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Clinical commentary

Perception of active head rotation in patients with severe left unilateral spatial neglect

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ABSTRACT

Unilateral spatial neglect is a common neurological syndrome following predominantly right hemisphere damage, and is characterized by a failure to perceive and report stimuli in the contralesional side of space. To test the reference shift hypothesis that contralesional spatial neglect in right-brain-damaged patients is attributed to a rightward deviation of the egocentric reference frame, we measured the final angular position to which controls and left-side neglect patients actively turned their head toward the left in response to a verbal instruction given from each of three locations—right, left, and front—in two conditions, with and without visual feedback. When neglect patients were asked to "look straight ahead", they deviated about 30° toward the right in the eyes-open condition. However, the rightward deviation was markedly reduced in the eyes-closed condition. Regardless of visual feedback, there was no significant difference between controls and neglect patients in the final angular position of active head rotation when the verbal instruction came from the subject's left or front side; however, the final angular position was significantly smaller in the neglect patients than in the controls when the verbal instruction was given from the right. These results support the contention that cervico-vestibular stimulation during active head rotation restores spatial remapping and sensori-motor correlations and so improves neglect without affecting the position of the egocentric reference; however, once left-side neglect patients respond to verbal instruction from the right side, they are unable to disengage attention from the hemispace, and the performance of head rotation is disturbed.

1. Introduction

Unilateral spatial neglect is a common neurological syndrome that interferes with most activities of daily life, undermines rehabilitation efforts and thereby creates a significant burden for patients and their relatives. The symptoms of unilateral spatial neglect are typically associated with cerebral damage involving the right hemisphere, although neglect also arises after left-sided lesions [1–3]. Neglect patients fail to detect, attend or respond to stimuli in spatial locations contralateral to the side of cerebral damage despite the absence of elementary sensory or motor deficits [4,5].

Spatial neglect is characterized by both spatial and non-spatial deficits [6–8]. Core spatial deficits involve mechanisms for saliency coding, spatial attention, and short-term memory, and occur in conjunction with non-spatial deficits that involve reorienting, target detection, and arousal/vigilance [6]. Clinical and experimental evidence indicates that attentional impairments are prominent in neglect. When presented with bilateral stimuli, left-side neglect patients may immediately look toward the rightmost stimulus, as if their attention were "magnetically" attracted [9].

In patients with right brain damage, the manifestation of neglect for the left side of space can be found not only in the visual but also in the auditory and tactile modalities although the severity of neglect is greater in the visual than in the non-visual modalities [10]. Several studies [10] have shown a systematic rightward shift of sound localization in neglect patients. Even in the absence of visual distractions the presence of multiple, spatially distributed sources of sound provokes a shift in sound localization toward the right side of space [11]. This suggests that not only visual stimuli but also auditory stimuli arising from the right side of space can automatically attract and orient the patient's attention.

A number of visual, vestibular and/or proprioceptive stimulation techniques have been developed to treat left-side neglect symptoms in patients with right brain damage. These techniques

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include optokinetic stimulation, vibration of neck muscles on the left side, vestibular stimulation, leftward trunk rotation, transcutaneous electrical stimulation of the left neck muscles, limb activation and prismatic adaptation [12,13]. It has been suggested that the spatial bias observed in left-side neglect patients due to a right-side lesion stems from a rightward deviation of the egocentric frame of reference. However, several lines of evidence have accumulated showing that there is no significant correlation between the position of this egocentric reference and the presence and severity of left-side neglect signs [14]. In light of this, Gainotti [15] proposed an alternative hypothesis that the positive effects of vestibulo-proprioceptive stimulation stem from a reorientation of attention toward the contralesional side of space. Based on an understanding of the processes by which visuo-vestibulo-proprioceptive stimulations lead to neglect remission [16,17], Chokron et al. [18] proposed that these stimulations restore spatial remapping and sensori-motor correlations, thereby improving neglect without affecting the position of the egocentric reference.

Since Chedru [19] first showed the negative effect of vision on the severity of left-side neglect symptoms, extensive evidence has accumulated indicating that visual feedback exacerbates left-side neglect behavior and that eliminating visual control thus improves performance [20–27]. Therefore, investigations of representational neglect should include two distinct testing conditions: with and without visual guidance. We hypothesized that left-side spatial neglect is attributed to a rightward deviation of the egocentric frame of reference, in which case (1) the final angular position of active leftward head rotation about a vertical axis would be shifted to the right, and (2) visual feedback would exacerbate the rightward shift of the final angular position of active head rotation due to the negative effect of vision on the severity of neglect signs [19,20].

2. Methods

2.1. Subjects

A total of 14 patients with right hemispheric lesions and left spatial neglect and 11 healthy control subjects participated in the study. All 25 subjects gave their informed consent to participate in the study, which was approved by the Ethical Committee of Kamojima Hospital and performed in accordance with the Declaration of Helsinki II. Table 1 summarizes the demographic and clinical data. Gender differences between the neglect patients and the healthy controls were assessed via the coefficient of contingency 'chi'. The ratio of the number of male to female subjects was not significantly different in the two groups ($\chi^2 = 0.889$, $p = 0.3457$). All subjects were right-handed. In all patients, the neglect was classified as severe by the criteria of Posner et al.: dense neglect with tonic head and/or eye deviation according to a five-point scale (minimal, mild, minor, moderate and severe) [28]; no patients had a neck disability or other neurological or psychiatric diseases or had received specific neglect rehabilitation like visual scanning training, optokinetic stimulation, neck muscle vibration, caloric vestibular stimulation, leftward trunk rotation, limb activation or prismatic adaptation.

The age of the neglect patients ranged from 37 to 84 years, with a mean age of 70.6 years (S.D. 12.5). The healthy control group consisted of 11 subjects who were age-matched to the neglect patients (49–89 years; mean 70.2 years; S.D. 14.5 years).

2.2. Experimental procedure

With the subject seated in the wheelchair in a room free from external stimuli, experimenter 1 gave the verbal instruction, "[Subject's name], please look straight ahead," from behind the subject. Next, he/she gave the verbal instruction, "please turn your face to the left," from each of three locations (the subject's right, front and left sides in order) at the distance of 2 m from the subject after moving along the trajectories 1–4 (dashed lines) shown in Fig. 1 so that he/she did not come into the subject's view. After informing the subject that he or she had finished the head rotation task in response to the verbal instruction, the experimenter asked the subject to look straight ahead. Then, the next head rotation task was performed. To measure the angular head position, experimenter 2 used a standard goniometer by placing the goniometer on the top of the subject's head with the stationary arm aligned with the acromion process and the moveable arm aligned with the center of the subject's nose. The subjective straight-ahead orientation and the angular position of active leftward head rotation were measured with and without a blindfold.

2.3. Statistical analysis

Data were tested for normality (Shapiro–Wilk test) and equal variance (*F*-test) first. The data for the head angular position were

Table 1
Summary of clinical and demographic data of the neglect patients (single subject data and group mean) and healthy controls (group mean).

Subjects	Sex	Age	Etiology	Months post lesion	Lesion location	Neurological deficit		Clinical neglect
						M	SS	
C	5 m/6f	70.2	–	–		–	–	None
N1	m	62	H	12	R: TP	+	+	Severe
N2	m	80	I	2	R: FT	+	+	Severe
N3	m	60	H	5	R: Th	+	+	Severe
N4	m	78	I	5	R: TP	+	+	Severe
N5	m	65	H	12	R: PO	+	+	Severe
N6	m	64	I	2	R: TP	+	+	Severe
N7	f	79	H	1	R: PO	+	+	Severe
N8	f	84	N	24	R: P	+	+	Severe
N9	f	70	I	1	R: TO	+	+	Severe
N10	f	82	I	1	R: TP	+	+	Severe
N11	f	76	I	1	R: TP	+	+	Severe
N12	m	37	H	2	R: Pu	+	+	Severe
N13	m	79	I	2	R: FTP	+	+	Severe
N14	m	72	I	1	R: TPO	+	+	Severe
N mean	9 m/5f	70.6		5.1 (1–24)				

Abbreviations: C: healthy control subject; N: neglect patient; m: male; f, female; I/H/N: ischemic/hemorrhagic/neoplastic lesion; R: right; F: frontal; T: temporal; P: parietal; O: occipital; Th: thalamic; Pu: putamen; M/SS: left motor/somatosensory deficit; +/−: presence/absence of impairment.