



Physiotherapy Theory and Practice

An International Journal of Physical Therapy

ISSN: 0959-3985 (Print) 1532-5040 (Online) Journal homepage: <https://www.tandfonline.com/loi/iptp20>

Impact of eliminating visual input on sitting posture and head position in a patient with spatial neglect following cerebral hemorrhage: a case report

Peii Chen, Shannon E. Motisi, Christina Cording, Irene Ward & Neil N. Jasey

To cite this article: Peii Chen, Shannon E. Motisi, Christina Cording, Irene Ward & Neil N. Jasey (2019): Impact of eliminating visual input on sitting posture and head position in a patient with spatial neglect following cerebral hemorrhage: a case report, *Physiotherapy Theory and Practice*, DOI: [10.1080/09593985.2019.1645252](https://doi.org/10.1080/09593985.2019.1645252)

To link to this article: <https://doi.org/10.1080/09593985.2019.1645252>



Published online: 18 Jul 2019.



Submit your article to this journal [↗](#)



View Crossmark data [↗](#)



Impact of eliminating visual input on sitting posture and head position in a patient with spatial neglect following cerebral hemorrhage: a case report

Peii Chen, PhD ^{a,b}, Shannon E. Motisi, DPT^c, Christina Cording, DPT^c, Irene Ward, DPT ^{b,c}, and Neil N. Jasey, MD^{b,c}

^aCenter for Stroke Rehabilitation Research, Kessler Foundation, West Orange, NJ, USA; ^bDepartment of Physical Medicine and Rehabilitation, Rutgers University - New Jersey Medical School, Newark, NJ, USA; ^cKessler Institute for Rehabilitation, West Orange, NJ, USA

ABSTRACT

Background: Spatial neglect is a neurocognitive syndrome. Affected individuals pay little or insufficient attention to the space contralateral to the injured cerebral hemisphere, often resulting in or exacerbating disability following an acquired brain injury. Eliminating visual input may increase attention toward the contralesional side of space, and improve symptoms of spatial neglect; however this has never been examined in a clinical setting. **Objective:** In this case report, we observed an individual demonstrate immediate and spontaneous postural changes once visual input was eliminated. **Methods:** The patient, a 53-year-old female, was admitted to a rehabilitation hospital after hemorrhagic stroke affecting her right basal ganglia and surrounding regions in the frontal lobe. She exhibited left-sided spasticity, severe right gaze preference, and stark rightward postural deviation. Neck passive range of motion was normal. Visual field integrity was inconclusive due to poor communication and impaired cognitive function. Contraversive pushing was ruled out. **Results:** Once visual input was eliminated by applying a blindfold, the patient turned to the left spontaneously, had more buttock contact on the left, and placed more weight toward the left side in a sitting posture. However, she returned to rightward deviation three minutes after blindfold removal. In addition, the patient's rehabilitation team reported that she was able to participate in more therapy activities with binocular occlusion than with eyes open. **Conclusion:** Binocular occlusion appeared to demonstrate an immediate, albeit transient, improvement in postural symmetry. The results warrant further research and exploration in clinical applicability.

ARTICLE HISTORY

Received 30 September 2018
Revised 20 May 2019
Accepted 20 June 2019

KEYWORDS

Spatial neglect; postural impairment; stroke rehabilitation

Introduction

Spatial neglect is a neurocognitive syndrome. Affected individuals pay little or insufficient attention to the space contralateral to the injured cerebral hemisphere, resulting in or exacerbating disability following an acquired brain injury (Adair and Barrett, 2008; Heilman, Watson, and Valenstein, 2012). Spatial neglect occurs most commonly after right brain injury, associated with attention and related networks. Areas in the parietal, frontal, and temporal cortices, subcortical structures, and longitudinal white matter tracts are critical to the occurrence and persistence of the syndrome (Corbetta and Shulman, 2011; Mesulam, 1999; Ramsey et al., 2017; Rengachary, He, Shulman, and Corbetta, 2011; Smith, Clithero, Rorden, and Karnath, 2013; Umarova et al., 2017). The most commonly observed and documented symptoms are visual symptoms based on voluntary responses to visual stimuli, including: performance in visual search tasks (e.g. crossing out targets among non-targets printed on a piece of paper); drawing tasks (e.g.

making a graphic copy of a figure); bisection tasks (e.g. marking the center of a horizontal line); and reading tasks (e.g. reading out loud a word or a paragraph of words). However, symptoms of spatial neglect are not limited in the visual domain. Spatial neglect affects spatial perception in the auditory, tactile, proprioceptive modalities, and has an impact on cognitive and motor functions (Gutschalk and Dykstra, 2015; Heilman, Bowers, and Watson, 1983; Nijboer, Ten Brink, van der Stoep, and Visser-Meily, 2014; Ogourtsova, Archambault, and Lamontagne, 2015; Rousseaux et al., 2013; Salvato, Sedda, and Bottini, 2014; Vallar et al., 1991). In addition to voluntary responses that show neglect symptoms, signs of spatial neglect can be observed in situations where no specific task is required, no external stimulus is presented, or no response is necessary. Spontaneous ipsilesional deviation of the head, trunk, and eyes during resting (i.e. awake but doing nothing in particular) is an extremely sensitive indicator of spatial neglect (Fruhmann-Berger and Karnath, 2005; Fruhmann-Berger, Pross, Ilg, and Karnath, 2006).

The following case report is of an individual who had a hemorrhagic stroke damaging her right basal ganglia and surrounding subcortical areas in the frontal lobe. Due to her severe posture impairment, extreme gaze preference toward the right side (Figure 1), and inconsistent responses to multi-step commands, the patient could not be assessed reliably using conventional paper-based visuospatial tests (e.g. line bisection and target cancellation) or through instruction-dependent examinations for extinction in any sensory modalities. Extinction refers to a phenomenon when ipsilesional stimuli extinguishes the perception of contralesional stimuli when both stimuli are presented simultaneously (Baylis, Simon, Baylis, and Rorden, 2002). The patient's spatial neglect was diagnosed via a standardized observation process during daily-life situations. Because of her low functional level, we found it challenging to administer evidence-based treatments such as prism adaptation, visual scanning, and optokinetic stimulation suggested in the practice guidelines by Winstein et al. (2016).

Based on the literature, we hypothesized that eliminating visual stimulation might reduce the patient's rightward deviation in her resting posture. In one case reported by Anderson (1993) and six cases by Chokron, Colliot, and Bartolomeo (2004), individuals demonstrated left-sided neglect when drawing tasks (e.g. drawing a clock, butterfly, and car) were performed with eyes open but were able to produce more symmetrical drawings with eyes closed. In another case report, Di Pellegrino (1995) reported the case of a patient who had difficulty in clock drawing in that the individual clustered all twelve numbers on the right side in the circle. However, the patient was able to allocate each number correctly (e.g. "10" at the 10-o'clock location)

in the condition where there were no other numbers in the circle. These case reports suggest that visual feedback affects performance in visuospatial motor tasks that rely on relatively intact spatial representation (i.e. long-term memory) of common objects. Other researchers employed different methods of eliminating visual feedback. Mark, Kooistra, and Heilman (1988) asked a group of 10 patients to mark or erase 40 lines one by one on a white board. As expected, the patients omitted more stimuli on the left than the right side, indicating left-sided neglect. Interestingly, the performance was better in the erasing than the marking condition, suggesting the beneficial effect of removing visual information (Mark, Kooistra, and Heilman, 1988). Schnider, Durbec, and Ptak (2011) asked a group of 13 patients to arrange 120 dots evenly on a computer monitor by dragging each dot with the mouse cursor. With visual feedback (i.e., dots stayed on the monitor), the patients placed the dots mostly on the right side of the monitor; however, with no visual feedback (i.e. the monitor remained blank), the placement of dots was relatively symmetrical. Thus, the literature suggests eliminating visual input may improve spatial awareness of the contralesional side among patients with left-sided neglect, and in turn, reduce ipsilesional bias or deviation.

In the following case report, we describe a patient's symptoms and progress during her stay in the inpatient rehabilitation facility where clinical observations took place. Toward the end of her stay, we conducted a systematic, albeit brief, session to demonstrate the immediate, transient, but observable effect of binocular occlusion (blindfolding) on her postural deviation. The local Institutional Review Board approved the project for medical record reviews, analyses, and the



Figure 1. The patient's resting posture at seated positions.

examination session. The patient's husband served as a proxy providing informed consent for this case report and the use of this technique during the patient's therapy sessions.

Case description

Clinical history

The patient, 53 years old, was admitted to an inpatient rehabilitation facility 16 days after experiencing an intracranial and intraventricular hemorrhage. Her right basal ganglia and subcortical areas in the right inferior medial frontal lobe were affected, and lateral ventricles were enlarged (Figure 2). Prior to the stroke, she was functionally independent, employed as a school teacher, living with her husband in a suburban area. With Portuguese as her first language, she learned English in her teens and used English primarily in daily life including at work and home. The patient had a past medical history significant for migraines, gastric bypass surgery, intestinal volvulus, intestinal intussusception, cholecystectomy, previous small bowel resection, and lumbar hemi-laminectomy due to lumbar stenosis. According to her husband, she was ambidextrous but favored right, and wrote with her right hand. Below, we describe her function and progress throughout the entire stay of inpatient rehabilitation. Following the inpatient rehabilitation standard, the patient received daily therapy for 3 hours each day including physical, occupational, and speech therapies.

Clinical observations

At the time of admission, the patient scored 18 on the Functional Independence Measure (FIM™), indicating that she was totally dependent on a caregiver for all her functional skills (Granger et al., 1993; Linacre et al., 1994). The FIM consists of 13 motor items and 5 cognitive items, and each item is scored from 1 to 7 with greater values indicating better functional independence. After 54 days of inpatient rehabilitation, her FIM score improved mildly to 29 out of the maximum

126. Scores of both motor and cognitive domains increased 60% (Motor FIM improved from 13 to 21 and Cognitive FIM improved from 5 to 8). Most notably, she progressed from total assistance to supervision with grooming, maximal assistance for bathing and upper and lower body dressing, and moderate assistance for functional transfers.

At admission, the patient presented severe symptoms of spatial neglect as indicated through the Catherine Bergego Scale (CBS), a 10-item measure in which each item is scored from 0 to 3 with greater values indicating greater degrees of severity (Azouvi, 1996). The CBS was administered through the Kessler Foundation Neglect Assessment Process (KF-NAP™), a standardized method using CBS during activities of daily living (Chen et al., 2015; Chen and Hreha, 2015; Chen et al., 2012). Her improvement was most observable in grooming and meals (Table 1).

The CBS via KF-NAP was the only feasible assessment for spatial neglect that could be administered. The patient followed commands inconsistently irrespective of the language in which those commands were given (i.e. first or second language). She rarely verbalized responses that required more than a yes or no response and her answers were not considered reliable. Thus, most of the conventional assessments for spatial neglect requiring instruction adherence were not performed, such as target cancellation, figure drawing, or line bisection. Visual field integrity was examined using the formal vision screening procedure, but the result was inconclusive about the presence or absence of a visual field cut. On the physical exam, she consistently reacted to visual threat in the right visual field, but not the left.

The patient had a severe rightward gaze preference and rightward resting head position. However, her passive range of motion of the cervical spine was within normal limits. Moderate spasticity was also noted in her left upper and lower extremities. She demonstrated some resistance during transfers between surfaces, but formal assessment for contraversive pushing yielded a negative result. She scored zero on the Scale for Contraversive Pushing, a 3-item scale with higher

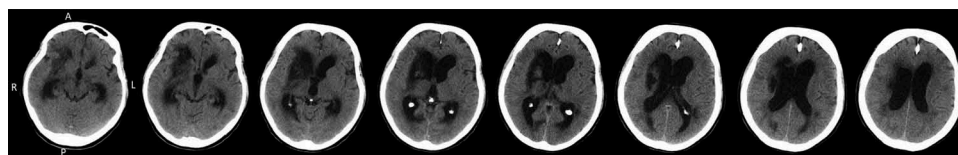


Figure 2. The patient's brain images obtained from a CT scan, 46 days post-stroke. Following the radiology convention, the left side of each brain image presents the right hemisphere.

Images are ordered from lower to higher sagittal planes. Abbreviations: A, anterior; P, posterior; R, right; L, left.

Table 1. Changes of spatial neglect severity from admission to discharge. Abbreviations: CBS via KF-NAP, Catherine Bergego Scale via Kessler Foundation Neglect Assessment Process; SN, spatial neglect.

Category of CBS via KF-NAP	Admission	Three weeks after admission	Discharge
Gaze orientation	3	3	2
Limb awareness	3	3	2
Auditory attention	3	0	0
Personal belongings	3	Not assessed due to difficulty in differentiating left vs. right side	
Dressing	3	2	2
Grooming	2	1	0
Navigation	2	2	3
Collision	Not assessed due to the inability to ambulate on her own		
Meals	Not assessed due to the "nothing by mouth" status		3
Cleaning after meals		1	0
Sum score (number of assessed categories)	19 (7)	15 (8)	10 (8)
Final score	27	18.75	12.5
SN severity	Severe	Moderate	Moderate

values indicating greater severity of the pusher syndrome (i.e. actively pushing from the ipsilesional side toward the contralesional side) (Baccini et al., 2008; Karnath, Ferber, and Dichgans, 2000).

Twenty days after admission, the patient showed little improvement in her preferred resting position of rightward-deviated gaze preference or head and neck posture. Her eyes were seemingly fixated on the floor without focusing at any specific stimulus. Her primary physical therapist obtained consent from her and her husband, and then tried binocular occlusion by blindfolding her, and the effect was immediately noticeable (Figure 3). The stroke rehabilitation care team then decided to blindfold the patient during therapy sessions, and the blindfolding duration was determined by the patient's tolerance (e.g. until the patient pushed or pulled away the blindfold). In comparison to eyes open, with eyes blindfolded the patient was able to sit up straighter by herself during physical and occupational therapies, and her posture was more centered and even facing leftward. In addition, she was less

resistant to cervical stretching and passive-range-of-motion activities. Other observations during therapy sessions were also documented in the clinical notes: when seated in her wheelchair at rest with eyes open, she demonstrated rightward deviation in her head and trunk posture with both legs relaxed and thighs on chair. Once blindfolded, she would spontaneously turn her head and trunk to midline and sometimes cross her right leg over her left without being instructed to do so. In addition, when asked to point to her body parts on the left side, the patient was unable to do so correctly with eyes open, but was able to point to her left ear, left arm, and left knee once blindfolded. On one occasion, her therapist asked her if she preferred to have the blindfold on or off, and she stated "on". However, she was unable to provide further explanation as to why she preferred it on.

Outside therapy sessions, the patient's husband applied the blindfold on her from time to time throughout the day. He reported that the duration of blindfolding was never longer than 10 minutes, and the

**Figure 3.** The patient changed her posture immediately once her eyes were blindfolded.

patient did not express any adverse feeling toward the blindfolding. Following these clinical observations, we designed a brief examination session to measure the effect of binocular occlusion systematically, described in the next sections. This examination session was conducted the day before discharge (i.e. 53 days after admission; 69 days post-stroke).

Systematic examination using binocular occlusion

The session was conducted with the patient while sitting at the edge of a standard therapy mat. The patient did not need physical assistance from her therapist to maintain her sitting posture, which was deviated toward the right side; however, she utilized her right upper limb for balance intermittently throughout the session. Three outcome measures were selected, including head position related to sternum, weight distribution, and buttock-mat contact bias. The head position was measured using a goniometer to note head position related to sternum (Figure 4(a)). Weight distribution and buttock-mat contact bias were measured using the BodiTrak BT510 System™ from Vista Medical, on which the patient was seated (Figure 4(b)), in order to obtain objective data about weight distribution under the buttocks. We measured each outcome at four time points: baseline (i.e. with eyes open), close to the end of the 5-minute binocular occlusion (i.e. with eyes blindfolded), immediately after intervention (i.e. after removing the blindfold), and 3 minutes after intervention. This 3-minute delay was determined based on her therapists' clinical reports that the patient had consistently demonstrated a transient effect. No verbal cueing was provided over those four time points. For all three outcome measures, a positive value was indicative of rightward deviation from the center, and negative leftward.

The patient's head position was facing 35 degrees right of midline before blindfolding, 6 degrees left of midline with blindfold, 6 degrees right of midline immediately after removing blindfold, and 14 degrees right of midline three minutes after removing blindfold (Figure 5(a)). Buttock-mat surface contact bias and weight distribution changed and in parallel to the change observed in head position (Figure 5(b,c)). The patient had more contact and placed more weight toward the right of midline at baseline, shifted to the left of midline during binocular occlusion, centered to midline immediately after the blindfold was removed, and returned to right of midline three minutes later. No adverse events were noted during the intervention.

Discussion

Eliminating visual input resulted in immediate, yet transient, spontaneous changes in the patient's head

position, weight distribution, and buttock-mat contact bias in a seated position. With blindfold, her posture was more centered rather than severely deviated toward the ipsilesional side. Once the blindfold was removed, the patient was unable to maintain her head and trunk at midline. She then spontaneously turned her head toward the right side and demonstrated a rightward deviated posture again. The results of the brief examination session and the clinical notes of her rehabilitation team suggested that the patient's postural impairment might have resulted from an abnormality in processing visual information and that her proprioceptive and vestibular processing were spared. In addition, her spatial representation of her body and body-environment relation may have remained intact.

At first glance, the observed changes in the patient are reminiscent of previous reports suggesting that visual input aggravates certain symptoms of spatial neglect (Anderson, 1993; Chokron, Colliot, and Bartolomeo, 2004; Di Pellegrino, 1995; Mark, Kooistra, and Heilman, 1988; Schnider, Durbec, and Ptak, 2011). Many researchers link those findings to a theoretical model of attention disengagement (Schnider, Durbec, and Ptak, 2011). The disengagement model states that affected individuals have difficulty not only in exploring the contralesional side of space voluntarily but also in directing attention away from stimuli presented in the ipsilesional side (Morrow and Ratcliff, 1988) due to the "magnetic power" of ipsilesional stimuli (Kinsbourne, 1987). Accordingly, patients direct attention to stimuli in the ipsilesional side of space and fail to disengage attention from them, which in turn, leaves contralesional stimuli unattended. While external visual information is capturing and distracting attention, internal visual information (e.g. mental imagery of a clock) does not have such a detrimental effect on spatial performance. Thus, once visual input is eliminated altogether with eyes closed, no external visual information would lead to abnormal ipsilesional deviation. Following the logic of this model, with eyes open, patients with left-sided neglect appear to pay much attention on the right side of a visuospatial task such as target cancellation or figure drawing while omitting information on the left. With eyes closed, they demonstrate relatively more symmetrical performance on both sides. However, this model cannot account for patients whose neglect symptoms are beyond the visual modalities (Heilman, Bowers, and Watson, 1983; Nijboer, Ten Brink, van der Stoep, and Visser-Meily, 2014; Vallar et al., 1991). The phenomenon observed in our patient may not be explained by the disengagement model, because it is unknown whether she was focused on and distracted by any specific visuospatial information with eyes open.

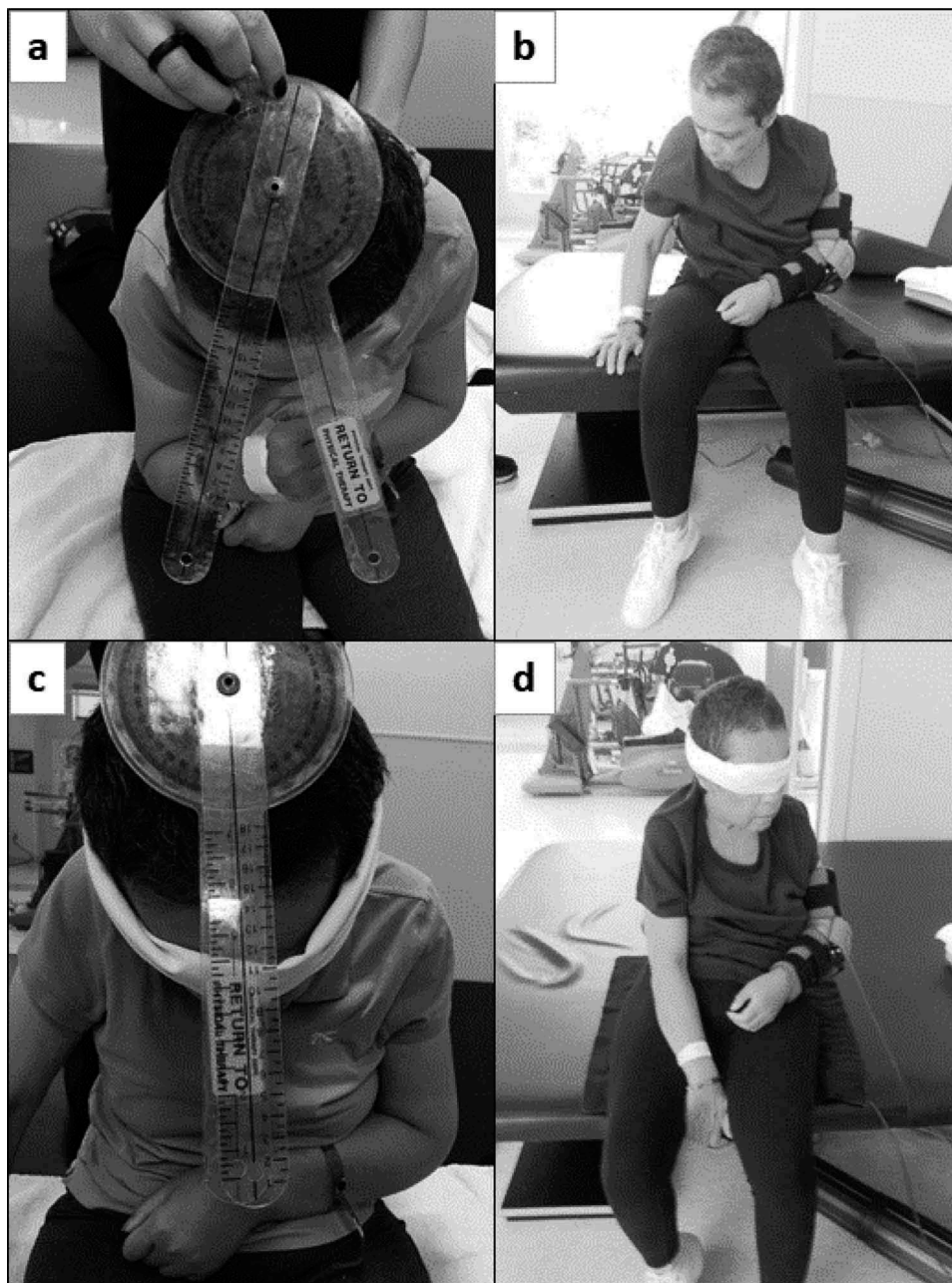
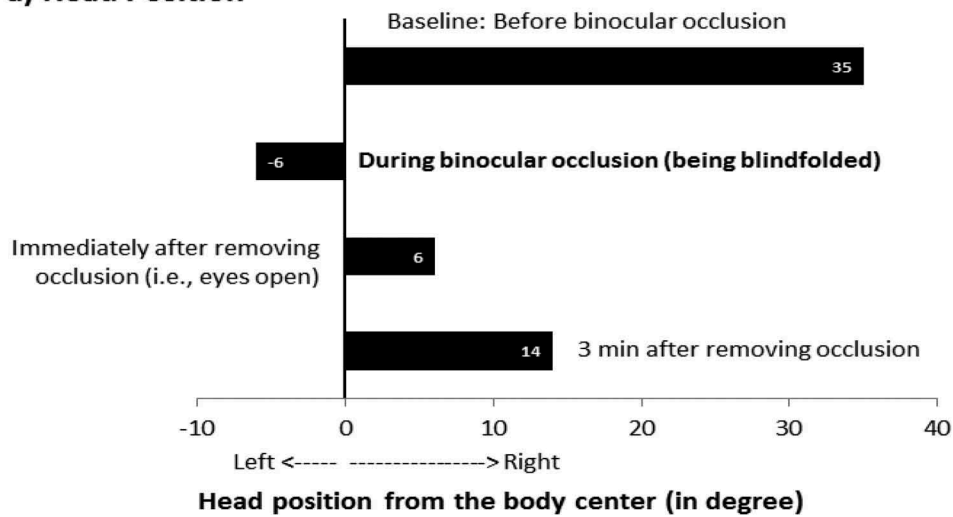


Figure 4. The patient's head and neck posture immediately changed from rightward and downward position (a, b) to centered or leftward position (c, d) when she was blindfolded.

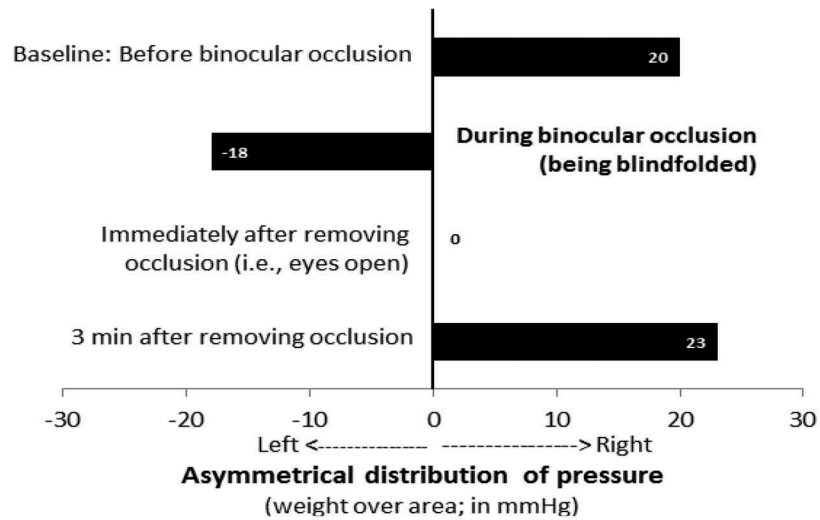
Sitting up with the head and trunk aligned in the midline is a highly automatized task such that one does it without thinking if the muscle strength and ability are present. Keeping a balanced upright posture against gravity relies on sensory sources and cognitive resources (Woollacott and Shumway-Cook, 2002). Sensory sources are external stimuli encoded by sensory receptors into neural signals, and hence, sensory information. When one source is missing (e.g. visual deprivation), the other sensory inputs are relied upon to greater degrees in order to stabilize the body posture

(Peterka, 2000). Cognitive resources refer to mechanisms of and capacity for information processing regardless of their accessibility to consciousness. In this framework for automaticity of postural control, cognitive resources are dedicated to: 1) processing and integrating afferent sensory information derived from visual, vestibular, and proprioceptive modalities; 2) responding to sensory input through the motor system (e.g. contrasting a group of muscles); 3) forming spatial awareness of a given posture, positions of body parts, and body-environment relation; and 4) if there are

a) Head Position



b) Weight Distribution



c) Buttock-Mat Contact Bias

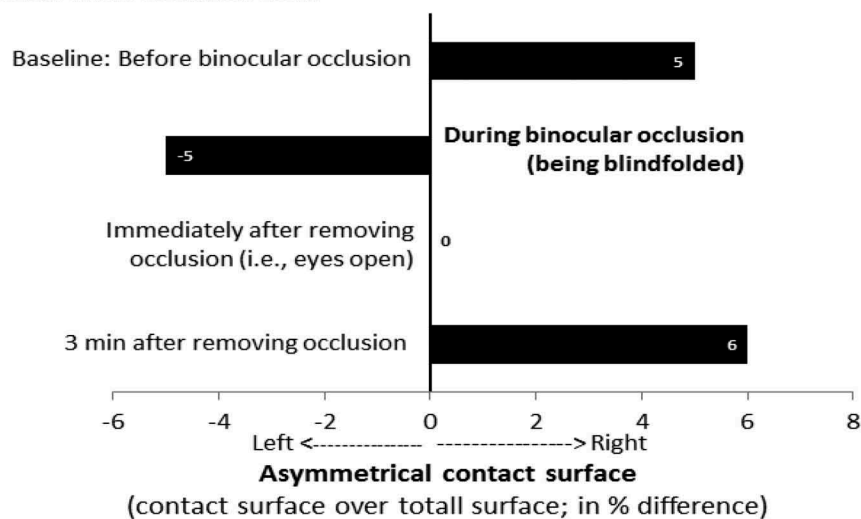


Figure 5. Outcome measures collected in the examination session: at baseline, during binocular occlusion, immediately after blindfold removal, and 3 minutes after blindfold removal in a) head position, b) weight distribution, and c) buttock-mat contact bias.

other simultaneous tasks (e.g. reading, texting, and talking), sharing the resources while maintaining posture balance. Thus, the patient's symptoms might have resulted from the deployment of excessive cognitive resources toward processing visual input, especially from the right side of space, and from the failure in integrating visual input with other sensory information. Once visual input was removed, the integrated information received from non-visual receptors such as the vestibular apparatus and proprioceptors could be registered and processed further to generate a response manifested as a balanced sitting posture with the head and trunk oriented upright and centered. However, it is unknown why visual input disrupted the process of multisensory integration in this patient.

We were unable to observe the patient's ocular movement during blindfolding and thus could not make direct inference. However, based on the findings of Fruhmann-Berger and Karnath (2005), we postulate that the patient may have moved her eyes toward the center as well. The authors measured eye-in-head, head-on-trunk, and gaze orientation in an examination room with normal lighting and in total darkness where study participants sat in a chair and were not required to perform any task in particular. Patients with spatial neglect after right brain stroke showed abnormal rightward deviations in all three measures, all significantly different from measures in patients without spatial neglect after right brain stroke or healthy control's measures under the light and dark conditions. Importantly, all the rightward deviations demonstrated in patients with spatial neglect were more pronounced in the light than in the dark condition. Furthermore, their deviations in darkness were still more rightward than those of patients without spatial neglect or healthy controls (Fruhmann-Berger and Karnath, 2005). This seems inconsistent with what we observed with the patient who turned her head to the center and sometime to the left with binocular occlusion. With a closer look at Fruhmann-Berger and Karnath (2005) study, variance was noted especially among patients with spatial neglect. It is possible that some of the patients with spatial neglect demonstrated similar deviation changes similar to our patient. In particular, three of the 12 patients with spatial neglect had focal damage in the basal ganglia, potentially similar to our patient's lesion profile.

The patient had a relatively focal lesion involving the right basal ganglia and subcortical areas in the right inferior frontal lobe. In particular, the patient's lesion was centered at the striatum, which has functional connectivity with the orbitofrontal cortex, cingulate cortex, thalamus, precuneus, insula, inferior parietal areas,

and various key regions in the frontal and temporal cortices (Di Martino et al., 2008). Thus, the basal ganglia subserves a wide range of functions, including motor, cognitive, motivational, and emotional processes. For spatial cognition, the basal ganglia is critical to sensorimotor integration and plays a key role in attention-related networks (Baldassarre et al., 2014). Basal ganglia lesions are associated with motor-related symptoms of spatial neglect such as directional hypokinesia and spatial aiming impairment (Chaudhari, Pigott, and Barrett, 2015; Heilman, 2004; Sapir, Kaplan, He, and Corbetta, 2007). Many individuals with spatial neglect after focal basal ganglia lesions have abnormal blood flow in cortical areas that are structurally intact, and lesions in these cortical areas are often associated with spatial neglect (Hillis et al., 2005; Karnath et al., 2005). Thus, due to cortico-subcortical dysfunction, the patient may have had impairment in recruiting and allocating resources to integrate vestibular, proprioceptive and visual input, which converge for encoding higher order spatial representations and for adjusting body position relative to external space (Karnath and Dieterich, 2006). Unfortunately, we do not have information indicating the integrity of the patient's functional or structural connectivity among lesioned and intact brain regions.

Clinical implications and limitations

Clinically, eliminating visual stimulation may help individuals with postural symptoms of spatial neglect participate more in therapy, as described in the patient's clinical notes. Many therapy activities and tasks require an individual to sit-up straight and face forward. With the posture centered, therapy is delivered more effectively even for short periods of time (<10 minutes). However, vision is required in many therapy activities and daily function, which limits the use of binocular occlusion as an assistive intervention for task-specific treatments. Although the patient did not exhibit any adverse reactions to this intervention, the negative impact of this treatment is not known. Needless to say, further research is necessary to investigate the safety and feasibility of integrating binocular occlusion into rehabilitative approaches for treating individuals with spatial neglect. If safety and efficacy can be determined, this simple, non-pharmacologic intervention presents a potential opportunity for enhancing intervention strategies for similar patients demonstrating spatial neglect.

The process of identifying the deficits and potential interventions during the case report highlights the importance of inter-disciplinary collaboration involving clinicians and researchers. Experienced clinicians often

find innovative ways to address impairment that is relatively rare or hard to treat, and their innovation can be expanded or enhanced after consulting with researchers whose skill set and expertise often provide depth and methodology to investigating a clinical question. Importantly, support from clinical leadership facilitates such collaborations. In the present case report, the attending physician and the clinical research coordinator played a crucial role cultivating the collaborative environment, facilitating communications with the patient and her family member, and encouraging problem-solving ideas from all disciplines.

Conclusions

The present case report demonstrated that eliminating visual stimulation, through binocular occlusion, reduced symptoms of postural asymmetry related to spatial neglect for this particular patient. The observation suggests the possibility that the patient's predominate abnormality came from an impairment in visual information processing. However, it is unknown why visual input was so detrimental to her postural control. The results warrant further research and exploration in clinical applicability.

Acknowledgments

We thank Tiffany DeVito and Katherine DeTata for data collection and data organization.

Declaration of interest

The authors declare no conflict of interest.

ORCID

Peii Chen  <http://orcid.org/0000-0002-6724-7046>
Irene Ward  <http://orcid.org/0000-0002-5056-9399>

References

- Adair JC, Barrett AM 2008 Spatial neglect: Clinical and neuroscience review: A wealth of information on the poverty of spatial attention. *Annals of the New York Academy of Sciences* 1142: 21–43
- Anderson B 1993 Spared awareness for the left side of internal visual images in patients with left-sided extrapersonal neglect. *Neurology* 43: 213–216
- Azouvi P 1996 Functional consequences and awareness of unilateral neglect: Study of an evaluation scale. *Neuropsychological Rehabilitation* 6: 133–150
- Baccini M, Paci M, Nannetti L, Biricolti C, Rinaldi LA 2008 Scale for contraversive pushing: Cutoff scores for diagnosing “pusher behavior” and construct validity. *Physical Therapy* 88: 947–955
- Baldassarre A, Ramsey L, Hacker CL, Callejas A, Astafiev SV, Metcalf NV, Zinn K, Rengachary J, Snyder AZ, Carter AR, et al. 2014 Large-scale changes in network interactions as a physiological signature of spatial neglect. *Brain* 137: 3267–3283
- Baylis G, Simon SL, Baylis LL, Rorden C 2002 Visual extinction with double simultaneous stimulation: What is simultaneous? *Neuropsychologia* 40: 1027–1034
- Chaudhari A, Pigott K, Barrett AM 2015 Midline body actions and leftward spatial “aiming” in patients with spatial neglect. *Frontiers in Human Neuroscience* 9: 393
- Chen P, Chen CC, Hreha K, Goedert KM, Barrett AM 2015 Kessler Foundation Neglect Assessment Process uniquely measures spatial neglect during activities of daily living. *Archives of Physical Medicine and Rehabilitation* 96: 869–876
- Chen P, Hreha K 2015 KF-NAP 2015 Manual <https://www.kflearn.org/courses/kf-nap-2015-manuals>
- Chen P, Hreha K, Fortis P, Goedert KM, Barrett AM 2012 Functional assessment of spatial neglect: A review of the Catherine Bergego Scale and an introduction of the Kessler Foundation Neglect Assessment Process. *Topics in Stroke Rehabilitation* 19: 423–435
- Chokron S, Colliot P, Bartolomeo P 2004 The role of vision in spatial representation. *Cortex* 40: 281–290
- Corbetta M, Shulman GL 2011 Spatial neglect and attention networks. *Annual Review of Neuroscience* 34: 569–599
- Di Martino A, Scheres A, Margulies DS, Kelly AM, Uddin LQ, Shehzad Z, Biswal B, Walters JR, Castellanos FX, Milham MP 2008 Functional connectivity of human striatum: A resting state fMRI study. *Cerebral Cortex* 18: 2735–2747
- Di Pellegrino G 1995 Clock-drawing in a case of left visuospatial neglect: A deficit of disengagement? *Neuropsychologia* 33: 353–358
- Fruhmann-Berger M, Karnath HO 2005 Spontaneous eye and head position in patients with spatial neglect. *Journal of Neurology* 252: 1194–1200
- Fruhmann-Berger M, Pross RD, Ilg U, Karnath HO 2006 Deviation of eyes and head in acute cerebral stroke. *BMC Neurology* 6: 23
- Granger CV, Hamilton BB, Linacre JM, Heinemann AW, Wright BD 1993 Performance profiles of the functional independence measure. *American Journal of Physical Medicine and Rehabilitation* 72: 84–89
- Gutschalk A, Dykstra A 2015 Auditory neglect and related disorders. *Handbook of Clinical Neurology* 129: 557–571
- Heilman KM 2004 Intentional neglect. *Frontiers in Bioscience* 9: 694–705
- Heilman KM, Bowers D, Watson RT 1983 Performance on hemispacial pointing task by patients with neglect syndrome. *Neurology* 33: 661–664
- Heilman KM, Watson RT, Valenstein E 2012 Neglect and related disorders. In: Heilman KM, Valenstein E (Eds) *Clinical Neuropsychology* 5th, pp. 296–348. New York: Oxford University
- Hillis AE, Newhart M, Heidler J, Barker PB, Herskovits EH, Degaonkar M 2005 Anatomy of spatial attention: Insights from perfusion imaging and hemispacial neglect in acute stroke. *Journal of Neuroscience* 25: 3161–3167

- Karnath HO, Dieterich M 2006 Spatial neglect: A vestibular disorder? *Brain* 129: 293–305
- Karnath HO, Ferber S, Dichgans J 2000 The origin of contraversive pushing: Evidence for a second graviceptive system in humans. *Neurology* 55: 1298–1304
- Karnath HO, Zopf R, Johannsen L, Berger MF, Nagele T, Klose U 2005 Normalized perfusion MRI to identify common areas of dysfunction: Patients with basal ganglia neglect. *Brain* 128: 2462–2469
- Kinsbourne M 1987 Mechanisms of hemispheric interactions in man. In: Jeannerod M (Ed) *Neurophysiological and Neuropsychological Aspects of Spatial Neglect*, New York: North Holland
- Linacre JM, Heinemann AW, Wright BD, Granger CV, Hamilton BB 1994 The structure and stability of the Functional Independence Measure. *Archives of Physical Medicine and Rehabilitation* 75: 127–132
- Mark VW, Kooistra CA, Heilman KM 1988 Hemispacial neglect affected by non-neglected stimuli. *Neurology* 38: 1207–1211
- Mesulam MM 1999 Spatial attention and neglect: Parietal, frontal and cingulate contributions to the mental representation and attentional targeting of salient extrapersonal events. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences* 354: 1325–1346
- Morrow LA, Ratcliff G 1988 The disengagement of covert attention and the neglect syndrome. *Psychobiology* 16: 261–269
- Nijboer TC, Ten Brink AF, van der Stoep N, Visser-Meily JM 2014 Neglecting posture: Differences in balance impairments between peripersonal and extrapersonal neglect. *Neuroreport* 25: 1381–1385
- Ogourtsova T, Archambault P, Lamontagne A 2015 Impact of post-stroke unilateral spatial neglect on goal-directed arm movements: Systematic literature review. *Topics in Stroke Rehabilitation* 22: 397–428
- Peterka RJ 2000 Postural control model interpretation of stabilogram diffusion analysis. *Biological Cybernetics* 82: 335–343
- Ramsey LE, Siegel JS, Lang CE, Strube M, Shulman GL, Corbetta M 2017 Behavioural clusters and predictors of performance during recovery from stroke. *Nature Human Behaviour* 1: 0038
- Rengachary J, He BJ, Shulman GL, Corbetta M 2011 A behavioral analysis of spatial neglect and its recovery after stroke. *Frontiers in Human Neuroscience* 5: 29
- Rousseaux M, Sauer A, Saj A, Bernati T, Honore J 2013 Mislocalization of tactile stimuli applied to the trunk in spatial neglect. *Cortex* 49: 2607–2615
- Salvato G, Sedda A, Bottini G 2014 In search of the disappeared half of it: 35 years of studies on representational neglect. *Neuropsychology* 28: 706–716
- Sapir A, Kaplan JB, He BJ, Corbetta M 2007 Anatomical correlates of directional hypokinesia in patients with hemispacial neglect. *Journal of Neuroscience* 27: 4045–4051
- Schnider A, Durbec VB, Ptak R 2011 Absence of visual feedback abolishes expression of hemispacial neglect in self-guided spatial completion. *Journal of Neurology Neurosurgery and Psychiatry* 82: 1279–1282
- Smith DV, Clithero JA, Rorden C, Karnath HO 2013 Decoding the anatomical network of spatial attention. *Proceedings of the National Academy of Sciences of the United States of America* 110: 1518–1523.
- Umarova RM, Beume L, Reiser M, Kaller CP, Kloppel S, Mader I, Glauche V, Kiselev VG, Catani M, Weiller C 2017 Distinct white matter alterations following severe stroke: Longitudinal DTI study in neglect. *Neurology* 88: 1546–1555
- Vallar G, Rusconi ML, Geminiani G, Berti A, Cappa SF 1991 Visual and nonvisual neglect after unilateral brain lesions: Modulation by visual input. *International Journal of Neuroscience* 61: 229–239
- Winstein CJ, Stein J, Arena R, Bates B, Cherney LR, Cramer SC, Deruyter H, Eng JJ, Fisher B, Harver RL et al. 2016 American Heart Association Stroke Council, Council on Cardiovascular and Stroke Nursing, Council on Clinical Cardiology, and Council on Quality of Care and Outcomes Research 2016 guidelines for adult stroke rehabilitation and recovery: A guideline for healthcare professionals from the American Heart Association/American Stroke Association. *Stroke* 47: e98–e169
- Woollacott M, Shumway-Cook A 2002 Attention and the control of posture and gait: A review of an emerging area of research. *Gait and Posture* 16: 1–14