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Impairment of attention choice in left spatial neglect patients: A behavioral study.

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Abstract

The aim of this study was to explore the changes in object-based and space-based attention choice in left spatial neglect. Eleven subjects with left spatial neglect were designated as viewer-centered neglect (viewer-centered group, n=5) or combined viewer-centered with object-centered neglect (combined group, n=6). All recruited subjects completed a modified cue-target paradigm, and their Response Times (RTs) to valid and invalid cues were recorded and analysed. The mean RT for targets located in the left space was longer than the mean RT for targets in the right space, especially in the combined group. Furthermore, with an invalid cue prompt, the RT was longer when attention was shifted between objects than when shifted within objects in any group, regardless of targets in left or right spaces. However, when attention shifted towards the left, the RT increased. Subjects with left spatial neglect manifest impairment of space-based attention choice and a disengagement disorder of the right space (or engagement disorder of the left space).

Keywords: Left spatial neglect, Attention choice, Object-based attention, Space-based attention.

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Introduction

Left spatial neglect is a common attention disorder after right hemisphere stroke [1-3]. The ability to focus one's attention on important environmental stimuli, whether space-based [4] or object-based [5], while ignoring irrelevant stimuli is fundamental to human cognition and intellectual function [6]. Unilateral spatial neglect patients always show viewer-centered neglect or stimulus-centered neglect [7] and visual input is represented in two modes simultaneously [8], which may be relevant to different attention selection disorders [9].

Schindler et al. [10] used a modified experimental paradigm on patients with strokes of the right hemisphere, including patients with left spatial neglect, no spatial neglect, and healthy controls. The researchers found that only those patients with left spatial neglect had disorders in transferring their attention between objects, rather than within objects. Their results showed that the attention disorder was object-based rather than space-based. Egly et al. [11] modified the classical cue-target paradigm to show that both space-based attention and object-based attention could be defined in the same experimental paradigm. The patients in Schindler's study were not grouped by their neglects, which would be considered an influencing factor in this study to analyse the differences in choice by patients with different neglect models.

Materials and Methods

Patient characteristics

This study comprised 11 cases of left spatial neglect caused by right-hemisphere stroke: 9 males and 2 females, all of whom had normal vision or vision corrected to normal. Other patient characteristics included age (51.7 ± 11.82 y; range, 32-66 y), years of education (11.5 ± 3.15 y), Mini-Mental State Examination (MMSE) score (27.1 ± 1.93), and handedness (10 patients were right-handed, and 1 was left-handed). This study was conducted in accordance with the declaration of Helsinki. This study was conducted with approval from the Ethics Committee of Hebei General Hospital. Written informed consent was obtained from all participants. Because this study required patients to cooperate, we performed relatively strict screening. All patients were in good physical and mental condition; therefore, no patients were excluded from the study.

Patients showed typical symptoms of left spatial neglect, such as watching the right space (or staring at the right) without awareness while the head rolled to the left, eating food on the right side, ignoring the contents of the right side of the paper while reading, etc. Neglect tests included line cancellation, line bisection, the clock drawing test, star cancellation, gap detection, and scene copy testing [12,13]. If positive results were shown in at least two of the tests above, the patient was considered to have spatial neglect. The patients were then grouped as viewer-centered neglect (n=5) or combined viewer-centered neglect and stimulus-centered neglect (n=6) based on the results of gap detection (Table 1).

Table 1. *The clinical information and test results of patients in neglect test.*

Group	Age/gender	Course of age (day)	Nidus	Neglect test					
				Line cancellation	Line bisection	Clock drawing test	Star cancellation	Gap detection	Scene copy testing
1	32/F	100	forehead, temporal,	15/15	6.23	0	########	0/0	2
2	50/M	16	basal ganglia, Corona radiata, parietal occipital	0/11	18.47	1	0/0/15	0.50/2	9
2	52/M	18	forehead, temporal, parietal occipital, basal ganglia	12/15	24.28	1	0/0/23	0.17/2	7
2	43/M	18	forehead, basal ganglia, periventricular	13/15	9.77	1	0/0/23	0/1	6
1	60/M	26	basal ganglia, periventricular	0/13	0.08	1	0/0/19	0/0	3
1	59/M	49	forehead, temporal,	11/15	-0.02	0	########	0.1/4	1
1	28/M	35	temporal	15/15	0.13	0	########	0/0	2
1	62/M	20	middle cerebral artery territory	0/8	0.34	1	0/0/8	0/1	5
1	53/M	23	temporal, islet, basal ganglia	10/15	-0.01	1	102/27	0/1	4
2	58/M	755	forehead, temporal, basal ganglia, thalamus	12/15	0.13	1	########	0.13/0	0
2	37/F	1825	forehead, temporal	14/15	0.06	0	########	0/0	1

The number of merging exists self-centered and non-self-centered neglect patients are 6 in Group 1. The number of simple egocentric neglect patients is 5 in Group 2.

Testing process

The stimuli were shown on the screen in a sequence of (1) fixation (1000 ms), (2) cue (100 ms, with 150-250 ms as an Interstimulus Interval (ISI)), and (3) target (until a response was received from the subject, which should not be longer than 2000 ms). The Intertrial Interval (ITI) was 1000 ms. The background consisted of a central cross fixation point (0.4 × 0.4º) and two rectangles (11.4 × 1.7º) above and below the cross point (or left and right). The width of the line was 0.2 cm. The total stimuli included 4 sessions (the two rectangles were placed above and below the cross point in 2 sessions, and placed left and right the cross point in the other 2 sessions), and each session contained 96 trials. Among all trials, 20% were empty test trials (with no target stimuli). The remaining 80% of trials (in which a target was shown) comprised 60% that included valid-cue stimuli, 10% with invalid-cue stimuli with the cue in the same rectangle but at the other side (within objects), 10% with invalid-cue stimuli with the cue in the other rectangle but on the same side (between objects), so valid-cue stimuli were shown in a total of 75% of the trials (Figure 1). Each patient sat in front of the computer at a distance of 57 cm and pressed the space key upon finding the target stimulus on the screen; patients remained seated until no additional target stimuli appeared. Patients were instructed that correctly identifying stimuli was as important as Response Time (RT).

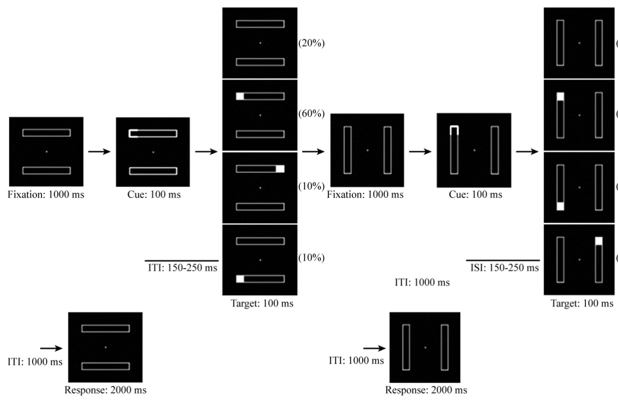

Figure 1. *Task flows.*

Data analysis and statistics

A paired t-test was used to analyse RTs between the target stimuli on the left and right sides in each patient. A 2 × 2 × 2 Analysis of Variance (ANOVA) was then performed to determine whether the location of the rectangles, the side where the target appeared, or the validity of the cue affected the RT (the independent variable, including the side of the target appearance, the orientation of attention transfer, and the validity of the cue). Analysis of variance was repeated (factors included the side of target appearance and different neglect types) to evaluate changes in RT. If the results did not meet the requirements of a spherically symmetric test, the degrees of freedom were adjusted by Huynh-Feldt correction, and we also used Bonferroni corrections for the alpha level.

The extra RT (obtained by RT on invalid cues minus RT on valid cues with all other factors being equal) was then evaluated. A 2 × 2 × 2 ANOVA was conducted to determine whether results were affected by the side on which the target appeared, horizontal or vertical attention transfer orientation, or whether the target was in the same rectangle as the cue. The analysis was performed also for types of attention shift (within-subject shift, or between-subject shift), using the side of target appearance and neglect group as subject factors.

All statistical tests were performed using SPSS 16.0 (IBM Corp., Armonk, NY, USA), and the level of significance was set at P<0.05. The results of RT were omitted if RT was shorter than 150 ms or longer than 3 standard deviations, which were considered due to guessing or inattention.

Results

Correct rates and omission rates of RT

The average correct rate of response was 96.55%, and the rate of incorrect responses for the empty target trials was 1.00%. For the left target, the average omission rate was 6.89%, and it was 0.01% for the right target. There were 5 false-positive results.

Left and right targets RT comparison

There was a significant difference in RTs between the left and right targets (t (10)=3.75, P=0.00). The RT for the left target was significantly longer than the RT for the right target, at 682.14 ms and 553.50 ms, respectively (Figure 2).

Space-based attention: RT difference analysis with valid and invalid cue: ANOVA (side of target appeared X validation of cue X orientation of rectangles) showed that the side on which the target appeared (F (1, 10)=12.79, P=0.002) and the validation of the cue (F (1, 10)=14.91, P=0.001) were relevant to RT. The interactions between the three factors and any of the two factors were insignificant (F (1, 10)<1.06, P=0.58).

ANOVA (validity of cue X different neglect type X side of the target appearance) showed that the differences between the valid and invalid cues (F (1, 10)=76.59, P=0.006), the different neglect groups (F (1, 10)=18.88, P=0.003), and the side of the target appearance (F (1, 10)=6.31, P=0.02) were all significant. The interaction between cue validity and the side of the target appearance (F (1, 10)=5.50, P=0.03), and cue validity and the different neglect groups (F (1, 10)=5.15, P=0.02) were all significant. Compared with the right side, when the target appeared on the left side, the RT was longer for the invalid cue than for the valid cue (left: 237.01 ms, right: 136.64 ms), especially in the combined group (Figure 3A).

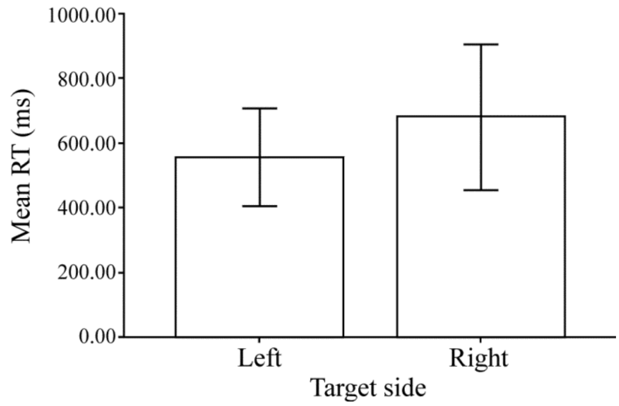

Figure 2. *Comparison of left and right target RT.*

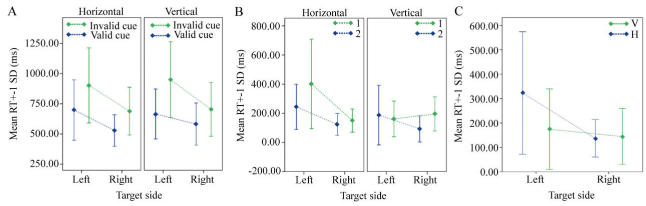

Figure 3. *A: Effects on RT (left: the target appeared at the left side; right: the target appeared at the right side); B: Effect of target appearance side, attention transfer orientation and whether target was on the cue rectangle on RTs (1: Target appears in the same rectangle with cue; 2: Target does not appear in the same rectangle with cue); C: Effect of whether target (whether left or right) was in the same rectangle with the cue on the RT (V: Vertical Transfer; H: Horizontal Transfer).*

Object-based attention: comparison of extra RT for targets following two kinds of invalid cues: We performed ANOVAs on the extra RT to evaluate the influence factors (the side of the target appearance, the orientation of attention transfer, whether the cue and the target in the same rectangle), which showed that the side of the target appearance (F (1, 10)=9.76, P=0.02] and the orientation of attention transfer (F (1, 10)=4.19, P=0.03) were significant, while the presence of the cue and the target in the same rectangle was insignificant (F (1, 10)=3.45, P=0.08). The interaction between the side of the target appearance and the orientation of attention transfer was significant (F (1, 10)=5.16, P=0.03), but the interactions among the other factors were not significant (F (1, 10)<3.54, P>0.05). The results of a paired t-test showed that there was no significant difference in RT between horizontal and vertical attention transfer when the target was on the right side (t (10)=-0.41, P=0.67). However, when the target appeared on the left side, there was a significant difference in RT between the horizontal and vertical attention transfer (t (10)=-2.50, P=0.02), and the RT was significantly longer in horizontal transfer than in vertical transfer (323.12 ms *vs.* 174.41 ms) (Figure 3B).

Analysis of the extra RT (factors including the side of target appearance, different neglect type, and within- or between-object attention shift) showed that the extra RT for the between-object shift was significantly longer than the extra RT for the within-object test (F (1, 10)=5.67, P=0.03). The interactions between any two of the three factors were insignificant (F (1, 10)<0.44, P=0.56) (Figure 3C).

Discussion

The lowest RT was achieved when the target appeared in the same location as the cue (valid cue), while the RT increased when the target appeared in different locations from the cue (invalid cue), confirming that there was space-based attention transfer [14]. The RT was longer when the invalid cue was in a different rectangle than when it was in the same rectangle but on a different side, which confirmed the attention facilitated the information processing and object-based attention choice [15].

We found that the RT for left spatial neglect patients was significantly longer for the left target, and the RT difference between valid and invalid cues was more obvious than for the right target, confirming that patients had space-based attention disorders. Although the RT in between-object attention transfer tests was longer than within-object tests with invalid cues, there was no significant difference between the left and right sides and the different neglect groups; the only significant result was that attention transfer to the left took longer.

Healthy control subjects showed a significantly longer RT for invalid cues compared with the RT measured for valid cues [6] that is, the processing of information appearing at the attention position was easier, reflecting the effect of space-based attention selection. In the case of two invalid cues, the RT for within-objects attention transfer was significantly shorter than the RT for between-object tests-that is, the processing of information appearing at the cued object was easier, which also reflected the effect of object-based attention selection [14] and was consistent with several other studies. In other words, the difference in RT between invalid and valid cues reflected space-based attention effects [16], and the difference in RT for between-object and within-object transfers reflected object-based attention effects [13,17,18]. Left spatial neglect patients were unable to recognize the stimulus at the left side or the left part of the stimulus.

In this study, we found that the attention pattern of left spatial neglect patients was different from that of healthy subjects and that there was a significant increase in RT when the target appeared on the left side. However, the RT was shorter with valid cues than with invalid cues when the target appeared on the right side. When the target appeared on the left side, the difference in RT was significant, confirming that patients had space-based attention disorder. This result was consistent with most previous studies [19,20], especially for the combined viewer-centered neglect and stimulus-centered neglect patients.

Another finding was that left spatial neglect patients had a much longer RT for between-object attention transfer tests than they did for within-object tests, and the same results were observed in both left and right sides, and in both neglect groups; these results were similar to those of healthy subjects. Egly et al. [11] also found that object-based attention selection by patients with right parietal lobe lesions did not change. Another study found that a patient with right parietal lobe lesions and who had left spatial neglect remained sensitive to the (left or right) border of the object [21]. However, one study [10] using the same experimental paradigm found that attention disorder in left spatial neglect patients was mainly manifest as attention transfer disorder between objects; after prism adaptation, the between-object attention pattern could be restored, so researchers believed that the left spatial neglect reflected object-based disengagement disorder. The reason for the discrepancy might be that the extra RT for invalid cues was compared with that for valid cues-all other factors being equal in this study-whereas that study directly compared the mean RT for invalid cues. For the neglect patient, the left side was the affected side, and the right side was a relatively complete side, and the experimental paradigm also involved the orientation of the rectangle. All of these factors could yield a different RT baseline for the same patient. In this study, the baseline was equal in all trials with valid cues, so the analysis of extra RT with invalid cues would better reflect the differences in attention transfer [11].

Considering that the experimental paradigm compared object-based attention and space-based attention, the experimental paradigm should, theoretically, be able to distinguish nonself-centered (stimulus-centered) neglect. The RT for within-object attention transfer should be longer or the same as the between-object RT in these stimulus-centered neglect patients. However, there were no differences in the extra RT between different neglect patients. The reason may be that the majority of neglect patients were both viewer-centered neglect and stimulus-centered neglect. To further evaluate whether the asymmetry of attention was lateral or directive, we analysed the RT with two invalid cues based on whether the attention transfer was vertical or horizontal. We found that the left spatial neglect patient presented with a left horizontal transfer disorder. When the target appeared in the right space, the vertical transfer required more time than the horizontal (without statistical difference); when the target appeared in the left space, horizontal transfer required more time than did the vertical transfer (with statistical significance), which was consistent with other studies [10].

In summary, we found that left spatial neglect patients mainly manifest as space-based attention disorder and attention disengagement disorder of the right space (or engagement disorder of the left space).

Conclusion

We used the cue-target paradigm to study left spatial neglect patients. We compared space-based attention and object-based attention, and found these patients primarily exhibited space-based attention disorder and right-space attention disengagement disorder (or engagement disorder of the left space).

Conflicts of Interest

The authors declare no conflict of interest.

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