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## Distracting Tracking: Interactions between Negative Emotion and Attentional Load in Multiple Object Tracking

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### Abstract

Stimuli that attract exogenous attention have been shown to interfere with behavioral performance on various tasks. In the present study, participants performed multiple object tracking (MOT) in conditions where either neutral or negatively valenced images were flashed at fixation. Results reveal a significant impairment of tracking accuracy in the emotional MOT conditions compared to the neutral conditions specifically at the highest level of task difficulty. These findings suggest that emotional distraction is most detrimental when maximal endogenous attentional engagement is required. This interaction between emotional distraction and attentional load is inconsistent with existing models of emotional distraction.

### Keywords

attention; emotion; distraction; multiple object tracking

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Exogenous attention is an automatic, stimulus-driven process engaged when a salient item suddenly appears within the visual field. This reflexive orientation confers an adaptive advantage when the distracting stimulus could be predator, prey or some other object of potential survival value (Berger, Henik, & Rafal, 2005; Carretié et al., 2013; Carretié, 2014; Corbetta, Patel, & Shulman, 2008). However, in cases with no imminent threat, as in experimental conditions involving exposure to emotionally salient yet innocuous distractors, exogenous attention generally interferes with performance (Carretié, 2014; Dolcos & McCarthy, 2006; Shackman et al., 2006; Shafer et al., 2012; Wessa, Heissler, Schönfelder, & Kanske, 2013). Indeed, numerous studies have demonstrated the negative impact of emotional distraction on various tasks, manifested in slowed reaction times, decreased accuracies, and increased latencies of and deviations in saccades (see Carretié, 2014, for a review).

Past research has also investigated the differential impact of emotional distraction at varying levels of task difficulty. Most findings suggest either that (1) emotions are processed automatically or that (2) attentional resources must be available for distraction to occur.

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Assuming (1), the “traditional” view, performance, whether assessed in terms of accuracy or reaction time, should be equally detrimentally affected by emotional distraction regardless of task difficulty, an observation supported by several experiments (Hindi Attar, Müller, & El-Deredy, 2012; Mitchell et al., 2007; Oei et al., 2012; Vuilleumier, Armony, Driver, & Dolan, 2001). On the other hand, under (2), the limited resources view derived from Desimone and Duncan’s (1995) biased competition model of attention, emotional stimuli, like all stimuli, must compete for attentional resources in order to be processed. According to this perspective, if participants are fully endogenously attending to a task with a high attentional load, they should be less likely to be as affected by emotional distraction than they would be when performing an easier task, as fewer resources are free to be absorbed by the distracting stimulus. Several studies have reinforced the validity of this competing theory (Erthal et al., 2005; Junhong, Renlai & Senqi, 2013; Pessoa, McKenna, Gutierrez, & Ungerleider, 2002) as well.

Despite intensive research on the effects of emotional distraction on working memory and attention, no literature specifically addresses the impact of emotional distraction on multiple object tracking (MOT; Cavanagh & Alvarez, 2005; Frank et al., 2016; Pylyshyn & Storm, 1988), a task permitting parametric modulation of endogenous attentional load. The MOT paradigm presents subjects with a set of visual items, a subset of which are initially and temporarily marked as targets and all of which subsequently move for a period of time. Participants must track the target objects while ignoring visually identical distractors. Increasing the number of targets augments endogenous attentional load.

Here we investigate the effects of emotional distraction on MOT performance at different endogenous attentional loads. Theories of type (1), according to which emotions are processed automatically, would predict that emotional images should hinder performance regardless of the degree of attentional load. Theories of type (2), according to which attentional resources must be available to become distracted at all, would predict that emotional images would be most distracting at low loads. The current study seeks to evaluate which theory, if either, best predicts performance, using a MOT paradigm in which images from the international affective picture system (IAPS) are presented at central fixation. Additionally, because the efficiency of endogenous attention may be sensitive to temporal predictability of distractors, presentation style is also varied in the experimental paradigm. Therefore, participants performed a MOT task involving either random or continuous presentation of either emotionally neutral or emotionally negative IAPS images at different tracking loads.

## Materials and Methods

### Participants

Twenty participants (11 females, mean age =  $21 \pm 3$  years) were recruited from the Dartmouth College community. This sample size is consistent with or larger than several of the earlier cited studies investigating both emotional distraction (Hindi Attar et al., 2012; Mitchell et al., 2007; Pessoa et al., 2002; Vuilleumier et al., 2001) and MOT (Alvarez & Franconeri, 2005; Pylyshyn & Storm, 1988). All participants had normal or normal-to-

corrected vision and gave informed written consent prior to participation. The study was approved by the internal review board at Dartmouth College.

### Multiple Object Tracking

**Cueing period (2 s)**—Participants were presented with eight stationary white balls on a black background placed at a distance  $7^\circ$  from the fixation point, aligned in a circle on a computer screen. A subset of one to four of these balls turned green for 2 s before turning white again, marking them as target balls (Figure 1). The non-target balls remained white. The initial position of each ball was slightly jittered for each trial.

**Tracking period (14 s)**—Subsequent to cueing, all eight balls began to move at a speed of  $7.5^\circ/s$ . The motion trajectory of each ball for every trial was precomputed but employed in random order; ball movement was restricted to the boundaries of the screen, and motion trajectories were constrained to avoid collisions or overlap with other balls or with the fixation point. Throughout the tracking period, either neutral or emotionally salient IAPS images were flashed at the center of the screen (image display size =  $5^\circ \times 4^\circ$ ) (Figure 1). Overlap between the balls and IAPS images was minimal, and the balls were outlined in black to ensure their visibility even when, on rare occasions, they did overlap the image. In the “emotional continuous” condition, emotionally unpleasant IAPS images flashed at a constant rate of three images per second; in the “emotional random” condition, emotionally unpleasant IAPS images flashed at pseudorandom intervals with an average rate of one image every four seconds; the “neutral continuous” and “neutral random” conditions were identical with the first two conditions, respectively, except that neutral images were presented. Each image appeared for one-third of a second. Participants were instructed to ignore these images but to maintain fixation and focus on covertly tracking the target balls.

**Response period (2 s)**—After the tracking period, all balls froze and one of the balls turned green in a two-alternative forced-choice paradigm (Figure 1). Participants indicated by buttonpress whether this ball was a target or distractor. Participants had 2 s to respond. For half of the trials for each tracking load, the response ball was a target. Thus chance performance would be 50% accuracy.

**Feedback Period (2 s)**—Following the response period, the central fixation point turned green to indicate a correct response and red to indicate either an incorrect response or absence of a response (Figure 1).

### Stimulus Presentation

Visual stimuli were presented using Psychtoolbox (Brainard, 1997; Pelli, 1997), running in MATLAB (MathWorks, Natick, MA). The stimuli were shown on an LCD monitor (15-inch,  $40.0^\circ \times 30.5^\circ$ ) with a 60-Hz refresh rate and 63-cm viewing distance. The order of presentation of each of the four conditions varied randomly. However, during one run, each condition appeared 16 times, summing to 64 trials per run. The number of balls tracked for a trial varied from one to four, a load evenly distributed across all conditions. For a given condition in a run, four trials were presented for each tracking load. All participants performed two runs, totaling 128 trials and taking approximately 45 minutes.

## IAPS Images

IAPS image ratings range from one to nine, with one representing a low rating on the dimension of pleasure (valence) or arousal and nine indicating a high rating. Images were randomly chosen from a pre-selected set of IAPS images (Lang, Bradley, & Cuthbert, 2008). For the emotional conditions, these images were highly unpleasant (mean valence =  $2 \pm 0.4$ ) and arousing (mean arousal =  $6 \pm 0.6$ ). During both neutral conditions, neutral IAPS images with average valence (mean valence =  $5 \pm 0.4$ ) and low arousal (mean arousal =  $3 \pm 0.6$ ) were presented. The set of emotional photos contained 136 items, including images of mutilated bodies, scenes of destruction, and vomiting; that of neutral images included 185 items, encompassing pictures of inanimate objects and plants, scenes, and people and animals. While the number of images in the neutral condition exceeds that in the emotional condition, this disparity should, if anything, enhance distraction during the neutral condition, an effect contrary to the later results. Similar reasoning applies to a *post-hoc* analysis of visual features: while the mean luminance of neutral images was greater than that of the emotional images (0.42 versus 0.38 normalized,  $t(321) = 2.2$ ,  $p = 0.03$ ), higher luminance should increase distractibility in the neutral condition. Comparing mean spatial frequencies of the emotional and neutral images (Willenbockel et al., 2010) yielded non-significant results ( $t(228) = 1.76$ ,  $p = 0.08$ ), though the average spatial frequency of neutral images was slightly higher than that of emotional images (2.76 versus 2.37 cycles/image).

## Eye Tracking

Participants wore an Eyelink 1000 Head Mount eye tracker (SR Research, Oakville, Ontario, Canada) that sampled the horizontal and vertical position of the right eye at a rate of 250 Hz. Subjects placed their chins on a chin rest for the duration of the experiment to enable proper functioning of the eye tracker. Before each run, the eye tracker was re-calibrated to ensure its accuracy.

## Results

### Behavioral Performance

As in previous MOT studies, tracking accuracy decreased with more target balls (see Figure 2). A repeated measures ANOVA with the three factors of Presentation (continuous or random), Emotion (emotionally negative or neutral images), and Tracking Load (one to four targets) confirmed the significant impact of task difficulty on performance ( $F(3, 19) = 28$ ,  $p < 0.001$ ,  $\eta_p^2 = 0.6$ , observed power = 1.0). Main effects of Emotion and Presentation were negligible, as were interactions between Emotion and Presentation; Presentation and Load; and Emotion, Presentation, and Load ( $p > 0.1$ ). However, the interaction between Emotion and Load was significant ( $F(3, 19) = 3.2$ ,  $p = 0.03$ ,  $\eta_p^2 = 0.14$ , observed power = 0.7), indicating that emotional and neutral distraction exerted differential influences at different loads. Examining each tracking load individually with a repeated measures ANOVA yielded a significant influence of emotion on participants' performance only at the highest tracking load ( $F(1, 19) = 6.5$ ,  $p = 0.02$ ,  $\eta_p^2 = 0.26$ , observed power = 0.7). For all other tracking loads, the impact of emotion was not significant ( $p > 0.3$ ). The interaction between Emotion and Tracking Load was mostly driven by a greater decrease in performance for the emotional

condition relative to the neutral condition for the tracking load of four compared to that at a load of one. Similar trends persisted with tracking loads of two and three, albeit more subtly (Figure 2).

### Eye-Tracking Data

Eye-tracking data confirmed that participants largely maintained fixation throughout the task. Average deviation of the eye over a trial across all conditions was  $0.92^\circ \pm 0.7^\circ$ . Examining the effects of the factors of Emotion, Presentation, and Load revealed no notable main effects and no interactions between Emotion and Presentation; Emotion and Load; or Presentation, Emotion, and Load. However, a significant interaction between Presentation and Load was found ( $F(1, 19) = 2.8, p = 0.05, \eta_p^2 = 0.13$ , observed power = 0.65), stemming from a marginally significant effect of Presentation at the tracking load of three ( $F(3, 19) = 4.3, p = 0.05, \eta_p^2 = 0.19$ , observed power = 0.5). As this interaction concerns different factors than the interaction found in performance, the interaction between Presentation and Load is irrelevant to tracking accuracy.

### Discussion

The present study aims to investigate emotional distraction at different levels of endogenous attentional load, using a MOT paradigm in which emotionally unpleasant or neutral IAPS images flashed centrally, either at fixed or pseudorandom intervals. The results show decreased performance with increasing tracking load and, more importantly, a greater negative impact of emotional versus neutral image distraction on performance only at the highest tracking load (four targets), regardless of presentation intervals.

The IAPS images were intended to engage exogenous attentional mechanisms, which enable a reflexive, transient response. This bottom-up process could interfere with endogenous attention, a more sustained and voluntary attentional process required for covertly tracking the target(s) during the MOT task. These two distinct components of attention thus conflicted with one another, with exogenous attention to the IAPS image drawing endogenous attentional resources away from tracking the moving target(s). Past studies have suggested that emotional stimuli are more salient than neutral stimuli and, consequently, may more strongly engage exogenous attention and impede behavioral performance (see Carretié, 2014, for a review). Because the neutral images involved the same degree and timing of abrupt onsets and offsets, any difference in MOT performance when distracted by IAPS emotional versus neutral images would arise from greater salience of emotional images.

The observed negative impact of task difficulty on tracking performance replicates past research utilizing MOT (see Cavanagh & Alvarez, 2005). However, the more intriguing finding is that emotional images are more distracting than neutral images only under conditions of high attentional load, when participants had to track four target balls. This result is inconsistent with most past studies, which have found either no impact of load on the influence of emotion (Hindi Attar et al., 2012; Mitchell et al., 2007; Oei et al., 2012; Vuilleumier et al., 2001) or a progressively weaker influence of emotion at harder levels of

difficulty (Erthal et al., 2005; Junhong et al., 2013; Pessoa et al., 2002). If emotions were processed automatically as supported by the former set of findings, emotions should be more distracting than neutral distractors at every load—a supposition undermined by the present study. Similarly, our results contradict the limited resources view, according to which emotions should be less distracting at higher loads.

However, our findings are consistent with several alternative explanations. For instance, it is possible that limited attentional resources are preferentially allocated to exogenous processing of emotions. Accordingly, as a task becomes more demanding, performance increasingly suffers due to emotional distraction: processing of emotion remains a priority, and insufficient endogenous attentional resources are left to perform the more challenging MOT task under high load. Another theory posits that greater task load consumes resources that otherwise would enable suppression of distraction, with emotional distractors requiring greater inhibition to ignore than neutral distractors (Engle, Conway, Tuholski, & Shisler, 1995; Hecker & Conway, 2010; Roberts, Hager, & Heron, 1994; Ward & Mann, 2000). Finally, increasing task difficulty may act as a stressor, augmenting susceptibility to threat-related stimuli (Eysenck et al., 2007). Future studies must evaluate which, if any of these alternative theories, best elucidates the mechanisms underlying emotional distraction.

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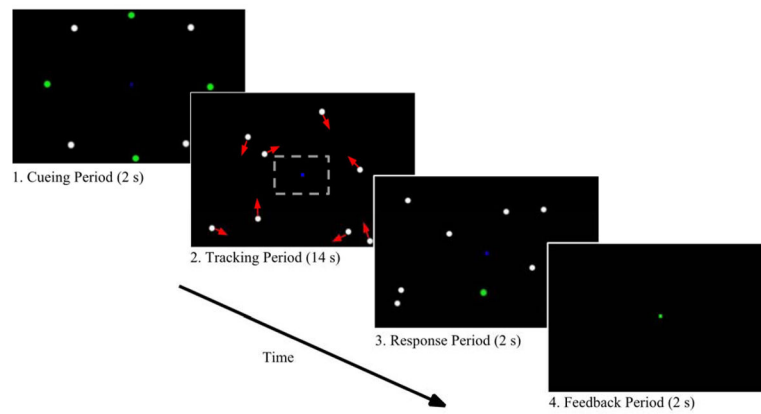
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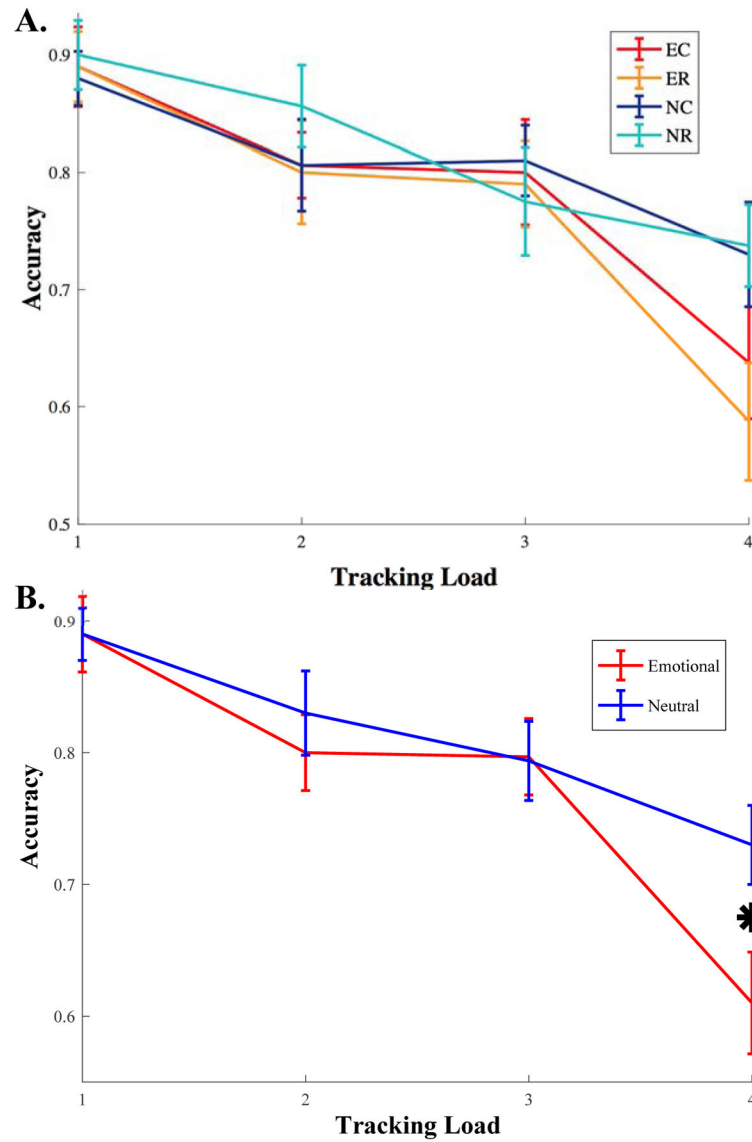
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**Figure 1.**

Example MOT trial. Each trial began with a cueing period (2 s; targets = green, distractors = white), which was followed by a period of active endogenous attentional tracking (14 s; all stimuli white), a response phase (2 s; green stimulus = tracked target or distractor?), and a feedback period (2 s; correct response = green, incorrect response = red). During the tracking period, IAPS images appeared at intervals in the center of the screen, represented by the area outlined in gray (rectangle not actually shown during the experiment).



**Figure 2.**

A) Average tracking accuracy under the four different conditions at each tracking load with standard error of the mean (SE). EC = emotional continuous (red), ER = emotional random (orange), NC = neutral continuous (blue), NR = neutral random (teal). B) Tracking accuracy with SE collapsed across the two different presentation conditions (that is, continuous and random presentations). The asterisk indicates a significant difference in performance between emotionally unpleasant and neutral distraction at the highest tracking load level (corresponding to track-four).