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VERSITA

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ANOSOGNOSIA FOR HEMIANESTHESIA: FROM THE SYNDROME TO TACTILE AWARENESS

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Abstract

Patients with a neurologically based loss of tactile processing on the contralesional side of the body can firmly deny the deficit (i.e., anosognosia for hemianesthesia). Previous studies attempted to feature the disease in both clinical and anatomo-functional terms. However, the picture is still incomplete and, most importantly, to date it is unclear whether and to which extent it can shed light on the mechanisms subserving tactile processing in the intact brain. Here we will briefly review the literature and we will put forward a possible anatomo-functional interpretation of anosognosia for hemianesthesia.

Keywords

• Anosognosia • Anterior putamen • Hemianesthesia • Sensory expectancies • Tactile awareness

Introduction

In the commonsensical view, the phenomenological experience of self-consciousness has a strong feeling of unity. However, the counterintuitive behavior of brain-damaged patients allowes to unmask the inadequacies of the theories on human brain functioning hidden from the view in the intact brain (see [1] for a discussion on this point). In particular, the discovery of selective, neurologically based disorders of conscious awareness has provided evidence for a complex and composite nature of the conscious processes.

A remarkable and well-known phenomenon in neuropsychology is the unawareness of cognitive/neurological deficits due to selective brain damage, namely anosognosia (from the Greek words "nosos" disease and "gnosis" knowledge; an- / a- is a negative prefix). Such a denial behavior has been described within different domains (see [2] for a review) as, for instance, sensory (e.g., cortical blindness and hemianesthesia), motor (e.g. hemiplegia) and cognitive (e.g. aphasia). A crucial challenge for cognitive neuroscience is to foster the understanding of the neurofunctional basis of these deficits in order to shed light on the mechanisms underlying the genesis of awareness in human's brain.

In anosognosia for hemianesthesia, patients frequently claim of being able to perceive tactile stimuli delivered to the contralesional part of the body despite the fact that, during the standard neurological examination with closed eyes, they never report such stimulations [3-8].

Clinical, neuropsychological and anatomo-functional investigations

The two first studies on anosognosia for hemianesthesia aimed at examining mainly its clinical features [5,7]. Both of them reported that anosognosia for hemianesthesia does not seem to be secondary to other deficits and is often functionally dissociated from the unawareness of other concomitant neurological diseases. Marcel and coworkers [7], for instance, reported that anosognosia for hemianesthesia is more frequent, though double dissociated from unawareness of hemiplegia, that is the denial of contralesional motor deficits (e.g., [9-12]). The subsequent study by Spinazzola and coworkers [5] confirmed those findings and added some anatomical considerations on the possible neural correlates of anosognosia for hemianesthesia. Indeed, the authors inspected the lesion pattern of their four patients affected by anosognosia for hemianesthesia. They presented with lesions mainly localized to insular, temporal and subcortical structures, particularly the basal ganglia.

Subsequent studies focused on a second important feature of anosognosia for hemianesthesia. As we said above, even if patients never report the perception of stimulations during the standard neurological examination with closed eyes, they may report of being able to perceive any tactile stimuli [3-8]. In details, after the neurological examination patients' unawareness of the deficit are assessed off-line with a questionnaire [5] related to tactile perception (e.g., "How is sensation in your arm?", "Are you able to perceive a light touch on your foot?"). For each question, patients have to rate their own perceptual abilities by means of a verbal judgment: normal perception, perception with difficulties, no perception. Awareness of the potential ability to feel sensations is scored by comparing the examiner's judgment with the patient's self-evaluation. Accordingly, two studies [13,14] aimed at analyze whether such report could represent a sort of mere verbal confabulation and/or simply a response bias

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or, rather, a real subjective experience of touch. Hence, they examined whether these patients actually report on-line a tactile sensation when they see the stimuli delivered to their anesthetic body parts. Pia and coworkers [13] confirmed the hypothesis, namely patients affected by anosognosia for hemianesthesia, but not patients with only hemianesthesia, reported to perceive tactile stimuli delivered to the anesthetic body part. Romano and colleagues [14] demonstrated that such behavior has a clear physiological counterpart: patients affected by anosognosia for hemianesthesia show normal physiological reactions (i.e., skin conductance response to those incoming stimuli). In other words, these patients appear to go through a real tactile experience. Additionally, in keeping with Spinazzola and coworkers [5], Romano and colleagues [14] examined the individual lesion pattern of five patients with anosognosia for hemianesthesia and reported that four of them had damages to the insular cortex, the basal ganglia, and the periventricular white matter.

By means of a lesion subtraction technique on a larger sample of patients, a very recent study [15] attempted to obtain a clearer anatomo-functional picture of anosognosia for hemianesthesia. The authors compared two groups of patients differing only for the presence/absence of anosognosia for hemianesthesia and found that the lesion cluster specifically associated to anosognosia for hemianesthesia was confined to the anterior putamen (inters tingly, primary (and secondary somatosensory cortices were partially spared). Hence, while being in line with previous anatomical studies [5,14], these results seem to suggest that a smaller set of brain structures (i.e., the anterior putamen) might be sufficient to induce anosognosia for hemianesthesia.

The nature of anosognosia for hemianesthesia

The next question is, "What might be the anatomo-functional signature of such an illusion of touch?"

Firstly, the above mentioned literature [13,14,16] suggests that tactile sensations are driven by the vision of the stimulus arising even when the tactile counterpart of the subjective sensation is absent (see Fig. 1). Hence, a crucial aspect for the emergence of such an illusion of touch is that the delivered stimulus must be seen. This is not trivial but, rather, consistent with the visual literature showing that humans can report vivid tactile sensation without any physical (tactile) counterpart. Stroking a fake hand with a laser light, for instance, can induce illusory tactile/thermal sensations in one's own arm [17]. It has been shown that during the rubber hand illusion, harmful stimuli approaching to a rubber hand may elicit the same brain activation [18] and skin conductance response [19] observed after the real stimulation of participants' hands. Similarly, brain damaged patients affected by a pathological embodiment of someone else's arm, show the same behavioral [13] and physiological [16] response regardless if the stimuli are delivered to the "embodied" or the own arm. In addition, synesthesic people (i.e., individuals who feel a stimulus in one modality when is actually delivered in another modality) can experience a tactile sensation in a given body part when observing another person being touched in the same part [20]. These results can be explained by the fact that the human brain operates under the principle of multisensory integration. In other words, if an incoming input has a high certainty in one sensory modality, it can induce perceptual consequences in a different modality [21]. Regarding touch, in normal circumstances humans employ all sources of incoming information (i.e., proprioception, vision and touch) in order to report consciously whether or not they are being touched. However, when sensory sources of information are in conflict with each other, vision can dominate, thus inducing an actual experience of touch (i.e., visual capture of touch) acting at the level of somatosensory cortex [22,23] or even at the level of subcortical structures as, for instance, the putamen [24].

Figure 1. Exemplification of the behavior often described in anosognosia for hemianesthesia. Patients not only claim of being able to perceive tactile stimuli, they may report vivid tactile sensation when they see stimuli actually delivered to their anesthetic body part.

An anatomo-functional account of anosognosia for hemianesthesia

At this point, the key open question is "What is the possible mechanism underlying anosognosia for hemianesthesia?"

The activity of the human brain can be largely tuned in advance, according to the expected stimulus modality. The functional meaning of this process is to give priority selectively to the elaboration of the specific stimulus in order to optimize its detection before the target event occurs (e.g. [25]). Accordingly, several studies demonstrated that valid expectancies improve detection (e.g., [26,27]). More specifically, explicit stimuli expectations are underpinned by an anticipatory increase and decrease of the baseline activity of relevant and irrelevant primary/higher order sensory cortices, respectively [28]. Interestingly, this expectancy-related activity is present also during stimuli detection. With respect to the specific cluster activated in tactile modality, it involves postcentral gyrus, supramarginal gyrus, parietal operculum, namely the brain areas that correspond to primary and secondary somatosensory cortices. Nonetheless, anterior putamen responds specifically to the omissions of any expected sensory stimuli, included the tactile modality [28].

On these bases, a network involving somatosensory areas and the anterior putamen might explain the illusory experience of touch in anosognosia for hemianesthesia. Tactile-specific expectancies driven by seeing the stimulus would be created and processed within spared somatosensory cortices. However, the subsequent comparison between expectancies and absence of stimuli would not be possible due to damages to anterior putamen. Since patients are unable to detect the mismatch between an expected tactile incoming stimulus and its actual absence, they rely entirely on their expectancies, and report stimuli in absence of perception (i.e., false belief of being able to perceive tactile stimuli).

In summary, anosognosia for hemianesthesia could be conceived as a consequence of an impairment of the brain mechanism that compares specificity of the expectations with the specificity of the actual stimulation. More specifically, anterior putamen damages would not allow detecting omission-related Bayesian surprise according to the specificity of the predictions [28]. However, this interpretation must be considered still speculative. Indeed, direct neuroimaging evidence of tactile expectancies-related activations in anosognosia for hemianesthesia is strongly required in order to draw firm conclusions. Additionally, more objective physiological measures of tactile processing impairments (e.g., discrimination, threshold) would foster our understanding of the neuro-functional bases of this disorder.

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