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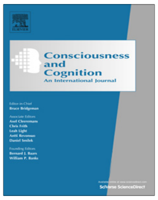

Unconscious and out of control: Subliminal priming is insensitive to observer expectations

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ABSTRACT

We asked whether the influence of an invisible prime on movement is dependent on conscious movement expectations. Participants reached to a central target, which triggered a directional prime–mask arrow sequence. Participants were instructed that the visible arrows (masks) would most often signal a movement modification in a specific (biased) direction. Kinematic analyses revealed that responses to the visible mask were influenced by participants' intentional bias, as movements were fastest when the more probable mask was displayed. In addition, responses were influenced by the invisible prime without regard to its relationship to the more probable mask. Analysis of the time of initial trajectory modifications revealed that both primes influenced responses in a similar manner after accounting for participants' bias. These results imply that invisible stimuli automatically activate their associated responses and that unconscious priming of the motor system is insensitive to the conscious expectations of the participant making the pointing movements.

1. Introduction

Visual masked priming can be used to explore visuomotor processing in the absence of conscious awareness. In a typical masked priming experiment, participants are instructed to make a speeded response based on a feature of a visible target shape (*mask*): for example, to press a left or right key in response to the direction of a centrally presented large arrow (see Vorberg, Mattleer, Heinecke, Schmidt, & Schwarzbach, 2003). Unbeknownst to the participants, an arrow shape (*prime*) precedes the mask shape, pointing in either the same or opposite direction as the subsequent mask. Even though the prime is rendered invisible to consciousness as a result of metacontrast masking (for reviews see Breitmeyer, 1984; Breitmeyer & Ogmen, 2000; Enns & Di Lollo, 2000; Kahneman, 1968), response times to the mask are dependent on prime–mask congruency. In particular, response times are facilitated when the prime shares attributes critical to the correct response (congruent trial) and delayed when it shares attributes critical to the alternative response (incongruent trial) (Ansorge, Heumann, & Scharlau, 2002; Dehaene et al., 1998; Neumann & Klotz, 1994; Schmidt, 2002; Taylor & McCloskey, 1990, 1996).

To explain how subliminal primes influence action, Kiesel, Kunde, and Hoffmann (2007) and Kunde, Kiesel, and Hoffmann (2003) have proposed the Action-Trigger Hypothesis (ATH), an elaboration of Neumann's (1990) theory of Direct Parameter Specification. According to the ATH, the ability of a subliminal stimulus to influence action is governed by one's intentions. Specifically, the model proposes that action triggers are established based on task demands, such that task relevant stimuli

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are mapped to appropriate responses. After establishing action triggers, stimulus processing is then restricted to determining whether an incoming stimulus is associated with an action trigger. If a match is obtained, the related action trigger is activated automatically, independent of participants' conscious awareness, with the potential to evoke a response. In particular, as suggested by Vorberg et al.'s (2003) accumulator model of priming, a response will be initiated when the accumulated neural evidence for one response alternative (or action trigger) vs. the opposite response alternative (the second action trigger) achieves a critical value. Thus, processing of a subliminal prime leads to activation of its associated response, driving the difference in accumulators towards the response associated with the prime.

In support of the ATH, electrophysiological indices of motor-related cortical activation and behavioural results have demonstrated that invisible primes activate their corresponding responses. In general, electrophysiological studies have derived lateralized readiness potentials (LRPs) from motor-related cortical activity during the reaction time interval of metacontrast masking experiments (e.g., Dehaene et al., 1998; Eimer & Schlaghecken, 1998; Jaskowski, Skalska, & Verleger, 2003; Leuthold & Kopp, 1998; Vath & Schmidt, 2007). Vath and Schmidt (2007) have shown that, in addition to obtaining the expected prime–mask congruency effects outlined above, the time-course and shape of the LRP indicate that the masked primes can activate the corresponding response at the level of the motor cortex.

Behavioural results from Schmidt et al. have demonstrated that even early phases of a movement can be governed by a prime (Schmidt, 2002; Schmidt, Niehaus, & Nagel, 2006; Schmidt & Schmidt, 2009, 2010; Schmidt & Seydell, 2008). In Schmidt's paradigms, participants were instructed to initiate a movement in a direction dictated by a mask stimulus. By analyzing the kinematics of the resulting movements, Schmidt found that the time of movement onset and direction was influenced by the prime, independent of the subsequent mask. Consistent with these results, Cressman, Franks, Enns, and Chua (2007) showed that an invisible prime stimulus can activate its associated response even when its presentation occurred during an already initiated action, demonstrating that a prime not only influences response selection or initiation processes but can also take over on-line control of one's movements.

In the paradigm by Cressman et al. (2007), participants were given the fixed movement goal of completing a rapid movement to a central target location. On the majority of trials a neutral prime–mask sequence was presented in the central target after movement initiation. On a small percentage of trials, the neutral sequence was replaced with a directional prime–mask arrow sequence. The directional mask was the signal for participants to change their pointing direction from the central target and move toward either a left or right eccentric target location, as specified by the direction of the mask arrow. Although participants were not conscious of the primes, kinematic analyses revealed that movement trajectories deviated in the direction of the prime (left or right) before deviating in the direction of the visible mask.

Although the ATH (Kiesel et al., 2007; Kunde et al., 2003) proposes automatic activation of established action triggers, the detailed content of these action triggers is not specified. Recent results by Jaskowski et al. (2003), Wolbers et al. (2006) and Ansorge et al. (2002), suggest that one is able to strategically mediate a prime's influence on response initiation. Jaskowski et al. (2003) manipulated the percentage of congruent and incongruent prime–mask trials between blocks of trials, reporting that a prime's influence was greater when there was a higher percentage of congruent trials. Jaskowski concluded that this action modification arose strategically, as a function of participants observing their own overt errors. While this study implies that the prime's influence on movement may be modified under certain circumstances, it remains unclear if consciously manipulating the probability of a mask-related response will lead to changes in how action triggers are established and hence affect automatic prime-related processing.

In the present study we tested whether the probability of making a movement in one direction or another has an influence on these prime-evoked directional responses. Specifically, we asked whether action triggers are established equally for low and high probability responses. To address this question, we manipulated the baseline probability of the directional masks that participants saw and responded to on each trial. Specifically, we modified the protocol of Cressman et al. (2007) such that on 80% of trials in which a mask arrow was presented, it pointed in a particular direction (either right or left). Participants were instructed of this bias and their experience in the testing session confirmed that one directional mask appeared with much greater frequency than the other mask.

Given that participants had both conscious knowledge and specific experience to support the expectation that one direction of movement modification would be more likely than another direction, we expected them to bias their movements intentionally. We anticipated that this bias would lead to faster responses when the more probable mask was displayed compared to the less probable mask (Blackman, 1972; Hawkins, MacKay, Holley, Friedin, & Cohen, 1973; LaBerge, Legrand, & Hobbie, 1969; Heuer, 1982; Schlaghecken & Eimer, 2001). Taking this conscious tuning of the response system into account (Bertelson & Barzeele, 1965; Gehring, Gratton, Coles, & Donchin, 1992; Laming, 1969; Miller, 1998), we then looked to determine whether action triggers were established equally for the two directional primes by asking two questions: (1) Does prime–mask congruency influence responses to the mask independent of the mask displayed? (2) Do the two directional primes automatically trigger their associated motor responses? If the influence of prime–mask congruency is similar across spatial–temporal movement parameters, independent of the mask probability (and thus the probability of making one response over the other), it would suggest that action-relevant stimuli are mapped to their respective responses, without any record of their relative probability. Alternatively, if the two primes differ in their influence on action under these conditions, it would imply that automatic movement modifications in response to unseen visual shapes are influenced by conscious expectations and tuning of the motor system. The implication of such a result for the ATH is that action triggers store information about response probability.