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Research report

A role for the insula in color-induced nasal thermal sensations

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ABSTRACT

This article is the first step towards understanding the mechanisms underlying the intriguing, recently discovered lateralized color-induced nasal thermal sensations. In the presence of color cues and complete absence of thermal stimulus, larger sensitivity of the left nostril/right hemisphere (RH) for warming sensations and larger right nostril/left hemisphere (LH) for cooling sensations were replicated several times. It was suggested that engagement in a temperature judgment task and the development of specific expectancies due to the presence of color cues could alter and enhance processing in brain areas involved in thermosensory processing, such as the middle/posterior insula. The lateralized patterns could thus intimate hemispheric specialization for thermosensory processing. However, such lateralization may be due to either exclusive specialization of each hemisphere or specialization-through-reciprocal inhibition between the hemispheres. The two hypotheses predict different results following a unilateral insular stroke. Here, we present the results of a sample of healthy volunteers and patient MB, a young woman suffering from unilateral left-side damage of the posterior insula, in a task involving color-induced nasal thermal judgment. The expected lateralized pattern was found in the performance of the controls. In line with our previous suggestions that the LH is more involved in the processing of cooling sensations, patient MB exhibited changes only in the judgment of cooling sensations. Her results also clearly support the specialization-through-reciprocal inhibition account since she exhibited decreased cooling judgments contralaterally but increased cooling judgments ipsilaterally. Accordingly, we conclude that (a) the lateralized patterns arise because of hemispheric specialization; (b) the LH is seemingly more involved in the processing of cooling sensations; (c) this specialization is underlain by reciprocal interhemispheric inhibition; and (d) even in the absence of thermal stimulus, the development of expectancies suffices to activate modality-specific brain areas involved in the current task in such a way that damage to these areas disturbs the corresponding specific processes.

1. Introduction

Intriguing color-induced nasal thermal judgments in healthy volunteers have recently been reported and replicated several times [1,2]. In a standard trial, subjects are required to judge whether a sniffed bottle, presented out of sight and containing odorless water and free of any thermal agent, evokes cooling or warming sensations in the nasal cavity. The sniff is taken with one nostril while simultaneously viewing a different solution, colored red or green. Two distinct behaviors are detected: first, subjects do not use strategies such as frequently giving a response that matches the color viewed (e.g., warming with red, and cooling with green); second, they preferentially associate warming responses with red when the sniff is taken with the left nostril, while more frequently associating cooling responses with green when they sniff with the right nostril. These findings are robust enough to resist changes in methodology, even when subjects are allowed to give an additional "ambient" response. They depend on task difficulty and the presence of colors, and are specific to unilateral nostril stimulation. Evidence points to fairly high order cognitive processes being responsible for modulating nasal thermal judgments. Such processes are guided by color cues and likely to intervene through modulation of activity in areas specialized in temperature processing. One possible candidate is the insular thermosensory cortex [3].

Differences observed between nostrils suggest these effects may depend upon specialization of the cerebral hemispheres. Trigeminal projections arising in the nasal cavity and conveying thermal signals are mostly contralateral, i.e., signals from the right nos-

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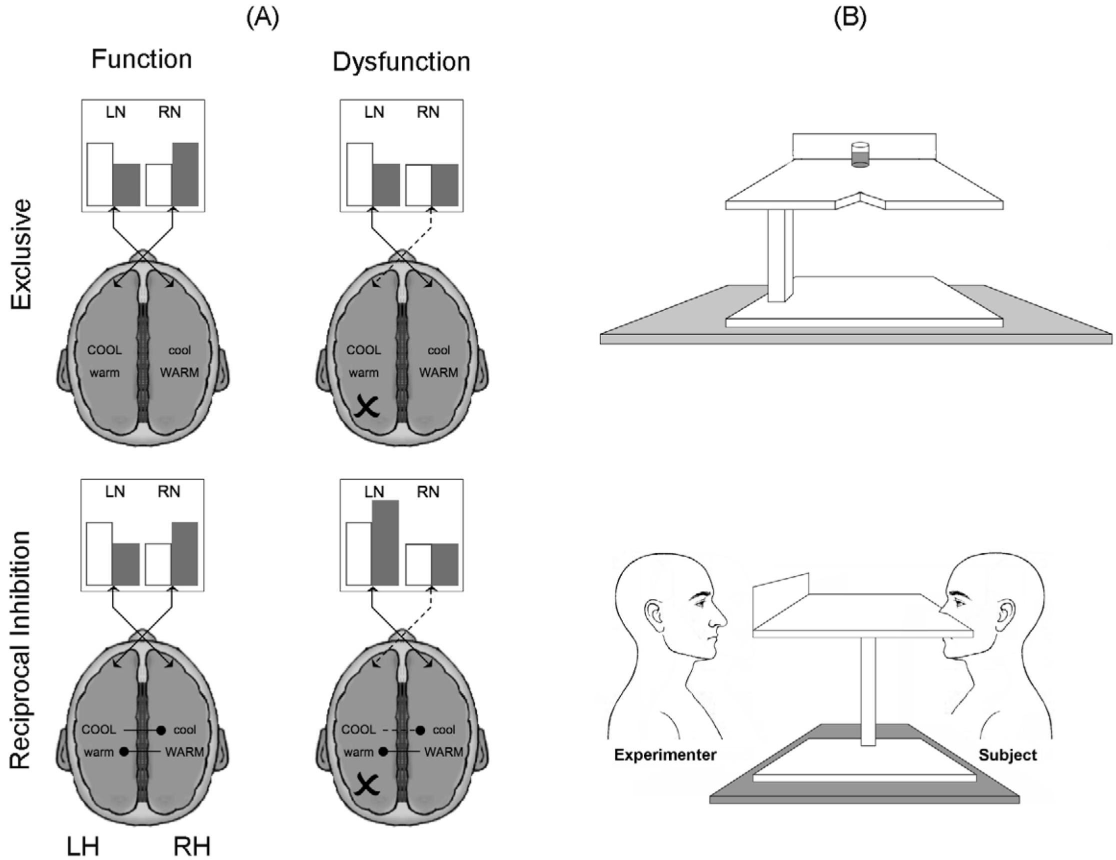

Fig. 1. (A) Graphic depiction of the hypothetical hemispheric functioning in normal subjects giving rise to lateralized color-induced nasal thermal judgments, and the dysfunction predictions that can be made after unilateral brain damage. White bars represent expected responses to red solutions, and grey bars represent expected responses to green solutions. "Cool" and "warm" denote specialized thermosensory neural circuits, with words in capitals denoting dominance. The upper part of the image represents the exclusive specialization hypothesis and the lower part the specialization-through-reciprocal inhibition hypothesis. Dotted lines represent weakened activity. LN, left nostril; RN, right nostril; LH, left hemisphere; RH, right hemisphere. Brain damage is shown with an X. Inhibitory activity is marked with a —●. Note that, while the exclusive and reciprocal inhibition hypotheses predict the same results under normal functioning, they predict different dysfunctions. See text for more details. (B) A front view (upper image) of the Eyes/Nostrils Dissociation Device (ENDD) and a lateral view (lower image) showing how subjects and the experimenter were placed during the Experiment.

tril are conveyed to the left cerebral hemisphere (LH), and those from the left nostril to the right hemisphere (RH). Warming and cooling signals may thus be processed via selective pathways [4,5], giving rise to hemispheric differences [1]. Other than identifying a central role for the insular cortex in thermosensory processing, imaging studies have shed little light on the lateralization of these processes [3,6]. Craig et al. [3] reported activation of a mostly left-sided network in response to cooling stimuli involving the middle/posterior insula. There is also evidence that, along with somatotopic organization of pain [7], such thermosensory representations in the insula are somatotopographically organized [8]. The hemispheric account is supported by insular pathology. Birklein et al. [9] reported a selective loss of contralateral cold perception, without any loss of warm perception, following a lesion of the left insula. Conversely, Cattaneo et al. [10] reported a selective loss of contralateral warm perception, without any loss of cold perception, following a lesion of the right insula. Cooling and warming signals are seemingly processed separately. Such processing is probably lateralized, and involves the insular cortex. A key question [2] has to do with the nature of these lateralized patterns. Are they due to exclusive specialization of the cerebral hemispheres, or to specialization that arises as a result of inhibition between the hemispheres [11]. In the first case, each hemisphere would be more involved than the other in one particular type of processing. Both hemispheres would process thermosensory signals [12] at different degrees, with the LH specializing in cooling signals and the RH in warming signals. In the second case, in addition to their relative specialization, the specific thermosensory systems of the two hemispheres would be mutually inhibiting (e.g., the dominant LH processing of cooling signals would inhibit the non-dominant cooling system of the RH), so that each could efficiently process the signals it is specialized to process [11]. Neuropsychological evidence would considerably help disentangle these two accounts since each one predicts different results in patients suffering from a unilateral lesion, especially involving the posterior insula [3,12]. The first account would gather support if a simple reduction in the color–temperature associations were to be found for the nostril contralateral to the lesion, where, for example, the right nostril dominance of green-cooling responses would diminish following a unilateral lesion of the LH. Apart from this pattern, the second account predicts an additional one, namely the increment of these responses ipsilaterally due to the release from inhibition exerted by the damaged hemisphere on the intact one. As a point of fact, over-responsiveness to ipsilateral stimuli is one of the phenomena observed after release from inhibition, revealing a loss of interhemispheric balance. For instance, a diminishing of green-cooling responses in the right nostril after unilateral left lesion would be accompanied by a rise in such responses in the left nostril. If this rise exceeded the level of the ipsilateral red-warming responses, then a supplementary compensation effect could be suspected (i.e., once disinhibited, the hemisphere overreacts). The two hypotheses are graphically represented in Fig. 1 for a LH lesion.