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Attention capture, processing speed, and inattentional blindness

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ABSTRACT

Previous theories of inattentional blindness (IB; a phenomenon of observers failing to notice a salient but unexpected event when attention is already occupied) have suggested that an unexpected object reaches conscious awareness when: 1) the location of the unexpected object and attention align, and 2) the unexpected object undergoes sufficient processing. Moreover, it is expected that the same factors that influence the allocation of observers' attention in attention capture studies influence what reaches conscious awareness in IB studies. We explored the degree to which individual differences in susceptibility to attention capture and processing speed are important predictors of IB. One hundred forty-six participants (from Study 1 of Roque, Wright, & Boot, 2016) completed four classic attention (implicit) capture tasks designed to assess stimulus-driven and contingent capture. Following the completion of these capture tasks, participants completed a sustained IB (multiple object tracking) task where an unexpected event appeared during the final critical trial. Indices of stimulus-driven and contingent capture were derived from the capture tasks, and a measure of processing speed was derived from aggregating reaction times from the three speed-based capture tasks. Surprisingly, results of logistic regression analyses revealed no relationship between measures of implicit and explicit capture (noticing the unexpected event). However, consistent with the a priori hypothesis, processing speed did predict IB. Findings suggest that attention capture is unrelated to the noticing of an unexpected stimulus, but efficient encoding and recognition of a stimulus is an important factor.

1. Introduction

The unintuitive finding that half of observers can fail to notice a salient event in their view while engaged in another task (inattentional blindness (IB); Simons & Chabris, 1999) sparked numerous attempts to account for this phenomenon. In one sense, selective attention is performing exactly as it evolved to do: when a task needs to be performed in the presence of non-task relevant information, it would be advantageous for distracting information to be filtered from reaching awareness and interfering with primary task performance. On the other hand, it is also important in many circumstances for novel or unique information within the field of view to capture attention because this information could signal a meaningful change in the observer's environment (e.g., in an evolutionary context the appearance of a predator, or in a modern context the approach of a fast-moving vehicle).

The IB phenomenon highlights the interaction between bottom-up (stimulus-driven) and top-down (goal-driven) processes that constantly determine 1) what visual information attracts automatic, often implicit, shifts of attention (e.g., Folk, Leber, & Egeth, 2002; Folk, Remington, & Johnston, 1992; Jonides & Yantis, 1988; Theeuwes, 1992; Yantis & Jonides, 1984) and 2) what information reaches conscious awareness (e.g., Koivisto & Revonsuo, 2008; Most et al., 2001; Most, Scholl, Clifford, & Simons, 2005; Simons & Chabris, 1999). The interplay between these bottom-up and top-down processes have most frequently been studied in the context of the former (implicit capture). In these implicit capture studies, observers are typically presented with search displays where they are asked to search for a target among distractors. Response time (RT) or search time is compared across trials with and without critical distractors that are either unique in their visual properties from the rest of the display (e.g., unique color or motion) or consistent with an observer's goals (e.g., share a feature with the observer's target). Evidence for stimulus-driven capture is observed when search is delayed by the presence of a visually distinct distractor regardless of observers' goals (e.g., Theeuwes, 1992). On the contrary, evidence for contingent capture is observed when delays are dependent on the goal of observer (e.g., a distractor shares a feature with the target).

Critical differences exist between attention capture paradigms and IB paradigms. For one, the method in which capture is assessed differs across the paradigms. In capture paradigms, capture is inferred from RT differences across search trials; however, in IB paradigms, capture is assessed explicitly through participants' report that they noticed the

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unexpected event. Moreover, the nature of the distractors differs across attention capture and IB paradigms. In attention capture studies, distractors appear across numerous, even hundreds of trials. Consequently, in these studies, the distractor is expected to some degree. On the contrary, in IB paradigms, the distractor is unexpected and often only appears on the final critical trial.

Despite critical differences across attention capture and IB paradigms, capture in both is typically assumed to be related and determined by similar bottom-up and top-down processes (Most et al., 2005; Simons, 2000). Most et al. (2005) linked the attention capture literature to the conscious awareness of an unexpected stimulus in IB paradigms. These researchers noted that explicit awareness does not demarcate attention capture (performance can be influenced by unnoticed distractors), but explicit awareness does define whether or not someone is inattentionally blind (Most et al., 2005). Moreover, Most et al. (2005) posited that the critical distinction between implicit capture by a stimulus and being consciously aware of it is the length of time attention dwells on it. Attention capture (implicit) is a result of a transient shift of attention whereas noticing an unexpected object (explicit capture) is a result of delayed disengagement from a stimulus that has captured attention. This delayed disengagement hypothesis would suggest that efficient encoding and recognition of a stimulus would predict whether or not an observer notices an unexpected event. That is, processing speed, or the time required to encode a visual stimulus and make an accurate judgment about it (Owsley, 2013), should be predictive of IB. Inconsistent with this idea, O'Shea and Fieo (2015) found that within a sample of older adults, individual differences in processing speed were not predictive of IB. However, due to the small sample size in this study ($N = 36$), further investigation is warranted regarding processing speed's ability to distinguish noticers and non-noticers.

While failing to notice an unexpected stimulus could be the result of it never attracting a transient shift of attention (see Most, 2010 for discussion), it is often likely a result of attention moving on from the critical stimulus before recognition can occur. Consistent with this idea, eye-tracking studies find that those who notice the unexpected object have just as many fixations on it than those who do not (Beanland & Pammer, 2010; Memmert, 2006). Most et al. (2005) suggested that both bottom-up stimulus properties of objects and top-down goals of the observer influence where attention is allocated, but the latter is the primary determinant of how long attention dwells on an object. More recent work is consistent with this hypothesis, as delayed disengagement of attention has been linked to goal-directed, top-down processes (e.g., Blakely, Wright, Dehili, Boot, & Brockmole, 2012; Boot & Brockmole, 2010; Wright, Boot, & Brockmole, 2015; Wright, Boot, & Jones, 2014). Most et al. (2005) further suggested that IB would be more heavily influenced by top-down mechanisms (i.e., the observer's target representation). Evidence showing that the similarity between the targets' defining feature and the feature of an unexpected event influence the rate at which the unexpected event is noticed is in line with this idea that IB is heavily reliant on top-down goal-driven factors (Koivisto & Revonsuo, 2008; Most et al., 2001; Most et al., 2005; Simons & Chabris, 1999).

This study explored whether individual differences in (bottom-up and top-down) attention capture and processing speed predicted observers' likelihood of experiencing IB. Four classic attention capture paradigms were used to measure each observer's susceptibility to both top-down and bottom-up distraction. It was predicted a priori that those with increased capture in these classic paradigms should be more likely to be captured by the unexpected event. Moreover, it was predicted a priori that those more efficient in encoding and recognizing information in attention capture paradigms (faster processing speed or RT in these classic paradigms) should be more likely to efficiently encode and recognize the unexpected event. This latter hypothesis related to processing speed is consistent with work showing individuals high in attentional control (i.e., working memory capacity) are less likely to experience IB (Hannon & Richards, 2010; Richards, Hannon, & Derakshan, 2010; Richards, Hannon, & Vitkovitch, 2012; Richards, Hellgren, & French, 2014; but see also Bredemeier & Simons, 2012; Kreitz, Furley, Memmert, & Simons, 2015; Kreitz, Furley, Simons, & Memmert, 2016).[2]

This study is also informative regarding the perceptual cycle framework proposed by Most et al. (2005). Most and colleagues hypothesized that awareness is a result of 1) a transient shift of attention and 2) sustained attentional processing; however, the current study will be the first to directly correlate measures of these cognitive processes with noticing the unexpected event. Attention capture scores from four classic attention capture paradigms served as indices of observers' transient shifts of attention, and RT from these paradigms served as an index of processing speed. If the features that influence an observer's spatial allocation of attention also determine whether or not a stimulus reaches conscious awareness, higher rates of implicit attention capture in classic attention capture tasks should predict higher rates of explicit capture (noticing the unexpected event). Furthermore, if efficient encoding of information determines what information reaches conscious awareness, individuals who notice the unexpected event should have faster processing speed than those individuals who do not notice the unexpected event.

2. Methods

The same methods and undergraduate sample from Study 1 of Roque, Wright, and Boot (2016) were used for the current study. Here we present an abbreviated version of the methods.

2.1. Participants

One hundred forty-six undergraduates (*M age* = 20 years; *SD* = 2.89 years) participated in an hour experiment for course credit. All participants reported normal or corrected-to-normal color vision. In addition, at the conclusion of the session, all participants reported unfamiliarity with the specific IB task used in the current study. Three individuals were missing IB data, and one participant was missing conscientiousness data due to technical issues. Participants capture scores and processing speeds were dropped if their accuracy in the respective capture measure was less than 3 SD below the mean (see sample size statistics in Table 2).

2.2. Apparatus

A 19-inch color monitor (1024 × 768 resolution) was used to display the attention capture and inattentional blindness tasks.

2.3. Overview of approach

2.3.1. Attention capture measures

In order to get indices of attention capture, subjects completed two of the most common visual search paradigms used in support of both bottom-up and contingent capture. Specifically, the Additional Singleton Paradigm (Theeuwes, 1992) and the Irrelevant Singleton Paradigm (Jonides & Yantis, 1988; Yantis & Jonides, 1984) were used for indices of bottom-up capture and the Contingent Cuing Paradigm (Folk et al., 1992) and the Contingent Blink Paradigm (Folk et al., 2002) were used as indices of contingent capture. Capture scores were then calculated in a manner consistent with the literature for each task (see

[2] While it was hypothesized that higher attentional control (faster encoding) would be associated with less IB, a reviewer proposed an alternative hypothesis that higher attentional control might be associated with more inhibition and more IB (suppression of the unexpected event). This hypothesis is intuitive but counter to the studies that do find a relationship between attentional control (working memory capacity) and IB.