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Modulation of visual attention by prismatic adaptation

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ABSTRACT

Visuo-motor adaptation via rightward-deviating prisms has been repeatedly shown to alleviate lateralized deficits in neglect, including detection of targets as well as endogenous and exogenous orienting of attention. We review here evidence relevant to the underlying neural mechanisms. Rightward prismatic adaptation was shown to shift visual field representation from right to left inferior parietal lobule, changing thus hemispheric dominance within the ventral attentional system. This change is likely to redirect visual input to the dorsal attentional system and to re-install balance between its left- and right-hemispheric components in neglect. We propose a model based on the shift in hemispheric dominance within the ventral attentional system (SHD-VAS), which offers a parsimonious explanation for the effect of rightward prismatic adaptation on spatial bias in neglect and on behavioral data in normal subjects.

1. Introduction

Rightward prismatic adaptation (PA) was introduced to neglect rehabilitation at the end of the last century (Rossetti et al., 1998). It was repeatedly shown to decrease lateralized deficits in neglect and is believed to alleviate attentional bias in neglect; however, its underlying neural mechanisms remain poorly understood (Barrett et al., 2012; Newport and Schenk, 2012; Redding and Wallace, 2006; Rode et al., 2003). The overall effect of rightward PA in neglect was interpreted as modulation of visual spatial attention, modification of spatial representations and/or changes in visually guided motor behaviours (Pisella et al., 2006; Striemer and Danckert, 2010; Jacquin-Courtois et al., 2013).

We review the current evidence and discuss the putative mechanisms by which rightward PA affects the attentional systems. After a brief introduction to rightward PA and neglect (Sections 2 and 3) we outline the effects of PA on endogenous and exogenous orienting of attention and on target detection (Sections 4 and 5). We then formulate a model that explains how rightward PA is likely to modulate spatial and attentional representations (Section 6).

2. Rightward prismatic adaptation: a brief intervention that changes visuo-motor realignment and visual representations

PA is based on early experiments that were published 130 years ago (Stratton, 1896). In its most used version today it requires the subject to point toward a visual target with his hand while wearing prismatic goggles that deviate the visual field unilaterally to the right or left. During the first trials of pointing toward the target, the visuo-proprioceptive conflict produced by the prisms induces a pointing error in the same direction as the optical deviation. Usually within 10–15 trials, subjects adapt their pointing responses, and the pointing errors disappear. If the prisms produce a deviation of the visual field toward the right, the subject has to orient his movements to the left to compensate for the deviation, thereby inducing a leftward drift of the sensori-motor coordinates (Jacquin-Courtois et al., 2013; Redding et al., 2005; Rossetti et al., 1998). When the goggles are removed, the after-effects of such adaptation can be observed, for example, a leftward shift of the perceived proprioceptive midline (evaluated by pointing straight-ahead without visual feedback). These after-effects compensate for the visuo-proprioceptive discrepancy introduced by the prisms.

In normal subjects, two types of activation studies have been carried out. First, neural activity has been investigated during the actual adaptation to prisms, showing differential activation patterns during the initial phase of the adaptation to right- or leftward deviating prisms (i.e., during the error pointing and its correction), while the adaptation is stable, and during the de-adaptation phase. During the adaptation phase, activation has been reported in the parieto-temporal cortex and the cerebellum, subserving a mechanism of spatial realignment (leftward PA: Chapman et al., 2010; Luauté et al., 2009; rightward PA: Danckert et al.,

Abbreviations: FEF, frontal eye field; IPL, inferior parietal lobule; IPS, intraparietal sulcus; PA, prismatic adaptation; SPL, superior parietal lobule; STG, superior temporal gyrus; TPJ, temporoparietal junction

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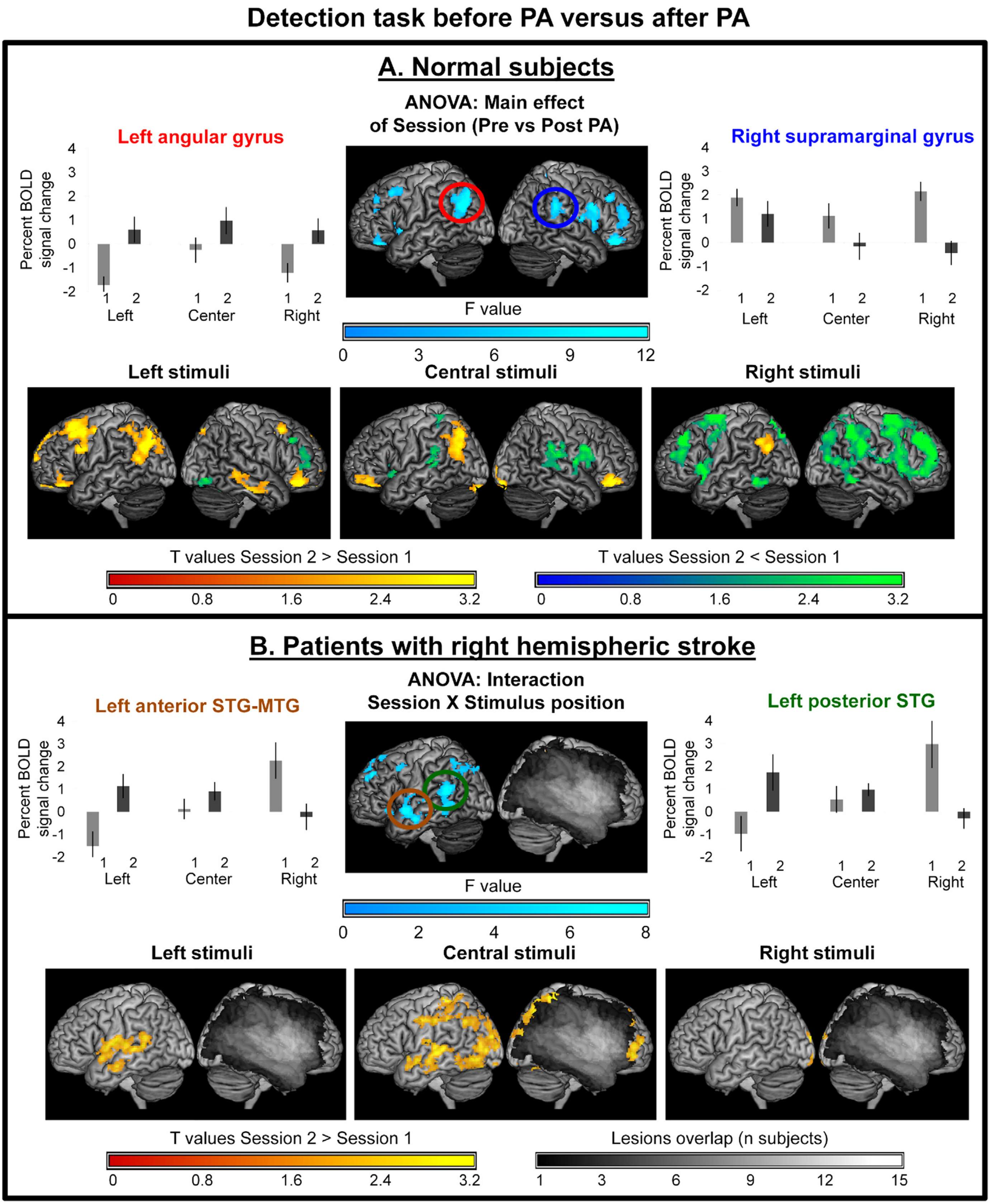

Fig. 1. Activation studies in normal subjects and in patients with right hemispheric stroke. A. Brain activation in a group of 15 normal subjects during a visual target detection task before and after a session of rightward PA (adapted from Crottaz-Herbette et al., 2014). Top row: Surface renderings of the brain activation showing significant differences before (1: Pre-PA) vs. after PA (2: Post-PA). Graphs: Percent (mean ± SEM) BOLD signal changes in session 1 (light gray) and session 2 (dark gray) as function of the position of visual targets in the left angular gyrus (red circle) and in the right supramarginal gyrus (blue circle). Bottom row: Surface renderings of the brain activation showing significant changes in activity elicited by left, center and right targets: increased representation of the left, central and right visual field within the left IPL and decreased representation of the right and central visual field within the right IPL. B. Surface renderings and graphs of percent BOLD signal changes for a group of 15 patients with right hemispheric stroke (adapted from Crottaz-Herbette et al., 2016), same comparisons as in A. Display of the lesions overlap across the 15 patients with a gray scale on the surface rendering.