Neuropsychologia 99 (2017) 165–171

Contents lists available at ScienceDirect

Neuropsychologia

journal homepage: www.elsevier.com/locate/neuropsychologia

# Orienting of attention with and without cue awareness

Laura Herreros[a], Anthony J. Lambert[b], Ana B. Chica[a,*]

[a] Department of Experimental Psychology, and Brain, Mind, and Behavior Research Center (CIMCYC), University of Granada, Spain
[b] School of Psychology, and Research Centre for Cognitive Neuroscience, University of Auckland, Auckland, New Zealand

ARTICLE INFO

*Keywords:*
Attentional orienting
Conscious perception
Exogenous attention
Near-threshold stimulation

ABSTRACT

Many cognitive processes operate without consciousness, and exogenous attentional capture seems to be one of them. While endogenously attending to the opposite location of a cue cannot occur without cue awareness, attending the cued location in an exogenous or stimulus driven form can occur even when participants are not aware of the presence of the cue (McCormick, 1997). Orienting attention to a specific location shortens reaction times to supra-threshold stimuli, and increases the likelihood of consciously perceiving near-threshold stimuli in that location. Effects of unconscious cues have mostly been demonstrated in reaction times to supra-threshold targets. In some studies, unconscious cues were perceptually less salient than conscious cues, which introduced a confound between cue awareness and cue saliency. In the present study, we used near-threshold cues and targets, which were titrated to be consciously perceived in ~50% of the trials, therefore eliminating the cue saliency confound. Moreover, we explored for the first time the effects of cue awareness on the conscious perception of subsequently presented near-threshold targets. Our results demonstrate that when cues and targets did not spatially overlap, conscious cues enhanced target localization when they appeared near the target location. In contrast, non-consciously perceived cues impaired target localization when they appeared near the target location, producing a cost in detecting subsequently presented near-threshold targets. This indicates that attentional orienting by unconscious cues cannot be accounted for by the idea that attention modulates perceptual representations, boosting them nearer to the conscious threshold. Rather, the effect of unconscious cues on target localization is qualitatively different to that elicited by conscious cues.

## 1. Introduction

Generally speaking, our environment is littered with stimuli that compete to be perceived by our sensorial organs (Treisman, 1960). Frequently, this competition implies that we can consciously perceive only part of the available information, especially when we have to verbally report it (Sperling, 1967). This limitation of conscious perception could explain why some cognitive processes, such as for example attentional orienting, may not require consciousness. Many tasks can be performed even without being conscious of the stimuli (Gaillard et al., 2006; Kentridge et al., 1999, 2004; Sklar et al., 2012; van Gaal et al., 2010, 2014), the relations between stimuli (Bartolomeo et al., 2007; López-Ramón et al., 2011; Ristic and Kingstone, 2012), the relations between stimuli and responses (Raio et al., 2012; Reber, 1967; Pessiglione et al., 2008; Seitz et al., 2009), or the responses (Jiménez et al., 2009; Lau and Passingham, 2007; Reuss et al., 2015; Soon et al., 2008; van Gaal et al., 2009, 2010).

Much evidence suggests that attention enhances neural processes irrespective of whether they reach consciousness (see Koch and Tsuchiya, 2007, for a review). Neuropsychological evidence has been crucial for this literature. Blindsight patients, despite cortical damage in the visual cortex, can guess the orientation of stimuli they deny seeing (Weiskrantz, 1997). When the location of the unseen stimulus is indicated by an attentional cue, blindsight patients can perform faster (Kentridge et al., 1999, 2004), demonstrating that they can pay attention without being conscious of the cues *or* targets (see also Schurger et al., 2006). In people without brain damage, there have been numerous demonstrations of attention without consciousness (see e.g. Kentridge et al., 2008; McCormick, 1997; Mele et al., 2008; Reuss et al., 2011). An appealing explanation for attentional modulations of unconscious stimuli might be that attention boosts the perceptual representation of weak stimuli toward the conscious threshold, enhancing their perceptual strength, even if they do not reach consciousness (Sumner et al., 2006). In this case, unconscious information should produce effects comparable to conscious information, although reduced in size.

In the present paper, we focus on attentional orienting mechanisms with and without cue awareness. Attentional orienting is one of the

* Correspondence to: Departamento de Psicología Experimental, Facultad de Psicología, Universidad de Granada, Campus de Cartuja S/N, CP 18071 Granada, Spain.
*E-mail addresses:* lauraherreros@correo.ugr.es (L. Herreros), anachica@ugr.es (A.B. Chica).

http://dx.doi.org/10.1016/j.neuropsychologia.2017.03.011
Received 21 July 2016; Received in revised form 7 March 2017; Accepted 7 March 2017
Available online 08 March 2017
0028-3932/ 

three attentional subsystems proposed by Posner and Petersen (1990) and Petersen and Posner (2012). This system prioritizes selection of spatial information to accomplish two important goals (Chica et al., 2013). Orienting of attention in space can be controlled either endogenously by the system (endogenous orienting of attention, which is also known as top-down or voluntary attention), or exogenously, by external stimulation (exogenous orienting of attention or bottom-up, involuntary or stimulus-driven attention). Some studies have demonstrated that we can endogenously attend to the location of an informative peripheral cue, and even to the opposite location, without being conscious of the probabilistic relationship between the cue and target location (Bartolomeo et al., 2007; Lambert et al., 1999; López-Ramón et al., 2011; Ristic and Kingstone, 2012). Other experiments have even shown that we can exogenously orient attention to the location of a cue that is not consciously perceived, although we cannot orient endogenous attention to the opposite location without cue awareness (McCormick, 1997). Consistent with these data, Mele et al. (2008) also demonstrated that peripheral cues could produce another exogenous attentional effect, Inhibition of Return, observed at longer cue-target intervals (Lupiáñez et al., 2006) without being conscious of the cues (see also Lambert et al., 1999; Mulckhuyse et al., 2007). These studies reported reaction time (RT) effects when targets were clearly visible and cues were either highly visible (conscious condition) or completely invisible (unconscious condition) (except for Exp. 3 in McCormick, 1997, discussed below).

Because consciously seen and unseen cues differed in perceptual saliency in the previous studies (see also Lambert et al., 1999) results assumed to be produced by the conscious - non-conscious processing of the cue could be confounded with cue perceptual saliency. In this line, some studies have demonstrated that reducing either the cue saliency (Pack et al., 2013) or target saliency (Shin and Lambert, 2012) enhances attentional effects. This is why McCormick (1997) used a single cue in Exp. 3. The cue was titrated for each participant, manipulating its saliency to achieve conscious perception of the cue in ~75% of the trials. Therefore, a single cue was used that was judged as seen or unseen in every trial. Results replicated his previous experiments, indicating that unconsciously perceived cues could exogenously orient attention to the cued location.

In the present study, we used near-threshold cues and targets, which were titrated for each participant before the experimental blocks to be consciously perceived in ~50% of the trials, therefore eliminating the cue saliency confound. Moreover, based on previous work, we knew that exogenous attentional orienting is an important modulator of target awareness, i.e. exogenously attending to a certain location increases perceptual sensitivity to detect near-threshold stimuli in that location. In other words, exogenous attentional orienting modulates perceptual threshold, boosting the perceptual strength of near-threshold stimuli (Chica and Bartolomeo, 2012; Liu et al., 2005). Here, we explored for the first time the effects of conscious and non-consciously perceived cues on the capacity to detect near-threshold targets. Our findings show that non-consciously perceived cues elicit robust effects on attention, and that these effects are not merely a weaker version of those elicited by conscious cues, but are qualitatively different from conscious cueing effects.

### 1.1. Experiment 1

In the present study, we used Gabors as cues and targets. Cue and target Gabors only differed in the orientation of the lines that composed them (tilted either left or right). Before the experimental blocks, the Gabor was titrated so that ~50% of stimuli were seen consciously. Therefore, we used a single Gabor contrast, which was the same for the cue and target, eliminating the perceptual confound described above, in our design. During the experimental blocks, cue and target Gabors were presented either at the same spatial location (valid trials) or at the opposite location (invalid trials). To our knowledge, this is the first experiment in which both the cue and target are near-threshold stimuli, allowing us to measure the influence of cue awareness on the conscious perception of a subsequently presented target. The objective of this study was to compare, for the first time, the effects of conscious and unconscious cues on perceptual sensitivity and response criterion to detect subsequently presented near-threshold targets.

## 2. Method

### 2.1. Participants

Twenty-three students from the Faculty of Psychology of the University of Granada voluntarily participated in the present experiment in exchange for course credit (4 men; mean age 21 years, SD = 2.23). All participants in Experiments 1 and 2 reported having normal or corrected-to-normal vision and no clinical history of neurological or neuropsychological disorders. The local research ethics committee from the University of Granada approved the experiments.

### 2.2. Apparatus and stimuli

E-prime software was used to control the presentation of stimuli, timing operations, and data collection (Schneider et al., 2002). Participants were seated at an approximate distance of 57 cm from the computer screen. At this distance, 1 cm corresponds to 1° of visual angle. All stimuli were presented on a gamma corrected monitor (30 cm height × 54 cm width), with a refresh rate of 60 Hz. Stimuli were presented against a grey background (luminance = 90 cd/$m^2$). In each trial, a fixation point (a plus sign, 0.5° × 0.5°) was presented at the center of the screen. Two black boxes (5.3° in height by 7° in width) were displayed, centered 7.8° to the left and right of the fixation point (as measured from the center of the box to the fixation point). Both the cue and target consisted of Gabors (0 phase, 4 cycles per degree of visual angle, with a diameter of 3°, and SD of 0.3) with a maximum and minimum Michelson contrast of 0.92 and 0.02, respectively. Both cues and targets could appear in any of the two boxes. The Gabor used as a cue was composed of lines tilted 10° to the right, while the Gabor used as a target was composed of lines tilted 10° to the left (see Fig. 1).

### 2.3. Procedure

Fig. 1 displays the sequence and timing of a trial. Trials started with a fixation point presented for 1000 ms. Then, the cue appeared for 32 ms, 50% of the trials within the left marker and the remaining 50% of the trials within the right marker. The inter-stimulus interval (ISI) lasted for 218 ms. After this interval, the target was presented on 67% of the trials, while in the remaining 33% of the trials no target was presented (catch trials). If the target was present, it appeared for 32 ms in one of the markers, with equal probability (50%). When the target disappeared (or after 32 ms), the fixation point increased its size (0.6° × 0.6°), indicating to participants that they should respond to the target localization task. Participants were instructed to respond accurately, with no time pressure, and therefore, this display remained on the screen until a response was detected. Participants had to press the "n" key if they saw the target in the left box, the "m" key if they saw the target in the right box, and the spacebar if they saw no target. After the target response, participants had to indicate if they saw the first stimulus (the cue). They were presented with the symbol "¿1?" at fixation. If they consciously perceived the cue, they were asked to press (with their left hand) the "a" key, while if they did not see the cue, they were asked to press the "z" key.

Gabor contrast was manipulated before the experimental trials in order to adjust the percentage of consciously perceived stimuli at ~50%. In a separate calibration block, we presented participants with a single Gabor stimulus during blocks of 24 trials (fixation = 1000 ms, Gabor = 32 ms, Until response). All participants started with a supra-