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Differences of Neglect in Peripersonal Space and Extrapersonal Space in a Patient with Unilateral Spatial Neglect

Daisuke Kimura[1], Ken Nakatani[2], Masako Notoya[3], Aiko Imai[4], Hiroki Bizen[1], Minoru Toyama[3], Kazumasa Yamada[4]

[1]Department of Occupational Therapy, Faculty of Health Sciences, Kansai University of Health Sciences, Osaka, Japan
[2]Department of Rehabilitation Sciences, Faculty of Allied Health Sciences, Kansai University of Welfare Sciences, Osaka, Japan
[3]Department of Speech and Hearing Sciences and Disorders, Kyoto Gakuen University, Kyoto, Japan
[4]Faculty of Care and Rehabilitation, Seijoh University, Aichi, Japan
Email: d.kimura@kansai.ac.jp, bizen@kansai.ac.jo, knakatani@tamateyama.ac.jp, notoya@kyotogakuen.ac.jp, toyama@kyotogakuen.ac.jp, aikorima393939@gmail.com, yamada-k@seijoh-u.ac.jp

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Abstract

Unilateral spatial neglect (USN) is characterized by neglect in peripersonal and extrapersonal space, the disparity of which is unknown. We assessed these forms of neglect in a patient with USN. We promoted sight scanning in extrapersonal space and used an eye camera to measure gaze movement. We found left-sided sight scanning in peripersonal space, but right-side-biased sight scanning in extrapersonal space. Additionally, line of sight was corrected when the patient was instructed to look left in extrapersonal space and to focus the line of sight at the center. Gaze measurement thus helped to assess disparities in spatial neglect in USN.

Keywords

Unilateral Spatial Neglect, Extrapersonal Space, Peripersonal Space

1. Introduction

Healthy people are able to look around their space and attend to both the right and left sides. These normal perceptions in peripersonal and extrapersonal spaces are bilateral. Unilateral spatial neglect (USN) describes the failure to attend to one side of space. USN is regarded as a higher brain dysfunction that most commonly follows right hemisphere damage; the frequency of USN is high in these patients, approximately 40% [1]. Most USN cases improve within six months [2], however, USN persists in 25% of patients [3]. This can severely affect the ability to carry out activities of daily living (ADL). For instance, patients with left USN may not eat food on the left side of their plate, or may forget to use the brake on a wheelchair if it is located on the left-hand side. In this way, USN has a great influence on ADL, and it is a factor that makes it difficult to return discharge to home.

USN is commonly evaluated using desk evaluations, which include, for example, the line cancellation and line bisection tasks. A correlation has been reported between desk evaluation results and ability to perform ADL [4]. However, desk evaluation results can be improved by using the compensation strategy that aims attention to the left side [4], however, behavior may be unadaptable in daily living [5] [6]. Indeed, a previous study reported a difference between desk evaluation results and ADL performance, whereby desk evaluation results do not necessarily predict USN symptoms in ADL [7]. One explanation for these conflicting findings may be the individual differences in the types of spatial neglect.

The human brain has a standard perception of space. The range of the hand is called peripersonal space, and the space outside this is called extrapersonal space. USN is often characterized by neglect in both peripersonal and extrapersonal space. For instance, Buxbaum *et al.* [8] reported the onset of neglect in peripersonal space in one case, but without neglect in extrapersonal space, but in another case, the opposite was true. Thus, even now, there is no consistent opinion about neglect in these different spaces. This could explain the disparity between ADL results and desk evaluation results, and suggests that separate evaluations for peripersonal and extrapersonal space are required for the true evaluation of USN.

Differences between desk evaluation and ADL results can also be seen in clinical practice. One approach to improve ADL in patients with USN involves correcting spatial attention or visual search. For the approach targeting spatial attention, patients adapt to the neglect space voluntarily via a language strategy (a language-related cue for example, or a strategy of internal speech, such as "you must turn attention to the left side"). In addition, USN is attracted by unilateral stimulation, from which it is hard to release attention. Therefore, USN is interpreted as not visually scanning in one direction. In contrast, there is training to correct sight scanning using the language strategy to the left side. Many clinical practitioners use these methods, and it is assumed that the effects spill over into ADL. However, this is not necessarily the case. For example, language strategies may help patients with USN to adapt to peripersonal space (relevant to desk evaluations), but this does not affect extrapersonal space (relevant to ADL), in which neglect persists.

In extrapersonal space, Nakatani *et al.* [9] measured rotation of the head by attention to the left side in a patient with left USN. Consequently, the patient turned the head to the left trying to find the left side. However, their report did not consider compensatory strategies such as sight scanning. Prior to this, reports have analyzed the movement of the gaze point using an eye camera that tracks the sight scanning of a patient. Such an eye camera can observe movement of the gaze point continuously and when the subject is in the active state, the advantage of which is that the USN symptom can be clarified. For example, Ishiai *et al*. [10] used an eye camera to record the movement of the gaze point when a patient with USN who showed a left-side preference for visual search performed the line bisection task.

In the current study, we describe the case of a patient with left USN following right putamen bleeding, and in whom USN symptoms disappeared 85 days later, according to desk examinations. Nevertheless, monitoring was necessary for the ADL. We measured the movement of the gaze point of the left USN patient with an eye camera and examined the following: 1) The difference between neglect in peripersonal space and in extrapersonal space, and 2) The method to promote sight scanning in extrapersonal space. Our findings seem to reveal the neurological differences in spatial neglect in USN, and may facilitate the management of USN.

2. Presentation of Case

The patient was a 75-year-old right-handed man. Following the development of right headache and left hemiparesis in May 2010, he was urgently admitted to hospital. On admittance, the patient showed anisocoria (Rt. 2 m/Lt. 3 m), severe left hemiplegia, and left USN. The National Institutes of Health Stroke Scale (NIHSS) [11] was 16/42 point at that time. A CT scan showed bleeding in the left temporal lobe and the frontal lobe, and he was diagnosed with cerebral hemorrhage. He was transferred to a specific hospital for rehabilitation 28 days later.

The patient provided informed consent to participate in this study, which was conducted in accordance with the tenets of the Declaration of Helsinki.

2.1. Neurological Findings

The patient showed lucidity, left central facial palsy, and left shift of tongue. Left hemiplegia was upper limb stage I, lower limb stage II, and finger stage III. Knee abduction-adduction and finger flexion was present, but only a little. The patient showed deep tendon hyperreflexia of the left pectoralis, left biceps, left deltoid, and brachioradialis. He showed the Hoffmann reflex and Babinski reflex. He did not have hemianopia, apraxia, or aphasia.

2.2. Neuropsychological Findings

The patient scored 25/30 on the Mini-Mental State Examination. Bisection of three 205-mm lines revealed slight rightward deviation (20 mm) from the midpoint, and he received a diagnosis of USN (**Figure 1**).

2.3. Neuroradiological Findings

Twenty-eight days later, a CT scan showed a high-density area of the right frontal

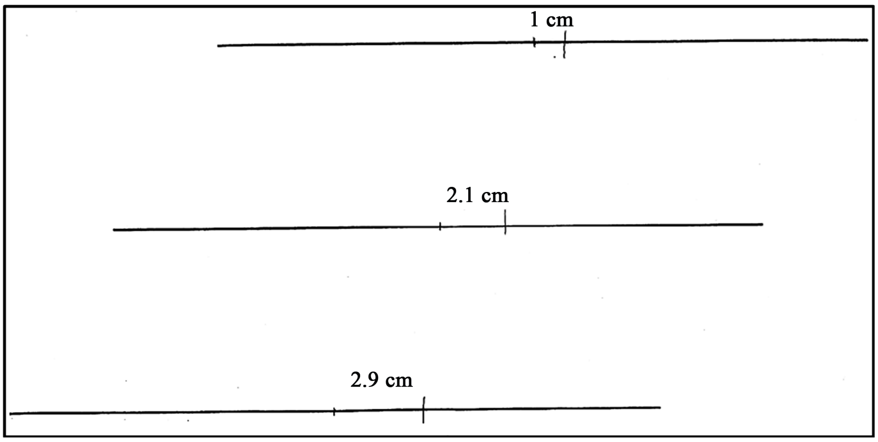


Figure 1. Results of the line bisection tasks revealed slight rightward deviation (20 mm) from the midpoint.

lobe and right caudate nucleus, and a low-density area of the right frontal lobe, caudate nucleus, and corona radiate (**Figure 2**).

2.4. Activity of Daily Living Findings

Occupational therapy in the specific hospital began 28 days after the onset of symptoms. ADL was evidently affected by USN; the patient did not finish food on the left side of his plate and frequently drove the left side of his wheelchair into the wall. The patient received orally directed desk training by an occupational therapist to improve left-sided awareness. Forty-nine days after the onset of symptoms, recognition on the left side of the desk improved, and oversight of the left side of meals decreased. However, this improvement was not reflected in ADL scenarios that required wider spatial attention. The Catherine Bergego Scale (CBS) was used to evaluate the influence of USN of all aspects of ADL. Results of this test showed that while there was no deficit in meal scenarios, there was a deficit in wheelchair driving, use of the restroom, and walking.

3. Methods

3.1. Measurement and Analysis of the Eye Gaze Point with the Eye Camera

Eighty-eight days after the onset of symptoms, movement of the patient's gaze point was measured with an eye camera (Takei Scientific Instruments Co. Ltd; TalkEye Lite [T.K.K.2950]) (**Figure 3**). TalkEye Lite is an eye motion measuring system that utilizes USB cameras for eyeball detection and field of vision capturing. It directly connects to a processor PC and represents the newest image-processing technology to detect eye movements. The automatic adjustment of the detecting camera and simplification of processing program means that there is a short preparation time from setting to measuring. The power source of TalkEye Lite is supplied from the processor PC; it is therefore easy to carry and can be used for longer periods of time.

Figure 2. Computed Tomography scan showing a low-density area in the right frontal lobe, caudate nucleus, and corona radiata.

Figure 3. Takei Scientific Instruments Co., Ltd: TalkEye Lite [T.K.K.2950]. TalkEye Lite is an eye motion measuring system that utilizes USB cameras for eyeball detection and field of vision capturing. It directly connects to a processor PC and represents the newest image-processing technology to detect eye movements. The automatic adjustment of the detecting camera and simplification of processing program means that there is a short preparation time from setting to measuring. The power source of TalkEye Lite is the processor PC; it is therefore easy to carry and can be used for longer periods. Through communalization of data recording, it also corresponds to the previous analysis software.

Using this eye camera, two evaluations were carried out using data of the movement of the gaze point: 1) The difference between peripersonal space and extrapersonal space, and 2) The method to promote sight scanning in extrapersonal space.

3.2. Difference between Neglect in Peripersonal Space and in Extrapersonal Space (Task 1)

Concerning the eye camera measurement, peripersonal space was measured by a desk evaluation. The examination paper (A4 size) with a printed horizontal line of 20 cm was used. Extrapersonal space was measured from a whiteboard 1 m in front of the patient. A horizontal line was drawn on the whiteboard at the same width as the 20 cm desk line. In both tasks, the patient was asked to focus on the middle point of the horizontal line. The subject underwent all examinations in a sitting position, and was instructed not to rotate his head, neck, or body. If rotation was observed, the test was canceled and restarted. The examination protocol is shown in **Figure 4**. A paired t-test was used to compare the ocular movement angle between the two tasks (with 5% levels of significance). We performed all statistical analyses using Statistical Package for the Social Sciences, version 17 (SPSS, Inc., Chicago, IL).

3.3. Method to Promote Sight Scanning in Extrapersonal Space (Task 2)

Concerning the eye camera measurement, examination space was set on a whiteboard 1 m ahead of the patient. The horizontal line was written on the whiteboard. The tasks were as follows: a) The subject focused on the middle point of the horizontal line; b) After having focused on the left edge of the horizontal line, which an inspector pointed to closely, the subject focused on the middle point of the horizontal line; c) After gradually moving from the left edge of the horizontal line to the middle point, and having watched a fingertip closely, the subject focused on the middle point of the horizontal line. The eye camera was used to measure the movement of the ocular movement angle of the subject from a) to c). A two-way repeated measures analysis of variance (if significant) was followed by a Tukey's post-hoc test, to analyze the ocular movement angle before the examination and after 9 seconds of closely watching the middle point.

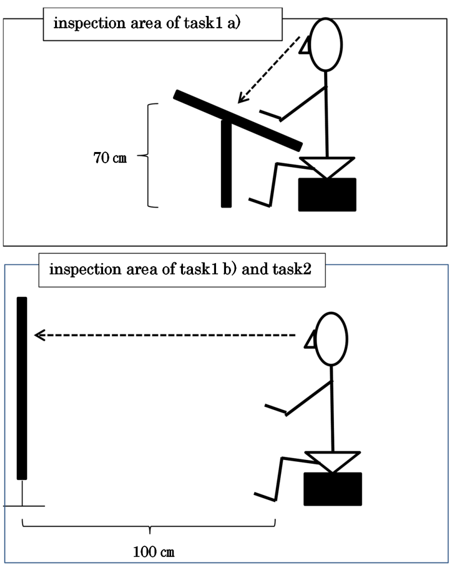


Figure 4. Schematic view of the inspection area. Task 1: a) Peripersonal space: The examination paper (A4 size) with a printed horizontal line of 20 cm was used. The paper was placed on the desk (at a height of 70 cm). b) Extrapersonal space: A whiteboard was set 1 m in front of the patient and the horizontal line was written on the whiteboard. Task 2: The inspection area was the same as b).

3.4. Additional Neuropsychological Examination

Five days after the eye camera measurements, neuropsychological examinations were performed. The examinations were based on the Wechsler Adult Intelligence Scale-Revised (WAIS-R), the star cancellation task, the line cancellation task, and the cube copying task. A Speech-Language-Hearing therapist performed all neuropsychological examinations.

4. Results

4.1. Results of Task 1

The movement of the gaze point is shown in **Figure 5**. In peripersonal space, the line of sight was turned to the center just after instructions. The line of sight was biased toward the right side, and the patient was relatively stable after having searched in the left direction. Only the right search was carried out without searching for the left side in extrapersonal space and the line of sight was biased towards the right side and was stable. Consequently, the ocular movement angle of extrapersonal space (an average of 30 Hz/sec of 10.33 +/− 5.26) was significantly smaller than that seen in peripersonal space (an average of 30 Hz/sec of 3.71 +/− 2.29) (**Figure 6**).

To summarize the results of Task 1, there was a search to turn the line of sight to the left side in peripersonal space inspected on the desk. In contrast, in extrapersonal space, there was no search to the left side across the centerline.

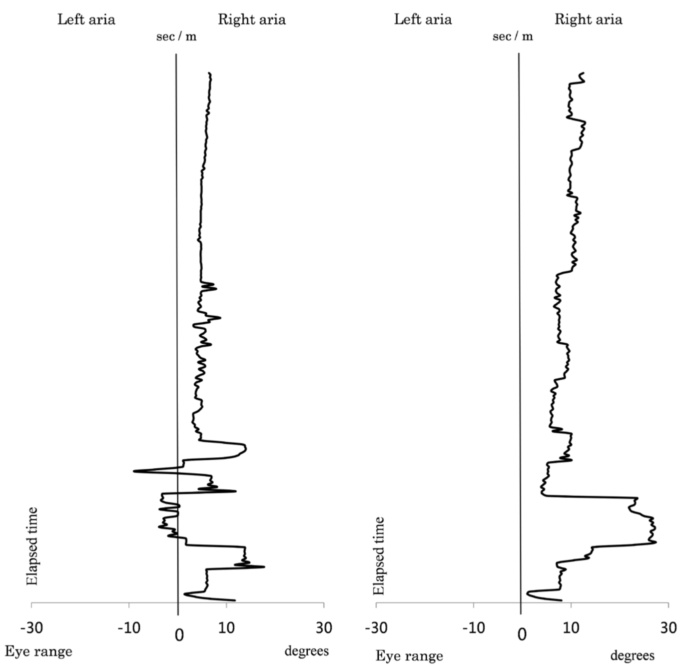


Figure 5. Results of Task 1 in the movement of the gaze point. The horizontal axis indicates eye movement of the gaze point and the vertical axis indicates time. There was a search to turn the line of sight to the left side in peripersonal space inspected on the desk. In contrast, in extrapersonal space, there was no search to the left side across the centerline.

1. Results of Task 1

	peripersonal space	extrapersonal speace	p value
an average of 30 Hz/sec (˚)	4.99 ± 3.5 (4.54 - 5.44)	10.33 ± 5.26 (9.63 - 10.97)	*

means ± SD (95% CI) peated t-test

* = p < 0.01

2. Results of Task 2

	Task 2 a)	Task 2 b)	Task 2 c)	p value
an average of 30 Hz/sec (˚)	−4.38 ± 8.84 (−5.11 - −3.65)	9.53 ± 3.92 (9.21- 9.85)		*
an average of 30 Hz/sec (˚)		9.53 ± 3.92 (9.21- 9.85)	−7.31 ± 13.90 (−5.11 - −3.65)	*
an average of 30 Hz/sec (˚)	−4.38 ± 8.84 (−5.11 - −3.65)		−7.31 ± 13.90 (−5.11 - −3.65)	*

means ± SD (95% CI) Two-way repeated-measures ANOVA (Boneferroni correction)

* = p < 0.01

Figure 6. Results of statistical analysis of eye movement angle of Task 1 and Task 2.

4.2. Results of Task 2

The movement of the gaze point is shown in **Figure 7**. In task a) (the subject focused on the middle point of the horizontal line), only the right search was carried out without searching for the left side. Moreover, the line of sight was biased to the right side and was stable. In task b) (after having focused on the left edge of the horizontal line, which an inspector pointed to closely, the subject focused on the middle point of the horizontal line), the patient was able to watch the left edge closely for several seconds. The inspector directed him to watch the middle point of the horizontal line closely afterwards. The line of sight was more stable by the center than task a). In task c) (after gradually moving pointing from the left edge of the horizontal line to the middle point, and having watched a fingertip closely, the subject focused on the middle point of the horizontal line closely), the subject could follow the orbit of pointing and gradually sent a line of sight to the middle point from the left edge. However, the line of sight was slightly stable at the position that inspector biased into the right side when the examiner let the patient closely watch the middle point of the horizontal line again. Mauchly's sphericity test was significant ($p < 0.01$), so we used the ε correction of the Greenhouse-Geisser test. As a result, the three task means were significantly different between all groups. Successive multiple comparisons found the mean of the three eyeball angles to be significantly different. The mean of 30 Hz/sec of the three ocular movement angle conditions was as follows: 1) = −4.83 ± 8.84; 2) = 9.53 ± 3.92; 3) = −7.31 ± 13.90. Analysis of variance revealed that the shift on the right side of the eye was in the order of task a) < task c) < task b) (**Figure 6**).

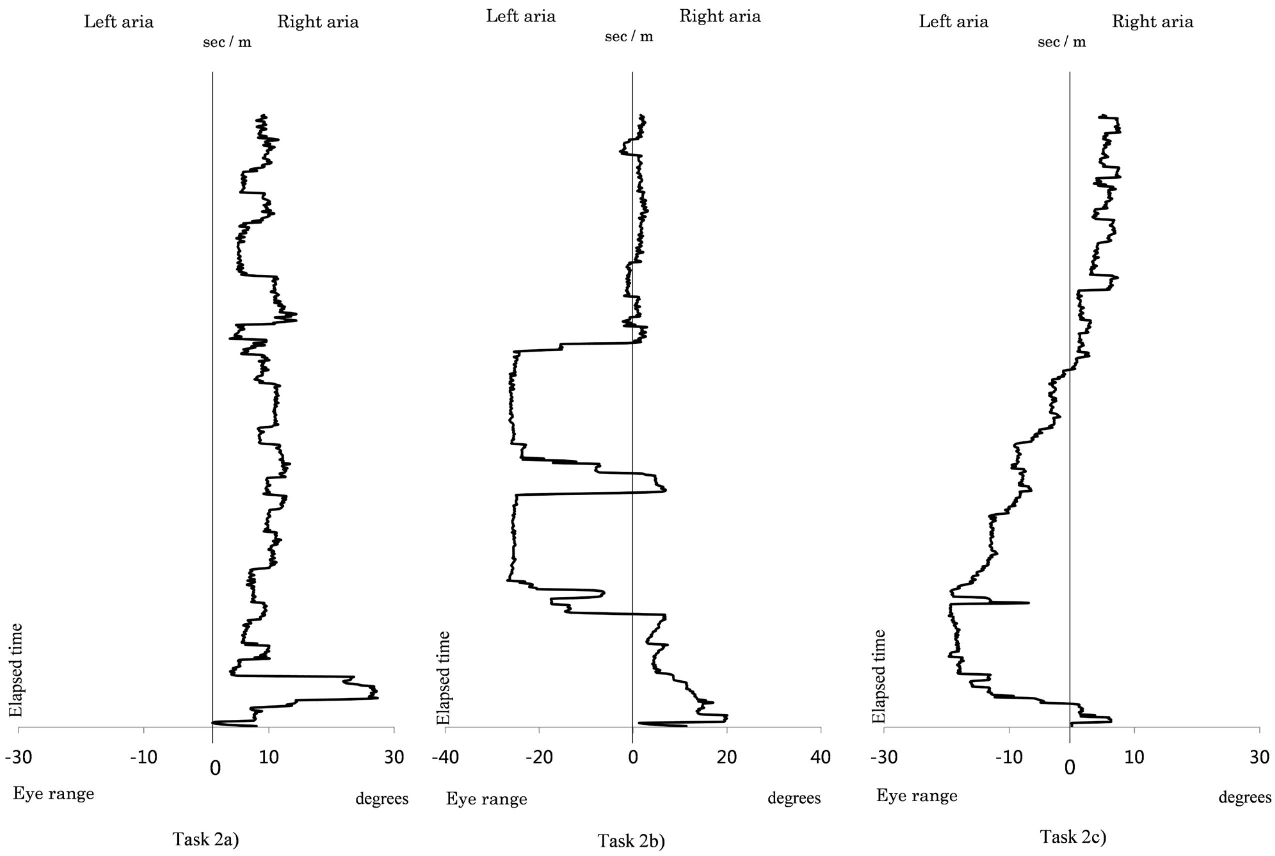


Figure 7. Results of Task 2 in the movement of the gaze point. Task 2b) was centered on the viewpoint more than Task 2a) and Task 2c).

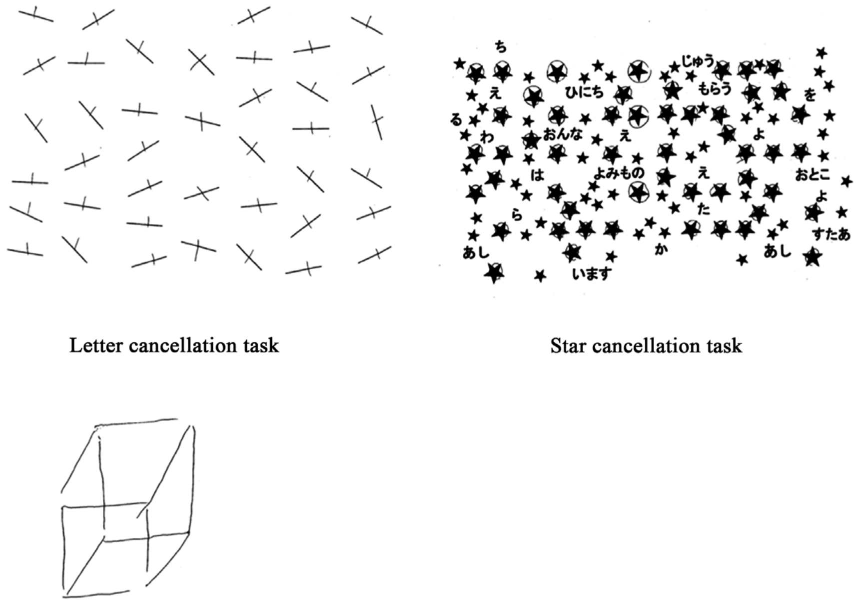
4.3. Neuropsychological Examination Results

Neuropsychological examination of the star cancellation, line cancellation, and cube copying tasks revealed no impairment. WAIS-R subsection results were as follows: VIQ = 125 points, PIQ = 91 points, and FIQ = 109 points (**Figure 8**).

5. Discussion

We evaluated a patient with left USN that appeared 85 days after right putamen bleeding. USN symptoms disappeared according to desk inspection; however, monitoring of ADL was still required. We examined the difference between neglect in peripersonal space and extrapersonal space (Task 1) and the method to promote sight scanning in extrapersonal space (Task 2) from the movement of the gaze point. We observed a left-sided sight scanning in peripersonal space, but a right-sight scanning bias in extrapersonal space. In addition, the line of sight was corrected when the inspector orally instructed the patient to watch the left edge closely in extrapersonal space so that the line of sight stopped in the center.

The difference found between neglect in peripersonal space and extrapersonal space may be explained on the basis of the differences in stimulation in the space and VIQ. With regards to the subject, the language-related strategy was



Letter cancellation task

Star cancellation task

Cube copying task

Figure 8. Neuropsychology test results. No impairment was revealed on any tasks.

promoted by oral instructions, which encouraged the patient to search for the left side to promote peripersonal space awareness. Following training, in peripersonal space with little stimulation, the patient needed less attention and was able to apply attention to the language-related strategy. However, this language-related strategy may not be suitable for extrapersonal space, because this requires more attention. Furthermore, the VIQ of the patient was relatively high.

It is thought that this contributed to the effectiveness of the language-related strategy. A previous study reported that unimpaired people tend to pay attention to all stimulations in a scene [12]. This tendency is strengthened in patients with USN [13]. Therefore, USN patients tend to be more attentive to stimulation in stimulative extrapersonal space.

On the other hand, multiple reports suggest that VIQ influences the directing of attention to the left side, which indicates the efficacy of the language-related strategy [14]. Using the clock description task, Ishiai *et al.* [15] found that, even if there was a USN, if the VIQ was over 90, the patient could answer the task correctly by using the language-related strategy. For example, the patient could correctly state the time by adopting the linguistic strategy of writing the reference time, such as 12, 6, and 3 hours, in the correct position. Therefore, as VIQ was high in our patient, the left side search could be performed by adopting the language-related strategy in peripersonal space with little stimulation, but in extrapersonal space, there were many stimuli and so attention could not be directed effectively by the language-related strategy. It thus seemed that USN symptoms appeared in ADL.

To conclude, if VIQ is high, as it was in the present case, patients may be able to overcome USN by using the appropriate language-related strategy. However, this is limited to peripersonal space, which has fewer stimuli and thus a greater capacity to concentrate on tasks; it is not known whether the language-related strategy is useful in extrapersonal space, which has many stimuli. Thus, Task 2 tested whether the language-related strategy effective for peripersonal space is also applicable to extrapersonal space. We found that the right side shift in our patient was indeed enhanced in extrapersonal space after directing the patient to focus closely on the left edge of a line. This shows that the language-related strategy is effective even in extrapersonal space.

It has been previously reported that a right side shift in peripersonal space decreases after watching the left edge of bisection line closely for a certain period [16]. In addition, the same study found that attention moves to the left side when ocular movements are directed to the left side. Both of these are alternative strategies to the language-related strategy. In the present study, we found that a similar method was effective in extrapersonal space with a high degree of stimulation.

In addition, in this case, practicing training using the verbal compensation method may improve the USN of extrapersonal space (yet there is a possibility that the effect may be less than for peripersonal space).

6. Conclusion

We evaluated a case with left USN that appeared 85 days after right putamen bleeding. While desk evaluations showed that USN symptoms disappeared over time, it was necessary to continue to monitor ADL. This difference in USN symptoms may be due to differences in neglect in peripersonal space and extrapersonal space. However, these differences have not been verified or tested in previous studies. We therefore compared neglect in peripersonal space and extrapersonal space (Task 1), and investigated a method to promote sight scanning in extrapersonal space (Task 2) using an eye camera that measured movement of the gaze point. For Task 1, we found differences in neglect that were able to explain the unimpaired desk evaluation performance (left-sided sight scanning in peripersonal space) and the remaining deficit in ADL (no sight scanning to the left side in extrapersonal space, and a bias to the right side). For Task 2, orally-guided instructions led to a correction in the line of sight in extrapersonal space. There is a possibility that ADL in extrapersonal space may be improved by using a compensation method based on this language-related strategy. This study therefore has a strong clinical significance.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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