ヘッドマウントディスプレイを利用した左半側空間無視に対する臨床応用

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【目的】
左半側空間無視の左半側麻痺患者は他の患者より日常生活活動に支障を来たし、かつ、転倒が多く認められる。本研究の目的は、バーチャルリアリティ技術の臨床応用としてヘッドマウントディスプレイ（HMD）を使用による半側空間無視症の改善の可能性を検討した。

【方法】
右脳損傷患者6名を選び、半側空間無視の検査を行った。HMDを使用しない状態（VR-）と、HMDを使用した状態（VR+）の4つの条件で検査を行った。

【結果および考察】
結果として、80%もしくは90%の映像縮小修正し示した場合の得点は、無視部分が多い100%の映像示す時の得点より有意に得点が改善した。また、70%の縮小率では得点がのびず、縮小率の限界で示唆された。本研究で構築されたHMDシステムの使用により、半側空間無視の評価と治療に有益な神経心理学的リハビリテーションとしての臨床応用の可能性が示唆された。

(キーワード：ヘッドマウントディスプレイ、半側空間無視、リハビリテーション工学)

1. INTRODUCTION

Unilateral spatial neglect refers to a condition in which the patient visually disregards objects located to one side of the patient’s field of perception, and which generally occurs in cases of right cerebral lesions. Patients with unilateral neglect of the left

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hemispace require longer hospitalization, have greater difficulties in resuming activities of daily living (ADL)\(^2\), and fall more frequently while hospitalized than do other rehabilitation patients\(^3\).

Several sensory manipulations may be temporarily effective for improving unilateral spatial neglect. Karnath\(^3\) indicated the effectiveness of neck vibration. Pizzamiglio et al.\(^4\) also adopted an effective means of optokinetic stimulation. However, these manipulations have not yet succeeded in bringing about a consistent improvement of neglect.

Virtual reality (VR) refers to a computer-generated, usually visual, representation of real-world objects in which a user can navigate or manipulate\(^5\). The elements of a VR system can be assembled along several lines which vary in cost and complexity. The most well-known approach is “immersive,” where the real world is opaque to the user and he or she is provided the sensation of interacting directly with the computer-generated objects. In other approaches, VR shares certain attributes of three-dimensional computer-aided design (CAD). In immersive VR, a head-mounted display (HMD) is worn and its position in space is tracked. As the user moves his or her head, aspects of the computer-generated object appropriate to the HMD position are displayed.

The aim of our study was to investigate the effect of a head mounted display (HMD) system connected to a computer for improving neglect symptoms as a clinical device for assessment and training using VR technology.

2. METHODS

2-1. Head-Mounted Display (HMD) system

The wide view HMD system was used for a visual display in order to produce a reduced or extended picture. The HMD (GT 270: Canon, Inc.) was suitably compact (150 g weight) and contained a 270,000-pixel display, which had a 30 degree horizontal field of view and was less than 15 mm in prism thickness.

A 3-Charge-Coupled device (CCD) camera recorded an object or a view and then visual data was stored into a computer (O2R5000: JAPAN SGI, Inc.). The computer changed the visual data into a reduced or an extended picture. Finally, the reduced or extended pictures were displayed on the right and left lenses in the HMD system (Fig. 1). The HMD system used the reduction rates of 70, 80, 90, and 100 percent of a real picture in the experiment.

2-2. SUBJECTS AND PROCEDURES

Six right brain-damaged patients (mean age 67.7 years) who have left hemispatial neglect were selected for this study (Table 1). All subjects had been admitted to a rehabilitation hospital for moderate to severe hemiplegia and various degrees of somatosensory dysfunction. All patients were right-handed and had a documented, single unilateral hemis-
pheric lesion, and no past history of a previous stroke. None of the patients suffered from impaired vigilance, confusion, general mental deterioration or psychiatric disorders. Informed consent was obtained from the subjects. Our experiment investigated whether the HMD could improve the significant clinical manifestation of neglect. We used a line cancellation task that was one of the classic tests for assessing hemispatial neglect known as the Albert test. The task was performed with the subject seated at a desk. A sheet of A4 test-paper (210×295 mm) was used for the task. The paper was placed directly in front of the subjects and centered at the midline of their bodies. Subjects held a red felt-tip pen in their right hands. No time limit was imposed, and head movements or their lines of vision were not restricted. All subjects performed the test first without and then with the HMD (Fig. 2). By using the common Albert test first without HMD, the subjects could avoid unfamiliar influences on the Albert test using HMD. The test trials were carried out under 4 conditions: 70% (70VR+), 80% (80VR+), 90% (90VR+) of reduced visual display and the real image (no reduced visual display; VR−). The subjects were tested for a total of 4 trials. Testing took place between 4 weeks and 5 months post-onset (average 9 weeks).

3. RESULTS

Figure 3 shows the results obtained for the Albert line cancellation test by one representative patient under the conditions of 90VR+ and VR−. The patient improved under the 90VR+ condition compared to the VR− condition. The tendency was recognized for all subjects. Figure 4 shows the results obtained by all subjects on the Albert line cancellation test under the 4 conditions. An improvement was seen in 70VR+, 80VR+, and 90VR+ of the compiled data by use of the HMD as compared to the data of the VR− condition. Sheffe’s tests demonstrated that significant differences were found between 90VR+ condition and the VR− condition, and between 90R+ condition and the 70VR+ condition, whereas there were no significant differences among the 70VR+, 80VR+, and VR− conditions.

Fig. 2 A scene of a patient using the HMD system during a line cancellation test (the Albert test).

Fig. 3 A representative example from a patient first without and then with the HMD system during a line cancellation test (the Albert test).

Fig. 4 A line cancellation test under the 4 conditions. Significant differences were obtained between 90 VR+ condition and the VR− condition \((p<0.01)\), and between 90 R+ condition and the 70 VR+ condition \((p<0.05)\). Abbreviations: VR−; no reduced, VR70+, VR80+, VR90+; 70%, 80%, 90% of reduced, a; significant difference at 1% or 5% significant level.
4. DISCUSSION

Use of the HMD improved the neglect symptoms in all subjects who had right cerebral hemisphere damage. Rossetti et al.7) investigated the effect of prism adaptation on neglect symptoms, including the pathological shift of the subjective midline to the right. They reported that all patients exposed to the optical shift of the visual field to the right were improved in their manual body-midline demonstration and on their classical neuropsychological tests. Lee et al.8) and Woo and Mandelmant9) also suggested the effectiveness of the Fresnel prism when placed on a spectacle lens for improving various visual-field losses. The improvement induced by the HMD indicates that a signal is given to the brain that stimulates the natural recovery process in the same manner as the prism adaptation method. Moreover, the HMD system may lead to the further correction of left neglect than a Fresnel prism placed on a spectacle lens. Since a high power Fresnel prism membrane for obtaining a wide field of view is not clear, the prism produces a distortion of a real image and has the low capabilities of visual acuity. By contrast, the HMD has the possibility of obtaining various fields of view without deterioration of visual acuity.

The HMD system has the advantage of being non-invasive, safe, and one can easily change the size of the visual field. Furthermore, the standard clinical examinations10) (line cancellation, line bisection), copying a simple drawing made of five items11) were used in a two-dimensional plane. However, the HMD system can produce a standard clinical examinations related more closely to ADL in a three-dimensional plane. On the other hand, the system has to develop more portability, lighter weight and a decreased delay of response between the computer and the HMD regarding a transformation of data. The system's delay time is 50 m seconds. Therefore, the HMD system needs a higher technology of processing, recording and displaying a changed visual field of view in near or real time. There was a significant difference between 90VR+ condition and the 70VR+ condition. The result suggests that the excessive reduced visual field produced by the HMD system may not be effective for improving various unilateral spatial neglect symptoms.

These results suggest that the technique of the HMD system may play an important role in the neuropsychological rehabilitation of unilateral spatial neglect as an evaluation and training devices. In the near future, we will develop various images in HMD by a computer such as change of colors and partial enlarge or reduce of real image, and to produce suitable visual information in HMD for each patient who has USN. Moreover, we should identify the mechanisms behind the effectiveness of the HMD system and gather more patients' data.

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