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Priming of Pop-out does not provide reliable measures of target activation and distractor inhibition in selective attention: Evidence from a large-scale online study

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ABSTRACT

Lamy, Antebi, Aviani, and Carmel (2008) reported that in a simple search task where participants located an odd coloured circle, the inter-trial relations could be used to derive robust and independent measures of target activation and distractor inhibition. When a target feature repeated there was a benefit, and when the previous target feature became the distractor feature there was a cost. These two measures correlated and were taken to reflect a measure of target activation. When the distractor feature repeated there was a benefit and when the previous distractor feature became the current target feature there was a cost, these two measures correlated and were taken to reflect a measure of distractor inhibition. In the current study we examined the same colour search task online on a large group of 312 participants. The results revealed significant effects of target and distractor repetition and switching. However, the correlations reported by Lamy et al. (2008) were non-significant. Instead we found the correlations between the two measures of repetition and the two measures of switching.

1. Introduction

The visual environment presents the human visual system with a vast amount of information; more information than can be fully processed at any one time (Broadbent, 1958; Tsotsos, 1990). As a consequence, effective human behaviour requires mechanisms that enable efficient selection of relevant stimuli for detailed processing; collectively known as selective attention. The visual search task in which an observer must find a target amongst a set of irrelevant distractors has been used extensively as a tool to characterise these mechanisms of selective attention. In particular, the relative contribution of positive activation of potential targets and negative inhibition of distractors to efficient target selection have been extensively debated (see, Dent, Allen, Braithwaite, & Humphreys, 2012 for a review). Some authors (e.g. Duncan & Humphreys, 1989; Treisman & Sato, 1990; see also Moher et al., 2014) have argued for a major role for distractor suppression. In contrast other authors (e.g. Wolfe, Cave, & Franzel, 1989) have emphasised the importance of target activation. Some authors (e.g. Tsal & Makovski, 2006; MacLeod, Dodd, Sheard, Wilson, & Bibi, 2003) even challenge the possibility of inhibition of distractor representations.

1.1. The priming of pop out (PoP) effect

The operation of visual selective attention is influenced not only by the characteristics of the current stimulus, but also by previous events and behaviours. Maljkovic and Nakayama (1994, 1996) demonstrated that even responses in a fast and efficient search task were strongly influenced by prior trials. In particular, in bicoloured displays where the target is the item coloured differently to the distractors, participants responded faster when the targets and distractors remained the same on two consecutive trials relative to when they switched, an effect they referred to as Priming of Pop-out (PoP).

Explaining how and why PoP occurs and what it tells us about the visual system has become the focus of a sustained research effort, but remains controversial (see Kristjánsson, 2008; Kristjánsson and Campana, 2010; Lamy and Kristjánsson, 2013, for reviews). It is clear that there are multiple possible contributing factors to the global PoP effect. Firstly, there are the effects of repeating or changing the target and distractor features. Secondly, there are the additional effects of switching the roles of the features involved, target to distractor colour and vice versa. These “role reversals” may have effects additional to those of simple repetition. Maljkovic and Nakayama (1994) compared target or distractor feature repetitions against a baseline with new rather that reversed feature values. RTs remained facilitated and facilitation grew larger with a greater number of repetitions, consistent with

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roles for both distractor and target repetition in PoP. Maljkovic and Nakayama (1996) localise these repetition effects to changes in the attentional priority or valence that is associated with particular features, these values being increased or decreased as appropriate by recent events, easing the selection of a target. However, Maljkovic and Nakayama (1994, 1996) did not isolate the effect of role reversal. Subsequently, by using four different stimulus items, and allowing all possible combinations of these stimuli to occur over trials, Kristjansson and Driver (2008) were able to demonstrate effects of both target and distractor repetition and role reversals. However, although Kristjansson and Driver provide an empirical demonstration of role reversal and simple repetition effects, they do not offer a full theoretical account of the relationships between these different components. Can these repetition effects and role reversals be explained by a common mechanism?

1.2. Priming of Pop-out, target activation and distractor inhibition

Lamy et al. (2008) also provided evidence for the existence of distractor and target repetition and role reversal effects. Importantly, they argued that the effects of intertrial relations in visual search can be used to identify processes of target activation and distractor inhibition, and that these processes can explain both repetition benefits and switch costs. In particular, they argued that both target activation and distractor inhibition can manifest and be measured in search in a manner invariant with respect to the method used to measure them. In the experiments reported by Lamy et al. (2008) participants searched for an odd coloured target circle and reported the direction of tilt of an embedded letter T target. The target and distractor colours could repeat, could exchange roles (target colour becomes distractor colour or vice versa), between trials, or could be new (not presented on the preceding trial). The results showed that both target and distractor repetitions and switches affected performance. Lamy et al. (2008) went on to examine the correlations between each of these component effects, and reported two significant correlations: one between the target repetition effect, and the distractor switching effect (when the distractors take the previous target value), and one between the distractor repetition effect, and the target switching effect (when the target takes the previous distractor value). The pattern of correlations was explained by suggesting that one pair of variables (target repetition and distractor switching) measures activation of target features, and the other pair (distractor repetition and target switching) measures inhibition of distractor features in search.

In terms of repetition, activation of a target on trial $n-1$ assists the activation of the same target on trial n, inhibition of distractor features on trial $n-1$ assists the inhibition of distractor features on trial n. In terms of switch effects, when the current distractors take the value of the previously activated target, they are more difficult to inhibit, and when the current target takes the value of the previously inhibited distractors it is more difficult to activate. This explanation recruits similar mechanisms to those suggested by Maljkovic and Nakayama (1996). This explanation also meshes well with the broader literature where the idea that different visual representations may have different levels of activation or weights has been influential (e.g. Duncan & Humphreys, 1989; Wolfe et al., 1989; Houghton & Tipper, 1994).

If it were true that this identification between these different intertrial effects and processes of activation and inhibition could in fact be made then this would be a very important and quite neat finding. However, it is perhaps equally compelling on a priori theoretical grounds to draw a distinction between repetition effects (for both targets and distractors), and switch effects (for both targets and distractors). Some accounts of PoP emphasise perceptual mechanisms attributing faster performance to improved processing for selection or rejection of target and distractor features (e.g. Maljkovic & Nakayama, 1994, 1996). More recent neurophysiological evidence also supports the existence of relatively early attentional-perceptual contributions to PoP. Kristjánsson et al. (2007) for example demonstrated changes of brain activity in areas associated with perceptual processing of colour as a function of PoP.

1.3. Priming of Pop-out, perception, selection, and decision

In contrast, some accounts of PoP emphasise later mechanisms related to episodic retrieval, decision making, and response selection. Lamy, Yashar, and Ruderman (2010) propose that both perceptual and non-perceptual mechanisms affect performance, but for the non-perceptual component they emphasise selection of the overt motor response (see also, Yashar & Lamy, 2011). According to this dual stage account, both target and distractor representations may be modulated at a perceptual level, and response repetition also acts to facilitate selection of the appropriate motor response. However, of greater relevance to the current article are accounts which emphasise processes intermediate between perception and response selection. In particular, the process of determining if an item should be attributed target status and used to drive a response or not, a stage of processing prior to overt motor response selection.

Huang, Holcombe, and Pashler (2004) localize all PoP effects to a decisional stage that seeks to verify whether a selected candidate target is indeed a target. This verification process takes the form of consulting retrieved episodes that match the current trial in various ways, when targets and distractors match over trials performance is fast but costs occur when there is a mismatch. Other authors (Meeter & Olivers, 2006; Olivers & Meeter, 2006) suggest that ambiguity regarding which item should be attributed target status can be a key factor in determining the presence of priming effects (implemented as role reversals). However, in this ambiguity resolution account priming does not stem from an explicit checking process, occurring following target selection, rather mechanisms sensitive to trial history play a greater role in situations of ambiguity, and this can include calculations of perceptual salience.

Tseng, Glaser, Caddigan, and Lleras, (2014; see also Lleras & Buetti, 2014) explicitly suggest that priming effects in Pop-out search should be understood in the context of “attention decision making”. In particular, these authors attribute particular importance to assigning target and distractor status to features present in the display. For example, in the context of search for an odd coloured item, in red and green displays, there is ambiguity in determining whether red is target feature and green a distractor or vice versa. Resolution of this ambiguity results in target or distractor tags being assigned to features prior to target selection, and response execution (Lleras & Buetti, 2014; see also Neill, Valdes, Terry, & Gorfein, 1997). Tseng et al. (2014) also suggest that similar mechanisms may also underlie the related Distractor Preview Effect (DPE). The DPE refers to the finding that target responses are slowed when the current target feature was previously a distractor feature even though no target was present. Note that this decision stage of processing may be particularly important in the compound search tasks typically used to study PoP, since here it is not sufficient to make this assignment, this information must then be used subsequently to drive selection of the target to determine its response relevant feature. When status switches between trials there is conflict which must be resolved and RT costs result. This account is reminiscent of the proposals of Hillstrom (2000) who suggested that priming could be thought of as stemming from the reinstatement of selection rules (essentially mapping features to target and distractor status), however Hillstrom did not explicitly model this mechanism as a formal decision process.

In summary, an alternative to the idea that repetition and switch components in PoP map cleanly onto activation and inhibition of features is that the more important distinction is between earlier perceptual effects and later decision making effects. In particular, we propose that repetition effects when measured against a baseline of new features, and without target-distractor role reversals, may reflect the relatively passive accumulation of attentional priority in early feature representations; a perceptual effect. In contrast switch effects when