A New Portable Clinical Device for Measuring Egocentric Localization

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Abstract

An individual's perception of straight-ahead (i.e., egocentric localization) may be shifted in patients with acquired brain injury (ABI). Using a unique optical system, we have designed a small, portable device for use in the clinic. Data are presented on 14 visually-normal adults, ranging from 23 to 53 years of age, as well as on 10 acquired brain-injured adults, ranging from 37 to 82 years in age. The group mean, as well as the individual subjects' mean, two-dimensional egocentric localization values agreed with the established normative data using larger and more complex laboratory devices. Preliminary data on the 10 acquired brain-injured adults demonstrate its clinical diagnostic and therapeutic applications. The new device has been demonstrated to be as precise, accurate, valid, and reliable as the larger enclosures described in the literature. Furthermore, the device's compactness aids in continued testing on acquired brain-injured patients in our clinic.

Key Words

acquired brain injury, neglect, hemi-inattention, posterior parietal area, egocenter, spatial localization

INTRODUCTION

Patients with acquired brain injury (ABI), such as traumatic brain injury and stroke, present with a variety of vision problems such as oculomotor deficits, accommodative anomalies, strabismus, and visual field defects.[1-3] Of those presenting with visual field defects, many exhibit hemianopia[1-3] and vary in their awareness of or attention to the visual space contralateral to the cerebral lesion.[1-4] Unawareness or inattention to a given field of space may occur with or without a manifest visual field defect and is commonly referred to as neglect.[1,4,5-14] However, there exists a continuum with respect to conscious awareness of visual space contralateral to the lesion, ranging from complete unawareness (i.e., total visual neglect) to complete awareness (i.e., absence of visual neglect).[2]

Furthermore, some patients with neglect, or hemi-inattention, have an anomalous shift in their spatial egocenter, or subjective sense of straight-ahead, of up to 15 degrees from the normal objective straight- ahead position (0 +/- 2 degrees, horizontally and vertically).[4-8,15,16] We speculate that a mismatch between their subjective, anomalous perception of straight-ahead (i.e., abnormal egocentric localization) and the objective, veridical straight-ahead has occurred as a result of the stroke which affected parietal lobe spatial representation, in particular those patients with visual neglect (Figure 1). Due to this mismatch in egocentric localization, patients report that they feel "unsteady", not as "grounded", and "out of synch with the world", i.e., they manifest a disturbance in their global visual spatial sense. Application of yoked prism spectacles (i.e., with the ophthalmic prism bases oriented in the same direction)[3] appears to reduce the mismatch between the subjective and objective visual spaces, as the prisms optically shift the visual world in the direction of the anomalous egocenter (Figure 2). Such patients immediately experience greater perceptual and motor stability upon application of the yoked prisms, especially during ambulation.

Researchers have designed devices (Figure 2) to measure egocentric localization in the laboratory.[5-7,11,15] While these

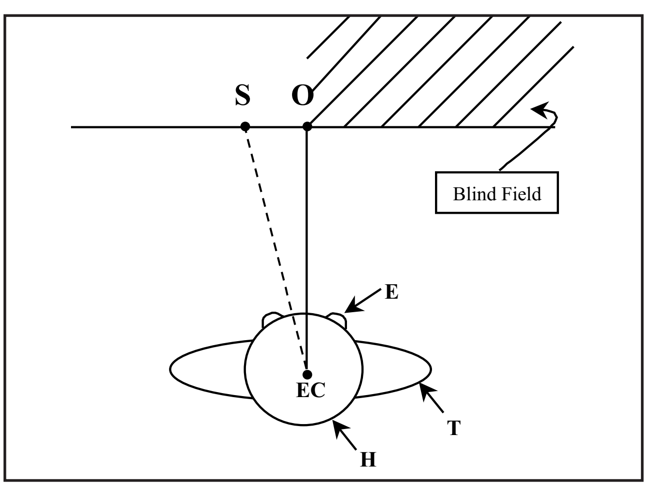

Figure 1. Schematic representation of anomalous egocentric localization in a patient with hemianopia and visual neglect (top view). Symbols: E = eyes, EC = egocenter, H = head, T = torso, O = normal objective straight-ahead, and S = anomalous subjective straight-ahead.

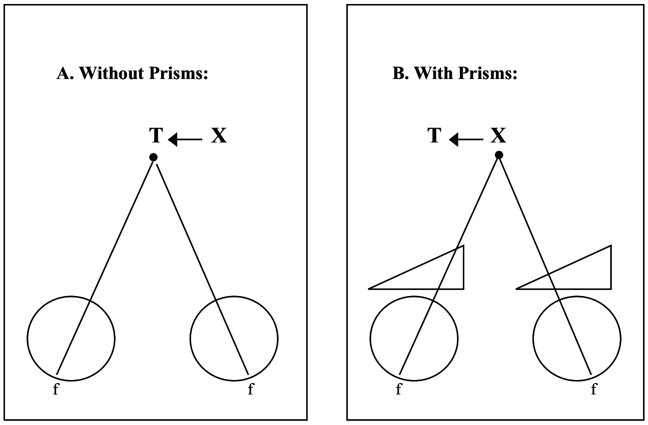

Figure 2. Schematic representation of yoked prism effect on spatial localization with the subject instructed to gaze straight ahead (top view): (A) Without the yoked prisms, where T = midline object, X = object to the right of midline, (B) With the yoked prisms, where objects T and X are now optically displaced laterally to the left by the prisms without any change in eye position.

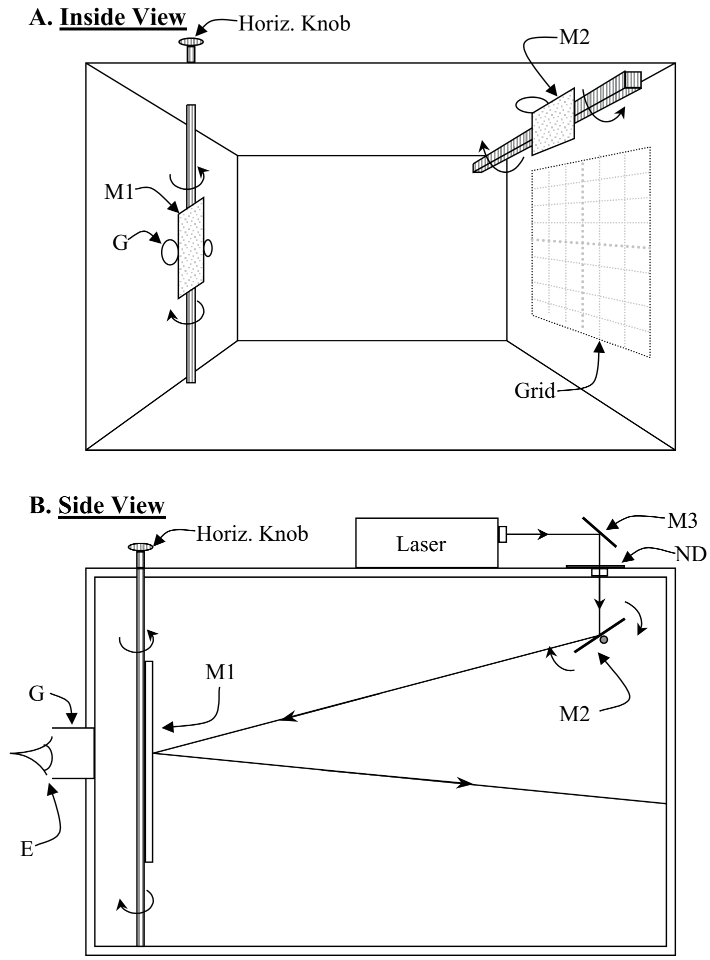

Figure 3. Egocentric localization device. A. Internal perspective view showing the viewing goggles (G), horizontally- (M1) and vertically- (M2) deflecting mirrors, as well as the externally-located calibrated grid (Grid) which is visible only to the experimenters and not to the subject. B. Internal side view showing: subject's eye (E), viewing goggles (G), horizontally-deflecting mirror (M1), laser (top of enclosure), mirror deflecting laser target into the enclosure (M3), neutral density filter (ND), and the vertically-deflecting mirror (M2).

devices have produced repeatable and reliable data from normal subjects, as well as from selected patients with head trauma-related neurological dysfunction, some such devices are large and cumbersome and furthermore require the individual to be placed within a full body enclosure.[5,15] Other means of diagnosing neglect, such as mid- line pointing and pencil/ paper tasks, may require varying degrees of fine motor control, which may be compromised by an acquired brain injury.[16] Thus, some of the current devices are less than ideal for routine clinical practice and investigation in some cases.

A small, portable device was designed by us which circumvented the above problems with minimal complexity. It was tested on non-brain-injured individuals first to assess its possible future use in the clinic to measure egocentric localization rapidly in both the horizontal and vertical directions. Similar testing then followed on patients with acquired brain injury to assist in the determination of the appropriate therapeutic yoked prism spectacle prescription. This paper reports the test findings with our new device in a normal population,[17] as well as presenting preliminary results in patients with acquired brain injury.

METHODS

Subjects

The subjects comprised 14 visually-normal adults with corrected visual acuity of 20/30 or better in each eye. Most were students at the SUNY-State College of Optometry. There was no history or evidence of binocular vision dysfunction, ocular disease, neurological disease, acquired brain injury (i.e., head trauma or stroke), or visual field defect. None of the subjects was taking any drugs or medications that would affect their sensori-motor, perceptual, or attentional aspects. They ranged in age from 23 to 53 years, with a mean of 27.8 years (s.d. = +/- 7.8 years). Subjects participated in this study under the Helsinki accord for human subjects.

Apparatus

The apparatus consisted of a black lucite cube (12" per side) (Figure 3). Welder's goggles were attached to one side into which the individual placed their head and viewed the test target with their habitual, near vision optical correction in place. Atop the box was mounted a small, low-powered (Class II), He-Ne laser (wavelength = 628nm), whose beam was reflected off fully-silvered mirror, M3, and then markedly reduced in intensity using a neutral density filter (ND=1.3). The image of the laser beam was subsequently reflected into a dual-mirror system of the enclosure where it could be displaced either horizontally by rotating the vertically-oriented mirror, M1, or vertically by rotating the horizontally-oriented mirror, M2, with both mirrors M1 and M2 also being fully-silvered. Knobs situated external to the enclosure allowed the experimenter to manipulate the horizontal and vertical position of the laser beam manually. A fine-lined, calibrated grid pattern, which was only seen by the experimenter from behind the device, was carefully marked on the outside of the enclosure, so that readings could be obtained by the experimenter with 0.5 degrees of resolution. Similarly-calibrated paper could be attached to the back grid to obtain a hard copy of the individual egocentric values for a given subject. The objective zero mark of the laser pointer was centered about a fixed point specified on the calibrated grid, which in turn was referenced to the objective veridical midline of the

Table 1: Group and individual egocentric localization (EL) values for both instructional sets.				
Instructional Set	Horizontal EL Grand Mean (degrees)	Vertical EL Grand Mean (degrees)	Individual Range for Horizontal ELMean (degrees)	Individual Range for Vertical EL Mean (degrees)
#1	-0.51 +/- 1.08	-0.83 +/- 0.84	-2.63 to +1.66	-1.77 to +0.86
#2	-0.12 +/- 0.62	-0.52 +/- 0.92	-1.37 to +1.26	-1.71 to +1.26

TABLE 2: Patient demographic data.				
Patient #	Age at testing (yrs)	Year of trauma	Year of testing	Site of lesion
1	37	1997	1999	left temporal region
2	71	1998	1998-1999	left temporal region
3	72	1998	1998	left occipital region
4	65	1997	1998	left parietal region
5	66	1998	1999	right parietal region
6	48	1996	1998	right parietal region
7	53	1995	1995-1996	right anterior temporal region
8	82	1999	2000	right temporal region
9	55	1998	1999-2000	right parieto-occipital region
10	49	1995	1998	right occipital region

subject's head. The laser target could be displaced +/-14.3 degrees both horizontally and vertically, with a resolution of 0.5 degrees. The horizontal and vertical binocular fields-of-view were 28.6 degrees and 26.9 degrees, respectively.

Subject alignment

The subject was positioned in the apparatus in a completely darkened room, with the exception of a small, very dim desk lamp unseen by the subject and used by the experimenter for recording purposes only. They were then instructed to keep their head and body stationary and straight ahead, to gaze straight ahead (i.e., "as if they were looking at their own eyes in a mirror reflection of themselves."), and not to attempt to track or look at the laser target. If the subject inadvertently briefly gazed at the target, this would have little if any effect on the measurements which are egocentric, or body-based, and not oculocentric, or eye-based.

Procedure

Each subject wore their habitual, near-vision spectacle correction. The subject's head was placed in the instrument-mounted goggles and secured by an elastic headband. Each subject then partially dark-adapted for at least one minute prior to the practice measurements. Once the learning curve was established over the next 5 minutes such that the variation in measurement was within +/- 2 degrees of the true objective midline both horizontally and vertically,[5,15] testing commenced. Subjects who could not meet this criterion due to marked measurement variability were excluded (n=2). Measures to the left of and below the objective midline were assigned minus values, whereas those to the right and above were specified as positive.

Two-dimensional egocentric localization was determined using two instructional sets. The first required the subject to look straight and inform the examiner when the slowly-moving laser target appeared to be directly in front of them. The second instructional set was identical to the first, except that the objective (i.e., veridical or zero midline) straight-ahead position was demonstrated to the subject prior to providing the instructional set for both the horizontal and vertical measures. Individual values were recorded by the experimenter.

For each subject, the magnitude of the initial target offset was randomized, and the direction of movement was alternated to minimize bias effects. The experimenter slowly and smoothly (i.e., approximately 0.5 degrees per second) displaced the laser pointer, while the subject indicated with a hand-held clicker when the laser spot appeared to be localized directly straight ahead. For a given subject, ten measurements were taken for each instructional set. The mean (+/- 1 SD) for each subject, and the grand mean (+/- 1 SEM) for all subjects, were calculated for both the horizontal and vertical egocentric measures under both sets of instructions.

RESULTS

The egocentric localization (EL) values are presented in Table 1 for the horizontal and vertical grand means (+/- 1 standard error of the mean), as well as the range for the mean EL values of the 14 individual subjects, for both instructional sets. The group mean values and ranges were within normal limits.[5,15]

A comparison was made to determine the effect of instruction set on egocentric localization. Correlations between the two instructional sets for the horizontal and vertical values were similar and significant [r= +0.72 ($p<0.05$) and r=+0.75 ($p<0.05$), respectively]. In addition, the t-test for non-independent samples showed no significant difference based upon informing the subject for horizontal [$t(13)=1.91$, $p=0.08$] and vertical [$t(13)=1.86$, $p=0.09$] values. Thus, there was no difference due to instructional set.

DISCUSSION

The purpose of the study was to test a new device for measuring egocentric localization in both normals and patients with ABI that would be smaller, easier to use, and less cumbersome than some other devices, while still providing a valid and reliable measure. Our device fulfilled each of these criteria. Further, it was determined to be as precise, accurate, and reliable as the larger enclosures described in the literature,[5-7,15] as well as other techniques for measuring egocentric localization.[11] An additional important feature was that it provided a graphical hard copy of the individual egocentric values. All of the above factors make the device appropriate in the clinical environment for the diagnostic assessment of egocentric localization, the scientifically-based prescription of the therapeutic yoked prism spectacle correction, and the filing of this information within the patient's medical record for subsequent retrieval.

We are beginning to collect preliminary data on brain-injured patients before yoked prism application, upon initial yoked prism application, one week post-prism application, and one month post-prism application. We are hopeful that extensive analysis of egocentric localization data over both short- and long-term periods will assist in providing a scientific basis for the diagnosis of a shifted egocenter, as well as the therapeutic yoked prism spectacle prescription, in specific

TABLE 3
Preliminary data for egocentric localization and yoked prisms in patients with acquired brain injury.

Patient #	No Prism	Prism On	One month later	Three months later
1*	4.7 deg L	1.5 deg L; 2.3 BR; (+)	1.5 deg L; (+)	1.3 deg L; (+)
2*	3.4 deg L	3.2 deg L; 2.9 BR; (+)	3.0 deg L; (+)	3.2 deg L; (+)
3*	2.9 deg L	2.3 deg L; 2.3 BR; (-)	No prism prescribed	No prism prescribed
4*	3.6 deg L	3.6 deg L; 4 BR; (-)	No prism prescribed	No prism prescribed
5	7.9deg R	9.7 deg R; 4 BL; (+)	8.9 deg R; (+)	7.5 deg R; (+)
6	3.2 deg R	2.5 deg R; 2 BL; (+)	2.6 deg R; (+)	2.4 deg R; (+)
7	5 deg R	3.5 deg R; 2.9 BL; (+)	3.5 deg R; (+)	3.2 deg R; (+)
8	4.7 deg R	2.3 deg R; 2.3 BL; (+)	2.3 deg R; (+)	2 deg R; (+)
9	3.2 deg R	2.3 deg R; 2 BL; (+)	2.5 deg R; (+)	2.5 deg R; (+)
10	1.7 deg R	1.5 deg R; 2 BL; (-)	No prism prescribed	No prism prescribed

*Symbols: * = left brain-injured patients; L = left; R = right; deg = degrees; BL = yoked prisms bases left; BR = yoked prisms bases right; (+) = positive subjective response to the yoked prism spectacles; (-) = negative subjective response to the yoked prism spectacles. The values in the column labeled "No Prism" indicate the magnitude (in degrees) and direction (left or right) of the patient's habitual egocentric localization. There are three notations in the column labeled "Prism On": the first represents the magnitude (in degrees) and direction (left or right) of the patient's subjective egocentric localization while wearing diagnostic yoked prism spectacles; the second represents the magnitude (in degrees) and direction of the bases (bases left or bases right) of the diagnostic yoked prism spectacles; and the third represents the patient's subjective response upon application of the yoked prisms (either positive or negative). The notations in the column labeled "One Month" indicate whether the diagnostic yoked prism spectacles were prescribed, and, if so, the magnitude (in degrees) and direction (left or right) of the patient's egocentric localization while wearing diagnostic yoked prism spectacles, as well as the patient's subjective response (positive or negative) after having worn the diagnostic yoked prism spectacles for one month. The notations in the column labeled "Three Months" indicate whether the diagnostic yoked prism spectacles were prescribed, and, if so, the magnitude (in degrees) and direction (left or right) of the patient's egocentric localization while wearing diagnostic yoked prism spectacles, as well as the patient's subjective response (positive or negative) after having worn the diagnostic yoked prism spectacles for three months.*

categories of brain-injured patients. Thus far, ten patients have been tested. Demographic data for the ten patients are shown in Table 2, and their respective egocentric values are shown in Table 3. Patients #1-4 each incurred left brain lesions. Of these four patients, two (patients #1 and #2) manifested a consistent egocentric shift that responded favorably to the yoked prism application. The remaining six patients had incurred right brain lesions. Of these six patients, five manifested a consistent egocentric shift that responded favorably to the yoked prism application (patients #5-9). Subjective responses to the yoked prism application are indicated in parentheses in Table 3 by the negative sign (i.e., the patient did not respond well to the prism) and plus sign (i.e., the patient reported positive subjective changes with the prisms). Thus, the results so far are encouraging. However, three patients (#3,4,10) were not prescribed yoked prisms based on our egocentric measurements. Both patients #3 and #4 suffered left brain lesions. Patient #3 was not prescribed yoked prisms because his egocentric measurements and subjective responses were not favorable upon application of the yoked prism spectacle correction. With patient #4, there was too much measurement variability about the mean value of 3.6 degrees left. And, in patient #10, the only right brain- injured patient who was not prescribed yoked prisms, the egocentric shift was relatively small (1.7 deg right) and just outside normal limits; and therefore yoked prism spectacles were not prescribed.

However, there are still refinements to be made on our device based on our personal experience with the apparatus thus far. First, a small, infra-red video camera will be installed atop the enclosure to view the patient's eye position continually via hot-mirror reflection. This will assure that appropriate eye position and stability are maintained throughout the testing, as there is a natural tendency by some to gaze periodically at the eccentrically-moving target. Second, movement of the laser target will be computer-controlled via an externally mounted x-y, mirror galvanometer system. This will assure constancy of target velocity, as well as provide us with the ability to alter target velocity, if needed, perhaps to find a subject's optimal test target velocity. Third, data acquisition and analysis will be automated by the same computer via A/D technology and specialized software, respectively. Lastly, a head/chin rest assembly will be incorporated as an integral part of the device. This will assure both more accurate head position and stability, as well as prevent fatigue effects in some of the subjects during the sustained head maintenance in the viewing goggles.

Future research directions include: (1) continued testing of this device in patients with ABI to assist in determination of the optimal yoked prism spectacle correction, and (2) investigating the short- and long-term adaptive effects of yoked prisms on patients with ABI. The outcomes of these proposed studies should provide additional insight into the notion of egocentric localization in ABI patients, as well as scientifically-based methodology to prescribe yoked prisms for improvement of their visual spatial perception.

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