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Attention capture without awareness in a non-spatial selection task ☆

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ABSTRACT

Distractors presented prior to a critical target in a rapid sequence of visually-presented items induce a lag-dependent deficit in target identification, particularly when the distractor shares a task-relevant feature of the target. Presumably, such capture of central attention is important for bringing a target into awareness. The results of the present investigation suggest that greater capture of attention by a distractor is not accompanied by greater awareness of it. Moreover, awareness tends to be limited to superficial characteristics of the target such as colour. The findings are interpreted within the context of a model that assumes sudden increases in arousal trigger selection of information for consolidation in working memory. In this conceptualization, prolonged analysis of distractor items sharing task-relevant features leads to larger target identification deficits (i.e., greater capture) but no increase in awareness.

1. Introduction

When attention is drawn to a stimulus despite an observer's intentions – or in conflict with them – attention is said to be *captured* by the stimulus. Typically, observers are well aware of the source of this distraction; it is difficult not to notice for example that someone has loudly entered a quiet room or that a picture has fallen off the wall. Indeed, classic demonstrations of the "inattentional blindness" phenomenon (in which, for example, observers counting basketball passes fail to see a gorilla walking among the players; Simons & Chabris, 1999) are thought to occur precisely because an event fails to capture attention when it is engaged elsewhere (Mack & Rock, 1998). Presumably, if attention had not been engaged in the counting task, the gorilla would have captured attention, drawing spatial attention to the location of the gorilla, which in turn would have led to awareness of it.

Rapid orienting to salient stimuli is frequently cast in terms of survival advantage. For example, Asplund, Todd, Snyder, Gilbert, and Marois (2010) note that "the [orienting response] is characterized by facilitated processing of the triggering event to ensure its speedy evaluation and the formulation of an appropriate response..." (p. 1372). Yet, surprisingly few

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studies have directly measured the extent to which the capturing stimulus is processed in such tasks. Indeed, in most studies, subjects are explicitly required to attend to, and evaluate the event that is then shown to capture their attention in order to determine whether the event in question corresponds to the target. For example, in some studies, observers are instructed to monitor a sequence of pictures for the one picture that is rotated by 90°. Would observers have become aware of stimuli that capture their attention, had the task not already made them aware of the presence of those stimuli? To what extent are such stimuli represented in the visual system, and in what kind of detail? Can a stimulus capture attention without also capturing awareness? In this paper, we revisit the relationship between attentional capture and awareness, showing that stimuli that are more effective in capturing attention do not necessarily undergo more extensive processing or lead to greater awareness than stimuli that are less effective in capturing attention.

Although it seems paradoxical to suggest that a stimulus that captures attention could escape awareness, we note that the capture of attention to the location of a distractor does not always lead to awareness of the capturing stimulus (Hsieh, Colas, & Kanwisher, 2011; Lambert, Naikar, McLachlan, & Aiken, 1999; Lamy, Alon, Carmel, & Shalev, 2015; Lin & Murray, 2015; McCormick, 1997). For example, McCormick (1997, Experiment 1) observed that subthreshold changes of luminance captured attention and facilitated responding to a target appearing in the cued location. Despite the fact the cue was noticed only about 3% of the time, on the 97% of trials on which subjects denied awareness of the cue, responses on validly cued trials were about 16 ms faster than on invalidly cued trials. This suggests that attention was drawn exogenously and without awareness to the location of the cue. Consistent with the view that capture does not necessarily lead to awareness, Lamy et al. (2015) found that the capture of attention was essentially independent of awareness. In their study, unseen spatial cues sharing a relevant feature of the target were shown to be just as effective in attracting attention as visible cues. Researchers using flicker fusion stimuli have also claimed independence of spatial attentional capture from awareness (e.g., Bauer, Cheadle, Parton, Muller, & Usher, 2009; Lu, Cai, Shen, Zhou, & Han, 2012; but see Alais, Locke, Leung, & Van der Burg, 2016), finding that invisible chromatic flicker increased alertness and induced attentional orienting beyond flicker fusion frequency. Such findings suggest that low visibility cues presented outside the current focus of attention can redirect spatial attention involuntarily, without leading to awareness of the capturing event.

In some tasks, however, the target is already within the focus of spatial attention, so there is no need for attention to be drawn to it to become aware of it. One such task is the rapid serial visual presentation (RSVP) task, in which a target is embedded within a rapid sequence of distractors, with items in the sequence presented at a rate of about 10 items per second. Under these conditions, distractors sharing task-relevant features of the target (e.g., Folk, Leber, & Egeth, 2008) or emotionally salient distractors (e.g., Arnell, Killman, & Fijavz, 2007; Most, Chun, Widders, & Zald, 2005) seem to involuntarily capture attention, impeding processing of subsequent stimuli presented in the same location. Presumably, these stimuli capture attention for the same reason as stimuli in the periphery: to redirect processing resources to the capturing stimulus, in case it is threatening or otherwise should be given processing priority.

When observers are given reliable information about the location at which a distracting event will occur, the potential for distraction by such events is reduced (Yantis & Jonides, 1990), although they can trigger an involuntary spatial shift of attention if they share a task-relevant feature of the target (Folk, Leber, & Egeth, 2002). As expected if spatial certainty is beneficial, the ability to identify any one item in RSVP sequences is generally very high, frequently exceeding 90% (Chun & Potter, 1995; Shapiro, Raymond, & Arnell, 1994). However, it is important to note that in most RSVP tasks subjects must evaluate each item in the stream to determine whether it possesses the features that define the target. Thus, awareness of the presence of an item might be a prerequisite for attention capture. If so, stimuli of which subjects have little or no awareness might be ineffective in capturing attention in this context, in contrast to the capture of spatial attention described above.

In the well-known attentional blink paradigm (Raymond, Shapiro, & Arnell, 1992), subjects are instructed to report two of the items in the RSVP sequence; thus, they are explicitly asked to evaluate whether each item in the sequence corresponds to the description of the target. Typically, identification of the leading target (T1) is accurate, but identification of the trailing target (T2) varies as a function of the delay between T1 and T2. With a short delay (~200 ms, or a lag of 2 items), identification of T2 is poor. As the delay is increased, identification accuracy increases.

One particularly influential account of the attentional blink is Chun and Potter's (1995) two-stage model. A similar account has been proposed by Olivers and Meeter (2008), who described a computational implementation of a two-stage model and potential neural correlates subserving the processing carried out during these stages. The two-stage model posits that items in the RSVP sequence are initially appraised for target-defining features. This first stage is assumed to proceed quickly, but to yield a representation that is insufficient to serve as the basis of an overt response. This fragile representation quickly deteriorates and is forgotten if the features of the item do not match those of the target. If target-defining features are detected, however, the item is passed to a second stage of target consolidation. This stage is assumed to be capacity-limited such that it can be carried out for only one item at a time (although targets immediately following the first target sometimes exhibit 'sparing'; Di Lollo, Kawahara, Ghorashi, & Enns, 2005; Potter, Chun, Banks, & Muckenhoupt, 1998). A second target cannot be consolidated until Stage 2 processing for the first target is complete; as such, identification of T2 is impaired at short lags. This model provides a good account of both behavioural (Chun & Potter, 1995) and electrophysiological (Kranczioch, Debener, & Engel, 2003; Vogel, Luck, & Shapiro, 1998) data.

Involuntary allocation of attention to an item in an RSVP sequence that does not contain a target-defining feature can also compromise identification of a subsequent target. Compelling demonstrations of this have been shown in studies in which the first target was replaced with a highly-arousing, but irrelevant distractor (Arnell, Killman, & Fijavz, 2007; Most, Smith, Cooter, Levy, & Zald, 2007). In such studies, subjects monitoring an RSVP sequence for a target word or picture are distracted