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Opinion Paper

Beyond Guidance: It's Time to Focus on the Consequences of Attentional Capture

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Abstract

Attentional capture is assumed to automatically trigger attentional engagement, which gates working memory access. However, recent studies show that engagement is not a necessary outcome of capture and can be disrupted by manipulations that leave capture intact. In this commentary, I suggest that these findings have important implications for the capture debate. Mainly, they suggest that capture may have different consequences under different conditions. Moreover, they caution against interpreting the absence of evidence for engagement as evidence that capture did not occur. Finally, they open the door to future investigation about factors that determine and modulate engagement, independently from capture.

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Subjectively, visual search can feel completely voluntary. In truth, however, eye movements are preceded by a complex analysis that assigns priority to specific events and areas of the visual field. Prioritized signals have the power to involuntary draw spatial attention towards them–a phenomenon known as attentional capture. As documented in the target article (Luck, Gaspelin, Folk, Remington & Theeuwes, 2020), what factors determine prioritization and therefore result in attentional capture, has long been debated. After a long deadlock between the main opposing viewpoints, the field is moving towards a consensus, according to which both stimulus-driven and goal-driven factors can determine attentional priority, with a possible role for distractor suppression as a mechanism that lowers the priority of specific irrelevant features or locations. In light of this welcome progress, I wish to emphasize in this commentary an often-neglected aspect of attentional capture–its consequences. Without detracting from the importance of the traditional capture debate, I will argue that focusing on the consequences of capture is equally important and can even help resolve outstanding issues about capture.

It is trivial to say that the consequences of prioritization lend importance to attentional capture as a field of inquiry. Prioritized signals are processed more thoroughly than unprioritized signals and are therefore more likely to guide our behavior. However, it has long been known that spatially selective attention involves an additional process that occurs before WM encoding. After attention shifts towards the location of a prioritized object, a burst of transient enhancement speeds the extraction of information at that location, binds different features to a single object, and gates its consolidation into working memory (WM). This later attentional process is often referred to as "attentional engagement" (or attentional selection). The first findings to support the distinction between attentional shifting and attentional engagement came from neurophysiological studies. These studies showed that pulvinar-lesioned patients show normal shifts of attention and impaired engagement, whereas parietal-lesioned patients show the opposite pattern, indicating that brain damage can selectively impair the two processes (Posner & Petersen, 1990).

Given the important role of attentional engagement in visual processing, it might be surprising that relatively little effort has been made to delineate the factors that determine and modulate attentional engagement, independently from capture. Such a discussion is also absent from the target article, which understandably focused on the factors that determine prioritization. A likely reason for this oversight is that models of spatial attention mostly share the underlying assumption that once a healthy individual shifts attention towards a prioritized object, attention is immediately and mandatorily engaged at that location (e.g., Wolfe, 2007). However, this assumption may be unwarranted. To demonstrate this, I will briefly review studies showing that (*i*) attentional capture is not necessarily followed by engagement, and that (*ii*) engagement can be selectively modulated by factors that do not affect attentional capture.

Attentional capture without attentional engagement

In the contingent-capture cuing paradigm, the target is preceded by a display containing a cue, which may or may not share the target's defining feature (Figure 1A). Attentional capture by the cue results in a shift of focused spatial attention towards the cue, which benefits processing at that location. Therefore, faster reaction times (RTs) or higher accuracy when the cue appears in the target location relative to when a different location is cued (Figure 1B), is evidence that attention was captured by the cue.

Since attentional engagement occurs only after the attentional shift, location benefits by themselves do not constitute evidence for attentional engagement. Instead, studies that assessed attentional engagement typically did so by measuring response compatibility effects. In these studies, the critical trials are when the attention-grabbing cue overlaps with a distractor. This distractor is associated with either the same

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response as the current target or with the alternative response. Poorer performance on incompatible- relative to compatible-response trials is taken to indicate that attention was engaged in the cue's location, because the distractor's identity was processed, and the response associated with it was prepared. Note that in a sparse visual field, distractor compatibility effects can emerge even from unattended distractors. However, in a busy visual field with multiple compatible and incompatible distractors, attentional engagement may be necessary for the identity of a specific distractor to affect response selection mechanisms.

Using a cuing paradigm developed by Gaspelin, Ruthruff and Lien (2016), two studies showed that location benefits and distractor compatibility effects do not necessarily go hand in hand. Zivony and Lamy (2018) found that abrupt onset cues that shared the target's color (relevant-color) produced both location benefits and compatibility effects (indicative of goal-driven capture and engagement). In contrast, abrupt onset cues that didn't share the target's color (irrelevant-color) produced location benefits (indicative of salience-based attentional capture) but did not produce distractor compatibility effects (Figures 1B). These results were replicated and further extended by Maxwell, Gaspelin and Ruthruff (2020), who showed that an irrelevant-color abrupt onset cue can result in distractor compatibility effects, but only if it is predictive of the target's location. Together, these results suggest that whether attentional capture results in attentional engagement is contingent on goal-driven factors (the contingent engagement hypothesis). This view is in agreement with the revised contingent orienting hypothesis, the only hypothesis of the three presented in Luck et al. (2020) to suggest that the control state can operate at multiple stages of processing, not only on priority maps.

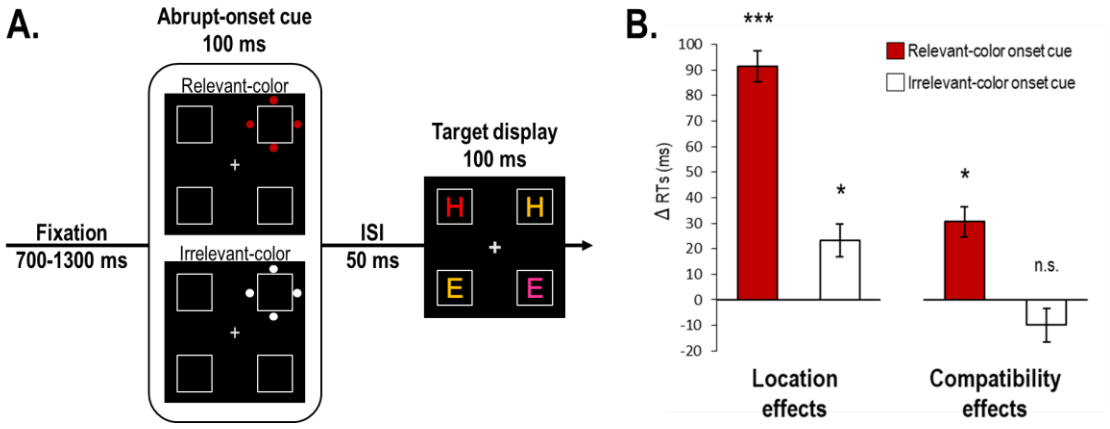

Figure 1. The spatial cuing paradigm and results from Zivony & Lamy (2018), Experiment 1. A) Participants searched for the red letter and reported whether it was an E or an H. Prior to the target display, an abrupt onset cue, either in the target's color or an irrelevant color, appeared randomly at one of the four possible target locations. In this example, the cue appeared at a distractor's location, which was compatible with the target. B) Location effects (RTs on different location cue trials – RTs on same location cue trials) and compatibility effects (RTs on incompatible distractor trials – RTs on compatible distractor trials) as a function of cue color. Reprinted with permission from Sage Publishing.

Intact attentional capture with disrupted attentional engagement

More evidence supporting the dissociation between attentional capture and attentional engagement in healthy adults are provided in studies of the attentional blink (AB). The AB refers to the finding that when participants try to identify two targets embedded within a rapid serial visual presentation (RSVP) stream of distractors, identification of the second target is impaired when this target appears within 200–

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500 ms after the first target. One line of research regarding the AB suggested that attentional shifting following exogenous cues is unaffected by the AB (Ghorashi, Enns, Klein & Di Lollo, 2009). A second line of research concluded that attentional engagement is disrupted by the AB (Nieuwenstein, 2006). The two disparate lines of research suggest that the deployment of attentional engagement is more sensitive to concurrent task demands (incurred by the processing of the first target) than attentional capture.

This conclusion was further confirmed in two studies (Zivony & Lamy, 2016; Zivony, Allon, Luria & Lamy, 2018) that combined measures of both attentional capture and attentional engagement. These studies showed that location benefits following relevant-color cues were of equal magnitude (either in RTs or accuracy) whether the cue appeared during or outside the blink period. In contrast, compatibility effects from cued distractors were reduced. Zivony et al. (2018) also measured the N2pc event-related potentials component. The N2pc is widely agreed to reflect a spatially selective process that occurs only after the attentional shift and can therefore be used to monitor the onset of attentional engagement (though the exact characterization of the N2pc is still debated). Like compatibility effects and unlike location benefits, N2pc components were delayed and suppressed during the AB. Thus, AB findings suggest that attentional engagement can be selectively disrupted under conditions where attentional capture remains intact.

Why focus on attentional engagement?

Studies of attentional engagement disconfirm the assumption that this process automatically follows attentional capture. Instead, they suggest that attentional capture is a necessary but not sufficient condition for attentional engagement to occur. Moreover, they suggest that the effect of attentional capture on processing may vary, depending on the degree of attentional engagement. According to the contingent engagement hypothesis, salient-but-irrelevant stimuli can produce capture without engaging attention. This view provides partial theoretical justification for Theeuwes' rapid disengagement account, because "shallow" capture effects might have little influence on high-level cognitive stages and impose little constraints on concurrent processes. In contrast, "deep" capture effects caused by events matching the attentional template may affect many downstream processes. For example, involuntary engagement might result in the encoding of irrelevant information, thereby disrupting the maintenance of relevant information in WM. It can also result in an AB, which further disrupts subsequent processing. These conclusions bear on how attentional capture studies should be interpreted.

First, focusing on attentional engagement can help researchers clarify the measures they use to study attentional capture. With the exception of Theeuwes, Luck et al. (2020) consider the absence of N2pcs evidence that singleton distractors do not capture attention. Similar conclusions have been made previously regarding the absence of compatibility effects. The presence of compatibility effects and the N2pc can be taken as evidence of capture because these effects reflect a process that occurs downstream from attentional shifting. However, the opposite conclusion is warranted only if one assumes that attentional engagement is a necessary outcome of attentional shifting towards a prioritized object. As this is not the case, it is possible that in some of these cited studies, attention was in fact captured by salient-yet-irrelevant distractors but was not engaged at that location. Similar complications arise in studies that compare two conditions and find existing compatibility effects or N2pcs under both conditions, but of differing size. In such cases, it is often unclear whether the disparity stems from differences in capture, engagement, or a combination of both. More research into attentional capture and engagement may help us find new measures and conditions that can differentiate between the two processes.

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Second, focusing on engagement can result in an arguably welcome shift from merely asking which events capture attention to asking how capture affects visual search performance. Many studies in attentional capture attempt to classify whether a specific type of stimulus can capture attention. From a purely theoretical point of view, this is an important effort as even small effects can advance our understanding of visual attention. However, from a practical point of view, larger effects have clearer and more immediate impact on our day-to-day life and behavior. The maturity of the visual attention field may depend on our ability to both detect true effects and provide more precise descriptions of their expected outcomes.

Finally, focusing on attentional engagement independently from attentional capture is fertile ground for future research. It is possible that many more factors (other than the AB) affect one process but not the other, or alternatively, affect both processes to different degrees. For example, selection history and factors that can suppress activity in the priory map (Luck et al., 2020) may result in additional engagement-specific modulations. According to the contingent engagement hypothesis, engagement-specific modulations are to be expected since this process is more costly than capture and should therefore be more sensitive to changes in the visual environment. This sensitivity can be expressed, for example, as changes to the threshold of perceptual evidence required to trigger attentional engagement, independently of any changes to priority.

To summarize, after decades of attentional capture research, it may be high time to give attentional engagement its moment in the proverbial limelight. Now that many issues regarding attentional capture have been resolved, focusing on how the outcomes of capture may vary is not merely the next logical step; it can also help address the thorny, and as yet unanswered, theoretical questions about capture.

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