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Subliminal priming of intentional inhibition ☆

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ABSTRACT

Intentional choice is an important process underlying human behaviour. Intentional inhibition refers to the capacity to endogenously cancel an about-to-be-executed action at the last moment. Previous research suggested that such intentional inhibitory control requires conscious effort and awareness.

Here we show that intentional decisions to inhibit are nevertheless influenced by unconscious processing. In a novel version of the Go/No-Go task, participants made speeded keypress actions to a Go target, or withheld responses to a No-Go target, or made free, spontaneous choices whether to execute or inhibit a keypress when presented with a free-choice target. Prior to each target, subliminal masked prime arrows were presented. Primes could be congruent with the Go or No-Go arrows, or neutral. Response times and proportion of action choices were measured. Primes were presented at latencies that would give either positive or negative compatibility effects (PCE, Experiment 1, and NCE, Experiment 2, respectively), based on previous literature.

Go-primes at positive-compatibility latencies facilitated speeded response times as expected, but did not influence number of choices to act on free-choice trials. However, when Go primes were presented at negative-compatibility latencies, "free" decisions to inhibit were significantly increased. Decisions to act or not can be unconsciously manipulated, at least by inhibitory mechanisms. The cognitive mechanisms for intentionally withholding an action can be influenced by unconscious processing. We discuss possible moral and legal implications of these findings.

1. Introduction

The idea of voluntary control over what to do, and indeed whether to do it at all- is a fundamental but controversial feature of human nature. For example, legal judgements about criminal behaviour are based on the view that the agent could have refrained from the criminal act. Further, the feeling of choosing to act in certain ways while resisting others is a common experience in everyday life. We use the term 'intentional inhibition' to refer to the process of voluntarily withholding the execution of an action at the last moment. Inhibition of impending action triggered by external stimuli has been widely studied, notably in stop-signal tasks (Logan, Cowan, & Davis, 1984; Verbruggen & Logan, 2008). In such cases, inhibition can be clearly distinguished from an early decision not to prepare an action. We use the term inhibition to mean an intervention mechanism that "applies the brakes" and actively overrides impending movement (see Aron (2011) for a review of these mechanisms).

Inhibition in this sense can result either from an external 'stop' signal, or from an internal decision. Internally-generated inhibition has been much less studied, although its importance in theories of cognitive control is recognised (Aron, 2011; Filevich, Kühn, & Haggard, 2012). Intentional

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inhibition has traditionally been linked with a conscious form of voluntary self-control. Libet, Gleason, Wright, and Pearl (1983) classically argued that the short delay between awareness of intention and movement onset was sufficient to allow a 'conscious veto' over action. On this view, people may not have free will, but they may have 'free won't'. Recent work in social psychology continues to emphasise the importance of conscious effort in refraining from apparently rewarding actions (Baumeister, Masicampo, & Vohs, 2011). In both instances, intentional inhibition seems like a paradigm case for a conscious form of "agent causation" (Kane, 1996a, 1996b). Importantly, however, it is quite possible that a capacity for internally-generated inhibition exists, yet its triggering could be unconscious.

Here we ask whether intentional inhibition can be influenced by external stimuli that are not consciously perceived. It is widely accepted that endogenous 'free' actions may nevertheless be influenced by external stimuli, including subliminal stimuli that are not consciously perceived, but whose informational content is processed in the nervous system. For example, subliminal perceptual priming can manipulate the subjective experience of the agency of a "free" action (Aarts, Custers, & Wegner, 2005; Linser & Goschke, 2007; Sato, 2009; Sebanz & Lackner, 2007; Wenke, Fleming, & Haggard, 2010). Moreover, subliminal priming can also influence a "free" decision regarding which of a number of alternative actions one selects.

However, some psychologists have argued that inhibition has a special relation to conscious awareness. Specifically, inhibition of action may be a necessarily conscious and effortful cognitive control process, and thus immune to unconscious information-processing (e.g., Dehaene et al., 2003). We cannot resist a prepotent action without consciously intending to resist it, and knowing that we are doing so. This view receives some support from anecdotal accounts of intense subjective experience of trying to overcome urges to prepotent action (St. Augustine, 2006). Overall this would suggest that intentional inhibition should not be manipulable by subliminal exogenous stimuli. Even if we do not really have 'free will', 'free won't', in the sense of top-down inhibitory self-control, might remain a distinct cognitive process, relatively free from such unconscious environmental determinants.

Subliminal stimuli can indeed influence inhibitory processing in externally-instructed forced-choice tasks. In many such studies, primes and targets are directional arrows indicating whether to make a left or right keypress. Targets preceded by congruent primes show decreased response times, and targets preceded by incongruent primes show increased response times, both relative to neutral primes (Neumann & Klotz, 1994). This positive compatibility effect (PCE) is thought to reflect facilitation of the primed response and/or inhibition of the alternative response. In contrast, in the negative compatibility effect (NCE; Eimer, 1999; Eimer & Schlaghecken, 1998) the congruent prime paradoxically inhibits responding. By increasing the stimulus onset asynchrony (SOA) between the onset of prime and target, the normal facilitatory effect of the congruent prime is reversed. Now a prime congruent with the target slows responses whilst the incongruent prime speeds responses.

One prominent theory for the process driving the PCE and NCE effects hypothesises that subliminal primes exert their influence by motor preparation and then inhibition of relevant responses. Initially, a prime will exert a facilitatory influence upon the appropriate motor response, activating it to a sub-response-threshold level. If a congruent supraliminal target appears, the facilitatory activity caused by the prime coincides and combines with that of the target, resulting in a faster response. However, the sub-threshold activation caused by the prime is assumed to be transient. If no further congruent evidence arrives shortly after the prime, the prime-induced activation is followed by a process of auto-inhibition, suppressing the activity below baseline. This process is thought to protect perceptual systems from oversensitivity to noise (Blankenburg et al., 2003). Long prime-target SOAs mean that the target appears during the auto-inhibitory period, thus resulting in the slowed responses that characterise the NCE. The NCE has also been explained in other ways. In particular, the interaction between the prime and the subsequent mask has been argued to facilitate perception of the alternative target that is not primed, thus producing a negative compatibility effect (Lleras & Enns, 2004; Verleger, Jaśkowski, Aydemir, van der Lubbe, & Groen, 2004). This question, which remains controversial, is revisited in the discussion.

Most previous subliminal priming studies focussed on decisions about what action to make, in two-alternative forced choice paradigms (Schlaghecken & Eimer, 2004). However, recent research has extended the method to decisions whether to act at all, by studying priming of inhibition in unimanual Go/No-Go tasks Hughes and colleagues used masked subliminal primes to influence responses in a Go/No-Go paradigm (Hughes, Velmans, & De Fockert, 2009). Participants were instructed to prepare a speeded response with a designated hand. They should respond rapidly following a Go stimulus, but inhibit execution of this action following a No-Go signal. Left and right arrow targets were preceded by left, right and neutral (double arrow) masked primes, at latencies appropriate for PCE. One arrow direction was designated as the Go and the other as the No-Go target. They found that Go targets preceded by a Go prime indeed elicited faster responses than Go targets preceded by a neutral prime, while a No-Go prime slowed responses to a Go target, again compared to neutral. Event-related potentials to No-Go targets revealed that fronto-central N2 and P3 components, previously associated with response inhibition (Falkenstein, Hoormann, & Hohnsbein, 1999), were modulated by the subliminal primes: No-Go primes reduced the magnitude of the negative N2 component ($\sim$300 ms after the target) elicited by No-Go targets, compared to effects of neutral and Go primes. This suggests that unconscious No-Go primes contributed to action inhibition. Thus, Hughes et al. (2009) argue that unconscious exogenous cues can indeed influence inhibitory control processes.

In another Go/No-Go experiment (van Gaal, Ridderinkhof, Fahrenfort, Scholte, & Lamme, 2008), a Go signal (black ring) indicated that an action should be performed, unless it was preceded by the No-Go signal (grey circle). If the stimulus onset asynchrony (SOA) between No-Go and Go signals was sufficient, the No-Go signal was consciously