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Speed of reaction to sensory stimulation is enhanced during movement

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ABSTRACT

We report four experiments on the speed of people's reactions to sensory stimulation while throwing and catching a basketball. Thirty participants participated in Experiment 1, split according to basketball expertise: none, intermediate (6 years on average), or advanced (20 years or more). The participants had to *catch* a bouncing basketball. The movement triggered a short tactile pulse in a tactor attached to their wrist to which they made a speeded vocal response (RT). The pulse could be presented either at rest, at two time-points during the reaching movement, or when the hand reached forward to catch the ball. The results indicated that participants responded more rapidly to vibrations on the moving hand relative to preparing or catching the ball, with expert athletes responding significantly faster than novices. In a second experiment, participants made a speeded vocal response to an auditory signal. As in Experiment 1, faster auditory RTs were observed when the hand was moving, as compared to the other time-points. In a third study, the participants responded to a pulse delivered at their resting hand at various time-points corresponding to the average timings of stimulation in Experiment 1. The results revealed comparable RTs across the tested time-points. In a final experiment, the participants made a vocal response to a pulse presented at various time-points while they were *throwing* the basketball. The results indicated faster tactile RTs while the ball was being thrown. These results are discussed with reference to the literature on goal-directed movements and in terms of current theories of attention and sensory suppression.

1. Introduction

Simple movements, such as a simple finger abduction (Williams & Chapman, 2002), as well as more complex goal-directed pointing or reach-to-grasp movements (Buckingham, Carey, Colino, DeGrosbois, & Binsted, 2010; Colino, Buckingham, Cheng, van Donkelaar, & Binsted, 2014; Juravle, Deubel, & Spence, 2011), are often accompanied by a reduction in what is felt, a phenomenon that researchers refer to as tactile gating, attenuation, or suppression (Chapman & Beauchamp, 2006). While the physiological and functional significance of this phenomenon still requires further experimental investigation, researchers tend to agree that it results from a combination of the descending motor command and sensory reafference (Chapman & Beauchamp, 2006; Juravle & Spence, 2011). Elegant experimental work has demonstrated that sensory suppression peaks at the onset of movement, with the movement-related detrimental effects on perceptual performance spanning a few hundred milliseconds prior to, and after, the onset of movement (Bays, Wolpert, & Flanagan, 2005). Furthermore, it appears that tactile suppression is highly dependent on the speed of movement. That is, it tends to be most apparent for those movement speeds faster than those used in tactile exploration (Cybulska-Klosowicz, Meftah, Raby, Lemieux, & Chapman, 2011; see also Juravle, McGlone, & Spence, 2013, for a commentary). Importantly, tactile suppression is modulated by response bias, suggesting that it is likely to be controlled by higher-order decision processes in the brain (Juravle & Spence, 2011, 2012.

To date, these detrimental perceptual effects have been demonstrated for those tasks where the participants have had to report the presence (Van Hulle, Juravle, Spence, Crombez, & Van Damme, 2013; Williams & Chapman, 2002), the force (Shergill, Bays, Frith, & Wolpert, 2003), or the intensity of a particular tactile stimulus (Juravle et al., 2011; Voss, Ingram, Haggard, & Wolpert, 2006; Voss, Ingram, Wolpert, & Haggard, 2008). Furthermore, although one might expect that performance in *unspeeded* discrimination and detection tasks would be similar to that seen in *speeded* tasks, it would seem as though this need not necessarily be the case. For example, we conducted a study in which participants made a speeded detection response to a tactile stimulus delivered with different probabilities to their moving or resting hand at three different timings during movement (e.g., preparation, execution, and post-movement, see Juravle et al., 2011). The results indicated a differential pattern of RTs with respect to the various phases of the goal-directed reach-to-grasp movements: Participants detected the tactile stimulus more slowly while preparing to move, as compared to while executing the movement, as well as during the post-movement period. These results made us argue in favour of there being a dissociation between

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discriminating the quality of tactile stimulation and the speed of response to tactile stimuli during movement.

This dissociation between the speed and quality of touches felt during movement found for the typical laboratory reach-to-grasp movements (Juravle et al., 2011) sparked the next series of experiments. There we were interested in investigating whether a similar distribution of tactile RTs would also be evident for other complex naturalistic goal-directed movements, such as the catching and throwing movements utilized in basketball. We have already demonstrated clear decrements in sensitivity as assessed by d' while preparing and executing a (self-generated) ball-throwing movement, whereas for ball-catching movements, which are reactive by nature, only a decisional shift, as assessed by criterion c response bias, was evident during movement preparation (Juravle & Spence, 2012). Here, the aim was thus to extend these findings and to test whether the speed of reaction to tactile events would also be differentially modulated over the various temporal phases of reactive versus non-reactive movements (i.e., the catches versus throws of a basketball).

In a first experiment, tactile perception was tested at different temporal phases during the execution of a ball-catching movement. It was hypothesized that a similar downward RT slope from preparation to post-movement (i.e., the catch of the ball) should be found, as in previous work on reach-to-grasp movements (Juravle et al., 2011). For this, in a first experiment of the series, the participants were instructed to catch a bouncing ball and to say 'BALL' in response to a tactile stimulus triggered at their wrist at certain hand positions during movement preparation and execution. This experiment also investigated whether long-term practice in ball-catching movements would be beneficial for what is felt during the execution of the movement. For this purpose, several groups of participants were tested, ranging from those with very limited expertise with ball games, through to those with intermediate, as well as advanced training.

2. Experiment 1

2.1. Methods

2.1.1. Participants

Thirty participants (15 male, two left-handed) took part in this experiment (mean age of 25 years; age range 19–37 years). All of the participants reported normal touch, normal hearing, as well as normal or corrected to normal vision. The participants were distributed in 3 ball-expertise groups: *novices* (they had no ball experience or a very limited one from school sports), *intermediate* (played basketball or other ball sports – American football, baseball, softball, cricket, rugby, volleyball, netball – for 6 years on average), and *advanced* (participants had played basketball or baseball for 20 years on average, college 1st division or Première League athletes). The experimental session lasted for approximately 20 min and the participants received a £5 gift voucher in return for taking part.

2.1.2. Apparatus

The participants had one tactor attached to their left wrist with an adjustable sports strap. The participants also had a microphone (Pro-Sound Uni-directional Dynamic YU-33 600 Ω and 50 kΩ) attached with thread around their neck and interfaced through a custom-built voice response key connected to the main computer. Moreover, the participants had the Wii Remote attached to their left forearm with another adjustable sports strap. The Wii accelerometer (±3 g sensitivity range, 8 bits per axis, 100 Hz update rate, Lee, 2008) was interfaced through MATLAB (Psychophysics Toolbox 3; Brainard, 1997; Pelli, 1997) on Windows XP. The Wii communicated with the main computer via Bluetooth (IVT BlueSoleil v2), and the communication between the Wii Remote and Matlab was interfaced through the open source library FWIINEUR (fWIIne v0.3; http://fwiineur.blogspot.com/, downloaded in July 2009). A commercially available men's basketball (Adidas; approximately 24 cm in diameter) was used.

2.1.3. Procedure

In each trial, the participants were instructed to stand with their arms at their sides. The experimenter (the same for all participants) was located approximately 2.7 m in front of the participant, with the basketball in her hands, ready to throw. An auditory signal (800 Hz, 100 ms), that participants could also hear, instructed the experimenter to throw the ball toward the participant. The experimenter ensured that the ball always bounced approximately 1.0–1.2 m in front of the participant. When the ball arrived in their vicinity, the participants reached for it and the movement of their hand triggered a 100 ms vibratory pulse to which they were instructed to give a speeded vocal response by saying the word 'BALL'. The short vibration was delivered at one of four hand positions: in the *preparation* period of the movement, at two points in time during *movement execution* (i.e., first, when the hand formed an angle of 25° with respect to the body, and second, at an angle of 45° with respect to the body), and lastly, at the *catch* of the ball when the hand reached forward and formed a straight angle with the body. The experimental script waited for 2 s for the participants to make a response after which it asked the experimenter to confirm that the current trial has come to an end. The experiment went on to the next trial once the experimenter pressed a key on the keyboard. At the end of the experiment, the participants filled in a short questionnaire concerning their athletic expertise (see Swann, Moran, & Piggott, 2015, for a recent classification of athletic expertise).

2.1.4. Design

Basketball expertise was manipulated as a between-participants factor, resulting in three experimental groups: novice, intermediate, and advanced athletes. For each of the participants, the experiment consisted of 160 trials. The manipulated variable was the Timing of tactile stimulation delivery: 40 trials were performed for each of the four timings (preparation, early movement execution, mid-movement execution, and catch). The order of the trials was randomized across trials and participants.

2.1.5. Data analysis

Outliers in the RTs were excluded by using the z-score > 3 rule (Pukelsheim, 1994), such that RT analysis was conducted on only the correct trials where the participants made a vocal response to the tactile stimulus. This operation led to a rejection of 104 trials (2.2%) of the data. The remaining data were analysed with a mixed factorial ANOVA with a within-participants factor of Timing of tactile stimulation delivery (preparation, early movement execution, middle movement execution, and catch), and the between-participants factor of Expertise (basketball novices, intermediate, or experts). Mauchly's test of sphericity was used to ensure that the data did not violate the sphericity assumption. In case of a violation being detected, the Greenhouse–Geisser correction was applied to correct the degrees of freedom; the sphericity violation is reported with ε throughout text. Partial η^2 is reported as an effect size estimate for the ANOVA results.

2.2. Results

The results indicated a main effect of the Timing of tactile stimulation delivery [$F(3,81) = 27.83$, $\varepsilon = .615$, $p < .001$, $\eta^2_p = .508$], with participants responding more rapidly to the tactile stimulus when this was delivered to the moving hand during both execution periods, as compared to the preparation and ball-catching periods (all $ps < .001$). RTs were comparable for the preparation and ball-catching phases, as well as between the two early and mid-movement execution periods (all ps = n.s.).

Moreover, a main effect of Expertise [$F(1,27) = 9.56$, $p = .001$, $\eta^2_p = .415$] was found, with novices being significantly slower than