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Cue discriminability predicts instrumental conditioning

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ABSTRACT

Charting mental acts that succeed or fail under unconscious instances of cognition informs debates on the nature and potential functions of consciousness. A prominent method to exclude conscious contributions to cognition is to render visual stimuli unconscious by short and pattern-masked presentations. Here, we explore a combination of visual masking and pixel noise added to visual stimuli as a method to adapt discriminability in a fine-grained fashion to subject- and stimulus-specific estimates of perceptual thresholds. Estimates of the amount of pixel noise corresponding to perceptual thresholds are achieved by psychometric adaptive algorithms in an identification task. Afterwards, the feasibility of instrumental conditioning is tested at four levels of cue discriminability relative to previously acquired estimates of perceptual thresholds. In contrast to previous reports (Pessiglione et al., 2008), no evidence for the feasibility of instrumental condition was gathered when contributions of conscious cognition were excluded.

1. Introduction

The delineation of mental acts that depend on consciousness from the ones that do not has been instrumental to investigate potential functions of consciousness (Baars, 1997; Kouider & Dehaene, 2007). Knowledge about the limits of unconscious cognition not only informs debates on the nature of consciousness in general (Dehaene & Changeux, 2011; Dehaene, Charles, King, & Marti, 2014; Mudrik, Faivre, & Koch, 2014) but also has an impact on further topics in cognitive science such as cognitive control (van Gaal, De Lange, & Cohen, 2012), language processing (Rastle & Brysbaert, 2006), or learning & memory (Greene, 2007; Hannula & Greene, 2012; Henke, 2010).

It seems undisputed that unconscious processing can go beyond the integration of low-level visual features such as size, shape, color and motion (e.g., Blake & Fox, 1974; Watanabe, Náñez, & Sasaki, 2001). Consciousness may be the crucial ingredient for cognition to succeed at higher levels of complexity, such as the learning of dependencies between temporally discontiguous events (e.g., Clark & Squire, 1998). However, conflicting evidence exists on whether, to what extent, and under which circumstances e.g. unconscious numerical cognition (Bahrami et al., 2010; Hesselmann, Darcy, Sterzer, & Knops, 2015), unconscious response inhibition (Chiu & Aron, 2014; Lin & Murray, 2015; van Gaal et al., 2012; van Gaal, Ridderinkhof, Scholte, & Lamme, 2010), or unconscious long-term memory (Clark & Squire, 1998; Duss et al., 2014; Greene, Spellman, Levy, Dusek, & Eichenbaum, 2001; Hannula, Ryan, Tranel, & Cohen, 2007; Konstantinidis & Shanks, 2014; Pessiglione et al., 2008; Reber, Luechinger, Boesiger, & Henke, 2012; Ryan, Althoff, Whitlow, & Cohen, 2000; Smith & Squire, 2005) succeeds or fails.

Unconscious processing is often investigated by assessing effects of visual stimuli that are delivered such that they are not perceived consciously. Methods to hide visual stimuli from awareness include among others interfering with cognitive processes such as e.g. attention (e.g., Raymond, Shapiro, & Arnell, 1992; Reber et al., 2017) or perception by e.g., flash suppression (Hesselmann

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et al., 2015; Kreiman, Fried, & Koch, 2001) or backward masking (Greenwald, Klinger, & Schuh, 1995; Quian Quiroga, Mukamel, Isham, Malach, & Fried, 2008). Masking has been a prominent method to reliably render stimuli unconscious (reviewed in Kouider & Dehaene, 2007). Masked presentations are considered to elicit unconscious processing when two conditions are met. First, participants either report complete unawareness or perform at chance on tasks that require them to directly discriminate or identify the masked stimulus, i.e., direct tests or awareness tests (Greenwald et al., 1995). Second, stimulus presentations nevertheless affect behavior indirectly. Such indirect or unconscious effects are usually obtained on tasks that are not directed at masked stimuli per se but at something else such as a clearly discriminable and detectable stimulus following the masked stimulus (Greenwald et al., 1995).

A challenge is to stimulate weakly enough to reliably obtain chance performance on direct tests but nevertheless strongly enough to obtain significant effects on indirect tests. Often, presentation duration of the stimulus is the parameter of choice to adjust stimulation intensity. However, presentation duration can only be adjusted with limited precision using standard computer hardware (Elze, 2010). Duration can only be varied in discrete steps corresponding to the display's refresh-rate (approximately 16.6 ms at 60 Hz). Thus, a participant may be aware of most of the stimuli at 3 refresh-cycles (50 ms) while stimulation is very weak or even too weak at 2 refresh-cycles (33 ms) to elicit even unconscious processing. Furthermore, researchers tend to choose conservative values of presentation duration that are also fixed across participants. Together, coarse-grained resolution of presentation duration and the choice of a fixed presentation duration across subjects may result in high inter-individual variability. In the current work, we propose a method of individual adjustments of stimulus intensity using a more fine-grained method than presentation duration to render stimuli indiscriminable. Random pixel noise added to brief and masked visual stimuli can be varied in a virtually continuous fashion and is efficient to render stimuli indiscriminable when applied in combination with brief presentation duration and pattern masking.

Assessing effects of various kinds of noise has a long tradition in psychophysics (Lu & Dosher, 2008) but only few studies we are aware of have used noise as a tool to investigate unconscious processing (e.g., Seitz & Watanabe, 2003). Both masking and pixel noise can be seen as forms of noise added to a perceptual signal. Regarding perception as a process that accumulates sensory evidence over time (Parker & Newsome, 1998), a pattern mask acts as noise in the temporal domain while pixel noise added to an image acts as noise in the spatial domain. Numerous previous masking studies have made efforts to keep noise in the spatial domain constant e.g. by matching visual features between stimuli and using the same or highly similar masking images throughout the experiment (Greenwald et al., 1995; Mastropasqua & Turatto, 2015; Pessiglione et al., 2008). Rather than in the spatial domain, they adjusted the signal to noise level in the temporal domain by varying the presentation duration of the stimuli, i.e., the signal, and the masks (i.e., the noise; see e.g., Pessiglione et al., 2008). We here propose to fix the timing aspects of the masking procedure but adjust the amount of spatial noise added to the visual signal. As we combine pixel noise with backward masking and short presentation duration, the amount of pixel noise required to render stimuli unconscious is rather low such that the image information is well preserved.

Individual adjustments of discriminability are achieved by psychometric adaptive algorithms of noise-level. Individual estimates are obtained before the main experiment using a psychometric adaptive algorithm (QUEST; Watson & Pelli, 1983). These procedures enable to investigate effects of masked stimuli at several degrees of discriminability within-subject. As we use procedures from psychophysics, we use the term 'threshold' as is common in psychophysics. We refer to the 'threshold' as the stimulus intensity at which subjects report having seen the stimulus 50% of the time (Kingdom & Prins, 2009). Thus, such a threshold intensity, as well as some intensities below this threshold, i.e., sub-threshold or subliminal intensities, can result in significantly above chance performance in a direct discrimination or detection test (i.e., $d' > 0$). In unconscious processing research, in contrast, the term 'threshold' is defined as the maximal stimulus intensity at which direct detection or discrimination test performance does not exceed chance (i.e., $d' = 0$: Greenwald et al., 1995). Thus, 'sub-threshold' or 'subliminal' stimulus intensities are defined as intensities at which, ideally, the participants report never having seen or being able to discriminate masked stimuli at all.

It is therefore important to keep in mind that significant effects on indirect tests at stimulus intensities corresponding to below-threshold stimulus intensities on direct tests do not per se index purely unconscious processing according to the terminology we use. To make claims of truly unconscious processing, one can either require a d' that is insignificantly different from zero on a direct test in combination with a d' significantly above zero on the indirect test, or use the regression method introduced by Greenwald, et al. (1995). Here, we assess claims of unconscious processing by the regression method as it makes more efficient use of all the data gathered, especially in the design we use here. To this aim, a regression model ($y = ax + b$) is fitted to the data taking the direct measure as predictor (x) and the indirect measure as criterion (y). Claims of unconscious processing can be made if the regression line is above zero at $x = 0$, i.e. if the intercept (b) is significantly larger than zero.

Here, we test the proposed procedures by adapting a paradigm to assess the feasibility of unconscious instrumental conditioning (Pessiglione et al., 2008), that has also been replicated in different contexts by others (Atas, Faivre, Timmermans, Cleeremans, & Kouider, 2013; Mastropasqua & Turatto, 2015).

2. Methods

2.1. Design

The study consisted of three parts. In the first part, subject- and stimulus- specific thresholds were estimated in an identification task in which the noise level was varied continuously according to an adaptive psychometric algorithm (QUEST; Watson & Pelli, 1983). Note that we refer to the noise level at which participants report having been able to identify the image in 50% of the trials as 'the threshold of perception' as is common in psychophysics. In studies of unconscious perception, in contrast, the threshold often denotes stimulus intensity at which participants perform at chance level in a direct discrimination or identification test. The second part tested for instrumental conditioning (Pessiglione et al., 2008). This test was conducted at four levels of discriminability that were