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The Attentional Boost Effect: Transient increases in attention to one task enhance performance in a second task

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ABSTRACT

Recent work on event perception suggests that perceptual processing increases when events change. An important question is how such changes influence the way other information is processed, particularly during dual-task performance. In this study, participants monitored a long series of distractor items for an occasional target as they simultaneously encoded unrelated background scenes. The appearance of an occasional target could have two opposite effects on the secondary task: It could draw attention away from the second task, or, as a change in the ongoing event, it could improve secondary task performance. Results were consistent with the second possibility. Memory for scenes presented simultaneously with the targets was better than memory for scenes that preceded or followed the targets. This effect was observed when the primary detection task involved visual feature oddball detection, auditory oddball detection, and visual color-shape conjunction detection. It was eliminated when the detection task was omitted, and when it required an arbitrary response mapping. The appearance of occasional, task-relevant events appears to trigger a temporal orienting response that facilitates processing of concurrently attended information (*Attentional Boost Effect*).

1. Introduction

Most of the time the external environment is relatively constant. Even when driving a person's immediate environment changes little: Her position within the car stays the same and the car typically moves straight and at a steady speed. However, sometimes the external environment changes in meaningful ways, requiring a reevaluation of the current situation and perhaps a response. For example, a traffic light may change from green to yellow, or a pedestrian may step into the road. Several theories of perception and attention suggest that changes in events may lead to improved perceptual processing (Aston-Jones & Cohen, 2005; Bouret & Sara, 2005; Grossberg, 2005; Zacks, Speer, Swallow, Braver, & Reynolds, 2007). Increased attention to novel events, or to events that mark a change in context has long been associated with better memory for those events (Fabiani & Donchin, 1995; Hunt, 1995; Newtson & Engquist, 1976; Ranganath & Rainer, 2003; Swallow, Zacks, & Abrams, 2009). An important and as yet unanswered question, however, is how task-relevant changes in events (e.g., the traffic light changing from green to yellow) impact the way other, task-relevant information is processed (e.g., the pedestrian on the corner).

Theories of cognition and perception suggest two opposite predictions about the relationship between the occurrence of a task-relevant change in an event and the way other information is processed at that time. In

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general, when attention to one task increases, performance on a second task suffers (Pashler, 1994). In one study, Duncan (1980) asked participants to search for two briefly presented targets that appeared either at the same time or at different times. Participants were more likely to miss a target in one location if they detected a simultaneously presented target in the other location. Furthermore, work on the psychological refractory period (PRP) has shown that when two tasks share a limited capacity processing step (the "central bottleneck"), processing for the second task is delayed until processing for the first task is complete (Pashler, 1994). It is therefore likely that the detection of task-relevant changes draw attentional resources away from processing other information or performing other tasks (*interference hypothesis*).

However, several theories of perception, attention, and learning suggest that perceptual processing temporarily increases in response to goal-relevant changes in the external environment (Aston-Jones & Cohen, 2005; Bouret & Sara, 2005; Grossberg, 2005; Zacks et al., 2007). For example, in the Adaptive Gain Theory of locus coeruleus–norepinephrine (LC–NE) function, Aston-Jones and Cohen (2005) characterize the phasic response of LC neurons as a temporal attentional filter. This theory suggests that once a task-relevant event has been detected LC neurons fire to increase the sensitivity (or gain) of target neurons, leading to a transient increase in perceptual processing. In addition, a recent theory of event perception suggests that changes in observed activities trigger additional perceptual processing, updating internal representations of the current event (Zacks et al., 2007). These theories suggest that increasing attention in response to task-relevant changes in events may facilitate cognitive processing at the moment of the change (*facilitation hypothesis*). They further suggest that this facilitation may result from orienting attention to the moment in time that the change occurred, perhaps through the opening of an attentional gate (cf. Olivers & Meeter, 2008). It is unclear, however, whether the facilitation from temporal orienting is restricted to the changed event, or whether it also spreads to concurrently presented, secondary tasks.

To examine how task-relevant changes in events influence the way other relevant information is processed we asked participants to encode a long series of briefly presented images while they simultaneously performed an unrelated, continuous detection task. For this *dual-task encoding* phase participants encoded images as they monitored a second stimulus stream (e.g., a square or a letter in the center of the picture) and pressed a key whenever they detected an infrequent target (e.g., a white square among black square distractors, or a red-X among other red letters and other non-red Xs). Because distractors were usually presented, the appearance of a target constituted a task-relevant change that required additional attention to process. In addition, previous research has shown that identifying a target, but not rejecting a distractor, interferes with the processing of a second target (the *attentional-dwell time*) for several hundred milliseconds (Duncan, Ward, & Shapiro, 1994; Moore, Egeth, Berglan, & Luck, 1996; Raymond, Shapiro, & Arnell, 1992; Wolfe, 1998).[1] Therefore, attention to the target-detection task should be greater when a target appears than when a distractor appears. The effect of this change of attention on encoding was examined by presenting the background images at a set serial position relative to the targets. Thus, some images were presented at the same time as a target, some images were presented immediately after the target and some images were presented immediately before the target. In a second phase participants performed a recognition test on the images.

This design has two important features. First, because the targets were not part of the background images, the target-detection task was separate from the image-encoding task. Second, by presenting background images at a set time relative to the targets, the effects of the targets on memory for background images presented with the target as well as that for images presented before or after the target could be examined. The interference and facilitation hypotheses suggest opposite effects of the appearance of targets on later memory for concurrently presented images: These images could be more poorly remembered than images encoded when distractors appeared (interference) or they could be better remembered than images encoded when distractors appeared (facilitation). In addition, it is possible that increasing attention to the targets could have long-lasting or even retroactive effects on background image processing. The appearance of occasional targets could interfere with subsequent as well as concurrent background scenes, or it could increase levels of arousal, perhaps facilitating memory for the *preceding* images (Anderson, Wais, & Gabrieli, 2006).

1.1. Overview of the experiments

Several experiments were performed, first, to evaluate how the appearance of targets in one task influences performance on an image-encoding task, second, to evaluate the role of attention in this relationship, and third, to provide boundary conditions for this relationship. Experiment 1 showed that when scenes were presented at the same time that a visual feature-oddball target occurred they were later better remembered than scenes presented before or after the target. Experiment 2 demonstrated that this effect is not modality specific, and that detecting auditory targets can facilitate image-encoding. Because increasing attention to the target appears to boost encoding of the concurrently presented background image we

[1] In a pilot study, we used the attentional blink procedure (see Duncan et al., 1994; Raymond et al., 1992) to measure the attentional-dwell time for white target items presented among black distractor items. Eight participants viewed a stream of letters presented at a rate of 105 ms/item. Most of the letters were black but on half the trials one letter was white. At the end of the stream, participants reported whether a white letter was present or absent (T1 task), and whether the letter X was present or absent (T2; T2 trailed T1 by 1, 2, 4, or 8 lags). We found that T2 performance was impaired at lag 2 on T1-present trials (69% at lag 2 vs. 89% at lag 8, $p < .01$); T2 performance was highly accurate on T1-absent trials (89%). These results indicate that detecting a simple feature oddball places demands on attention, a conclusion supported by other visual attention tasks (e.g., Wolfe, Butcher, Lee, & Hyle, 2003).