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Expectancies modulate attentional capture by salient color singletons

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Abstract

In singleton feature search for a form-defined target, the presentation of a task-irrelevant, but salient singleton color distractor is known to interfere with target detection [Theeuwes, J. (1991). Cross-dimensional perceptual selectivity. *Perception & Psychophysics, 50*, 184–193; Theeuwes, J. (1992). Perceptual selectivity for color and form. *Perception & Psychophysics, 51*, 599–606]. The present study was designed to re-examine this effect, by presenting observers with a singleton form target (on each trial) that could be accompanied by a salient) singleton color distractor, with the proportion of distractor to no-distractor trials systematically varying across blocks of trials. In addition to RTs, eye movements were recorded in order to examine the mechanisms underlying the distractor interference effect. The results showed that singleton distractors did interfere with target detection only when they were presented on a relatively small (but not on a large) proportion of trials. Overall, the findings suggest that cross-dimensional interference is a covert attention effect, arising from the competition of the target with the distractor for attentional selection [Kumada, T., & Humphreys, G. W. (2002). Cross-dimensional interference and cross-trial inhibition. *Perception & Psychophysics, 64*, 493–503], with the strength of the competition being modulated by observers' (top-down) incentive to suppress the distractor dimension.

Keywords: Attentional capture; Oculomotor capture; Singleton distractor interference; Top-down modulation; Cross-trial priming

1. Control of attention in singleton feature search

While it is generally accepted that stimulus- and goal-driven mechanisms of attention can influence target detection in visual search, there has been a great deal of interest recently in whether and how these mechanisms interact with each other in singleton feature search. While some researchers have claimed that salient feature singletons automatically capture attention (e.g., Theeuwes, 1992), others have proposed that bottom-up attentional capture by salient feature singletons is modulated by top-down attentional set (e.g., Bacon & Egeth, 1994; Folk, Remington, & Johnston, 1992).

1.1. Attentional capture and visual salience

Our ability to direct visual attention to goal-defined target features has been investigated in a number of studies (e.g., Pashler, 1988; Theeuwes, 1991, 1992). For example, in Theeuwes' (1991) Experiment 2, there could be two feature singletons, one unique in form (e.g., circle) and one unique in color (e.g., red) amongst homogeneous non-target items (e.g., green squares). One singleton (e.g., the unique form item) was defined as the task-relevant target, and the other as irrelevant distractor (the unique color item). For half of the observers, the target was a form singleton and the distractor a color singleton, and vice versa for the other half. Search performance in these distractor conditions was compared to performance in no-distractor conditions in which the target was always a single unique form or, respectively, color item. Observers' task was to

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respond to the orientation of a line located inside the target singleton. At the beginning of the experiment, observers were informed about the target's defining dimension (e.g., form) and that the presence of an additional feature singleton (e.g., color distractor) would be irrelevant to the task. Distractor presence was manipulated block-wise and the distractor singleton, if present, appeared always at a location different from the target location. Note that the color singleton was more salient than the form singleton (i.e., the former was detected faster than the latter in no-distractor conditions). Theeuwes hypothesized that, if search for a singleton target is guided purely by bottom-up saliency, then a color distractor (more salient) should interfere with detection of the form target (i.e., RTs should be slower for distractor compared to no-distractor trials); in contrast, a form distractor (less salient) should not interfere with detection of a color target (i.e., RTs should be comparable between distractor and no-distractor trials). The results agreed with this pattern. These, and other, findings led Theeuwes (1991), Theeuwes (1992) to conclude that visual selection in singleton feature search is purely bottom-up controlled: attention is automatically captured by the most salient feature in the search array. That is, selection is uninfluenced by top-down factors—because, in search for a form singleton, observers were unable to overcome the detrimental effect associated with the appearance of a salient color distractor. Subsequently, these results have been replicated and extended in several studies (e.g., Bacon & Egeth, 1994; Folk et al., 1992; Jonides & Yantis, 1988; Kumada & Humphreys, 2002). Critically, however, these studies found that salient feature singletons do not necessarily capture attention when they are irrelevant to the task—which has led to various revisions of Theeuwes' automatic-capture account.

1.2. Feature singletons do not always capture attention

For instance, in a series of experiments modeled after those of Theeuwes (1991, 1992) and Bacon and Egeth (1994) observed that the (color) distractor interfered with the detection of the (form) target only when the target itself was also a feature singleton. In contrast, when the (form) target was not unique with respect to its defining feature, that is, when single-target trials were intermixed with two- and three-target trials (multiple targets were form-identical: circles amongst diamond non-targets), the singleton color distractor no longer caused interference. This suggests that salient feature singletons do not necessarily capture attention. Replacing the notion of automatic-capture, Bacon and Egeth proposed that attentional capture by feature singletons is dependent on observers' chosen search strategy: when the target is a feature singleton (as in Theeuwes' studies), it may be beneficial for observers to adopt a singleton search mode, in which they will look for any singleton. This strategy would then also allow a salient singleton distractor to interfere with target detection. In contrast, when the target is not a feature singleton, observers may adopt a feature search mode, in which visual selection can be confined to a specific (target) feature, preventing the distractor from interfering with target detection. A related proposal has been made by Folk et al. (1992), who argued that attentional capture by salient, but irrelevant singletons is contingent on feature- or dimension-based (top-down) attentional control settings adopted to implement the task instruction (contingent-capture account).

More recently, Kumada and Humphreys (2002) proposed an alternative account for singleton distractor interference, namely in terms of cross-trial inhibitory priming. Under conditions similar to those of Theeuwes (1992), Kumada and Humphreys found that, when the trial N form singleton target was presented at the location of a trial $N-1$ color singleton distractor, search RTs were lengthened by some 30 ms relative to the presentation of the target at the location of a previous 'neutral' distractor of the same color as the target. This inhibitory effect was observed both when a distractor was presented on each trial (i.e., 'pure' presentations) and when only half the trials contained a distractor (i.e., 'mixed' presentations). Importantly, with mixed presentations, RTs were hardly different between trial N distractor and no-distractor trials. In this (mixed) condition, a distractor or no-distractor trial N was equally likely to be preceded by a distractor or no-distractor trial $N-1$, so that inhibitory priming would have influenced both distractor and no-distractor trials N (reducing RT differences between the two types of trial). On this basis, Kumada and Humphreys proposed that cross-trial inhibitory priming, rather than within-trial attentional capture, largely accounts for the observed RT pattern and the singleton distractor interference effect in general. That is, cross-dimensional distractor interference results from the competition, on a given trial, between the singleton target and distractor for attentional resources, with selection of the target being accompanied by positional distractor inhibition (e.g., Humphreys & Müller, 1993; see also Müller, von Mühlenen, & Geyer, 2007) which is then carried over to the next trial.

In summary, prior results in the literature are equivocal with regard to whether feature singletons do or do not capture attention and to the mechanism(s) to which the interference effect can be attributed. Bacon and Egeth (1994) reported evidence that singleton distractors can be ignored when the target itself is not a feature singleton. In contrast, when the target is a singleton, singleton distractors may interfere with target discrimination (e.g., Theeuwes, 1992). These contrasting findings have led to the assumption of different attentional control settings (Bacon & Egeth, 1994; Folk et al., 1992): (i) a feature search mode, in which observes deliberately adopt an attentional control set for a specific target feature, which prevents a singleton distractor defined by some other feature (in another dimension) from affecting RTs; and (ii) a singleton detection mode, in which observers allow focal attention to be drawn to the most salient feature in the display; in this mode, sin-