0.33)
			Affect			
Sad	0.95 (0.32)	−1.45 (0.28)	−1.85 (0.32)	−1.40 (0.31)	−1.95 (0.36)	−1.50 (0.29)
Anxious	1.90 (0.30)	−0.60 (0.27)	−1.65 (0.29)	−0.80 (0.28)	−1.65 (0.29)	−1.10 (0.30)
Happy	1.20 (0.40)	2.45 (0.24)	2.50 (0.22)	1.85 (0.22)	2.40 (0.30)	2.00 (0.29)
Calm	0.80 (0.29)	1.90 (0.28)	2.20 (0.25)	1.95 (0.22)	1.90 (0.29)	1.70 (0.25)
Neutral	1.74 (0.44)	1.74 (0.28)	1.74 (0.28)	1.53 (0.29)	1.53 (0.30)	1.21 (0.28)

Note. Standard errors are given in parentheses.

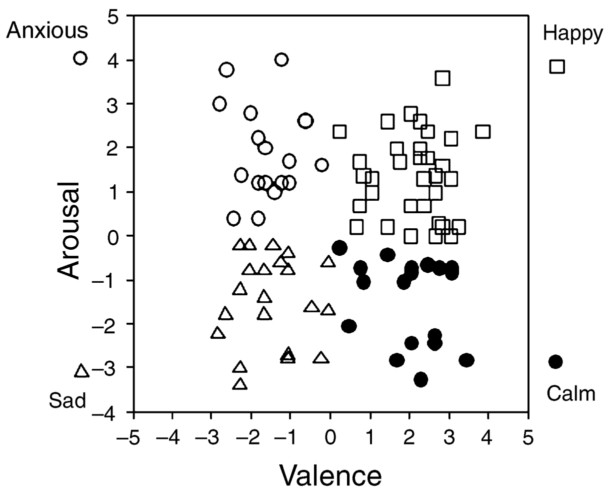

Fig. 1. Mean self-reported ratings of affective valence (*x*-axis) and arousal (*y*-axis) of the 95 participants in the study: 19 participants in each of the groups receiving a mood induction (sad, anxious, calm, happy) and 19 participants in the neutral condition (no mood induction). The mood groups (identified by different symbols) were formed by subdividing the ratings on each dimension into positive and negative categories.

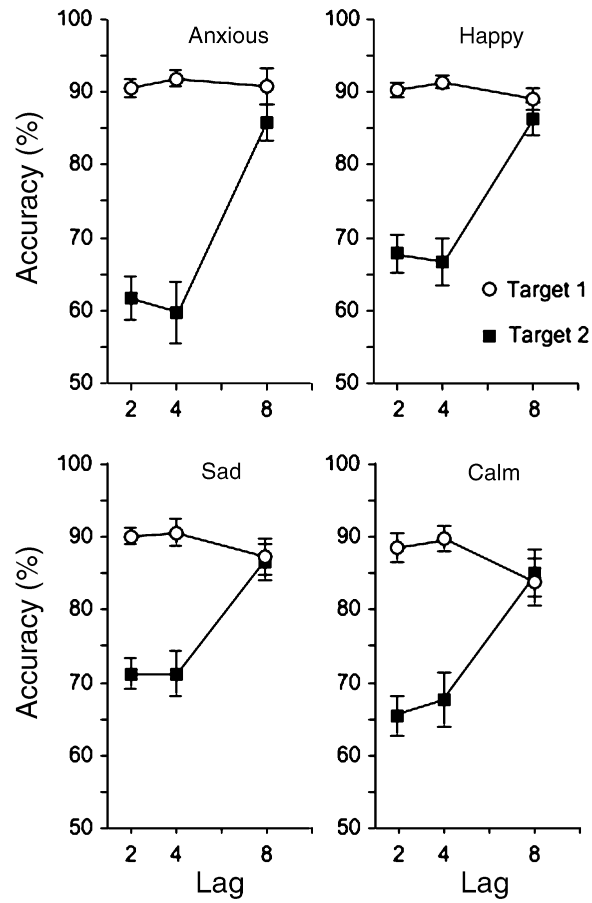

Fig. 2. Mean identification accuracy for the first and second targets as a function of lag. Results are reported separately for the anxious, happy, sad, and calm groups. Second-target accuracy was included only for trials on which the first target was identified correctly, to ensure that only trials on which attention was focused on the task were included.

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

Second, first-target accuracy and second-target accuracy were examined separately in ANOVAs that included the factors of arousal (low, high) and affect (negative, positive). Analysis of first-target accuracy showed only that accuracy decreased about 2% from 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 in interactions (all ps $> .10$). For the analysis of second-target accuracy, the dependent variable was the difference between first- and second-target accuracy at lags 2 and 4, the lags at which performance differences between the targets were greatest. 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 relative to anxious and happy ones, and a significant interaction of arousal and 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 relation between visual attention and the self-reported mood of participants. In contrast to previous studies comparing specific moods with neutral baseline conditions (Olivers & Nieuwenhuis, 2005, 2006; Isaak & Uthaiya, 2006; Rokke, Arnell, Koch, & Andrews, 2002), this study compared moods that varied independently in valence (negative vs. positive) and arousal (low vs. high). Instead of finding separate influences of arousal or valence, we found that specific combinations of these dimensions best predicted performance. That is, sadness (low arousal with negative affect) produced the highest levels of performance, anxiety (high arousal with 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 that these findings were specific to one 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), which suggests that the effect of mood was not to generally improve or impair performance. This finding 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, and happiness. This position has been 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 evaluating danger and flight (Lang et al., 2000), disgust might 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; Gasper & Clore, 2002; Huber et al., 2004). Applied to the present results, this account suggests that the overfocusing on detail applies not only to spatial features, but also to temporal ones. A system with a finer temporal resolution should indeed enhance 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 and Nieuwenhuis (2006). In this view, sadness was more successful than other mood inductions in distracting participants from allowing nontarget items to gain entry to the limited-capacity processes of target identification. Another finding consistent with this account is that calm and happy participants performed better than anxious ones; anxious participants may have been overly focused on the task, whereas calm and happy participants may have found their emotional state to be more of a distraction from the AB task. But there are also questions that remain. For example, why did an effective mood induction not have any influence on first-target accuracy, as it should if some moods reduce normal "overfocusing"? Also, why did our sad induction occupy participants with their own thoughts more effectively than the other mood inductions, especially given that participants reported equal ratings of genuineness for the different moods (Eich, Ng, Macaulay, Percy, & Grebneva, 2007). Future research will have to resolve this question by disentangling the effects of distraction from those of mood.

Caution should be exercised to avoid overinterpreting the results suggesting "benefits of sadness," because a study using a similar task demonstrated 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 current theories of the AB. Resource-depletion models claim that a limited cognitive resource (visual short-term memory or consolidation) is busy with the first target, so that the second target is deprived of the same resource (Chun & Potter, 1995; Shapiro, Arnell, & Raymond, 1997). From this perspective, our results imply 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, and that anxiety slows down the transfer of information into a stable form. Attentional filtering theories propose that the conscious mind can direct only one high-level task at a time. Thus, when a target that fits the current task filter is found, subsequent distractors reset the filter in their own image (Di Lollo, Kawahara, Ghorashi, & Enns, 2005) or are strongly inhibited (Olivers & Nieuwenhuis, 2006). In this view, our results imply that sad individuals either have an enhanced ability to switch efficiently between tasks or are resistant to having their filter altered by extraneous events.

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