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Short Communication

Comparing intensities and modalities within the sensory attenuation paradigm: Preliminary evidence

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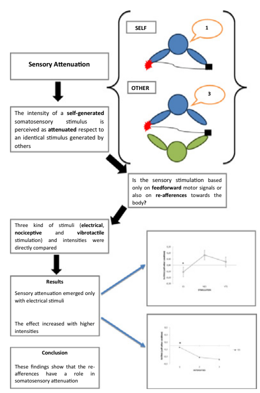
GRAPHICAL ABSTRACT



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ABSTRACT

It is well-documented that the intensity of a self-generated somatosensory stimulus is perceived to be attenuated in respect to an identical stimulus generated by others. At present, it is not clear whether such a phenomenon, known as somatosensory attenuation, is based not only on feedforward motor signals but also on re-afferences towards the body. To answer this question, in the present pilot investigation on twelve healthy subjects, three types of stimulations (sensory non-nociceptive electrical – ES, nociceptive electrical – NES, and vibrotactile – VTS) and intensities (1 = sensory threshold ∗ 2.5 + 2 mA, 2 = sensory threshold ∗ 2.5 + 3 mA, 3 = sensory threshold ∗ 2.5 + 4 mA for ES and NES; 1 = sensory threshold ∗ 2 *Hz*, 2 = sensory threshold ∗ 3 *Hz*, 3 = sensory threshold ∗ 4 *Hz* for VTS) have been directly compared in a somatosensory attenuation paradigm. The results show that the attenuation effect emerged only with electrical stimuli and that it increased with higher intensities. These pilot findings suggest that, depending on the type and the intensity of stimulation, re-afferences can have a role in somatosensory attenuation. Additionally, it is possible to speculate the effect is present only with electrical stimuli because those stimuli are prospectively judged as potentially dangerous. This, in turn, would optimize planning successful reactions to incoming threatening stimuli.

Introduction

It is often thought that the sensory consequences of our own willed actions are unimportant and therefore should be discarded. Indeed, this is not trivial but, rather, well known in the scientific

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literature as sensory attenuation. Self-directed, intended stimuli are attenuated compared to the same stimuli generated by others (both phenomenologically and anatomo-functionally [1–5]).

Sensory attenuation is vital for survival, since attenuation of self-generated stimuli allows enhanced salience of unexpected external events. This, in turn, makes us able to distinguish between sensations generated by our own actions and sensations resulting from external causes. It is notable that despite these considerations, which suggest the universality of such phenomena among sensory domains, current findings remain scant. Indeed, sensory attenuation has been clearly demonstrated within auditory and tactile domains (e.g., [6–8]) but few data are available within the visual domain [9,10]. With respect to the interpretation of such a phenomenon, a first explanation states that it depends entirely on motor-related signals which would modulate the activity evoked by the incoming sensory signals. Such a hypothesis is rooted in evidence showing that various levels within the motor hierarchy affect sensory attenuation. For instance, the phenomenon emerges when actual sensory consequences of a voluntary action match the predicted consequences [7–11]. Nonetheless, since the phenomenon also arises when there is no physical contact, it has also been linked to motor predictions [1,11–13]. Additionally, prior belief of authorship [14], subliminal action priming [15] or expectation of movement [16] are known to modulate sensory attenuation. However, an alternative explanation pinpoints the role of re-afferent signals towards the body which, in turn, would mask the sensory probe. Accordingly, passive movements may also attenuate self-generated stimuli [17], and the type of movement may reduce the intensity of self-generated stimuli [16]. Overall, at present, it is not clear whether and to what extent re-afferences contribute to the emergence of sensory attenuation.

Capitalizing on all of these considerations, in the present study it has been further investigated the role of re-afferences *per se* in sensory attenuation. Specifically, it has been explored whether and how sensory modality and stimulus intensity affects the emergence of the phenomenon. Three somatosensory stimulations, often used in previous studies (i.e., sensory non-nociceptive electrical, nociceptive electrical and vibrotactile) [3,9,10,17–28], and three different intensities have been directly compared within a sensory attenuation paradigm (i.e., comparing self-versus externally generated stimuli). Importantly, since the two stimulus features were equiprobable within each block, any type of efferent signal prior to action was prevented.

Subject and methods

Twelve right-handed [29] healthy participants (7 females, mean age: 21.96 years; mean education level: 16.04 years) were recruited for the experiment, and *each signed an informed consent statement to participate in the study approved by the Bioethical Committee of the University of Turin*.

Participants were seated with their hands on a table and were instructed to always keep their sight in a specific point between their hands. During the experiment, the lateral digital nerve of the right (dominant) index finger was stimulated by attached electrodes (5 cm apart) at the lateral side of the tip and base of the finger [24]. Every 20 stimulations, the experimenter slightly shifted the position of the stimulator device (to not alter the subjective sensation). In addition, for every 20 stimulations, a catch trial (i.e., a trial without stimulation) was sent to avoid response biases and to control for phantom sensations. After each stimulus, participants verbally rated the perceived intensity sensation on a 0–10 point Likert's scale, in which 0 corresponds to "no intensity", and 10 corresponds to the "maximum perceived intensity". A within-subjects design study was run. Three types of stimulation were administered:

Sensory non-nociceptive electrical stimulation (ES)

For the ES, classical disposable surface electrodes (5-mm-diameter bipolar Ag/AgCl) were attached to a constant current stimulator (Digitimer Stimulator, Model DS7 A, Class 1 with Type BF applied part, EN 60601-1, produced by Digitimer Ltd, 37 Hydeway, Welwyn Garden City, Hertfordshire, AL7 3BE- England). Preliminarily, the electrical (both nociceptive and not) threshold of each participant was detected: subjects with closed eyes verbally reported perception of a stimulus to their right index finger (3 out of 6 repetitions). Next, stimuli were fixed at three intensities: intensity 1 = sensory threshold $*$ 2.5 + 2 mA, intensity 2 = sensory threshold $*$ 2.5 + 3 mA, intensity 3 = sensory threshold $*$ 2.5 + 4 mA. It has been decided to use three different intensities for each type of stimulation to avoid the risk of a bias and/or a habituation effect and to test for a possible main effect of intensity *per se*. The three intensities were administered in a random order in two conditions: in 60 trials, the electrical stimulus was self-generated (condition SELF), and in the other 60 trials, it was externally generated (condition OTHER) for a total of 120 stimuli.

Nociceptive electrical stimulation (NES)

For the NES, nociceptive electrodes that stimulate only alpha peripheral fibres, thanks to a pushpin-like needle electrode consisting of a plastic plate (1.2 cm in diameter) and a stainless steel needle (0.5 mm in diameter), were attached to the same devices used for ES [22]. The nociceptive threshold of each participant was detected using the same procedure as for the ES. Next, stimuli were delivered at fixed multiple intensities: intensity 1 = sensory threshold $*$ 2.5 + 2 mA, intensity 2 = sensory threshold $*$ 2.5 + 3 mA, intensity 3 = sensory threshold $*$ 2.5 + 4 mA. As for ES, nociceptive stimuli were randomly administered in three intensities and in two conditions (SELF and OTHER conditions, 60 for each condition, for a total of 120 stimuli).

Vibrotactile stimulation (VTS)

For the VTS, the experimental device was a vibrotactile stimulator. The stimulator worked with a printed circuit board Arduino (www.arduino.cc), an open-source microcontroller development platform connected to a homemade processing script. As for the ES and the NES, the vibrotactile stimuli were randomly administered in three intensities (1, 2, 3) and in two conditions (SELF and OTHER condition). For VTS stimuli intensity, it has been used the same ratio scale used in ES and NES by increasing the intensity of the vibration (i.e., the frequency of revolutions of the eccentric expressed in Hz), where intensities were 1 = sensory threshold $*$ 2 *Hz*, 2 = sensory threshold $*$ 3 *Hz*, 3 = sensory threshold $*$ 4 *Hz* for VTS.

The three types of stimulation (ES, NES, VTS) were administered in separated and balanced blocks between subjects to control a possible order effect; the order of stimuli intensities (1, 2 or 3) and conditions (SELF and OTHER) was randomized between subjects.

Consequently, the subject knows the agent of the action (himself in condition SELF and the experimenter in condition OTHER) and the kind of stimulation (accordingly to the block), but he/she was not aware of the forthcoming intensity of stimulation he/she must rate.

Statistical analysis

Data analysis were conducted with Statistica 6.0. Preliminarily, data were transformed into z-scores (within subject normalization, see for details [23]). All data were normally distributed (Shapiro-