Archives of Rehabilitation Research and Clinical Translation (2024) 6, 100322

Archives of Rehabilitation Research and Clinical Translation

Archives of Rehabilitation Research and Clinical Translation 2024;6:100322

Available online at www.sciencedirect.com

Original Research

An Initial Assessment of the Correlation Between Virtual Reality and Paper and Pencil Line Bisection Test Results

Takuma Miyaguchi, PT [a], Masayuki Tazawa, MD, PhD [a,b], Takafumi Kanaya, MD [c], Yoko Ibe, MD, PhD [b], Hironori Arii, MD [b], Kenji Yajima, MD [b], Yumiko Nakao, MD, PhD [b], Naoki Wada, MD, PhD [a,b]

[a] *Department of Rehabilitation Medicine, Gunma University Graduate School of Medicine, Maebashi, Japan*
[b] *Division of Rehabilitation Medicine, Gunma University Hospital, Maebashi, Japan*
[c] *The University of Tokyo Interfaculty Initiative in Information Studies Graduate School of Interdisciplinary Information Studies, Bunkyo, Japan*

KEYWORDS
Assessment;
Eye-tracking technology;
Hemispatial neglect;
Rehabilitation;
Virtual reality

Abstract *Objective:* To make an initial assessment of the correlation between immersive virtual reality—based (ILBT) line bisection testing and paper-and-pencil—based line bisection (PLBT) testing in healthy subjects.
Design: Diagnostic study.
Setting: Research laboratory.
Participants: Twenty healthy adults (51.5 [11.0] years old, 55% women; N=20).
Interventions: Participants underwent an ILBT and a conventional PLBT in near space (NS) and more distant space (MDS). Correlations between the ILBT and PLBT, deviation rates in the NS and MDS, horizontal gaze distribution, and presence of virtual reality sickness (VRS) were evaluated.
Main Outcome Measures: Correlation between the deviation rates of the PLBT and ILBT.
Results: There was no significant correlation between the ILBT and PLBT for evaluating the deviation rate of the line bisection test (LBT). There was no significant difference in the deviation rate of the LBTs between the NS and MDS, but there was a significant difference in the horizontal line-of-sight distribution. VRS was not observed as an adverse event.
Conclusions: In healthy adult subjects, our results suggested that there was no significant correlation between the deviation rates of the ILBT and PLBT. We also found that the ILBT is a useful

List of abbreviations: ADL, activity of daily living; BIT, Behavioral Inattention Test; DNS, distance of near space; HMD, head-mounted display; HSN, hemispatial neglect; ILBT, immersive virtual reality—based line bisection test; IPD, interpupillary distance; IVR, immersive virtual reality; LBT, line bisection test; MDS, more distant space; NS, near space; PLBT, paper-and-pencil—based line bisection test; VR, virtual reality; VRS, virtual reality sickness.

Disclosures: No commercial party with a direct financial interest in the results of the research supporting this article has or will confer a benefit on the authors or any organization with which the authors are associated.
Cite this article as: Arch Rehabil Res Clin Transl. 2024;6:100322

https://doi.org/10.1016/j.arrct.2024.100322

and safe method for evaluating the horizontal line-of-sight distribution and percentage deviation of line segments from the center in the NS and MDS without inducing VRS.

Hemispatial neglect (HSN) is a condition in which there is a loss of attention or lack of response to stimuli contralateral to the injured hemisphere.[1] HSN often appears in parietal lobe lesions in the right hemisphere but can also be seen in other lesions. HSN is common in patients with right hemispheric lesions, occurring in 13%-81% of cases.[2,3] Patients with HSN experience a variety of problems with activities of daily living (ADL), such as colliding with obstacles on their left side during movement. These problems impede poststroke rehabilitation and prevent functional recovery. Therefore, the assessment of HSN in patients with stroke is important, and various tests have been developed to evaluate HSN.

One of the most frequently used tests for evaluating HSN is the paper-and-pencil—based line bisection test (PLBT).[4] The PLBT is performed by placing an evaluation form with horizontal straight lines in front of the patient and letting the patient indicate the center portion. Subjective central deviation to the side contralateral to the lesion is considered an indicator of HSN. Schenkenberg et al reported this deviation as the deviation rate.[4] Because these evaluations are performed in spaces that are accessible to the patient, evaluation methods for spaces that are not accessible to the patient are also needed to generalize these evaluations to daily life.

The space around us can be divided into 2 categories: near space (NS) and more distant space (MDS), depending on the relative distance between the body and a given object. Some studies have conducted line bisection tests (LBTs) at various distances from the body. HSN has been reported to be worse in far spaces than in near ones.[5] Cowey et al[5] reported that the subjective center of patients with left HSN was significantly more deviated to the right than the true center at a distance of 4.00 m compared to the proximal space.

Based on previous findings, we planned to characterize HSN patients using the immersive virtual reality (IVR) method and examine the validity of LBTs with eye tracking in the NS and MDS. Ultimately, we would like to progress to testing people with virtual reality (VR). As a result, we decided to first assess and characterize healthy adults. We hypothesized that the evaluation with the IVR-based LBT (ILBT) would correlate with the evaluation using PLBT. We also hypothesized that the deviation rate of the line segment from the NS to the MDS would gradually deviate to the right and that the horizontal distribution of gaze, based on the relationship between attention and gaze, would also differ significantly between the NS and MDS.

The present study, thus, clarified the correlation between evaluations using the ILBT and PLBT methods in healthy subjects and assessed the usefulness and safety of the IVR evaluation method based on the characteristics of the deviation rate and horizontal distribution of gaze, as well as an evaluation of virtual reality sickness (VRS).

Methods

LBT using IVR techniques

Evaluation system

In our system, the position of a head-mounted display (HMD) worn by the subject was used as the center coordinate. We defined the frontal direction of the HMD as the *z* axis, horizontal direction relative to the ground as the *x* axis, and vertical direction as the *y* axis. We set the HMD position at the center coordinates as the start of the LBT measurements made at each distance. The distance from the subject to the whiteboard was defined as the distance from the coordinates of the HMD to the coordinates of the center of the line segment (fig 1A).

Practice task

We created a practice task to familiarize the participants with the operation of the controller. The task was to find a yellow cube among 20 randomly placed objects (19 light blue spheres and 1 yellow cube) at distances of 3.00, 4.00, and 5.00 m from the subject and to aim and trigger the green laser beam emitted from the controller (fig 1B). If the subject answered correctly, then 1 of the 20 objects was randomly changed to a yellow target. The exercise was completed when the subject felt comfortable with controller operation.

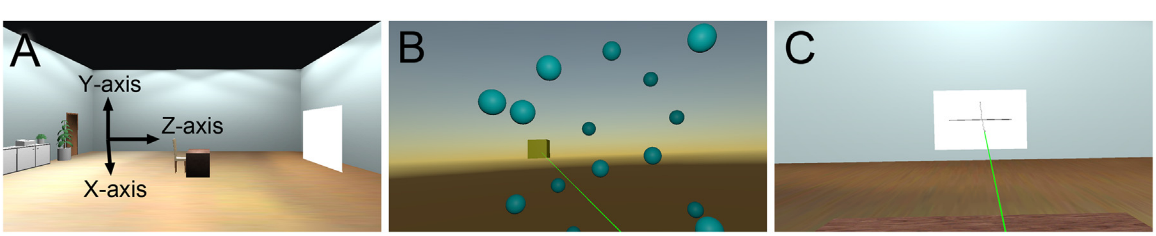

Fig 1 (A) LBTs using IVR techniques. Coordinate axis settings. (B) Practice task. (C) Line bisection tests.

Immersive virtual reality–based line bisection test

In the ILBT, the subject operates a controller in a VR space to bisect a line segment displayed on a whiteboard (fig 1C). The subject pulled the trigger of the controller with the index finger of the dominant hand to draw a line. In our system, the distance from the subject's acromion to the third metacarpal head was defined as the distance of NS (DNS) and the farther distance as the distance of MDS. Line segments on the whiteboard were displayed in sequence at 8 distances (0.25 m, 0.50 m, DNS, 1.00 m, 2DNS, 2.00 m, 3.00 m, 4.00 m) from NS to MDS at the front, center, and eye level of the subject. The size of the whiteboard displayed in the VR space was 0.297 m in horizontal length and 0.210 m in vertical length, with line segments of 0.200 m in length and 0.002 m in thickness, which are proportional to the distance. When the measurement distance was changed, the display was darkened for 1 second to wash out the line of sight.

Instrumentation

Hardware included an HMD with a resolution of 2880 $\times$ 1600 pixels, an attached controller, tracker, 2 sensors for tracking,[a] and a personal computer.[b] We used software programs to run the system,[c] a design tool,[d] a programming language,[e] and an eye-tracking development kit.[f]

Participants

Twenty healthy adults were recruited for the study. Subjects were excluded if they presented with 1) neurologic diseases, such as brain or spinal cord disease; 2) psychiatric disease; 3) head injury; 4) obvious disturbance of consciousness; 5) dementia (defined as a Mini-Mental State Examination score of $\leq$23); 6) visual impairment or loss of visual field (parafovea and occipital lobe); or 7) other conditions that would make the subject unsuitable for the judgment of the physician.

The study protocol was carried out in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of our hospital. Written informed consent was obtained from all participants (IRB: 2020-090).

Procedure

The Barthel Index was used to evaluate ADLs. First, to assess HSN, the widely used conventional PLBT of the Behavioral Inattention Test (BIT) was administered to all participants. The BIT is the most-used assessment method that can score the HSN and has high validity and reliability.[6,7]

The DNS and interpupillary distance (IPD) of the subjects were measured. Each subject wore an HMD and confirmed that the image on the display was clear. The subject sat on a comfortable chair in a comfortable position. Their head position was not fixed; they were able to move freely. They performed the practice task first, followed by the ILBT. We used the first measurement at a distance of 0.25 m as practice and acquired data from the second measurement. The sampling frequency of data were 90 Hz. The evaluation of the appearance of VRS was based on the presence of symptoms (nausea, headache, eye strain, dizziness, and other symptoms) during and after the HMD measurement. Systolic and diastolic blood pressures, pulse rate, body temperature, and arterial blood oxygen saturation were measured. All measurements were completed in 1 day.

The primary endpoint was the correlation between the PLBT and ILBT deviation rates in the NS and MDS. The secondary endpoints were the significance of differences in the NS and MDS between the PLBT and ILBT as well as the occurrence of VRS. The deviation rates for the LBTs using the PLBT and ILBT methods were calculated using the following equation:

$$\text{Schenkenberg deviation}(\%) = (\text{Subjective center} - \text{True center}) \times 100/\text{True center}$$

The subjective center is the length from the left end of the line segment to the position of the line segment bisected by the subject, whereas the true center is the length from the left end of the line segment to the center of the line segment. We used the average of the 3 lines for the PLBT deviations and the average obtained at each distance for the ILBT deviations. The data used for the horizontal line-of-sight distribution were eye-tracking data of the *x* coordinates present on the whiteboard. To compare gaze distributions at all distances, we converted the eye-tracking data into percentages, with the center of the whiteboard as 0%, the left edge as −148.5%, and the right edge as 148.5%. The percentage of the length from the center of the whiteboard to 1 end was determined by taking the length from the center of the line segment to 1 end as 100%. The center of the whiteboard and the center of the line segment were set at the same location.

Statistical analyses

Data are reported as the mean (SD), median (interquartile range), or number (%) unless otherwise specified. The Shapiro-Wilk test was used to confirm data normality. Spearman correlation coefficients were used to assess the relationships between PLBT and ILBT deviation rates. The Friedman test was used to assess significant differences in the ILBT deviation rates between distances. To determine whether the horizontal gaze distribution of the ILBT differed with distance, the Kruskal-Wallis test was performed, followed by an evaluation using the Dunn-Bonferroni method as a multiple comparison test.

Statistical significance was set at 5%. To avoid type I error, an alpha level of .002 was used as the Bonferroni correction. The SPSS ver. 27 software program was used for all statistical analyses.[g]

Results

The subjects were 9 men and 11 women who were a mean 51.5 (11.0) years old. The characteristics of the participants are shown in table 1. The average Barthel Index of all subjects was 100, and the mean BIT score was 145.7 (0.9) points. None of the healthy adults had HSN, and all were independent in their ADLs.

No significant correlation was observed between the deviation rates of the PLBT and ILBT (fig 2). There were also

Table 1 Summary of characteristics of 20 healthy subjects

Characteristics	Values
Age (y)	51.5 (11.0)
Sex (M/F)	9/11
Height (cm)	164.7 (8.5)
Weight (kg)	61.3 (9.9)
Dominant hand (R/L)	19/1
Visual impairment (y/n)	0/20
Experience with VR (y/n)	1/19
Experience with PCs (y)	22.4 (10.7)
MMSE	30.0 (0.2)

NOTE. Data are presented as mean±SD.
Abbreviations: MMSE, Mini-Mental State Examination; PC, personal computer.

no significant differences in the ILBT deviation rates among any distances (fig 3). The horizontal gaze distribution differed significantly between the NS and MDS. Multiple comparison tests (Dunn-Bonferroni) showed that 0.25 m and DNS ($P<.001$), 0.50 m and DNS ($P<.001$), 1.00 m and DNS ($P<.001$), 1.00 m and 2.00 m ($P<.001$), 1.00 m and 4.00 m ($P=.001$), 2DNS and DNS ($P<.001$), and 3.00 m and DNS ($P<.001$) were significant differences in the horizontal gaze distribution among distances (fig 4). The maximum and minimum values of the range of eye movement tended to move closer to the center of the line segment, with shrinkage and expansion allowed as the distance of the line segment increased. Outliers in the gaze distribution were observed at all distances.

No symptoms of VRS, such as nausea, headache, eye strain, or dizziness, were observed in the 20 healthy adults. Systolic and diastolic blood pressures, pulse rate, body temperature, and arterial blood oxygen saturation values did not change significantly after the study.

Discussion

The primary endpoint of this study was the PLBT correlation between the deviation rate and ILBT. No significant correlation was found between the deviation rates of the 2 assessment methods for the NS and MDS. Nakano et al reported a comparison of the 3-LBT used in the BIT with the 1-LBT for healthy adults in real space.[8] In the LBT used in the BIT, where 3 lines are displayed simultaneously, the subjective center is affected by the position of each line segment. Nakano found that the subjective center deviated to the left from the true center of the line segment, whereas in our study, the subjective center deviated to both the left and right sides of the line segment. However, the single-LBT is considered to be affected by the position in which the test paper is placed. When the test form was placed on the left or right side of the subject, the subjective center shifted toward the direction in which the form was placed, whereas no obvious shift was observed when the form was placed in the center. In the evaluation method using the IVR technique, the whiteboard was presented in front and at the center of the subject; therefore, there was no subjective central bias from positional effects. For these reasons, there was no significant correlation between the ILBT and PLBT in the NS and MDS settings.

We also found, contrary to our hypothesis, that even though the distance to the line segment increased from the NS to the MDS, the subjective center of the subject was near the true center of the line segment, and there was no significant difference in the deviation rate. Even in normal subjects, when the line segment presented in the NS is bisected, the subjective center is slightly deviated to the left from the true center, resulting in asymmetry of spatial attention, a phenomenon known as pseudoneglect.[9] Pseudoneglect is thought to be a phenomenon in which the subjective center is deviated to the left from the true center due to the dominant activity of the right hemisphere for visuospatial attention, and it has been reported that this deviation to the right increases with age.[10,11] Age has also been reported to influence the results of the LBT, with pseudoneglect observed in those <40 years old and a subjective center tending to be biased to the right in those >50 years old.[9] There are few reports of pseudoneglect focusing on subjects aged 40 to 50 years old. There are also reports of no spatial attentional bias when the average age is ≥50 years old.[12]

To improve internal comparability, the use of smaller age ranges within age groups has been recommended.[13] Although it has been pointed out that age-related screening for dementia is necessary, many reports indicate that pseudoneglect in healthy adults gradually decreases with age.[13] In the present study, the subjective center was located near the middle of the line segment in the ILBT performed in the NS, which we attributed to the effect of aging on reducing pseudoneglect. These results are consistent with those reported for healthy subjects with an average age of >50 years old.[12]

In the MDS, the subjective center of the healthy adult did not deviate to the right and was located near the center of the line segment. When healthy adults undergo LBTs, the subjective central deviation differs between the NS and MDS, depending on the tool used. When subjects used a laser pointer in a previous study, the subjective center, which was deviated to the left of the true center, gradually deviated to the right as the distance at which the line segment was presented increased.[14-16] When the stick was grasped and the line segment bisected, the subjective center was reported to be biased to the left from the true center for both the NS and MDS.[14,15] Furthermore, when a hand avatar is displayed in VR space and the line segment is bisected, the subjective center is reportedly deviated to the left from the true center, similar to the NS.[16] These results suggest that when a stick is used, the range of the subject's body representation is considered to be extended to the length of the grasped stick, and when a hand avatar is used, the hand-centered NS is extended only around this new point.[14-17] The range of NS does not appear to increase when a laser pointer is used.[13-15] Since the present study used a controller that emits a laser as a tool to bisect the line segment, we consider it unlikely that the healthy body representation in the NS was extended to the MDS. Previous studies have also reported that the body representation of healthy subjects in the NS does not expand to the MDS when a laser pointer is used.[14-16] Therefore, the reason why the subjective center in the MDS was located near the center of the line segment is thought to be due to the reduction in pseudoneglect, similar to the reason

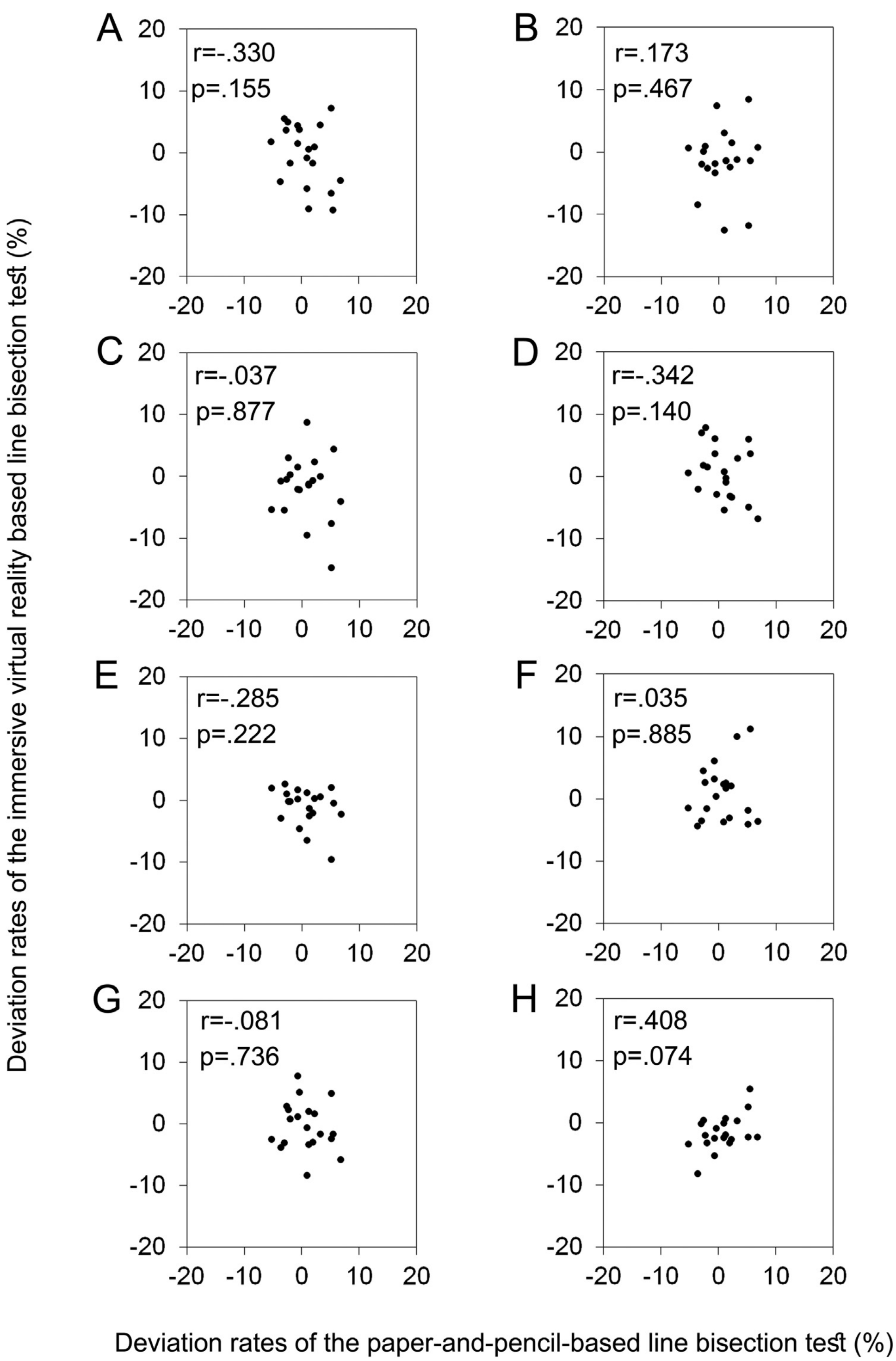

Fig 2 Correlation between the deviation rates of the PLBT and ILBT. (A) 0.25 m. (B) 0.50 m. (C) DNS. (D) 1.00 m. (E) 2DNS. (F) 2.00 m. (G) 3.00 m. (H) 4.00 m.

why the subjective center in the NS was located near the center of the line segment.

In our study, the horizontal line-of-sight distribution differed significantly with distance. The horizontal line-of-sight distribution was located near the center of the line segment, which differed from our hypotheses. The horizontal line-of-sight distribution at each distance showed a quadrant range near the center of the line segment, which was thought to be the result of finding the center of the line segment by a line-of-sight search.

Ohmatsu et al[18] focused on attention and gaze in patients with left HSN. They performed a horizontal gaze analysis using eye tracking on images projected on a monitor 0.6 m away from the subject and reported that the healthy group

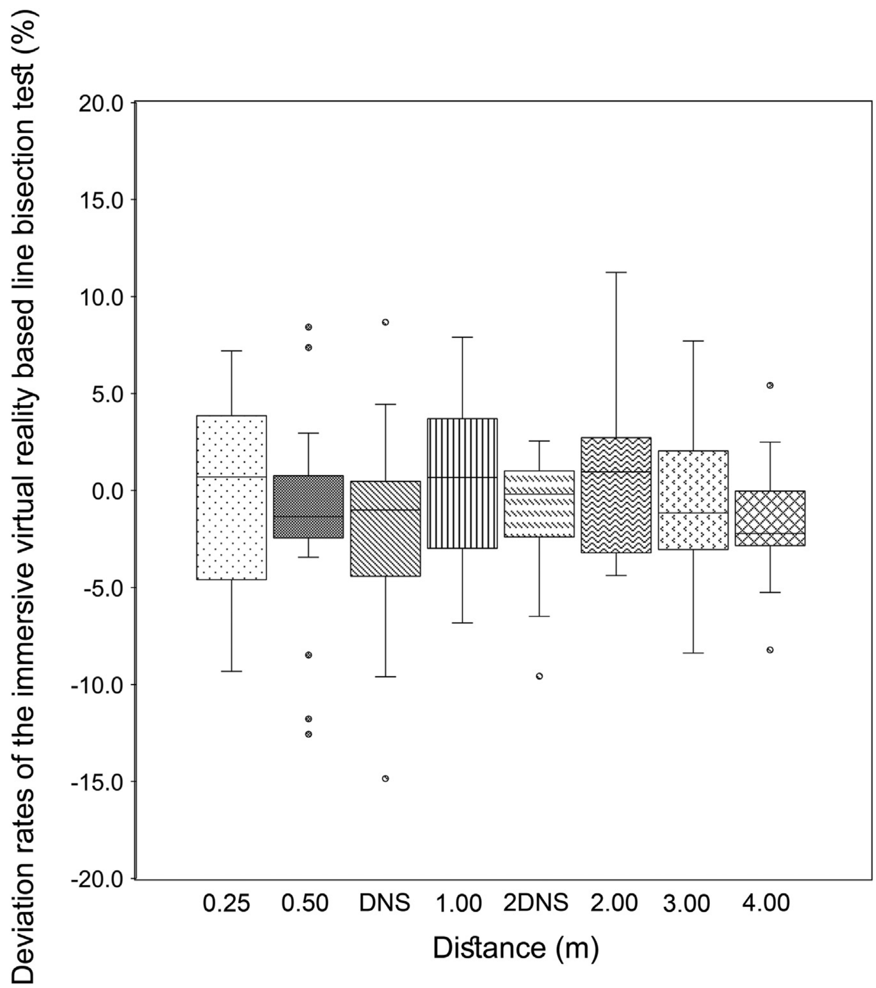

Fig 3 Deviation rates of the ILBT for all distances.

corresponded with the inversion of the image, while the HSN patients' gaze shifted significantly to the right side of the screen. Barton et al also reported that, in a horizontal gaze search when bisecting a line segment presented 1.14 m away, patients' gaze searched from the center of the segment to the right side of the line segment and bisected the right side of the line segment from the center of the line segment, whereas healthy adults searched the left and right parts of the line segment and bisected the center of the line segment.[19] The difference between the maximum and minimum values of the line-of-sight distribution tended to decrease gradually with increasing distance. This may be due to the gradual narrowing of the range of the line-of-sight search to find the center of the line segment from the NS to MDS.

In real space, studies using the NS or MDS as measurement conditions have reported that when normal subjects undergo an LBT, the horizontal distribution of gaze gathers around the center of the line segment, the horizontal gaze search is performed before bisecting the line segment, the minimum and maximum values are found on both sides of the line segment from the center, and there is rarely a gaze search to the edge of the line segment.[19,20] These results are similar to the results of the ILBT. The reason for the significant difference in horizontal gaze distribution by distance was thought to be that the range of gaze search in healthy adults depended on the distance at which the line segment was presented.

In our study, healthy subjects who underwent an ILBT did not experience VRS. There were no obvious changes in their vital signs throughout the measurements. Some studies have investigated the application of IVR in HSN rehabilitation. In recent years, HMDs have frequently been used in IVR research, as they provide a more realistic experience and acquire spatial information more accurately than other types of displays, such as a personal computer display. In addition, HMDs with eye-tracking capabilities that can analyze the eye gaze and use this gaze as the input method are now available. However, some adverse events can occur in VR environments with HMDs, including headache, dizziness, eyestrain, and VRS——similar to motion sickness; furthermore, users need to be aware of changes in their physical condition.[21,22] VRS is believed to be caused by a discrepancy between visual input and vestibular senses.[23] It has been reported that if the IPD setting worn by the subject is not appropriate, VRS can be more severe due to eyestrain and discomfort caused by image blurring.[24] It has also been reported that dynamic content is more likely to induce VRS than static content is.[25,26] In the present study, personal IPD settings were created when the subject was wearing the HMD, and the evaluation was carried out after confirming

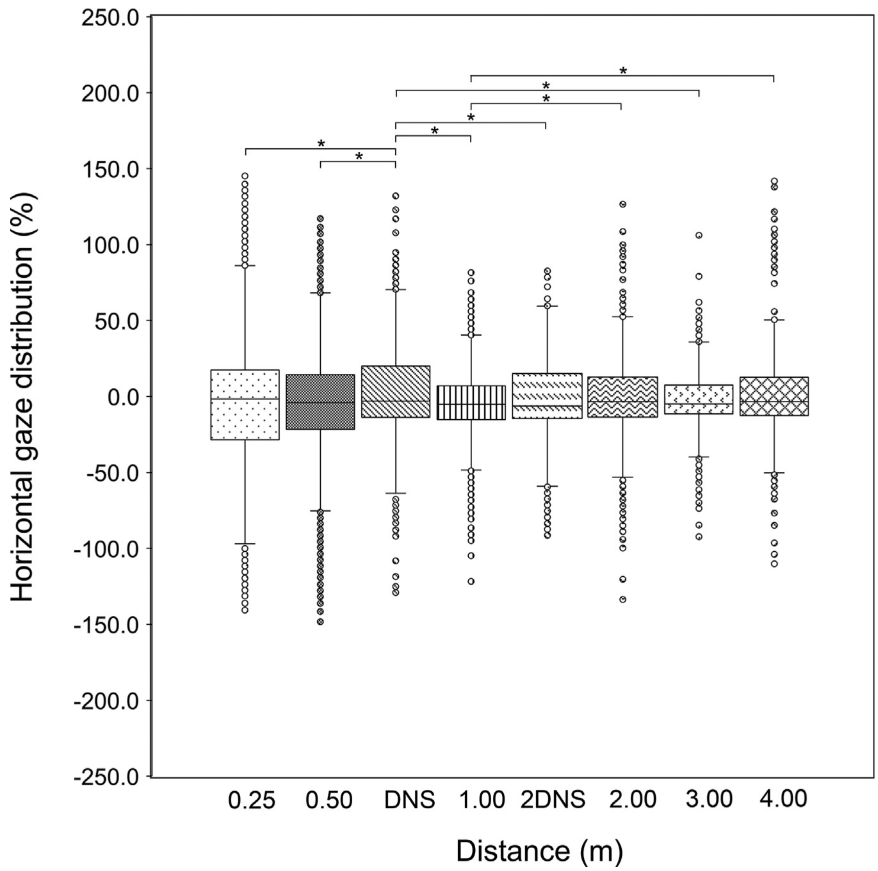

Fig 4 Horizontal gaze distributions. An alpha level of .002 was used as the Bonferroni correction.

that the images on the display were clear and not blurry. Furthermore, in our study, the LBT had static content, which was considered less likely to cause VRS than dynamic content. For these reasons, the subjects were considered to have been able to perform the task without VRS. The results of this study suggest that the ILBT is a safe evaluation method that does not produce VRS when performed in healthy adults.

Limitations

Several limitations associated with the present study warrant mention. The small number of cases may have affected the results. In addition, because our study was conducted in healthy subjects, the results in subjects with HSN remain unknown. To resolve this issue, we plan to conduct future evaluations in patients with HSN.

Conclusions

We investigated the correlation between the deviation rates of the ILBT and PLBT in healthy adult subjects. Our results suggested that there was no significant correlation between the deviation rates of the ILBT and PLBT. We also found that the ILBT is a useful and safe method for evaluating the horizontal line-of-sight distribution and percentage deviation of line segments from the center in the DNS and distance of MDS without inducing VRS.

Suppliers

a. VIVE Pro Eye; HTC.
b. OMEN 15; Hewlett-Packard.
c. Steam and SteamVR; Valve.
d. Unity v.2019.4.1f1; Unity Technologies.
e. C#; Microsoft.
f. SRanipal SDK; HTC.
g. SPSS ver. 27; IBM.

Corresponding author

Naoki Wada, MD, PhD, Department of Rehabilitation Medicine, Gumma University Graduate School of Medicine, 3-39-15, Showamachi, Maebashi, Gunma, Japan 371-8511. *E-mail address:* nwada@gunma-u.ac.jp.

References

1. Heilman KM, Valenstein E, Watson RT. Neglect and related disorders. Semin Neurol 2000;20:463-70.
2. Bisiach E, Perani D, Vallar G, Berti A. Unilateral neglect: personal and extra-personal. Neuropsychologia 1986;24:759-67.
3. Stone SP, Wilson B, Wroot A, et al. The assessment of visuo-spatial neglect after acute stroke. J Neurol Neurosurg Psychiatry 1991;54:345-50.

4. Schenkenberg T, Bradford DC, Ajax ET. Line bisection and unilateral visual neglect in patients with neurologic impairment. Neurology 1980;30:509–17.
5. Cowey A, Small M, Ellis S. Left visuo-spatial neglect can be worse in far than in near space. Neuropsychologia 1994;32:1059–66.
6. Wilson B, Cockburn J, Halligan P. Development of a behavioral test of visuospatial neglect. Arch Phys Med Rehabil 1987;68:98-102.
7. Hartman-Maeir A, Katz N. Validity of the Behavioral Inattention Test (BIT): relationships with functional tasks. Am J Occup Ther 1995;49:507–16.
8. Nakano N, Ishiai S, Koyama Y, Seki K, Hirabayashi H, Inaki K. Effects of space and frame on line bisection performance of patients with unilateral spatial neglect. Jpn J Neuropsychol 2002;18:200–7.
9. Jewell G, McCourt ME. Pseudoneglect: a review and meta-analysis of performance factors in line bisection tasks. Neuropsychologia 2000;38:93–110.
10. Kinsbourne M. Mechanisms of unilateral neglect. Adv Psychol 1987;45:69–86.
11. Benwell CSY, Thut G, Grant A, Harvey M. A rightward shift in the visuospatial attention vector with healthy aging. Front Aging Neurosci 2014;6:113.
12. Learmonth G, Papadatou-Pastou M. A meta-analysis of line bisection and landmark task performance in older adults. Neuropsychol Rev 2022;32:438–57.
13. Friedrich TE, Hunter PV, Elias LJ. The trajectory of pseudoneglect in adults: a systematic review. Neuropsychol Rev 2018;28:436–52.
14. Longo MR, Lourenco SF. On the nature of near space: effects of tool use and the transition to far space. Neuropsychologia 2006;44:977–81.
15. Gamberini L, Seraglia B, Priftis K. Processing of peripersonal and extrapersonal space using tools: evidence from visual line bisection in real and virtual environments. Neuropsychologia 2008;46:1298–304.
16. Mine D, Yokosawa K. Disconnected hand avatar can be integrated into the peripersonal space. Exp Brain Res 2021;239:237–44.
17. Mine D, Yokosawa K. Remote hand: hand-centered peripersonal space transfers to a disconnected hand avatar. Atten Percept Psychophys 2021;83(8):3250–8.
18. Ohmatsu S, Takamura Y, Fujii S, Tanaka K, Morioka S, Kawashima N. Visual search pattern during free viewing of horizontally flipped images in patients with unilateral spatial neglect. Cortex 2019;113:83–95.
19. Barton JJ, Behrmann M, Black S. Ocular search during line bisection. The effects of hemi-neglect and hemianopia. Brain 1998;121:1117–31.
20. Ishiai S, Furukawa T, Tsukagoshi H. Visuospatial processes of line bisection and the mechanisms underlying unilateral spatial neglect. Brain 1989;112:1485–502.
21. Cobb S, Nichols S, Ramsey A, Wilson JR. Virtual reality-induced symptoms and effects (VRISE). Presence Teleop Virt Environ 1999;8:169–86.
22. Kim HK, Park J, Choi Y, Choe M. Virtual reality sickness questionnaire (VRSQ): motion sickness measurement index in a virtual reality environment. Appl Ergon 2018;69:66–73.
23. Reason JT, Brand JJ. Motion sickness. London, England: Academic Press; 1975.
24. Stanney H, Fidopiastis C, Foster L. Virtual reality is sexist: but it does not have to be. Front Robot AI 2020;7:4.
25. Nesbitt K, Davis S, Blackmore K, Nalivaiko E. Correlating reaction time and nausea measures with traditional measures of cybersickness. Displays 2017;48:1–8.
26. Guna J, Geršak G, Humar I, Song J, Drnovšek J, Pogačnik M. Influence of video content type on users' virtual reality sickness perception and physiological response. Future Gener Comput Syst 2019;91:263–76.