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When endogenous spatial attention improves conscious perception: Effects of alerting and bottom-up activation

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ABSTRACT

Recent studies have consistently demonstrated that conscious perception interacts with exogenous attentional orienting, but it can be dissociated from endogenous attentional orienting (Chica Lasaponara, et al., 2011; Wyart & Tallon-Baudry, 2008). It has been hypothesized that enhanced conscious processing at exogenously attended locations results from a synergistic action of spatial orienting, bottom-up activation, and phasic alerting induced by the abrupt onset of the exogenous cue (Chica, Lasaponara, et al., 2011). Instead, as endogenous cues need more time to be interpreted, the phasic alerting they produce may have dissipated when the target appears. Furthermore, endogenous cues presumably elicit a weak bottom-up activation at the cued location. Consistent with these hypotheses, we observed that endogenous attention modulated conscious perception, but only when phasic alerting or bottom-up activation was increased. Results are discussed in the context of recent theoretical models of consciousness (Dehaene, Changeux, Naccache, Sackur, & Sergent, 2006).

1. Introduction

Although spatial attention and conscious perception have been historically considered as interdependent processes, some recent studies have challenged this widely accepted view, demonstrating the existence of reliable dissociations between some forms of selective attention and conscious perception.[1] Interesting examples of dissociations between the two processes have been observed both in blindsight patients (Kentridge, Heywood, & Weiskrantz, 1999a; Kentridge, Heywood, & Weiskrantz, 2004) suffering from severe conscious perceptual impairments, as well as in healthy individuals (Kentridge, Nijboer, & Heywood, 2008; Koch & Tsuchiya, 2007; Wyart & Tallon-Baudry, 2008). Nonetheless, it should be noted that most of the dissociations reported in the literature concern endogenous or top-down mechanisms of attentional selection. This is particularly important if we take into account that it has been widely shown that endogenous and exogenous attention constitute two independent attentional mechanisms. Most of what is known about these attentional orienting mechanisms comes from studies using Posner's cost and benefits paradigm (1980), in which endogenous and exogenous attention are studied by manipulating cue-type (see Chica, Martín-Arévalo, Botta & Lupiáñez, submitted for publication). In a typical costs and benefits paradigm, a cue is presented before the target onset and response times (RTs) and accuracy for targets presented at valid vs. invalid locations are compared. In the case of endogenous attention, a symbolic cue (e.g., an arrow or a number) is presented at fixation indicating the likely target location among the possible target locations. In the case of exogenous attention, the cue is presented directly

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[1] Here we will refer to attention as a mechanism for the selection of certain aspects of our physical environment. Specifically, in the present experiments, we will manipulate selective spatial attention by using endogenous cues. Furthermore, we refer to conscious perception as a mechanism allowing the reportability of near-threshold stimuli.

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near or at one of the possible target locations, and is absolutely unpredictive about the target location. For both cue types, there could be instances of valid trials (in which the cue reliably indicates the target location), neutral trials (in which neither location is signaled) and invalid trials (in which the cue indicates a different location than the target). The comparison between valid, invalid, and neutral trials, allows differentiating attentional orienting benefits (valid cue trials minus neutral trials) from costs (invalid cue trials minus neutral trials). Typically, the main finding is that, compared to neutral trials, valid trials produce faster and/or more accurate responses (benefits) while for invalid trials responses are slower and/or less precise (costs). The sum between costs and benefits represents the so-called attentional cuing effect (e.g., Posner, 1980).

Even though both endogenous and exogenous cues produce effects on reaction time and/or accuracy, they exert different functions that have been dissociated in many circumstances (Chica, Bartolomeo, & Lupianez, 2013; Funes, Lupiáñez, & Milliken, 2007; Hein, Rolke, & Ulrich, 2006; Yeshurun, Montagna, & Carrasco, 2008). Exogenous attention is assumed to represent the automatic capture of attention; it is relatively unaffected by cognitive load and cannot be suppressed (Jonides, 1981). Moreover, the temporal course of exogenous attention is characterized by a fast and transient response characterized by a quick rise at 150 ms and then by a fall to a lower asymptotic level, showing a typical inhibitory aftereffect, known as inhibition of return (IOR). Endogenous attention corresponds to the top-down, voluntarily deployment of spatial attention, is resource-limited, and easy to suppress. Furthermore its response is characterized by a monotonic rise to an asymptote at around 300 ms[2] and can last for several seconds (Posner, 1980). Finally exogenous and endogenous attention are implemented by partially segregated neural substrates (Chica, Bartolomeo, & Valero-Cabré, 2011; Corbetta, Patel, & Shulman, 2008; Corbetta & Shulman, 2002).

Therefore, it is possible that whereas endogenous attention does not modulate conscious perception, exogenous attention might in fact do so. Chica, Lasaponara, et al. (2011) addressed this issue by directly comparing the modulation exerted by endogenous vs. exogenous attention over conscious perception. Specifically, they presented normal participants with near-threshold target stimuli, preceded either by central endogenous cues or by peripheral exogenous cues. Target contrast was manipulated so that participants could only perceive a proportion of the targets. Their results demonstrated that while exogenous attention, especially when triggered by spatially predictive peripheral cues (see Chica, Lasaponara, et al.'s, 2011 Experiment 5), reliably modulated conscious reports, increasing conscious detection rates at valid vs. invalid locations, endogenous attention produced null or weak effects on conscious perception. These results have been widely re-confirmed by electrophysiological, neuroimaging, and non-invasive neurostimulation studies (Chica, Botta, Lupiáñez, & Bartolomeo, 2012; Chica, Paz-Alonso, Valero-Cabré, & Bartolomeo, 2012; Chica, Valero-Cabré, Paz-Alonso, & Bartolomeo, 2012; see Chica & Bartolomeo, 2012, for a review). This line of research convincingly demonstrates that endogenous attention can be dissociated from conscious perception, while exogenous attention strongly modulates it. However, exogenous attentional capture is not sufficient for conscious access, as there are many instances in which there is evidence of attentional capture with no subsequent conscious perception (Lambert, Naikar, McLahan, & Aitken, 1999; McCormick, 1997). For instance, it has been observed that, during visual search tasks, distractor stimuli can capture attention, affecting participants' performance and ocular movements, while participants are totally unaware of the presentation of these distractors (Theeuwes, Kramer, Hahn, & Irwin, 1998).

Apart from spatial orienting, other processes might be necessary for conscious processing. For example, phasic alerting,[3] manipulated by presenting alerting tones at predictable or unpredictable intervals before target appearance, increases conscious perception by modulating both perceptual sensitivity and response criterion (see Kusnir, Chica, Mitsumasu, & Bartolomeo, 2011).

Therefore, although important empirical evidence has been collected, the necessary and sufficient conditions for conscious perception still remain to be determined. The Global Neural Workspace, a very well-received theory of consciousness proposed by Dehaene et al. (2006; see also Dehaene & Changeux, 2011), states the existence of three important conditions for access to conscious report: (1) a sufficient level of vigilance, (2) a sufficient level of bottom-up activation of early sensory regions, and (3) the reverberation of brain activation to higher association cortices interconnected by long-distance fiber tracts. On the basis of this theoretical model, it may be possible to understand why exogenous attention is an important modulator of our conscious experience while top-down or endogenous attention seems not to be. Chica, Lasaponara, et al. (2011) hypothesized that the effect of exogenous attention on conscious perception might plausibly be explained as the result of a synergistic action of phasic alerting and attentional capture, both produced by the cue-related bottom-up activation. In other words, the presentation of a salient, abrupt-onset cue near the location of the subsequent near-threshold target, would produce, on the one hand, a bottom-up activation of early visual areas and, on the other hand, an increase of phasic alerting, which would synergistically produce an increase of conscious perception. This is important because stronger effects on conscious perception are observed when using spatially predictive peripheral cues, which can be considered as hybrid cues, producing a bottom-up activation (because they are salient and peripheral), and a top-down modulation (because they are spatially predictive of the target location) (see Chica, Lasaponara, et al., 2011). These cues are plausibly able to elicit phasic

[2] Note that the minimum cue-target SOA to obtain significant cuing effects depends of the type of central cue. While in fact arrow cues are interpreted in 300 ms, given our extended practice with them, color cues need at least 600 ms to be interpreted and orient endogenous attention accordingly with their meaning.

[3] Note that according with the three-network view of attention originally proposed by Posner and Petersen (1990) alerting and spatial attention play different functions. While orienting refers to spatial selection, that is, to the ability to select information from a specific location, phasic alerting refers to preparedness for an impending stimulus (Raz & Buhle, 2006).