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Original Article

Effects of prism directionality and active movement adaptation on the symptoms of unilateral spatial neglect

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ABSTRACT
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Objective: Prism adaptation therapy is one of the treatment methods for unilateral spatial neglect (USN). In this study, we examined the influence of prism deviations toward the right and toward the left. We also studied the additional effects of hand movements as performance adaptation to prisms.
Methods: Patients with left USN caused by stroke were split into 2 groups on the basis of whether or not they performed adaptation movements. In all the patients, prisms deviating the visual field 10° to the right and to the left were used, and the adaptation task consisted of right index finger movements to reach 3 targets on a desk, 50 times each. During the movements, hand trajectories were visible. In the group in which adaptation movements were not performed, the participants wore the prisms for 20 minutes. A line bisection test using a 50-cm tape was used to evaluate the USN before and after treatment.
Results: The use of left-deviating prisms resulted in worsening of the USN in the group in which adaptation movements were performed (p=0.01). In this group, the point of bisection showed a tendency to move toward the left (p=0.29) when right-deviating prisms were used.
Conclusions: The results indicated that adaptation treatment using right-deviating prisms might be effective for USN, even when the trajectory of the movements is visible.

Key words: left unilateral spatial neglect, prism adaptation therapy, prism deviation, reaching movements

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Introduction

Unilateral spatial neglect (USN) is a disorder caused by damage to the cerebral hemispheres in which the patient becomes unable to report, localize, or respond to stimuli presented on the side opposite to that of the damage [1]. Symptoms are often more frequent and more severe in patients with right cerebral hemisphere damage than in those with left cerebral hemisphere damage. After the acute phase, patients may recover spontaneously over time, but 40% of patients with chronic cerebrovascular disease have also been found to have USN [2].

Patients with USN often collide with obstacles on their left while they move, and during meals, they may leave food on the left side of their plates without noticing it; thus, USN is an aggravating factor for the prognosis of activities of daily living (ADL) [3].

In rehabilitation medicine, several approaches have been used to reduce USN and to improve the ability of patients to perform ADL [4‒6]. The approaches can be classified roughly into 2 types: top-down approaches, which aim to ensure that patients are independently able to turn their attention in response to stimuli; and bottom-up approaches, which aim to integrate stimuli from the periphery to influence higher brain functions. However, the positive effects provided by these approaches are of short duration and are rarely generalized to the patient's ADL. In addition, to date, no methods suitable for all patients with USN have been established.

Prism adaptation therapy is a bottom-up approach that is noninvasive, has a relatively long effect, and can easily be used in clinical applications. Prism adaptation consists of changes in which a mismatch between the visual axis (which is shifted due to the prisms) and the axis of the reaching movements (in which the hands are extended to reach a target) is gradually corrected through repetition of the reaching movements, and in which the subject ultimately succeeds in reaching the target with their hand, even when they do not wear the prisms. In addition, when reaching movements are performed after removing the prisms, a phenomenon known as the "after-effect" is observed in which the subject's hand reaches out to a position that is unaligned with the target, in a direction opposite to the shift due to the prisms. Prism adaptation therapy makes use of this after-effect. Rossetti et al. [7] used prisms that deviated the visual field 10° to the right side; and for adaptation, the subjects performed reaching movements 50 times with the right index finger from the midline to targets located at 10° on the right and on the left. These tests performed at the desk showed an improvement in the USN even 2 hours after performing the movements. Frassinetti et al. [8] also used prisms that deviated the visual field 10° to the right side, and for adaptation, the subjects were instructed to perform reaching movements using their right index finger from the midline to targets located at 21° to the left and to the right of the midline. Each of the movements was performed 30 times, twice a day, and continued for 2 weeks. Their results indicated that the behavioral inattention test (BIT) showed an improvement in the USN for up to 5 weeks after completion of the adaptation.

Our study examined the efficacy of prism adaptation therapy for two reasons. First, we sought to examine the effects of differences in the direction of deviation, using both right-deviating prisms (which have previously been shown to be effective) and left-deviating prisms. In addition, in previously reported prism adaptation therapies [7, 8], the participants were asked to perform reaching movements without looking at the trajectory of their hand. Thus, our second purpose was to examine the differences in effectiveness of the prisms under 2 conditions using right and left deviations. In the first condition, reaching movements were performed while the trajectory of the hand was visible, and in the second condition, the reaching movements were not performed.

Subjects

The study subjects consisted of patients with new-onset cerebrovascular disease in the right hemisphere, and who demonstrably neglected the space on their left side during ADL or during a line bisection test conducted at the desk using a 10-cm line.

After the study had been thoroughly explained to the patients and their consent had been obtained, they were sorted at random into 1 of 2 groups: group A received only left or right prism adaptation, whereas group B received prism plus movement adaptation therapy. Group A comprised 10 subjects (male/female = 6/4, mean age ± standard deviation: 70 ± 4 years), and group B comprised 9 subjects (male/female = 5/4, mean age ± standard deviation: 71 ± 9 years). The mean time from onset ± standard deviation was 124 ± 54 days in group A, and 93 ±32 days in group B. Disease breakdown by group was as follows: cerebral infarction (A: n = 8; B: n = 4), cerebral hemorrhage (A: n = 1; B: n = 5), and subarachnoid hemorrhage (A: n = 1; B: n = 0).

Methods

Two types of prisms were mounted on eyeglass frames; one deviated the visual field 10° to the right, and the other deviated the visual field 10° to the left. Left and right prisms were used for intervals of 1 week, with the initial direction determined randomly.

In group A, the participants wore the prisms for 20 minutes while seated and facing forwards, avoiding unnecessary stimuli from the outside world. In group B, the participants performed reaching movement tasks aimed at adapting themselves to the prisms. To do so, they used their right index finger (on the non-paralyzed side) to make back and forth movements 50 times between 1 main target and 3 other targets. One target was located on the desk at a distance of 15 cm from the anterior midline of the trunk; a second target was located on the midline at a distance of 30 cm from the first target; and the other targets were positioned 10° on the left and on the right sides of the second target. The movements were performed at a speed that was comfortable for each patient, and settings were made so that the trajectory of the hand was visible during the reaching movements. Assessment of USN, prior to donning the prisms and then 10 minutes after removing the prisms, was performed using the 50-cm tape bisection task in the Stroke Impairment Assessment Set (SIAS), by measuring the distance between the midpoint of the tape and the point of bisection [9]. Bisection tasks were performed 5 times in a row, and the mean values from the 5 tasks were calculated.

The results were analyzed statistically using a paired t test to compare the point of bisection measured in each group before and after wearing the prisms, and using an unpaired t-test to compare the between-group differences in the points of bisection, before and after wearing the prisms. For both tests, a p value of <0.05 was considered statistically significant.

Results

An improvement in USN was defined as a leftward decrease in the distance between the midpoint and the point of bisection after wearing the prisms, compared to before wearing the prisms. In both groups, there was no improvement in USN before or after wearing the right-deviating and the left-deviating prisms (group A: Table 1; group B: Table 2). Further, in many cases

Table 1. The distance between the midpoint and the point of bisection before and after wearing prism in group A

	Right−shifted prism		Left−shifted prism	
Subject	Before (cm)	After (cm)	Before (cm)	After (cm)
1	−0.1	+1.5	+1.2	+2.6
2	+0.6	+0.8	+1.4	+2.0
3	+0.2	+0.1	+1.4	+2.0
4	+9.3	+14.5	+14.4	+10.6
5	+7.0	+4.6	+1.2	+6.4
6	+1.8	+2.0	0	+1.4
7	+7.7	+9.5	+6.6	+10.7
8	+1.2	+2.2	+1.2	+1.3
9	+12.2	+11.8	+8.4	+12.1
10	+13.0	+10.8	+8.3	+11.9
p*	0.49		0.07	

(+=rightward displacement, −=leftward displacement)
*Paired *t*-test

Table 2. The distance between the midpoint and the point of bisection before and after wearing prism in group B

	Right−shifted prism		Left−shifted prism	
Subject	Before (cm)	After (cm)	Before (cm)	After (cm)
1	+14.2	+18.6	+13.4	+15.6
2	+7.3	+6.3	+6.0	+6.7
3	+3.2	+3.4	+1.6	+2.7
4	+3.2	+2.2	+2.9	+3.9
5	0	−7.6		0+3.4
6	+1.8	+0.2	−0.7	+0.6
7	+5.1	+1.2	+3.9	+4.9
8	+0.8	+0.6	+3.0	+3.8
9	−0.5	−0.9	+0.6	+0.4
p*	0.29		0.01	

(+=rightward displacement, −=leftward displacement)
*Paired *t*-test

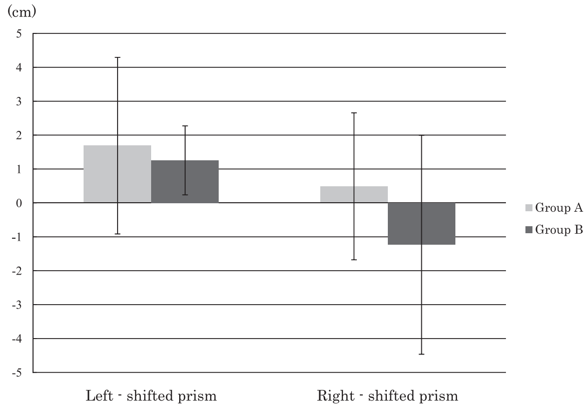

Figure 1. Changes in bisection point before and after wearing prisms.
The vertical axis shows the measured values of the coordinates of the point of bisection after wearing prisms subtracted from the measured values before wearing prisms. A positive value indicates that the USN has worsened after wearing the prisms, whereas a negative value indicates an improvement in USN after wearing prisms. The horizontal axis shows the mean and standard deviation of the bisection values obtained from the use of left-deviating prisms and right-deviating prisms in groups A and B. The point of bisection showed a tendency to shift towards the left (a tendency to show negative values) when participants in group B wore right-deviating prisms (left-deviating prisms: p=0.64; right-deviating prisms: p=0.58).

in both groups, the point of bisection was found to shift to the right after wearing the left-deviating prisms, compared to that before wearing the prisms. However, a statistically insignificant tendency for the point of bisection to shift to the left was found in group B after wearing right-deviating prisms (p=0.58; Figure 1).

Discussion

1. The influence of prism directionality

In our study, when prism adaptation was performed and left-deviating prisms were used, no improvement in USN was observed; however, when right-deviating prisms were used, a non-significant tendency toward improvement was seen. Previous reports have also stated that the use of left-deviating prisms has no positive effect on USN [7]. At the same time, studies have shown that prism directionality influences bisection shift; assessments via line bisection tasks performed before and after prism adaptation have shown that when left-deviating prisms are used, the point of bisection shifts markedly to the right side after adaptation; however, with right-deviating prisms, the shift was small. These results suggest that an asymmetric bias between the left and the right brain hemispheres might be responsible for adjusting the shift between visual perception and movements [10].

The bias was also observed in USN patients, and when left-deviating prisms were used, the point of bisection shifted further to the right after adaptation. Consequently, USN was intensified, whereas in the case of right-deviating prisms, there was little shift in the point of bisection.

2. The influence of active movement

When active movements did not initiate changes in visual perception beyond that already caused by the prisms, there was no further improvement in USN, even with right-deviating prisms. This result is similar to that obtained in previous studies [5]. It has been suggested that motor tasks are necessary in prism adaptation therapy; and according to the literature, neural circuits in the premotor cortex are involved in the processing of the information related to mismatches between motor and visual coordinates during the process of adaptation to the prisms [11]. It has also been shown that the cerebellum is important in visuomotor learning, and that nerve fiber connections between both the cerebellum and the frontal lobe and between the cerebellum and the parietal lobe might mediate an improvement in USN [12].

3. The influence of visible hand trajectory

It is believed that, during the correction of the shift between the target and the point actually reached by the hand, the effects of visual perception are stronger than the adaptation process occurring in the neural connections between the cerebellum and the rest of the brain. The particularity of this study is that the trajectory of the hand during the reaching movements was shown. The results of this study showed no significant improvement in USN even when the patients wore right-deviating prisms; this might have been due to a strengthening influence of visual perception and a lessening of the effects of neural connections between the cerebellum and the rest of the brain. However, given that the variety of everyday life movements are performed with the trajectory of the hand visible, a prism adaptation therapy that can be proven effective without hiding the trajectory of the hand would be more useful in clinical settings.

Conclusions

This study was based on a small sample and failed to show significant results. Analysis has shown that an estimated 72 or more patients are needed to demonstrate a significant difference. Thus, in the future, we would like to increase the number of patients to show that the combination of right-deviating prisms and active movements with visible trajectories is useful in the treatment of USN.

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