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Spatial attention and the malleability of bodily self in the elderly

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ABSTRACT

A right-hemispheric specificity has been suggested both for spatial attention and for the feeling of body-ownership. Here, we assessed lateralization of spatial attention (Milner landmark task), rubber hand illusion (RHI), and their relationship in a group of 59 healthy elderly subjects. The occurrence of the RHI was assessed by objective (proprioceptive drift) and subjective (questionnaire) measures.

Spatial attention was asymmetrical, with a slight, neglect-like overestimation of the right segment of mid-bisected lines. As to the RHI, the proprioceptive drift towards the plastic hand was significantly larger following synchronous compared to asynchronous stroking, but comparable between both sides. Subjective responses indicated an experience of the RHI during synchronous stimulation, without lateralization. On the left hand, however, the proprioceptive drift correlated significantly with the rightward bias of spatial attention.

Thus, reduced attention towards sensory signals from one's own limb might facilitate the process of embodiment of an artificial hand into one's body-representation.

1. Introduction

It has been suggested already several decades ago that spatial mapping of the extracorporal space may be viewed as an outgrowth of the perception of corporal space, both relying on the same mechanism ("morphosynthesis") (Bowers & Heilman, 1980; Denny-Brown & Banker, 1954; Denny-Brown, Meyer, & Horenstein, 1952). By now, a growing body of literature points to common mechanisms underlying our perception of the world around us and of our own body (Blanke, 2012; de Vignemont, 2011; Jeannerod, 2003). In both instances, a process of integrating multisensory input seems to be crucial in order to generate a coherent percept and to keep it updated over time (Blanke, 2012; Blanke, Slater, & Serino, 2015). In addition, both functions show some degree of right-hemispheric specialization, pointing to a right-hemispheric dominance for visuospatial attention processing (Benwell, Thut, Grant, & Harvey, 2014; Cai, Van der Haegen, & Brysbaert, 2013; Feinberg & Keenan, 2005; Feinberg & Venneri, 2014; Kerkhoff, 2001; Ocklenburg, Ruther, Peterburs, Pinnow, & Gunturkun, 2011; Reuter-Lorenz, Kinsbourne, & Moscovitch, 1990; Thiebaut de Schotten et al., 2011).

With regard to lateralization and localization of distinct neuropsychological brain functions, much of our knowledge has been obtained by lesion studies. However, stroke is highly variable in topography and size, and depending on the node of a particular network which is disrupted, it may affect a variable number of neuropsychological functions, some of which are related reciprocally to each other. Thus, results from lesion-based approaches might be ambiguous, especially in the case of studies questioning the association of two or more neuropsychological signs. On this account, physiological aging may offer the opportunity to study more subtle changes of brain functions. This may particularly apply to spatial attention which is known to show a bias towards the left hemispace ("pseudoneglect") in healthy young subjects (Bowers & Heilman, 1980), while there is a shift of this asymmetry towards a

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slight neglect-like condition in healthy elderly subjects (Benwell et al., 2014; Fujii, Fukatsu, Yamadori, & Kimura, 1995; Schmitz & Peigneux, 2011). As the extent of these physiological asymmetries – regardless of their direction – is rather small, there is no functional impairment on a clinical scale, whereas subtle behavioral implications may be suspected. Accordingly, while a number of clinically established tests of spatial attention are widely used in patients suffering from neurological conditions, many of them lack sensitivity to detect such slight asymmetries in healthy subjects. The active line bisection task, where subjects are asked to bisect horizontal lines into equal parts, has been shown to reveal even small asymmetries (Jewell & McCourt, 2000; Ocklenburg, Peterburs, Ruther, & Gunturkun, 2012). However, due to its active (motor) component, it may be confounded by factors other than spatial attention. Therefore, the Milner landmark task, which enforces a judgment of asymmetry of centrally pre-bisected lines and which has proved superior in identifying even slight perceptual bias (Harvey & Olk, 2004; Milner, Harvey, Roberts, & Forster, 1993), was chosen for the present study.

In view of the close relationship between the perception of extrapersonal and personal signals, it appears likely that any bias of spatial attention as detected in extrapersonal space may also impact aspects of bodily perception – and vice versa. Indeed, the rubber hand illusion (RHI), where synchronous tactile and visual stimulation result in the illusion of owning a plastic hand, has been shown to reduce pseudoneglect in young healthy adults (Ocklenburg et al., 2012). Moreover, experimental manipulation of the perceived size of one's own body can alter the perceived sizes of objects in the peri-personal and even in the distant extra-personal space, suggesting that the own body is used as a metric for the external world (van der Hoort & Ehrsson, 2014). This raises the question as to how an asymmetry of spatial attention, conversely, impacts the RHI as an example of experimentally induced limb ownership, in order to further explore the interrelationship of these two neuropsychological functions. Assessment in patients with neurological conditions like stroke or head trauma is complicated by the fact that lesions mostly involve several domains of the brain which may blur any inference on interactions.

Here, we used the RHI paradigm to probe multisensory aspects of bodily self and their relationship with spatial attention in healthy elderly subjects. We hypothesized to find (i) an attentional bias towards the right in terms of a slight hemineglect and (ii) an association of this attentional bias with measures of the RHI.

2. Methods

The study conformed to the principles of the declaration of Helsinki. It was approved by the Ethics committee of the Medical Faculty at the University of Würzburg.

2.1. Subjects

Fifty-nine volunteers with a median age of 75 years (range 60–90 years) without a history of neurological or psychiatric disease and without antipsychotic or antidepressant drugs were included. Additional exclusion criteria were as follows: (i) any sensory impairment of an upper limb; (ii) any spontaneous impairment of the feeling of limb ownership as inquired by a questionnaire (Groß, 2010); (iii) left-handedness or ambidexterity according to a modified version of the Edinburgh Inventory (Oldfield, 1971), which contains questions referring to hand preference in ten everyday activities. The total score ranges from −20 for strong left handedness to +20 for strong right handedness, with scores from −12 to +12 indicating ambidexterity. The clock-drawing test (Shulman, Gold, Cohen, & Zucchero, 1993) and the Parkinson Neuropsychometric Dementia Assessment (PANDA; Kalbe et al., 2008) served as screening tools for cognitive dysfunction and depression. The PANDA was used for the sake of data comparability with respect to a consecutive study in patients with Parkinson's disease. In the clock-drawing test, scores range from 1 (perfect drawing) to 6 (no recognizable clock), with the cut-off between normal and impaired between 2 and 3 (Shulman et al., 1993). For the PANDA, cognition was rated normal at scores from 18 to 30 and potentially impaired from 15 to 17, while a score below 15 indicated probable dementia. Probable depression was indicated by a mood subscore from 5 to 9 (Kalbe et al., 2008). All participants gave their written informed consent for research.

2.2. Spatial attention

2.2.1. Letter cancellation task (Weintraub, 1985)

The goal of this task is to detect all 60 occurrences of the letter "A" hidden among other letters printed on an A4 sheet of paper. The participant is asked to mark as many "A"'s as possible with a pen. The "Center of Cancellation (CoC)", ranging from −1 to +1 on a normalized scale with 0 marking the geometrical middle, was taken as a measure of the subjective middle (Rorden & Karnath, 2010).

2.2.2. Milner landmark task (Milner et al., 1993)

Lines of 20 cm length and 1.5 mm width were printed horizontally and centrally on sheets of A4 paper (used sideway), one line per sheet. Each line had been pre-transected at right angles with a "landmark" line 10 mm in length and 1 mm in width. The subjects had to make a forced-choice manual judgement as to whether each line was transected nearer to its right end or its left end. A total of 20 lines was presented, of which 10 were asymmetrically pre-transected, at 1, 2, 3, 4, or 5 mm to the right or the left of the true centre. These 10 asymmetrical stimuli served as fillers intended to encourage the impression that all 20 lines might be asymmetrically bisected and therefore were not analyzed further (Milner et al., 1993). The remaining 10 lines were transected at the midpoint. Patients were forced to make a left/right choice even if it was necessary to guess. Here, the number of left-end responses provides an