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Emotional Distractors Can Enhance Attention

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Abstract

The deleterious effects of emotional distractors on attention have been well demonstrated. However, it is unclear whether emotional distractors inevitably disrupt task-relevant attention. In the research reported here, the impact of the valence and arousal of distracting emotional stimuli and individual differences in anxiety on task-relevant processing were examined using multilevel modeling. Consistent with prior literature, results showed that high-arousal negative distractors, compared with positive and neutral distractors, were associated with poorer task-relevant attention. However, low-arousal negative distractors were associated with better task-relevant performance than were positive and neutral distractors. Furthermore, these effects were accentuated by individual differences in worry. These findings challenge assumptions that distraction and worry must be minimized for augmented attentional performance. Overall, these results emphasize the importance of taking into account emotional dimensions of arousal and valence as well as individual differences in anxiety when examining attention in the presence of emotional distractors.

Keywords

emotions, attention, distractors, valence, arousal, anxiety

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Attention serves to prioritize information that has survival value by preferentially allocating resources to stimuli that indicate threat or reward (for a review, see M. M. Bradley, 2009). A consequence of this preferential allocation of attention is that performance on concomitant tasks may be impaired (Algom, Chajut, & Lev, 2004). For example, a weapon in a scene captures attention at the cost of attention to peripheral details, such as the facial characteristics and clothing of the person holding the weapon (Loftus, Loftus, & Messo, 1987). In a search task, target detection is slow when one of the distractors is an emotional face compared with when there is no emotional distractor or the target is emotional and the distractors are neutral (Hodsoll, Viding, & Lavie, 2011).

Although the deleterious effect of emotional distractors on attention has been well demonstrated, three lines of research led us to question whether emotional distractors inevitably worsen task-relevant processing. First, dimensions of arousal and valence of a stimulus can differentially alter attention to a subsequently displayed target, which prompted us to examine whether these dimensions may also differentially affect attention to concurrently displayed attentional targets. High emotional arousal can enhance subsequent cognitive performance by improving perception of high-priority information and weakening perception of low-priority information (Mather & Sutherland, 2011). Low-arousal images presented prior to target identification broaden and high-arousal images narrow attentional scope (Gable & Harmon-Jones, 2010). Levels of valence also affect attention differently. Negative moods encourage focus on the finer details of a scene at the expense of gist, and positive moods promote attention to the gist of a scene at the expense of details (Gasper & Clore, 2002). Finally, arousal interacts with valence to affect attention in unique ways.

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Low-arousal negative mood improves and high-arousal negative mood impairs target-identification accuracy, with no difference between low-arousal and high-arousal positive-mood conditions (Jefferies, Smilek, Eich, & Enns, 2008).

A second line of research has demonstrated that task-irrelevant distractors can improve performance. Participants who were instructed to focus on music, their last vacation, or planning for a dinner party while detecting targets performed better than did participants who were asked to focus on the task (Olivers & Nieuwenhuis, 2005). These performance-enhancing effects could be due to modulation of attentional focus by arousal induced by the distractors (Easterbrook, 1959; Olivers & Nieuwenhuis, 2005). The effects of task-irrelevant distractors on performance have been examined more directly in research investigating the impact of irrelevant noise on task performance. Visual search and vigilance have been shown to improve in the presence of mild acoustic distraction (Broadbent, 1971). Researchers have hypothesized that these performance improvements occur as a result of the arousing nature of noise because optimum levels of arousal have been shown to enhance performance (Broadbent, 1971). Given that arousal is a key dimension of emotion, it is possible that, rather than universally impairing performance, emotional distractors enhance attentional performance under certain conditions.

A third line of research has indicated that individual differences in anxiety moderate the impact of arousal and valence on task performance. For example, poor attentional performance in the presence of task-irrelevant emotional distractors has been found across many types of anxiety (Williams, Mathews, & MacLeod, 1996). However, compared with other types of anxiety, worry has been hypothesized to enhance effort allocation and implementation of attentional-control strategies, thereby improving task performance (Eysenck & Calvo, 1992). Additional support for the multifaceted nature of anxiety has come from findings of distinct patterns of brain activation for different types of anxiety. For example, participants high in anxious apprehension (e.g., worry) displayed greater activation in left lateralized brain regions implicated in verbal processing, including the left inferior frontal gyrus and left inferior temporal gyrus, while ignoring negative words. In contrast, participants high in anxious arousal (e.g., panic) displayed greater activation in a right posterior brain region implicated in vigilance and arousal (Engels et al., 2007). Differences in the cognitive and brain mechanisms of anxiety dimensions (Nitschke, Heller, & Miller, 2000) suggest that individual differences in anxiety differentially affect attentional performance.

In summary, several lines of evidence have demonstrated complex relationships among arousal, valence, anxiety, and attention, which calls into question whether emotional distractors always impair attentional-task performance. In the research reported here, the effects of emotional distractors and individual differences in anxiety on task-relevant processing were examined using multilevel modeling. Results showed that emotional distractors do not inevitably impair task-relevant processing. Rather, the valence and arousal of distractors interact to affect task-relevant processing. Specifically, compared with positive and neutral distractors, high-arousal negative distractors are associated with poor performance, whereas low-arousal negative distractors are associated with improved task-relevant performance. This effect was accentuated in participants who scored high on a measure of worry. These findings indicate that it is critical to consider the arousal and valence of the distractors as well as individual differences in anxiety when examining attention and cognitive control in the presence of emotional distractors.

Method and Results

A total of 149 undergraduates (82 female and 67 male; mean age = 18.33 years, *SD* = 0.76) participated in return for course credit. Participants completed an attention task in which they viewed 256 images from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2005); each image contained a colored dot near one of its corners. Images were presented in 16 blocks of positive, neutral, and negative trials. Studies using blocked designs are generally more effective at eliciting emotion-related interference and are more ecologically valid than event-related designs (Compton et al., 2003). In the present study, there were 16 trials in each block with a new trial every 2,000 ms. On each trial, an IAPS image containing a superimposed dot was presented for 1,500 ms, followed by a fixation cross presented for 500 ms. The dots were red, yellow, green, or blue; no color occurred more than two consecutive times. Participants were asked to ignore each image and identify the dot color as quickly and accurately as possible (see Fig. 1 for an example of images used in the dot-color identification task). Dot colors were identified using a response pad with two buttons, one for each hand. Each button corresponded to a color response. The mapping of color-response buttons to the left and right hands was counterbalanced across participants to control for laterality-related effects in reaction time. STIM software (James Long Company, Caroga Lake, NY) was used for task presentation and data collection.

Distractor stimuli were 64 positive, 128 neutral, and 64 negative images with superimposed dots. The color and position (upper left, upper right, lower left, or lower right corner) of the dots were randomly assigned to the images.

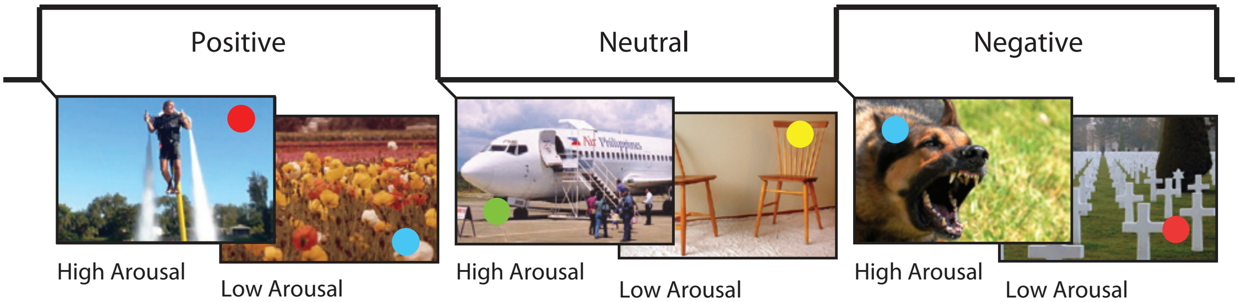

Fig. 1. Example stimuli similar to those used in the dot-color identification task. Participants' task was to identify the color of the dot on each image. The task-irrelevant images (drawn from the International Affective Picture System; Lang, Bradley, & Cuthbert, 2005) on which the dots were superimposed varied along dimensions of arousal and valence. The images in this figure are not from the International Affective Picture System, but they are comparable to the ones used in the task.

The dot-color identification task was relatively low in perceptual load, which allowed for sufficient perceptual resources to process the task-irrelevant images (Pessoa, 2009) and permitted examination of variance associated with emotional dimensions of the task-irrelevant stimuli. Anxiety was assessed using the Penn State Worry Questionnaire, a 16-item instrument designed to measure the trait of worry (Meyer, Miller, Metzger, & Borkovec, 1990). Anxious arousal and anhedonic depression were assessed using the Mood and Anxiety Symptom Questionnaire (with 17 items and 8 items, respectively; Watson et al., 1995).

Multilevel modeling is a form of advanced regression analysis that allows for the incorporation of both fixed and random effects in a nested model. Because multilevel modeling requires no aggregation across trials or participants (Linck, Kroll, & Sunderman, 2009), the full dimensions of each variable—arousal, valence, worry, anxious arousal, and anhedonic depression—could be employed as fixed effects and the participant as a random effect predicting reaction time for dot-color identification. Data from each participant and for each trial were included in the analyses without aggregation. Multilevel modeling analyses performed dimensionally in this manner avoid the loss of information that results from categorical analyses (Linck et al., 2009; Segerstrom & Sephton, 2010). Normative ratings of the images from the IAPS (Lang et al., 2005) were used as measures of arousal and valence, and scores from the questionnaires described earlier were used as measures of anxiety and depression. All predictor variables were tested simultaneously.

These analyses yielded main effects for arousal and valence, nonsignificant linear and quadratic effects for worry, two-way interactions between arousal and valence and between valence and worry, and a three-way interaction of arousal, valence, and worry (see Table 1 for variable effects and interactions and Fig. 2 for relationships between reaction time and arousal level). Anxious arousal and anhedonic depression did not show significant effects. To probe the structure of the three-way interaction, the significance of simple slopes and differences between the slopes were computed separately for arousal and valence (see Fig. 2) at lower and higher levels of worry (Aiken & West, 1991).

Although all analyses were performed using arousal, valence, and worry as continuous variables, the three-way interaction depicted in Figure 2 was based on predictor values 1 standard deviation above and below the mean for purposes of illustration (Aiken & West, 1991).

At lower levels of worry, scenes lower in arousal were associated with faster dot-color identification for negative, neutral, and positive distractors (see Table 2). The relationship between arousal and reaction time was stronger for more negative distractors compared with neutral distractors and for more neutral distractors compared with positive distractors. This pattern of results was exaggerated at higher levels of worry. Lower arousal was associated with faster reaction times, and this effect was greater for negative distractors than for neutral distractors. The relationship between arousal and reaction time was again stronger for more negative distractors compared with neutral distractors and for more neutral

Table 1. Characteristics of Distractor Images Predicting Reaction Time for Dot-Color Identification

Predictor	β	*t*	*p*
Arousal	0.0269 (0.0001)	28.28	.001
Valence	0.0027 (0.0012)	2.34	.019
Worry	–0.0001 (0.0005)	–0.24	.813
Arousal × Valence	–0.0070 (0.0006)	–10.76	.001
Arousal × Worry	0.0000 (0.0001)	0.034	.734
Valence × Worry	0.0002 (0.0001)	2.41	.016
Arousal × Valence × Worry	–0.0001 (< 0.0001)	–2.23	.026

Note: Standard errors are shown in parentheses.

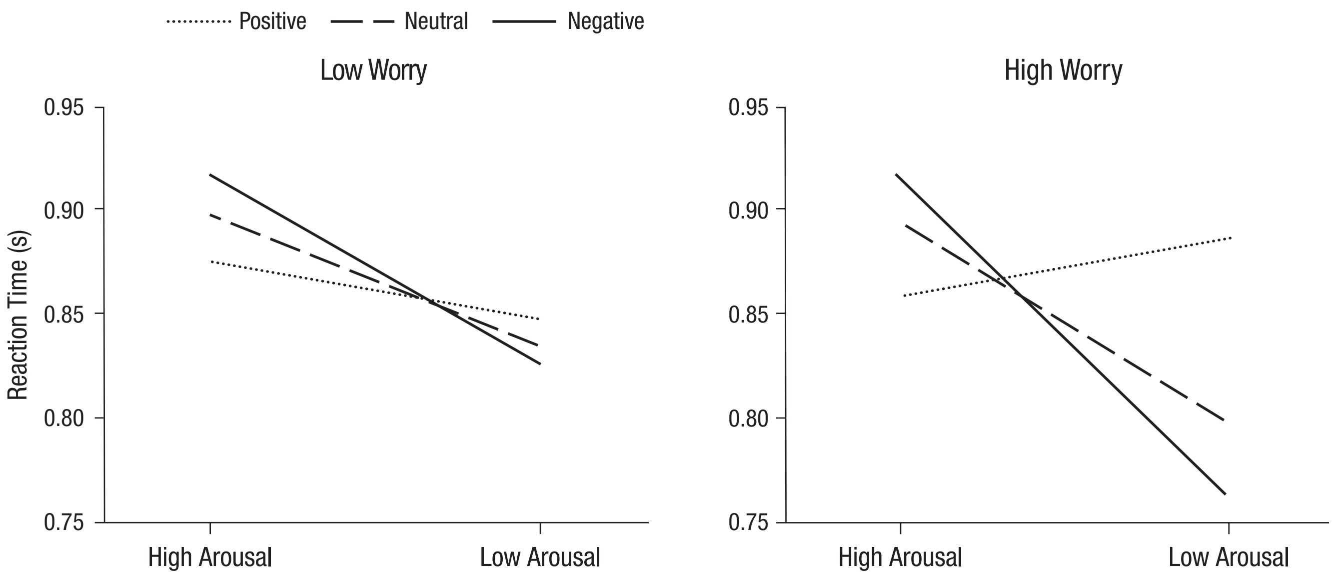

Fig. 2. Mean reaction time as a function of arousal and valence of distractor images. Results are shown separately for participants with (a) low levels of worry (1 *SD* below the mean) and (b) high levels of worry (1 *SD* above the mean).

distractors compared with positive distractors. Finally, the relationship between arousal and reaction time for negative distractors was stronger in participants with higher, relative to lower, levels of worry, $t = 181.89$,[1] $p < .001$. These results were not mediated by visual clutter (Rosenholtz, Li, & Nakano, 2007) or spatial frequency (Delplanque, N'Diaye, Scherer, & Grandjean, 2007) of the images.

Discussion

The present findings demonstrate that emotional distractors do not universally impair task-relevant processing. Distractor valence and arousal interact such that, compared with positive and neutral distractors, low-arousal negative distractors are associated with enhanced performance and high-arousal negative distractors are associated with degraded performance. This relationship between arousal and valence is exaggerated by worry. The enhancing effect of emotional arousal on task-relevant processing has been demonstrated in past studies but only when the arousing stimulus did not compete directly with the task-relevant stimulus, for example, when the arousing stimulus preceded the task-relevant stimulus or was presented in a different modality (Broadbent, 1971; Mather & Sutherland, 2011; Teichner,

Table 2. Results of Analyses on Image Valence as a Predictor of Reaction Time in Participants With High and Low Levels of Worry

	Slope		
Group and image valence	Slope	*t*	*p*
High worry			
Positive	.01 (.002)	5.03	< .001
Neutral	.03 (.001)	21.40	< .001
Negative	.04 (.002)	19.22	< .001
Difference in slopes: neutral vs. positive images	—	–17.30	< .001
Difference in slopes: negative vs. neutral images	—	16.40	< .001
Low worry			
Positive	.02 (.002)	6.97	< .001
Neutral	.03 (.001)	18.64	< .001
Negative	.04 (.002)	16.46	< .001
Difference in slopes: neutral vs. positive images	—	–10.36	< .001
Difference in slopes: negative vs. neutral images	—	12.53	< .001

Note: Standard errors are shown in parentheses. Although all multilevel modeling analyses were performed using arousal, valence, and worry as continuous variables, the results of slope analyses probing the nature of the three-way interaction were based on valence and worry values 1 standard deviation above and below the mean (Aiken & West, 1991).

Arees, & Reilly 1963). However, the present results demonstrate that even when a negative stimulus is in direct competition with the task-relevant stimulus, lower arousal is associated with improved task-relevant processing.

According to Scherer (1994), emotion has evolved as a relevance-detection and response-preparation system. The former function allows organisms to perceive and evaluate surrounding stimuli (some may be irrelevant for survival), and the latter allows for rapid, appropriate responses. Scherer reconciled the apparent contradiction between these two functions by considering the intensity (arousal) of the emotional stimulus. Presented with an intense emotional stimulus, the organism cannot take a risk and responds in a rapid, automatic manner. When presented with a less intense stimulus, the organism can appraise the context and gather information. In the present study, intense, high-arousal negative distractors may have been processed relatively automatically, which resulted in poorer task-relevant processing. However, low-arousal negative distractors may have promoted exploration, resulting in faster detection of task-relevant stimuli. This explanation is consistent both with Pessoa's (2009) dual-competition model, which posits that low-threat stimuli enhance processing of emotional items, and with Whalen's (1998) view that low-arousal information is difficult to interpret and thereby promotes vigilance and enhanced processing of the surrounding context. Research supporting these theories has shown that low-arousal information widens the scope of attention (Gable & Harmon-Jones, 2010) and enhances subsequent attentional performance (Jefferies et al., 2008; Pessoa, Padmala, Kenzer, & Bauer, 2012). The present study demonstrates that low-arousal information enhances task-relevant processing even when the information is in direct competition with the task-relevant stimulus.

The present findings are also consistent with research results showing that high-arousal, task-irrelevant stimuli and negative distractors impair performance (Algom et al., 2004; Easterbrook, 1959; Loftus et al., 1987). In the research reported here, higher arousal was associated with poorer task-relevant performance, and this association was stronger for negative than for neutral and positive distractors. This finding could be the consequence of high negative arousal narrowing the focus of attention to the arousal-eliciting stimulus, resulting in reduced processing of peripheral, task-relevant information (Easterbrook, 1959; Gable & Harmon-Jones, 2010). For example, eye movement studies have shown that participants direct more attention to negative images and less attention to peripheral details (Riggs, McQuiggan, Farb, Anderson, & Ryan, 2011).

The absence of arousal-related differences for positive stimuli in the present study is consistent with results of other studies finding no attentional difference between positive and neutral mood (Bruyneel et al., 2013) or between low-arousal and high-arousal positive mood (Jefferies et al., 2008). However, these findings are inconsistent with results from studies demonstrating that attention is modulated by motivational intensity, such that positive stimuli high in approach motivation narrow the focus of attention and positive stimuli low in approach motivation widen the focus of attention (Gable & Harmon-Jones, 2008). Although related to emotional arousal, the dimension of motivational intensity is distinct because it requires an impulse to move toward or away from a stimulus (Gable & Harmon-Jones, 2008). In the present paradigm, greater arousal-related differences for negative than for positive stimuli may have been due to a negativity bias in processing (Cacioppo & Berntson, 1994) or to the fact that the positive stimuli did not vary greatly in the approach motivation they elicited, which may largely mediate the attentional effects of positive stimuli (Gable & Harmon-Jones, 2008).

Finally, anxiety exaggerated the Arousal × Valence interaction effect on attentional processing. Anxiety biases attention toward threat and slows disengagement from threatening stimuli but not from neutral or happy stimuli (Fox, Russo, Bowles, & Dutton, 2007). This may explain why higher-arousal negative distractors were associated with poor task-relevant processing compared with neutral or positive distractors. Worry and low-arousal negative distractors both encourage a generic vigilance toward threat in the environment (Mathews, 1990; Whalen, 1998), and worry also has been hypothesized to improve effort allocation and attentional-control strategies in some contexts (Eysenck & Calvo, 1992), which could explain why these distractors were associated with faster target detection in high-worry participants than in low-worry participants.

Furthermore, these relationships between distractor arousal and performance were not associated with anxious arousal or depression. This finding is consistent with results from studies that have found an attentional bias to threat for participants high in trait anxiety but not for participants with elevated depression scores (B. P. Bradley, Mogg, Falla, & Hamilton, 1998). Different types of threat may encourage vigilance in different kinds of anxiety, whereby nonspecific threats promote vigilance in people with high levels of worry (Mathews, 1990) and immediate threats promote vigilance in people with high levels of anxious arousal (Nitschke et al., 2000). The IAPS images used in this experiment may not pose sufficiently immediate threat to produce an interaction between anxious-arousal scores and arousal and valence ratings.

Overall, the present results indicate that low-arousal negative information enhances task-relevant processing even when the information is in direct competition with the task-relevant stimulus—a novel finding that could be applicable in diverse situations requiring attention. A commonly held view is that environments should be distraction free and individuals should be worry free to reach top performance. Because the present study suggests that low-arousal distractors are associated with enhanced task performance, it is important to determine whether this commonly held view is based solely on distractors that are highly emotionally arousing or cognitively demanding. Furthermore, worry is associated with greater impairment in the presence of high-arousal distractors and with better performance in the presence of low-arousal distractors, which challenges the notion that minimizing worry enhances performance. The present findings highlight the need for future research examining whether low-arousal negative distractors are associated with improved performance across a range of attentional tasks and settings, as well as the clinical relevance of the present findings for anxiety. In sum, these findings suggest that a more nuanced view of emotion, incorporating dimensions of arousal and valence as well as individual differences in anxiety, is necessary for a complete understanding of how emotional distractors affect attention.

Author Contributions

A. Mohanty developed the study design and collected data. T. J. Sussman analyzed the data and drafted the manuscript. A. Mohanty, W. Heller, and G. A. Miller provided supervision and critically revised the manuscript. All authors approved the final version of the manuscript for submission.

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Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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Note

1. It is difficult to estimate degrees of freedom in a mixed multilevel modeling analysis with fixed and random factors because there is no definitive way to count the number of parameters (Baayen, Davidson, & Bates, 2008). Although the degrees of freedom can be approximated using certain techniques, given the large numbers of observations in our analyses, we can assume that the t distribution has converged to the standard normal distribution and that absolute t values greater than 2 are significant (ps < .05).

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