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Research Report

Visual search in temporally segregated displays: Converging operations in the study of the preview benefit

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Abstract

Preview benefit is an attentional phenomenon that enables observers to selectively search through new information in the visual field. In a preview search task, objects are presented in two sets, separated by a time interval (preview interval), and with the second set (new objects) containing the target. Event-related brain potentials (ERPs) were used to investigate whether preview benefit occurs via maintenance of inhibition of the old objects during the preview interval. ERPs time-locked to a color probe indicated that the old objects were actively attended rather than inhibited during the preview interval. Follow-up behavioral experiments produced converging results. The results suggest that, although participants might be using inhibition at later stages of the preview interval, they are not maintaining inhibition on the old objects throughout most of the preview interval.

Theme: Neural basis of behavior
Topic: Cognition

Keywords: Visual attention; Preview benefit; ERP

1. Introduction

In a dynamic visual world around us, it is often important to bias selection towards new, previously unattended information. For example, when we are looking for a shuttle in an airport parking lot, it might be a good strategy to narrow the search to moving vehicles, and to exclude the parked cars from detailed examination. A recently discovered attentional phenomenon, termed the preview benefit, confirms this observation. It is defined in terms of faster search rates when two sets of visual objects are presented at different points in time, compared to when they are presented simultaneously [27]. When the second set (new objects) arrives, its elements are interspersed among the elements of the first set (old objects). The target, if present, is always located within the second set of objects. It has been shown that the number of old objects in the display has a limited effect on the search slopes in the preview paradigm, suggesting that observers are able to restrict their search to the new objects and ignore the presence of the old physically interspersed objects [26,27].

The preview benefit does not seem to have substantial capacity limitations, since it has been observed with up to 15 new and 15 old (previewed) objects [5,26]. It is also not affected if previewed objects change color; however, the benefit is abolished when they undergo a large luminance change at the time the new objects are presented [15,27]. Watson, Humphreys, and colleagues [10,27,28] proposed that the mechanism that produces the preview benefit is top–down inhibition (termed "visual marking"), applied to previewed distractors during the preview interval.

The main evidence for the inhibitory nature of the preview benefit comes from the studies using a probe

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detection paradigm [23,28]. The authors found that when preview search was the primary task, detection of the probe after the preview interval was significantly worse at the locations of the old objects than at the locations of the new objects. However, such impairment was not evident when probe detection task was the only task participants had to perform. Furthermore, the top–down involvement in the preview benefit is also supported by studies that introduced a demanding secondary task in the preview interval, which decreased the preview benefit [23,27].

Although there seems to be some evidence supporting the inhibition account, an alternative explanation for the preview benefit has been recently proposed by Donk and Theeuwes [5,6]. They argued that inhibition of the old objects is unnecessary and that the preview benefit can be explained by attentional capture by onsets of the new objects [30]. The authors showed that unless the presentation of the new objects is accompanied by a luminance increment, the preview benefit is abolished ([5]; see also [24]). In addition, they argued that prioritization of the new objects occurs in a bottom–up fashion, since the preview benefit was observed even when the search target was twice as likely to appear in the old set than in the new set of objects [6].

It is worth noting, however, that in the attentional capture literature, it is typically reported that not more than four objects can be prioritized for search [4,30]. In the preview benefit studies, however, this number is substantially higher (up to 15 objects, [26]). In a recent study [2], we demonstrated that up to 14 objects defined only by luminance transients could be prioritized for search. Thus, it is possible that a similar attentional prioritization also takes place in the preview paradigm.

The slow time-course of the preview benefit is also often taken as evidence against the onset capture account. Generally, it takes at least 400–500 ms to observe some preview benefit and takes 600 ms or longer to fully filter the old objects from search [11,27]. Humphreys and colleagues [10] proposed that the preview interval is used for (1) establishing an inhibitory attentional set, (2) consolidating a representation of old objects, and (3) maintaining the representation using visual resources. They showed that the preview benefit is disrupted by visual secondary tasks, both when they begin at the start of the preview interval and when their presentation is delayed (i.e., the secondary task starts sometime during the preview interval). However, auditory secondary tasks disrupted the preview benefit only when their onset was synchronized with the start of the preview interval.

A similar conclusion regarding setting up and maintaining inhibition of old objects during the preview interval was also reached by Jacobsen and colleagues [14], who observed a sustained negative event-related brain potential (ERP) wave in the preview interval from 350 to 750 ms after the presentation of the first display. This ERP component was enhanced in a preview search task relative to a control condition, in which the search target could appear either at the old or at the new object location. This broadly distributed negativity appeared larger at frontal and central sites and larger over the left than right hemisphere. As acknowledged by the authors, based on its time-course, morphology, and scalp topography, this component did not resemble any ERP components previously reported in the literature, which complicates its interpretation as an index of setup and maintenance of inhibition. Unfortunately, the interpretation of the results of the Jacobsen et al. [14] study is also difficult, since the search was not more efficient in the preview search condition (49.8 ms/object) than in the control condition (40.3 ms/object). Finally, it is also possible that the ERP data are influenced by electrooculographic (EOG) activity.

Although the long duration of the preview interval is often taken as the evidence for inhibition, it was recently demonstrated that the preview effect could also be observed with an interval of only 50 ms [7], as long as the old objects are not presented with a luminance onset. According to the onset capture account, the long preview interval is necessary to prevent the onsets of the old and new objects from interfering with each other. When the old objects are presented without a luminance onset, the preview interval can be significantly reduced [7] or possibly even eliminated [2].

There are two major difficulties in testing the inhibition hypothesis of the preview benefit directly. First, it is difficult to measure attention allocated to the old objects during a preview interval without interfering with the primary task (search task). Secondly, a baseline is needed in order to make an unambiguous inference about active inhibition of the old objects.

1.1. The present study

The present study used both electrophysiological and behavioral techniques to determine if the preview benefit results from inhibition of the old objects, maintained throughout the preview interval. Using event-related potentials is advantageous since this method provides a precise measure of brain dynamics of attentional allocation without interfering with an ongoing behavioral performance. Converging use of ERPs and behavioral measures can result in a more complete understanding of the mechanisms underlying the preview benefit.

In ERP studies of spatial cueing and visual search, it has been demonstrated that P1 and N1 components reflect attentional modulation of early sensory processing, and appear to be localized in extrastriate cortex [21,22]. P1 and N1 were shown to be larger at validly cued locations relative to invalidly cued locations in spatial cueing tasks [8,20], and at the location of the target, relative to the locations of the distractors in visual search tasks [18,19]. These data suggest that differences in P1 and N1 amplitude from some neutral baseline condition should be found if attention modulates