The Nature of Unconscious Attention to Subliminal Cues

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Subliminal cues can affect attentional selection. A majority of studies have argued that attentional capture by subliminal cues is entirely automatic and stimulus-driven.

attention unconscious subliminal

1. Spatial Orienting Studies with Unconscious Cues

Another line of research that has demonstrated the influence of subliminal cues on response behaviour are the spatial orienting studies using the Posner cuing paradigm [1]. In a typical experiment, on each trial a peripheral cue is flashed briefly on the screen followed by a target which requires a response (manual or ocular). The influence of the cue is usually measured in terms of the cuing effect which is the difference in response times (RTs) on invalid (when cue and target locations do not match) and valid (when cue and target locations match) trials. If the delay between the cue and target is short (usually less than 100 ms), the cue facilitates responses to the target appearing at the cued location, resulting in faster RTs on valid trials. At longer delays, the pattern is reversed and is referred to as inhibition-of-return (IOR; [2]).

McCormick [3] was the first study to use a Posner cuing task with exogenous cues below the threshold of conscious awareness. The aim of McCormick [3] was to examine the role of awareness in exogenous capture of attention. The argument was that if it can be shown that exogenous orienting can happen even without awareness, then it proves that it is indeed automatic. The theoretical antecedents to this line of thinking once again goes back to traditional theories of attention and control (e.g., [4]) which made a case for the automatic and unconscious nature of exogenous control of attention, contrasting it with deliberate, voluntary, endogenous attention. In his study, McCormick [3] presented cues either subliminally or supraliminally. Participants were told that the target would appear most often at the uncued location. Faster orienting to the target when the cue and target locations matched was seen for subliminal cues. For supraliminal cues, participants were faster when the target appeared at the expected location (that is, the uncued location) suggesting that participants were strategically able to reorient their attention to the expected target location based on the cue. In the absence of awareness, the attention capture at the cued location was more automatic.

Surprisingly, McCormick [3] failed to observe IOR at long stimulus-onset-asynchrony (SOA). Ivanoff and Klein [5] explained the absence of IOR by conducting a similar study, but with cue-report and no-report conditions. In the cue-report condition, participants were asked to report on whether they detected the presence of the unconscious

cue on that trial. IOR was observed at long SOA (1005 ms) only in the no-report condition, but not in the cue-report condition. The inclusion of the cue-report task made the unconscious cues task-relevant and hence, part of the attentional set. Participants failed to disengage from the unconscious cues leading to the absence of IOR in the cue-report condition. This explained the lack of IOR in the McCormick [3] study as well because the participants in that study were additionally asked to report whether they had perceived the unconscious cue on each trial. Interestingly, Ivanoff and Klein [5] observed facilitation at short SOA (105 ms) only in the cue-report, but not in the no-report condition. The authors explained this finding by assuming that “early facilitation combined with early IOR leaving no net facilitation”. This did not happen in the cue-report condition because attention never disengaged from the cue location (hence the absence of IOR). These sets of results showed that unconscious guidance of attention is susceptible to attentional control settings.

Similarly, Mulckhuyse, Talsma, and Theeuwes [6] also showed that cues presented subliminally can exogenously capture attention. A single grey circle presented for 16 ms served as the subliminal cue. The target (a black dot within a grey circle) could be presented either left or right of a central grey circle. The subliminal cue was presented exactly at the target location or at the opposite location. The task was to press the SPACE bar as soon as the target was detected. A short (0 ms) or long (1000 ms) SOA between the cue and the target was used. At short SOA, the subliminal cues facilitated responses to target on valid trials (when cue location matched the target location) as opposed to invalid trials. However, the effect was reversed at long SOA (IOR). The authors argued that this showed exogenous capture by subliminal onset cues. It was considered exogenous for several reasons: the cue was uninformative, it did not resemble the target and gave no information regarding the appropriate response for the target. Further, inhibition of return is considered to occur only when attention has initially shifted reflexively to a location (and not voluntarily). Thus, the authors argued that finding IOR at long SOA can be considered as evidence for exogenous capture of attention at short SOA by the subliminal cues (however, see [7]). This was the first study of unconscious spatial cuing used to show the classic facilitation-followed-by-inhibition effect for unconscious cues. Subsequently, several studies claimed to have shown exogenous attention capture by subliminal cues (see [8] for a review).

In contrast, Ansorge, Kiss and Eimer [9] claimed to show that subliminal stimuli can trigger goal-directed attention capture. The method used in the study was said to be based on the seminal study by Folk, Remington and Johnson [10] using the contingent-capture paradigm. In Folk et al. [10] participants searched either for a red coloured target among white distractors (colour singleton: a unique element in a display with homogenous items) or for a white cross in one of the locations (abrupt-onset: a sudden flashing of a stimulus for a brief duration). Crucially, before the target display, a cue was presented in any of the four possible target locations. The cue could be a colour singleton (one location surrounded by red dots and the others by white dots) or an onset cue (one locations surrounded by white dots). It was found that colour singleton cues captured attention when participants had to look for a colour target. Similarly, the onset cues captured attention when participants looked for an abrupt onset target. Thus, the current task goals of the participant determined what was selected for further processing. With these findings as the basis, in an ERP study, Ansorge et al. [9] presented a cue-display consisting of four circles for 17 ms. One of the colours matched the colour of the target to be searched for. The cue-display was followed by a target display on half of the trials, where the participants had to decide whether the coloured target was a diamond

or a square. On the other half of the trials, no coloured target was presented. Participants were faster responding on trials when the cue location matched the target location. The key evidence came from the N2pc ERP component, which is a signature of attentional allocation to an item. Crucially, this component was observed for the target-coloured cues even when there was no target to be searched for. Based on this, the authors argued that the task-instructions ("look for x coloured target") lead to goal-oriented attentional capture by the target-coloured cues, irrespective of whether the task was to be subsequently performed on that trial or not. This was taken as evidence for the claim that the top-down attentional set a priori determines selection priority, even for unconscious stimuli. However, one major difference between the study and the contingent capture studies such as Folk et al. [10] needs to be noted. Ansorge et al. [9] only used target-matching colour cues. In contrast, Folk et al. [9] used both mismatching- and matching-colour cues and the the key argument for top-down control in their study comes from the fact that cue-validity effects were seen for colour-cue-colour-target—but not for abrupt-onset-cue-colour-target (and vice versa for abrupt-onset cues). Thus, the cue either matched/mismatched the task-set, which was not the case in Ansorge et al. [9]. To what extent this difference raises questions regarding the claim by Ansorge et al. [9] for top-down control will be discussed in later sections.

2. Neural Mechanisms of Top-Down Attention to Unconscious Stimuli

Is there any neural evidence for top-down selection of unconscious stimuli? As mentioned before, Ansorge et al. [9] found a significant N2pc (which reflects spatial shifts in attention, [11]) for the relevant subliminal cues. Using the continuous flash suppression paradigm, Travis et al. [12] recently replicated the contingent capture findings of Ansorge et al. [9] to find the neural correlates of top-down suppression of unconscious cues. Using a similar feature-based cuing paradigm, the authors found that only subliminal cues that matched the target colour were successful in orienting the participants' attention to the cued location, thereby eliciting cuing effects. More importantly, authors found a significant N2pc for the target-colour cues and Pd (distractor positivity—a signature of distractor suppression, [13]) for the distractor coloured cues. The authors interpret the findings based on the signal suppression hypothesis [13][14] according to which top-down suppression mechanisms inhibit attention capture by distractor stimulus and enhance the processing of task-relevant stimuli. This position is a radical departure from earlier theories of visual selection, according to which attention is initially captured by salient distractors, and then redirected to task-relevant stimuli. Support for the signal-suppression hypothesis also comes from a recent study on monkeys, which used a combination of single neuron recordings and surface ERP measures [15]. Cosman et al. [15] found that neurons in the pre-frontal cortex and frontal eye field are responsible for both selection of relevant features and the suppression of irrelevant distractor items. Thus, the findings of Ansorge et al. [9] and Travis et al. [12] provides neural evidence of goal-oriented processing of relevant stimuli even in the absence of awareness.

Goal-directed processing of relevant stimuli or cognitive control has typically been associated with activations in the higher-order brain areas such as the pre-frontal cortex. Whereas such complex control of behaviour by the brain has been mostly restricted to the domain of consciousness [16], more recently, evidence has emerged that areas in the pre-frontal cortex can also be activated in response to unconscious stimuli [17][18]. Evidence has come from

studies that have tracked the neural correlates of unconscious inhibition using tasks such as go no-go or stop-signal tasks, which tap into inhibitory control or conflict resolution [18][19][20][21]. Additionally, Ulrich, Adams, and Kiefer [22] showed dynamic functional connectivity between brain areas depending on the configuration of the task-set using fMRI. In a semantic categorisation task with subliminal primes, higher activation was found in regions responsible for semantic processing. This in turn led to enhanced processing of the semantic properties of the unconscious stimuli. Researchers provides neurobiological evidence for the attentional sensitisation model of unconscious cognition [23] and explains how the selective processing of unconscious stimuli based on their relevance to the current task goals is realised in the brain.

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