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Editorial comment

Psychophysiological effects of threatening a rubber hand that is perceptually embodied in healthy human subjects

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In this issue of *Scandinavian Journal of Pain*, a study by Johnson and colleagues investigated the roles of arousal and threatening in the peripersonal space during a rubber hand illusion [1]. The study is designed to evaluate whether or not arousal is selectively associated with threatening stimuli entering into the peripersonal space. The study uses the paradigm of the rubber hand illusion, where participants are induced to behave as if a rubber hand is part of their own body. The illusion is usually induced by brushing a person's hand, hidden from view, while synchronously brushing a visible rubber hand. In this study, the authors used brushing to simulate a non-threatening condition and a needle to modulate a threatening condition.

This paper outlines one of the most intriguing aspects: how self-body representation influences perception and cognition. Recent theories are suggesting that perception and cognition are influenced by internal representations of the body. This hypothesis is corroborated by research evidence showing for example that vision of the body increases spatial acuity of touch.

Both experimental and clinical studies also highlight the importance of body representation in the modulation of pain experience using cross-modal illusions. These studies show that body self-representation and pain perception are related.

1. The use of cross-modal illusion (rubber hand illusion) in pain research

In recent years, an increasing number of studies on cross-modal illusions (i.e.: rubber hand illusion, mirror box illusion) have investigated how multisensory interactions shape human body representation and in turn modulate pain perception.

The most widely known example of a cross-modal illusion is the rubber hand illusion (RHI) [2]. RHI is a suitable paradigm to uncover mechanisms of body ownership, plasticity of body representations, and in particular disentangle the influence of alterations in self-representation on sensory processing.

It has been suggested that one of the mechanisms through which RHI arises is due to the resolution of a multisensory conflict involving visual, tactile and proprioceptive information, culminating in a re-calibration of the location of the touch and the felt position of the hand with the result that touch appears to be felt by the rubber hand. Nevertheless, alternative explanations have also been proposed, i.e. Bayesian perceptual learning. RHI involves a number of multisensory areas of the brain including premotor, parietal and cerebellar structures.

RHI has been widely investigated in experimental and clinical settings, although its applicability in rehabilitation is still in an early stage of study. In pain research, RHI has produced alterations in sensory processing, in particular resulting in powerful analgesic effects. These analgesic effects are explained with an increase of ownership over a fake "pain-free" hand, while a concomitant reduction in awareness (or dis-ownership) of one's own affected body part is experienced.

This is fascinating, but not all the experimental results have reported a reduction of pain perception. In fact, well-powered experiments have shown no effect on RHI on experimental pain perception over the real hand [3,4]. Recently, modifications of the classical rubber hand with an "injured/wounded" rubber hand have generated a reduction of thermal pain threshold [5] and tolerance threshold as well as an increase in pain intensity and unpleasantness [6].

2. Plasticity of body representation

We often have the impression that our body representation is stable and relative fixed over time. Experiments using the RHI have shown, instead, that our body representation is more fragile and malleable than it seems. Body representation requires indeed some degree of plasticity so that changes in the actual physical body can be mirrored by corresponding changes in the brain's maps and in the conscious body image [7]. More bizarre variations of the RHI, such as having the illusion of an elongated arm or owning a third arm, have produced changes in the corresponding somatosensory maps [8]. Interestingly, body maps topography seems to reflect the perceived rather than the physical aspects of the peripheral stimulus.

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Growing evidence shows that people with chronic pain have a distorted body image, defined as a conscious representation of the body, *the way one's body feels to be its own* [9]. The most obvious example is related to phantom limb pain, where amputees report that their missing limb feels heavy, swollen, floating, stuck in a particular position, missing digits or entire segments ("telescoping"). Patients affected by Complex Regional Pain Syndrome (CRPS) report similar evidence, often describing their painful limb as swollen and depicted as lager than it really is. Distortions in shape are also observed such as too short or with a missing segment [9].

Often, however, the symptoms resemble the ones seen in patients with hemi-spatial neglect, therefore these symptoms are referred to as "neglect-like". In these cases, patients reported that the affected limb seemed foreign or did not seem to belong to them. Sometime they have difficulties in identifying which finger is touched, or they cannot move their fingers unless they look at them.

3. The role of peripersonal space in perception

Johnson et al. recorded skin conductance response (SCR), in order to provide a more objective measure of the psychological and autonomic arousal caused by the rubber hand illusion [1]. It is in fact preferable to combine objective and subjective methods to avoid ambiguity especially when subjects answer to self-report questionnaires. These answers, in fact, can be easily biased by the task demand or by the metaphorical descriptions of the experience. This is even more true in the case of perceptual illusions.

Johnson et al. reported no differences in SCR between non-threatening and threatening stimuli when entering into the peripersonal space (space around the body) [1]. This is *per se* an interesting aspect since it adds extra value to the discussion of the role of the peripersonal space in the construction of the body perception. Probably, any type of stimulus approaching the rubber hand is able to evoke a protective response. Thus, it seems that we not only own our body parts but also the space around them as well. Similar examples are also seen in pain perception. Pain can be precipitated by viewing an object approaching the limb and pain increases as the object gets closer.

4. Phantom-like sensations in healthy individuals

In the study of Johnson et al. some participants reported sensations, such as tingling and numbness, as they were generated from the rubber hand, although there was a high inter-individual variability in the generation of these experiences [1]. These projected sensations resemble phantom-like sensations observed in amputees, and are also reported by other authors [10]. Recently, Lewis et al. [11] using a RHI with a missing finger reported similar sensations, such as tingling and numbness together with the vivid presence of a finger that they could not see.

5. Conclusion and implications

Cross-modal illusions, such as RHI, are essential experimental paradigm for pain research. Further research is necessary to understand the complex relationship between body self-representation and pain perception.

Conflicts of interest

None has been declared.

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