Voluntary choice tasks increase control settings and reduce capture

Dion T. Henare and Anna Schubö

Cognitive Neuroscience of Perception and Action, Department of Psychology, Philipps-University Marburg, Marburg, Germany

ABSTRACT

In their article, Luck et al. (2021) outline alternative hypotheses regarding the cognitive mechanisms that modulate attention capture. This commentary addresses how control signals can be used to modulate feature gain control prior to saliency computations, in addition to the implicitly learned effects of alternate selection histories. We suggest that voluntary choice paradigms provide much stronger task-induced attentional control than pre-trial cueing, and allow a comparison of the same search stimuli under different control states. We argue that voluntary task choice results in an attenuation of salience signals, eliminating attention capture, although response time distractor costs remain.

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Commentary

In their seminal article, Luck et al. (2021) combine the perspectives of three competing models of attention capture into a common framework, demonstrating broad areas of agreement in the literature while highlighting prominent discrepancies that should guide future research. The contingent involuntary orienting hypothesis (Folk et al., 1992) and the signal suppression hypothesis (Gaspelin & Luck, 2019) agree that control signals can be used to proactively enhance the feature gain for task-relevant features, however, Gaspelin and Luck argue that proactive suppression of features is based exclusively on implicit learning. Gaspelin and Luck point to evidence from studies where participants are not able to suppress distractor features using explicit pre-trial cues (of, for example, the upcoming distractor colour), but rather build up suppression on the basis of repeated experience with that distractor (Gaspelin et al., 2019; Stilwell et al., 2019; Vatterott & Vecera, 2012).

In the view of Folk and Remington, salient objects not part of the task set will still capture attention when that task set is weak or absent. Cuing distractor identity immediately before search onset may fail, therefore, because it provides only very weak task set instantiation. The task-switching literature has shown that voluntary choice designs in which participants choose what they will respond to, allow for optimal task set preparation when compared to trial-by-trial cuing paradigms (Arrington & Logan, 2005; Chen & Hsieh, 2015). This was confirmed with a comparison of a cuing and a voluntary choice variant of matched attention capture tasks, using the pre-stimulus CNV component as an index of proactive task set preparation (Henare et al., 2020). In contrast to the cuing task, results showed more pre-stimulus activation in the voluntary task that was also unaffected by intertrial factors. Comparing attention capture in a voluntary task that maximizes proactive task preparation, to a non-voluntary task where preparation is weak or absent, is thus a better approach to examine whether control signals can be used to modulate feature gain prior to saliency computations. Importantly, such a comparison manipulates only the pre-trial control state and uses otherwise identical tasks. This eliminates any effects that might be caused by differences in search displays or changes in participant search strategy, for example, when implementing feature- vs singleton-search.

In this commentary, we reanalyzed data from two attention capture studies that used the same stimulus display and task. In the non-voluntary version...
(Feldmann-Wüstefeld et al., 2015) participants performed either a categorization task or a search task, randomly selected by the computer on each trial thereby limiting their ability to prepare. In the search task, participants searched for a shape singleton and responded to the line it contained (sometimes in the presence of a colour singleton distractor). In the categorization task, they categorized either a colour or shape singleton depending on group assignment. In the voluntary version of the experiment (Henare et al., 2020) participants performed the exact same tasks except that prior to trial initiation, they made an un-speeded decision about whether they would do a search trial or categorization trial. These data provide two main avenues for analysis. Firstly, by comparing results between the voluntary and non-voluntary task we can observe the impact of optimized control settings on attention capture. Secondly, by comparing the shape group and the colour group within a task, we can observe how the processing of identical stimulus displays diverges as a consequence of the functional relevance of those stimuli within the task context.

The comparison between voluntary and non-voluntary tasks is shown in Figure 1(A–C). In the voluntary choice experiment (shown in green) we see not only a larger target-elicited $N_T$ (indicating enhanced target selection) but also a reduced distractor-elicited $N_T$ and a reduced $P_D$ (distractor capture and distractor suppression, respectively). By maximizing a participant’s preparatory control set, the voluntary choice task, therefore, modulates attention capture, producing proactive increases of target features, but also proactive suppression of distractor features. As compared to the non-voluntary task, colour distractors in the voluntary task produced a weak attend-to-me signal (Sawaki & Luck, 2010) that required significantly less suppression for both groups of participants (Figure 1(B)). It is important to note that in the voluntary task, participants were required to perform an equal number of search and categorization trials across the experiment, and participants with a low switch rate were excluded from the analysis. Our results are, therefore, not the result of differences in the frequency of search or categorization trials.

These results are also not the product of implicit learning which, while contributing to suppression over time, will be equivalent in both experiments and therefore cannot account for the differences we observe between them. Similarly, the effects we see cannot be attributed to differences in salience given that identical stimulus displays were used that neither differed in local feature contrast nor in distractor homogeneity (Duncan & Humphreys, 1989). According to the stimulus-driven account, the salient distractors should have generated equivalent attend-to-me signals in both tasks (Theeuwes, 2010). Also, the display size was the same, containing 8 display items which are large enough for singletons to be salient (Wang & Theeuwes, 2020).

This analysis strongly supports the claim that previous research may have failed to eliminate capture because task set instantiation was not strong enough. The voluntary choice task required a permanent comprehensive reinstatement of the relevant task set which includes stimulus-response mappings, specification of response hand, and an updating of search templates. These processes require the involvement of higher-level control and working memory processes as evidenced by the increased preparatory activity seen in the CNV (Henare et al., 2020).

This may also explain why a previous attempt to use voluntary choice failed to reduce distractor capture (Gaspelin et al., 2019). Gaspelin, Gaspar and Luck had participants repeatedly respond to a line contained within a target shape, presented concurrently with a colour distractor. Although participants were given a choice over the colour that the distractor singleton would take, they did not observe a requisite reduction of capture. However, the voluntary choice in their task was much more restricted. The task set was largely unchanged between trials and their choice was limited to a within-dimension feature selection. Indeed, previous work has shown that suppression of a specific within-dimension feature is a uniquely difficult process, especially in comparison to suppression at the dimension level (Liesefeld & Müller, 2019). Proactive suppression of salient distractors might, therefore, only be observed when participants are forced to constantly update their entire task set across dimensions, requiring higher-level control and working memory processes.

To gain an understanding of how selection history operates within the context of strong proactive control, we turned to the second avenue of analysis, namely, a comparison of the shape group and the
As mentioned earlier, both groups of participants carried out the exact same search task (respond to the line within a target shape, ignore the colour singleton), but differed in how they responded to otherwise identical categorization displays. While the colour group responded to the colour singleton (green or blue), the shape group responded to the shape singleton (triangle or pentagon). For the colour group, the relevant feature dimension switched from shape to colour between tasks which made attending shape singletons and suppressing colour singletons more difficult in the search task. For the shape group, relevant stimuli only changed within (and never between) feature dimensions, allowing implicit learning to optimize for shape selection and colour suppression. In this case, the difference between distractor ERPs reflects differential processing of a colour distractor as a result of its historic relevance within the task context, while controlling for the history of mere exposure to that colour singleton. The results reveal no significant deviation from zero for participants in the shape group, and no sign of capture (Figure 1D). There was also no evidence of capture in the colour group, showing that strong control settings elicit an ERP pattern that indicates effective suppression in all participants. The colour group does retain some residual suppression, however, suggesting that proactive suppression was less efficient when targeted at a specific within-dimension feature like red, than in the shape group where suppression could be implemented at the level of the entire colour dimension (Failing et al., 2019; Liesefeld & Müller, 2019).
The response time data reveal that while the colour group incurred larger distractor costs during search, the shape group also retained a small behavioural cost in distractor present trials (Figure 1(D)). Therefore, the shape group also retained a small behavioural group incurred larger distractor costs during search, participants nevertheless struggle with the salient distractor while preparing their target response. This effect is mirrored in the between-group comparison described earlier. While ERP evidence demonstrated improved distractor suppression in the voluntary task, and overall response times were faster, response time distractor costs were not reduced (Figure 1(C)). These differences between ERP and behavioural results suggest that although proactively suppressed distractors no longer capture attention, they might alter downstream processes like the rate of evidence accumulation or raise the decision threshold for a target.

In summary, preliminary analysis of extant data suggests that preparatory control settings can have important effects on attentional capture, on the condition that experimental paradigms encourage active adoption of strong task sets at the start of each trial. These effects are observed in addition to the orthogonal effects induced by group differences in selection history. The current approach controls for implicit learning effects elicited by stimulus exposure, and isolates the impacts of different histories of selection and proactive control. However, these results are limited by the between-group comparison of past data, and future work will need to use purpose-designed tasks to provide conclusive, controlled evidence of the observed effects.

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**ORCID**

Dion T. Henare [http://orcid.org/0000-0003-4788-0677](http://orcid.org/0000-0003-4788-0677)

Anna Schubö [http://orcid.org/0000-0002-3274-1693](http://orcid.org/0000-0002-3274-1693)

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