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Altering movement parameters disrupts metacognitive accuracy

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ABSTRACT

Correctly estimating the confidence we should have in our decisions has traditionally been viewed as a perceptual judgement based solely on the strength or quality of sensory information. However, accumulating evidence has demonstrated that the motor system contributes to judgements of perceptual confidence. Here, we manipulated the speed at which participants' moved using a behavioural priming task and showed that increasing movement speed above participants' baseline measures disrupts their ability to form accurate confidence judgements about their performance. Specifically, after being primed to move faster than they would naturally, participants reported higher confidence in their incorrect decisions than when they moved at their natural pace. We refer to this finding as the adamantly wrong effect. The results are consistent with the hypothesis that veridical feedback from the effector used to indicate a decision is employed to form accurate metacognitive judgements of performance.

1. Introduction

Humans are unique amongst animals in being able to provide explicit reports on the reliability of, or confidence in their decisions. Previous studies have demonstrated that our confidence in our decisions or opinions plays a key role in group interactions (Bahrami et al., 2010; Koriat, 2012). Whenever people express an opinion, they are likely to also communicate their confidence in that opinion, be this explicitly through what they say or implicitly in their movements and facial expressions (Aitchison, Bang, Bahrami, & Latham, 2015). Accurate understanding of confidence has obvious implications for high-risk decision making domains such as financial investment (e.g. Broihanne, Merli, & Roger, 2014), medical diagnosis (e.g. Berner & Graber, 2008), jury verdicts (e.g. Tenney, MacCoun, Spellman, & Hastie, 2007), and politics (Johnson, 2004).

Theoretical models of perception have proposed that confidence is related to the quality or strength of sensory processing (Barthelmé & Mamassian, 2010; Kepecs, Uchida, Zariwala, & Mainen, 2008; Kiani & Shadlen, 2009; Vickers, 1979; Zylberberg, Barttfeld, & Sigman, 2012; see Yeung & Summerfield, 2012, for a review) and speak to a domain-specific formation of confidence judgements. However, there is increasing evidence that perceptual-decision signals are also seen in neural circuits specialised for motor actions (Cisek & Kalaska, 2005; Freedman & Assad, 2011; Hernández, Zainos, & Romo, 2002; Romo, Hernández, & Zainos, 2004; Shadlen & Newsome, 2001), suggesting a contribution of the motor system to estimates of confidence, and supporting the idea of metacognition as a domain-general process. Indeed, it has recently been shown that disruption of the motor system, specifically the dorsal premotor cortex, reduces metacognitive ability when performing a perceptual discrimination task (Fleming et al., 2014). In addition, Allen et al. (2016) report the results of an interoceptive priming manipulation where autonomic arousal modulates subjective confidence on a motion-discrimination task. Thus, it is has been suggested that movement parameters proprioceptive and interoceptive states may also serve as a useful cue for the inference of confidence in our own decision-making.

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Indeed, previous research has shown that the speed at which a participant makes a forced choice decision is correlated with their confidence, with faster reaction times associated with more confident decisions (Fleming, Weil, Nagy, Dolan, & Rees, 2010). Moreover, subjects are able to infer the subjective confidence of another person simply by the observation of their actions (Patel, Fleming, & Kilner, 2012), with faster movements rated as more confident and vice versa. This is reliant on the motor system as subjects with movement disorders have difficulty inferring the confidence of others moving at speeds very different from their own (Macerollo, Bose, Ricciardi, Edwards, & Kilner, 2015), and disrupting activity in the motor system reduces healthy individuals sensitivity to infer confidence from the kinematics of others (Palmer, Bunday, Davare, & Kilner, 2016).

These findings suggest that an individual may in part infer their confidence in their decisions from their own movement parameters. Here, we tested this hypothesis using a behavioural priming task to alter movement speed, while participants performed a perceptual contrast discrimination task. We recorded the speed at which the participant made their decisions. After each trial of the perceptual decision task, we asked the participant to rate their confidence in their performance, and calculated their metacognitive ability, as a measure of the relationship between their confidence and accuracy.

2. Method

2.1. Participants

Forty-eight healthy participants with normal or corrected-to-normal vision were recruited (31 female, 17 male), with a mean age of 27 (range 18–53, median 24). Forty-four reported being right-handed, four reported being left-handed. The experiment was fully explained to participants, apart from the aim of the project and the true aim of the priming task, which were not disclosed until debriefing to prevent bias. The experiment was approved by the University College London Ethics Review Board. Informed written consent was obtained from all participants and procedures were conducted in accordance with the Declaration of Helsinki.

2.2. Equipment

Participants were seated at a table, 60 cm in front of a Dell laptop computer, and responded using the standard QWERTY keyboard, a marble and three touch-sensitive containers (Fig. 1). Stimulus display and response collection were controlled by MATLAB 7.8.0 (Mathworks Inc., MA, USA) using the Cogent 2000 toolbox (http://vislab.ucl.ac.uk/cogent.php).

2.3. Stimuli and procedure

The experiment was carried out at the Institute of Neurology, University College London. All participants were tested individually, in the presence of the experimenter. Participants completed two blocks of a metacognition task described below (50 trials per block), followed by a movement speed prime (50 trials), a third block of the metacognition task, a second movement speed prime, and finally a fourth block of the metacognition task (Fig. 2a). The first block of the metacognition task was used as a practice session and was not included in the analyses.

2.3.1. Metacognition task

The metacognition task was a perceptual contrast discrimination task used in previous studies (Fleming et al., 2010; Patel et al., 2012). The stimuli were comprised of two images shown in quick succession on the laptop computer screen. Each image comprised a circular clock-face with six Gabor gratings (circular patches of light and dark bars) arranged around a central fixation point (Fig. 2b). The background was uniform grey, with a luminance of 3.66 cd/m^2.

In one of the two images, all the Gabor gratings were set to the same contrast, that is, a 'baseline' Gabor grating. In the other image, one of the Gabor gratings was set to a higher contrast than the other five baseline gratings, causing it to appear as a 'pop-out'. Pop-out gratings were drawn from a stimulus set that varied in contrast between 23 and 80% in increments of 3%. The pop-out Gabor

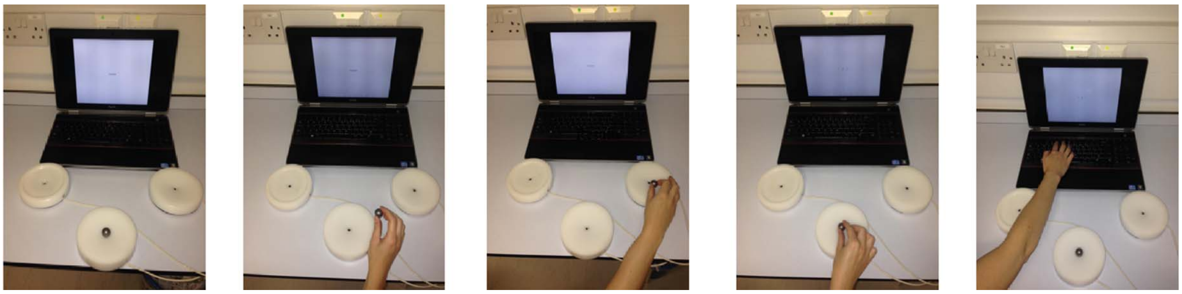

Fig. 1. Experimental setup (photo). Participants moved the marble from the central homepad container to the rightmost container if they believed the pop-out Gabor was present in the first interval, or the leftmost container if they believed the pop-out Gabor was present in the second interval. They then returned the marble to the homepad container. They were then prompted by the computer to enter the value between one and 99 that represented their relative confidence in their decision using the numbers of the keyboard of the laptop.