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BRIEF REPORT

Upbeat and happy: Arousal as an important factor in studying attention

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The present study examined the effects of music-induced mood changes on different components of visual attention. Affective valence (positive vs. negative) and arousal (high vs. low) were manipulated by having participants listen to one of four versions of a Mozart Sonata that varied in mode (major or minor) and tempo (fast or slow). Attention was measured in three domains—alerting, orienting, and executive control. Affective valence and arousal had an effect on executive control, but not on alerting or orienting. Individuals who experienced positive valence had less efficient control over their responses than those who experienced negative valence, but only when arousal levels were high. Positive and negative valence did not influence executive control measures when arousal levels were low. These findings demonstrate that affective valence and arousal interact with one another to influence the processing of items in visual attention.

Keywords: Mood; Information processing; Attention networks; Arousal; Valence.

The mood of an individual can influence a wide variety of cognitive processes, such as categorisation (Isen & Daubman, 1984), cognitive control (Gray, 2001), false memory generation (Storbeck & Clore, 2005), regulatory focus (Förster & Higgins, 2005), motivation (Erez & Isen, 2002) and spatial memory (Brunyé, Mahoney, Augustyn, & Taylor, 2009; Crawford, Margolies, Drake, & Murphy, 2006). Due to the prevalence of mood in everyday functioning, it is important to determine the extent to which specific affective factors influence performance on cognitive tasks. In this experiment, we sought to examine the relation between music-induced mood changes and various aspects of visual attention.

The levels-of-processing hypothesis (Clore et al., 2001) explains how feelings influence the processing of items in visual attention and provides a fruitful way to frame the relationship between mood and various aspects of visual attention. According to this hypothesis, positive moods promote global, heuristic information

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processing while negative moods encourage local, systematic processing of information. In other words, individuals in positive states tend to focus on information at the global level, thereby viewing a given scene as a unitary whole, whereas people in more negative states focus on local information and attention is drawn to the individual details of a scene (Basso, Schefft, Ris, & Dember, 1996; Clore et al., 2001; Fredrickson & Branigan, 2005; Gasper, 2004; Gasper & Clore, 2002; Jefferies, Smilek, Eich, & Enns, 2008; Rowe, Hirsh, & Anderson, 2007; Storbeck & Clore, 2005). For example, individuals experiencing positive moods tend to use global features to classify geometric objects, whereas individuals experiencing negative moods tend to use local features (Gasper & Clore, 2002). Experimentally manipulating mood also influences perceptual biases; positive feedback produces a global bias, whereas negative feedback produces a local bias (Brandt, Derryberry, & Reed, 1992, as cited in Fredrickson & Branigan, 2005, pp. 316–317). Additionally, individuals who are in a positive affective state are more susceptible to information provided by misleading, spatially proximate distractors than those in a negative state (Rowe et al., 2007).

While a great deal of research supports the levels-of-processing hypothesis (i.e., positive moods broaden the focus of attention and negative moods narrow it; Erez & Isen, 2002; Fredrickson, 1998, 2003, 2004; Fredrickson & Branigan, 2005; Gasper, 2004; Gasper & Clore, 2002; Rowe et al., 2007; Storbeck & Clore, 2005; Wadlinger & Isaacowitz, 2006), this research has focused solely on affective valence (i.e., positive vs. negative), and not given equal consideration to the factor of emotional arousal (i.e., high vs. low) despite the research showing that mood can be organised along these two orthogonal dimensions (Purcell, 1982; Russell, 1979, 1980; Russell & Carroll, 1999). Surprisingly, only a handful of studies have examined the extent to which both arousal and valence influence information processing. These studies have revealed that arousal levels can influence cognitive processing, independent of an individual's emotional state. For example, arousal has been shown to influence global versus local spatial memory, whereby high arousal levels encourage individuals to create global representations of map-based information for both positive and negative valence levels (Brunyé et al., 2009). Similarly, false memory acquisition is enhanced under conditions of high arousal versus low arousal, regardless of participants' emotional valence (Corson & Verrier, 2007). Temporal resolution is highest for participants experiencing sadness (low arousal with negative affect), lowest for those experiencing anxiety (high arousal with negative affect), and intermediate for those experiencing positive affect, regardless of their arousal levels (Jefferies et al., 2008). Valence and arousal can even have differential effects on height perception, whereby individuals in a high arousal state overestimate the height of a two story balcony, irrespective of their valence (Stefanucci & Storbeck, 2009). These experiments demonstrate that valence and arousal can have independent effects on attention in some instances and inseparable effects in other instances.

The present study examined the combined effects of mood and arousal on a variety of attention measures. The specific goals included: (1) examining whether both valence and arousal influence attentional processing; and (2) whether these two dimensions of mood have separable or interactive effects on attention.

While our primary focus was to examine the influence of these affective dimensions on the breadth of attentional processing, it is important to remember that attention is not a unitary concept. As such, mood might have strong effects on some components of attention and no effect on others. Therefore, we chose to use the Attention Network Test (ANT; Fan, McCandliss, Sommer, Raz, & Posner, 2002) to measure individual differences in attention networks (see Figure 1). The ANT combines multiple warning cues and target flanker displays to obtain independent measures of three attention networks in a single task. These three networks include the alerting network, which maintains a state of vigilance in preparation for upcoming stimuli; the orienting network, which enables individuals to selectively

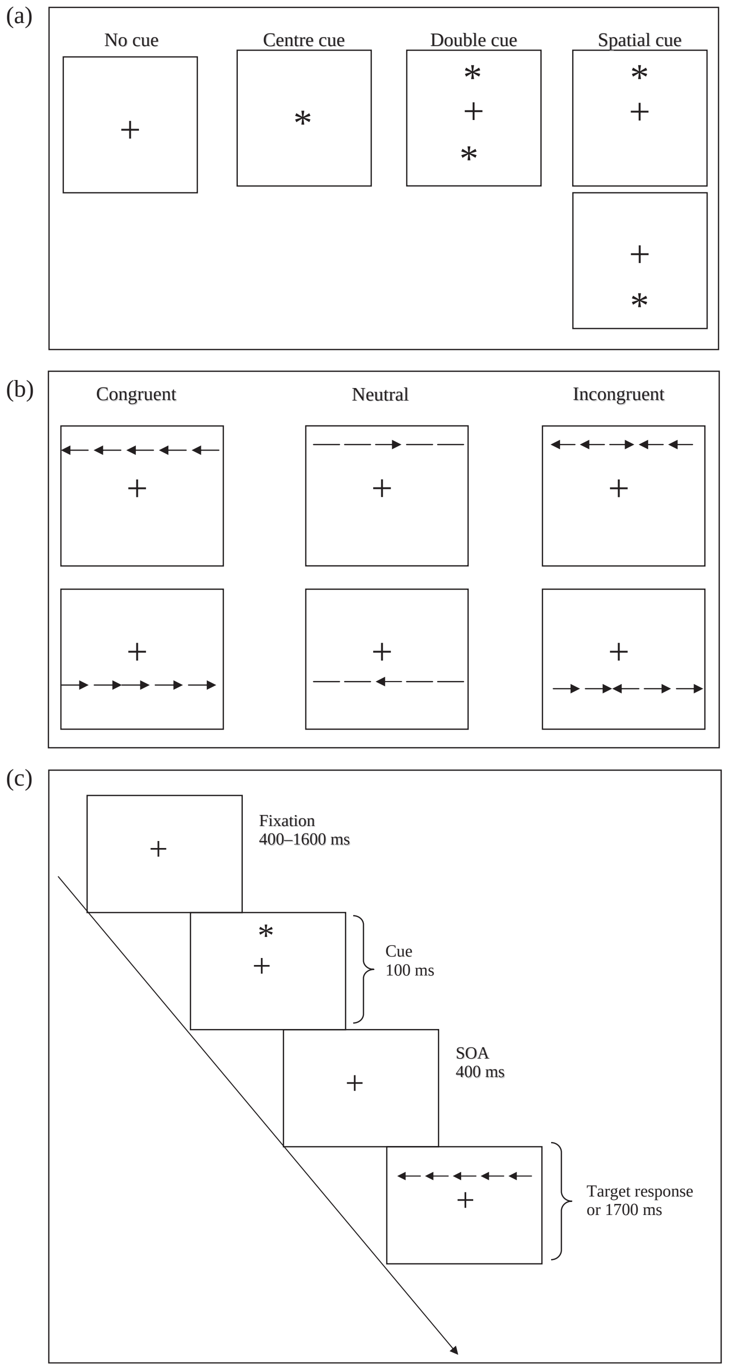

Figure 1. *Attention Network Test (ANT) design and procedure: (a) the four warning cue conditions; (b) the three flanker conditions; (c) the sequence of events for a given trial. The participants' task was to determine whether the central arrow in the flanker display was pointing to the left or right.*

attend to regions of space; and the executive function network, which enables conflict resolution, error detection, and inhibitory control. The ANT requires participants to report the direction of a central arrow (left or right) that is surrounded by two flanking arrows pointing in the same direction as the central arrow (congruent), the opposite direction (incongruent), or in neither direction (straight lines; neutral condition). The arrow display is preceded by one of four cue conditions (centre cue, double cue, spatially informative cue, or no cue) that can inform the participant a target will occur soon.

The design of the ANT allows researchers to extract measures of alerting, orienting, and executive function through a series of orthogonal contrasts between mean reaction times (RTs). The alerting network is measured by subtracting RTs to targets preceded by a double cue from RTs to targets preceded by no cue. The appearance of the double cue alerts the participants to the upcoming onset of the target display and because such a warning is not present in the no-cue condition, the RT difference between these two conditions should provide a measure of alerting efficiency. Larger difference scores indicate more efficient alerting.

The orienting network is measured by subtracting RTs to targets preceded by a spatially informative cue from RTs to targets preceded by a central, non-informative cue. The central cue provides no information regarding the location of the target display, whereas the spatial cue tells the participants exactly where the target is going to appear. Larger difference scores indicated greater control over spatial orienting.

The executive function is calculated by subtracting the mean RT in the congruent condition from the mean RT in the incongruent condition. When presented with an incongruent target display, participants must deal with the conflicting information provided simultaneously by the target and flanker arrows. On the other hand, during congruent target displays, the flanker and target arrows provide participants with the same information about the target response and, thus, no conflict resolution is required. Larger scores are associated with *less* efficient control.

In the context of the levels-of-processing hypothesis, the executive function calculation provides us with a measure of the breadth of attentional processing—individuals in happy emotional states experience greater flanker interference than those in neutral or sad emotional states (Rowe et al., 2007). The use of the ANT afforded us the opportunity to explore whether alerting and orienting scores could also be influenced by affective valence and arousal. There is a semantic relation between arousal and alertness, and, accordingly, arousal levels may modulate participants' alertness scores. Furthermore, music-induced changes in mood and arousal have been shown to influence spatial abilities (Husain, Thompson, & Schellenberg, 2002; Rauscher, Shaw, & Ky, 1993; Thompson, Schellenberg, & Husain, 2001), which may be related to the spatial orienting measure provided by the ANT.

STUDY 1: MOOD INDUCTION VALIDATION

We used music to induce affective states that varied in valence and arousal. We used four versions of the same Mozart sonata that differed in mode (major or minor) and tempo (fast or slow) instead of using different pieces of music, as is commonly done in emotion–attention studies. These recordings were originally used to investigate whether musical mode and tempo could modulate measures of spatial abilities (Husain et al., 2002). Musical mode influenced valence levels while musical tempo influenced arousal levels. For the present purposes, the term "arousal" refers to perceived rather than physiological arousal. The goal of this first study was to validate the effectiveness of this mood induction since we did not want to administer the various mood measures in the actual experiment examining the relation between mood and attention (see results and discussion to Study 1).

Method

Participants. Twenty-four undergraduate students (mean age = 19.7 years, 8 males, 2 left handed) from McMaster University participated in the current experiment for course credit. Subjects were randomly assigned to listen to one of four musical pieces, with six participants listening to fast-major music, six participants listening to fast-minor music, six participants listening to slow-major music, and six participants listening to slow-minor music. All participants reported normal or corrected-to-normal vision.

Materials. The musical excerpts consisted of four versions of Mozart's sonata K. 448 (courtesy of Dr Gabriela Husain, University of Toronto; Husain et al., 2002).[1] The different versions of the sonata varied in both tempo (fast vs. slow) and mode (major vs. minor), creating four different conditions. For a detailed explanation of these musical excerpts, please see Husain et al. (2002).

Changes in mood and arousal were examined through the use of two measures: the Affect Grid (Russell, Weiss, & Mendelsohn, 1989) and the Profile of Mood States (POMS), short form (McNair, Lorr, & Droppleman, 1992). The Affect Grid is a single-item measure that assesses mood along the dimensions of pleasure–displeasure and arousal–sleepiness. Participants were asked to rate their current valence and arousal by placing an "x" in one square of a 9×9 matrix. Arousal corresponded to the vertical axis, with low arousal/sleepiness represented at the bottom of the grid and high arousal represented at the top of the grid. Affective valence was characterised along the horizontal axis, with unpleasant feelings corresponding to the left side of the grid and pleasant feelings corresponding to the right side of the grid. Both valence and arousal scores could range from one to nine.

The POMS consists of 30 adjectives that describe a participant's affective state at that time. These adjectives are partitioned into six subscales. The Depression–Dejection subscale includes adjectives that describe negative affect (i.e., *sad*, *gloomy*, *discouraged*), whereas the Vigour–Activity subscale includes adjectives that describe positive arousal (i.e., *lively*, *active*, *energetic*). The Fatigue–Inertia subscale describes low arousal (i.e., *fatigued*, *exhausted*, *work out*). While only three of the six POMS subscales were of interest, we administered the entire scale to be consistent with previous research (Husain et al., 2002).

Procedure. Each participant was tested individually. Participants were first administered the Affect Grid and the POMS (order was counterbalanced across participants). After completion of the mood-arousal measures, the participants were seated in a dimly lit room and were asked listen to a piece of music for 10 minutes. To ensure that they actively attended to the music, participants were told they would have to answer a series of questions about the piece afterward. After listening to one of the four versions of the sonata, participants were again administered the Affect Grid and the POMS.

Data analysis. Because we were interested in changes in mood and arousal that occurred after listening to the musical excerpt, we calculated difference scores (after-listening minus before-listening) for each of the five measures (Affect Grid–Arousal, Affect Grid–Pleasure, Depression–Dejection subscale, Vigour–Activity, and Fatigue–Inertia subscale). A 2 (Mode: major vs. minor) by 2 (Tempo: fast vs. slow) analysis of variance (ANOVA) was conducted for each dependent measure.

Results and discussion

Based on Husain et al. (2002), we expected musical mode to influence Affect Grid–Pleasure and POMS Depression–Dejection measures while we expected musical tempo to influence Affect Grid–Arousal, POMS Fatigue–Inertia, and POMS Vigour–Activity subscales. The mean difference

[1] We thank these authors for allowing us to use their music stimuli for the present study.

scores for the five dependent measures are presented in Table 1.

The mode of the musical excerpt had a significant effect on both Affect Grid–Pleasure, $F(1, 20) = 4.33$, $p = .05$, and POMS Depression–Dejection measures, $F(1, 20) = 5.39$, $p = .03$. Participants were in a more pleasant mood after listening to music written in a major mode relative to music written in a minor mode. Tempo had no effect on these two measures ($F < 1.74$, $p > .20$).

The tempo of the music influenced measures of arousal obtained by the Affect Grid–Arousal, $F(1, 20) = 6.50$, $p = .019$, and by the POMS Fatigue–Inertia subscale, $F(1, 20) = 7.04$, $p = .015$, suggesting that participants had higher arousal ratings when listening to fast-tempo music relative to slow-tempo music. Contrary to our predictions, no effect for tempo was found for the POMS Vigour–Activity subscale, $F(1, 20) = 2.17$, $p = .15$. Musical mode had no effect on these three measures ($F < 0.68$, $p > .42$).

Tempo and mode had relatively discrete influences on arousal and mood. Overall, music in a major mode was associated with positive shifts in mood, while music in a minor mode was linked to negative shifts in mood. Furthermore, fast-tempo music increased arousal levels whereas slow-tempo decreased arousal levels. These results verify Husain et al.'s (2002) report that music mode and tempo modulate valence and arousal, respectively.

Typically, when investigating the influence of emotional state on cognitive abilities, researchers verify any changes in mood at the time of the cognitive task. That is, participants complete a questionnaire to register their initial mood, undergo some sort of mood-induction procedure, and then complete the questionnaire again to determine whether any changes in mood occurred, presumably due to the mood-induction procedure. At some point during the experiment, the participant is asked to complete some sort of cognitive task. As we planned to administer the ANT to our participants, we faced a conundrum: When should we administer the second questionnaire to register any mood changes? We could administer it prior to the administration of the ANT (i.e., directly after listening to the musical excerpt). However, there is the possibility that the second mood scale could contaminate the results of the ANT, for example, by making the participants aware of the purpose of the study. To avoid such contamination, we could administer the second mood questionnaire after the completion of the ANT. However, given the duration of the ANT (20 minutes), it is possible that any measurable mood changes would have dissipated by the time the participant finished the experiment. Given that musical mode and tempo have been linked to changes in mood and arousal in several different studies (e.g., Husain et al., 2002; Jefferies et al., 2008; Thompson et al., 2001), and given that the same musical excerpts used in the present study have already been shown to have

Table 1. *Mean (and standard error scores) for each valence/arousal measure across the different musical mode and tempo conditions. The mean values represent difference scores (before-listening minus after-listening)*

Difference scores	*Fast-Major*	*Fast-Minor*	*Slow-Major*	*Slow-Minor*
Affect grid-arousal	1.67 (0.6)	1.83 (0.7)	−0.17 (0.8)	−0.17 (0.9)
Affect grid-pleasure	1.50 (0.8)	−0.33 (1.1)	0.67 (0.6)	−1.17 (1.0)
POMS depression-dejection	−1.00 (1.3)	2.83 (1.8)	−0.83 (1.3)	3.83 (3.1)
POMS Vigour-activity	0.33 (1.5)	1.17 (2.3)	−3.17 (2.5)	−2.17 (2.8)
POMS fatigue-inertia	−4.30 (1.4)	−2.17 (1.7)	−0.83 (1.4)	1.83 (1.0)

Note: For Affect grid-arousal, Affect grid-pleasure, and POMS Vigour-activity measures, positive values correspond with increases in arousal or mood, while negative values correspond with decreases in arousal or mood. For POMS depression-dejection and POMS fatigue-inertia measures, positive values represent decreases in arousal or mood while negative values represent increases in arousal or mood.

orthogonal influences on mood and arousal (Husain et al., 2002), we felt that replicating these results would provide sufficient evidence that musical mode and tempo influenced affective valence and arousal, respectively. Thus, these measures were not administered in the next study where we examined the effect of mood on attention.

STUDY 2: ATTENTION NETWORK TEST

Method

Participants. Sixty-six undergraduate students (mean age = 19.3 years, 16 males, 4 left handed) from McMaster University participated in the current experiment for course credit. Two participants were removed for having a mean error rate greater than 35%. Subjects were randomly assigned to one of four experimental conditions, with 32 participants listening to music written in a major mode (16 for each tempo) and 32 listening to music written in a minor mode (17 for fast tempo and 15 for slow tempo). All participants reported normal or corrected-to-normal vision.

Materials. The music excerpts were the same as used in Study 1. Visual stimuli were presented on a 17-inch computer monitor using MATLAB software and the Psychophysical Toolbox (Brainard, 1997). The target display consisted of a central arrow, pointing either to the left or the right, and four flanking stimuli that could be either straight lines or arrows pointing in the same or opposite direction of the target arrows. Each arrow stimulus subtended approximately 1.6° of visual angle and was presented approximately 1.0° of visual angle above or below fixation in equal proportions.

Procedure. All participants were tested individually. After being seated in a dimly lit room, participants were asked to listen to a piece of music for 10 minutes. To ensure that they actively attended to the music, participants were told they would have to answer a series of questions about the piece afterward. After listening to one of the four versions of the sonata, participants completed the ANT.

Following the music induction, participants completed one block of 24 practice trials and three blocks of 96 experimental trials. During the practice trials, but not during the experimental trials, participants received feedback on their accuracy. The sequence of events for a given trial can be seen in Figure 1. Each trial began with the presentation of a fixation point for a variable duration (400 ms–1600 ms), followed immediately by one of the four cues, which remained on the screen for 100 ms. The target was presented 400 ms after the offset of the cue either above or below the fixation point. The participant responded to the direction of the central arrow as quickly and accurately as possible by pressing the Z key if the target arrow was pointing to the left or the M key if the target was pointing to the right. On one-third of the trials, the target and flanking arrows pointed in the same direction (congruent trials), and on another third of the trials, target arrow pointed in a direction opposite from the four flanking arrows (incongruent trials). The remaining trials contained the target arrow flanked by four straight lines (Figure 1b). The target display remained onscreen until a response was made, to a maximum of 1700 ms. After participants made their response (or after 1700 ms if no response was made), the target display disappeared while the fixation point remained on screen for a duration that depended on the duration of the first fixation period minus the participant's RT. As a result, all trials had the same duration (3500 ms). Alerting, orienting, and executive function scores were calculated using orthogonal subtractions across cue and target conditions as described in the introduction.

Data analysis. Correct reaction times were subjected to a trimmed mean procedure. Classic parametric statistics tend to overlook violations of normality and homoscedasticity, and ignoring these data characteristics can lead to erroneous results (see Erceg-Hurn & Mirosevich, 2008, for a review). We chose to use the trimmed mean as our measure of central tendency because it is less susceptible than the arithmetic mean to the effects of outliers and violations in normality and heteroscedasticity. For each participant, the top and bottom 10% of the data were removed from each of the 12 factorial cells (3 flanker and 4 cue conditions) of the reaction-time data after error trials were removed.[2] We chose to use this trimming procedure because our data demonstrated a strong positive skew. The application of the trimmed mean procedure removed any significant violations of homoscedasticity and non-normality. Measures of alerting, orienting, and executive function were calculated by making orthogonal comparisons across trimmed RTs and error rates for different cue and flanker conditions. These difference scores were used for all analyses.

Trimmed mean RTs and mean error rates were assessed using a multivariate analysis of variance (MANOVA) with the three Attention Networks (alerting, orienting, and executive function) as the within-subject dependent measures and Emotional Valence (positive vs. negative) and Arousal (high vs. low) as between-subject independent variables. Bonferroni corrections were applied to all multiple pairwise comparisons.[3]

Results and discussion

The mean error scores for alerting, orienting, and executive function networks can be viewed in Table 2. The only statistical effect that approached significance in the analysis of error rates was the main effect of Valence on the alerting scores, $F(1, 60) = 3.03$, $p = .09$, $\eta^2 = .008$, with larger alerting scores for negative valence levels than for positive valence levels. All other effects failed to reach significance (Fs < 1.47, $p > .23$).

The trimmed mean RTs for the three networks can be seen in Table 3. There was no effect of emotional valence or arousal on either the alerting or the orienting network (Fs < 1.53, $p > .19$). Individually, Emotional Valence and Arousal did not influence the executive function scores, but the interaction between Valence and Arousal was significant (Figure 2); $F(2, 60) = 7.10$, $p < .01$, $\eta^2 = .11$. When Arousal levels were high, participants in positive valence states had larger flanker congruency effects relative to those in negative valence states, $t(31) = 2.71$, $p < .01$. However, when Arousal levels were low, Emotional Valence did not influence the magnitude of the flanker effect, $t(29) = -0.96$, $p = .34$.

To investigate whether the reduced flanker congruence effects for negative valence was driven by increased RTs for congruent trials or by reduced RTs for incongruent trials, we conducted a 2 (Flanker Congruency: congruent vs. incongruent) × 2 (Valence: positive vs. negative) × 2 (Arousal: high vs. low) mixed-design ANOVA on trimmed mean reaction times. There was a marginal three way interaction between Congruency, Valence, and Arousal, $F(1, 60) = 3.23$, $p = .07$, $\eta^2 = .08$. Although this interaction appeared to be driven by a disproportionate slowing of incongruent RTs in the positive valence, high-arousal condition relative to the other conditions, no post hoc comparisons were significant.

These results indicate that mood inductions influenced executive control scores, but not alerting or orienting scores. More specifically, valence and arousal interacted with one another to moderate the efficiency of executive control, as measure by the ANT.

GENERAL DISCUSSION

The present study sought to determine the extent to which music-induced manipulation of arousal and valence influenced the efficiency of the three

[2] Across all participants, 13 to 22 observations were used in each cell to calculate the individual network scores.

[3] Because the trimmed mean procedure is not commonly applied to reaction-time data, we conducted a secondary analysis to determine whether our results changed when more other outlier rejection procedures were applied to the data. Importantly, there were no differences in the outcome of our analyses whether we used (1) an outlier rejection algorithm (see Van Selst & Jolicoeur, 1994) or (2) log transformations of reaction times.

Table 2. *Mean error scores for alerting, orienting, and executive function networks as a function of emotional valence and arousal. Standard error values are in parentheses*

	Alerting		*Orienting*		*Executive function*	
	No cue	*Double*	*Central*	*Spatial*	*Incongruent*	*Congruent*
Positive mood						
High arousal	2.3% (0.7)	2.6% (0.9)	3.6% (0.9)	2.3% (0.6)	4.6% (1.4)	2.9% (0.7)
Low arousal	4.9% (1.4)	4.4% (1.0)	5.6% (0.8)	3.3% (1.1)	8.5% (2.0)	4.5% (0.9)
Negative mood						
High arousal	1.7% (1.7)	2.4% (1.0)	3.4% (1.0)	3.3% (1.1)	5.9% (1.9)	3.1% (1.1)
Low arousal	3.5% (0.8)	2.1% (0.7)	2.7% (0.8)	2.5% (1.0)	4.9% (1.3)	2.7% (0.8)

attentional networks, as indexed by the ANT. We manipulated emotional valence (positive vs. negative) and arousal (high vs. low) by having different participants listen to music that varied in both mode (major vs. minor) and tempo (fast vs. slow). In a separate experiment, we verified that tempo and mode manipulations did in fact influence arousal and valence, respectively, which is consistent with previous research (Husain et al., 2002; Thompson et al., 2001). Valence and arousal interacted with one another to moderate the magnitude of flanker congruency effects. When arousal levels were high, participants experiencing positive valence showed larger flanker effects relative to participants experiencing negative valence. However, when arousal levels were low, emotional valence had no influence on flanker congruency effects.

These data qualify the levels-of-processing hypothesis (Clore et al., 2001) by highlighting the importance of considering the arousal state of the observer. The data from the high-arousal conditions replicate the recent findings that happy moods produce greater flanker interference than neutral or sad moods (Rowe et al., 2007). However, the data from the low-arousal conditions failed to replicate these results—when participants experienced low-arousal moods, affective valence had no effect on flanker congruency effects. These results suggest that the effect of mood on the scope of attentional processing relies on both valence and arousal. Since the relation between emotional valence and attentional breadth depends on arousal levels, we contend that the levels-of-processing hypothesis needs to be revised so as to address the interactive nature between emotional valence and emotional arousal.

One possible modification to the levels-of-processing hypothesis would consider the independent effects of arousal on object-based properties (Mather, 2007). By this account, arousal serves to enhance within-object feature binding, which biases attention to be directed towards either individual items (i.e., local focus) or associations among the items (i.e., global focus). That is, arousal

Table 3. *Trimmed mean scores for alerting, orienting, and executive function networks as a function of emotional valence and arousal. Standard error values are in parentheses*

	Alerting		*Orienting*		*Executive function*	
	No cue	*Double*	*Central*	*Spatial*	*Incongruent*	*Congruent*
Positive mood						
High arousal	555.6 (19.9)	506.0 (13.4)	515.4 (15.2)	472.9 (15.9)	563.4 (18.7)	513.0 (15.6)
Low arousal	537.5 (8.7)	500.8 (10.5)	502.8 (11.6)	470.7 (10.0)	546.7 (10.9)	501.2 (10.9)
Negative mood						
High arousal	546.1 (15.9)	503.1 (14.9)	512.9 (14.8)	486.4 (11.0)	545.5 (15.0)	509.0 (14.3)
Low arousal	567.3 (14.3)	520.0 (12.0)	521.2 (10.4)	486.8 (11.8)	570.0 (11.9)	522.7 (12.6)

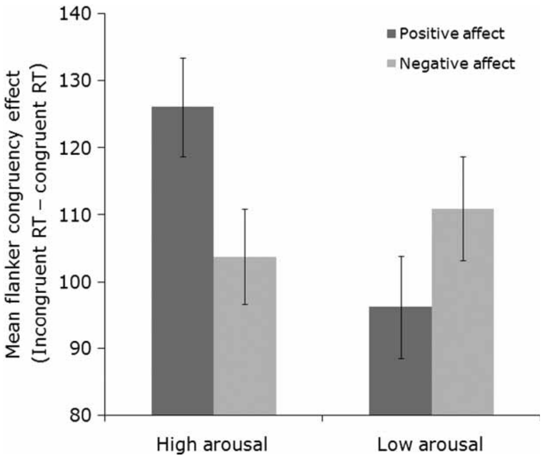

Figure 2. *Trimmed mean flanker congruency effect (incongruent RT–congruent RT) for the four groups of participants induced into different emotional states. Larger executive function scores are associated with poorer executive control. Error bars represent standard error of the mean.*

focuses attention so as to enhance within-object binding. When arousal levels are low, perceptual grouping will be degraded, making the effects of affective valence less evident. While consistent with the data and the findings from both Clore et al. (2001) and Mather (2007), this explanation is speculative and must be examined with future research. Additionally, there are several alternative explanations. For example, it is possible that moods characterised by high arousal are viewed as more intense, and as a result, the effects of valence on global/local processing are enhanced when arousal is high. Another possible explanation is that arousal heightens self-focused attention, which may consequently enhance the effects of valence on the scope of attention. Self-focused attention has been defined as "an awareness of self-referent, internally generated information that stands in contrast to an awareness of externally generated information derived through sensory receptors" (Ingram, 1990, p. 156). Highly arousing emotions, such as fear and joy, have been shown to heighten an individual's self-focus (Panayiotou, Brown, & Vrana, 2007). Therefore, when experiencing high arousal, participants exhibit more self-focus, which could enhance the influence of positive and negative valence on global and local processing, respectively. Further research is needed to understand how arousal influences the predictions made by the levels-of-processing hypothesis. Nonetheless, it is clear from the present research that arousal and valence interact with one another to influence the scope of attentional processing, making it essential for researchers to consider both of these affective dimensions when examining links between mood and attention.

The lack of an effect of valence and arousal on alerting and orienting scores should be interpreted with caution. Several reasons are possible for the lack of an observed effect. For example, the ANT may not possess sufficient sensitivity to detect the effect. The reliability of the ANT's measures for the three networks has not been particularly high in the few studies that have examined it (i.e., Fan, Wu, Fossella, & Posner, 2001; MacLeod et al., 2010; Rueda et al., 2004). For example, Fan et al. (2001) reported test–retest reliability scores for the alerting, orienting, and conflict measures of .36, .41, and .81, respectively. MacLeod et al. (2010) found similar patterns of reliability using a much larger sample size ($N = 1129$); reliability estimates were moderate for the executive control network ($r = .68$) and low for both the alerting ($r = .24$) and orienting ($r = .38$) networks. These results suggest that the ANT may not be the most efficient way to measure alerting and orienting. Future researchers should consider the effects of affective valence and arousal on other measures of alerting and orienting.

In fact, there is some evidence that arousal may modulate spatial orienting. In a classic exogenous cueing task, participants were asked to respond to targets that were preceded by pictorial cues varying in valence and arousal. Spatial orienting was modulated by the arousal level of the cue stimulus; disengagement of spatial attention was slower for cues high in arousal than for cues low in arousal (Vogt, De Houwer, Koster, Van Damme, & Crombez, 2008). While the task used by Vogt et al. measures a different type of orienting than the ANT, it is still possible that our experiment could have revealed a similar effect had we used a more sensitive task. Based on these findings, we cannot definitely say whether the absence of an effect for alerting and orienting measures occurs because it is a true effect or because the ANT is simply not powerful enough to detect a true effect of valence and arousal on alerting and orienting scores.

Furthermore, it is also possible that our mood inductions were too weak to have a measurable influence on alerting or orienting scores. While music is commonly used to induce different affective states (e.g., Corson & Verrier, 2007; Jefferies et al., 2008; Rowe et al., 2007; Storbeck & Clore, 2005), many of these studies also had participants recall mood-appropriate events during the mood-induction process. Even though the music used in the present study has been shown to influence valence and arousal in a previous study (Husain et al., 2002), it is still possible that the mood changes induced by these stimuli were not sufficient to influence alerting and orienting scores. Nonetheless, the influence of arousal on flanker congruency effects in the present study suggests that valence and arousal may not have independent effects on some dependent measures.

The pattern of results observed in the present study emphasises the importance of manipulating both emotional valence and arousal when investigating the effects of emotion on visual processing. Individuals who experienced positive valence levels had less efficient control over their responses than those who experienced negative valence levels, but only when these moods were accompanied by high arousal levels. When participants experienced low arousal, emotional valence did not influence the scope of attentional processing. These results partially support the levels-of-processing hypothesis (Clore et al., 2001) but suggest that the hypothesis be updated to consider the influence of emotional arousal on the scope of visual attention. We theorised that arousal serves to enhance within-object feature binding, which biases attention to be directed towards either individual items (i.e., local focus) or associations among the items (i.e., global focus). Future researchers need to examine emotional valence and arousal together in order to determine whether experimental effects are due to valence, arousal, or the interaction between the two.

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