Neuropsychologia 49 (2011) 2090–2096

Contents lists available at ScienceDirect

Neuropsychologia

journal homepage: www.elsevier.com/locate/neuropsychologia

Shifting attention in viewer- and object-based reference frames after unilateral brain injury

Alexandra List[a,b,1], Ayelet N. Landau[a,b,1], Joseph L. Brooks[a,b], Anastasia V. Flevaris[a,b], Francesca C. Fortenbaugh[a,b], Michael Esterman[a,b], Thomas M. Van Vleet[a], Alice R. Albrecht[a,b], Bryan D. Alvarez[a,b], Lynn C. Robertson[a,b], Krista Schendel[a,*]

[a] *Department of Veterans Affairs Northern California Health Care System, Martinez, CA, USA*
[b] *Department of Psychology, University of California, Berkeley, USA*

ARTICLE INFO

Article history:
Received 8 October 2010
Received in revised form 31 March 2011
Accepted 4 April 2011
Available online 9 April 2011

Keywords:
Attention
Space
Objects
Neglect
Reference frames
Brain injury

ABSTRACT

The aims of the present study were to investigate the respective roles that object- and viewer-based reference frames play in reorienting visual attention, and to assess their influence after unilateral brain injury. To do so, we studied 16 right hemisphere injured (RHI) and 13 left hemisphere injured (LHI) patients. We used a cueing design that manipulates the location of cues and targets relative to a display comprised of two rectangles (i.e., objects). Unlike previous studies with patients, we presented all cues at midline rather than in the left or right visual fields. Thus, in the critical conditions in which targets were presented laterally, reorienting of attention was always from a midline cue. Performance was measured for lateralized target detection as a function of viewer-based (contra- and ipsilesional sides) and object-based (requiring reorienting within or between objects) reference frames. As expected, contralesional detection was slower than ipsilesional detection for the patients. More importantly, objects influenced target detection differently in the contralesional and ipsilesional fields. Contralesionally, reorienting to a target within the cued object took longer than reorienting to a target in the same location but in the uncued object. This finding is consistent with object-based neglect. Ipsilesionally, the means were in the opposite direction. Furthermore, no significant difference was found in object-based influences between the patient groups (RHI vs. LHI). These findings are discussed in the context of reference frames used in reorienting attention for target detection.

Published by Elsevier Ltd.

1. Introduction

A common problem following unilateral brain injury is an inability to orient or attend to items appearing on the contralesional side of space (Driver & Vuilleumier, 2001; Halligan & Marshall, 1998; Heilman & Valenstein, 1979; Rafal, 1994). Such contralesional deficits in attention are clinically referred to as unilateral neglect and are most flagrant immediately following brain injury. However, sensitive tests can reveal persisting contralesional deficits in attention many months or even years after neurological insult (Deouell, Sacher & Soroker, 2005; List et al., 2008; Rengachary, d'Avossa, Sapir, Shulman, & Corbetta, 2009; Schendel & Robertson, 2002).

Interestingly, neglect can occur in a variety of spatial reference frames. For instance, in viewer-based reference frames, awareness of stimuli on the contralesional side of the trunk, head and/or eye midline is impaired compared to stimuli on the ipsilesional side (e.g., Behrmann, Ghiselli-Crippa, Sweeney, Di Matteo & Kass, 2002; Bisiach, Capitani & Porta, 1985; Karnath, Schenkel & Fischer, 1991). Viewer-based neglect has been dissociated from neglect in other reference frames, such as neglect defined by the gravitational environment (e.g., Calvanio, Petrone & Levine, 1987; Ladavas, 1987) or, most relevant to the current study, objects (e.g., Baylis, Baylis & Gore, 2004; Behrmann & Tipper, 1999; Driver, Baylis, Goodrich & Rafal, 1994; Driver & Halligan, 1991; Gainotti, Messerli & Tissot, 1972; Marshall & Halligan, 1993a, 1993b; McGlinchey-Berroth

* Corresponding author at: Department of Veterans Affairs NCHCS, 150 Muir Road, Building R4, Martinez, CA 94553, USA. Tel.: +1 925 372 2513; fax: +1 925 372 2561.
E-mail address: schendelk@gmail.com (K. Schendel).

[1] The first two authors contributed equally in the research and manuscript preparation, and their order of authorship was determined by coin flip.

Lynn C. Robertson, Krista Schendel, and Thomas M. Van Vleet have VA appointments in VA Clinical Sciences Research Service, Department of Veterans Affairs Medical Center, Martinez, CA. Lynn C. Robertson is a Senior Research Career Scientist, Thomas M. Van Vleet is a Clinical Neuropsychologist and Krista Schendel is a Health Science Research Specialist. All other authors were, at the time, part of the research staff at the institutions designated by the author affiliations.

Alexandra List is now at the Department of Psychology, Northwestern University. Ayelet N. Landau is now at the Ernst Strüngmann Institute in Cooperation with Max Planck Society, Frankfurt (Germany). Joseph L. Brooks is now at the Institute of Cognitive Neuroscience, University College London (UK). Anastasia V. Flevaris is now at the Department of Neuroscience, UCSD. Michael Esterman is now at the Boston VA Healthcare System. Alice R. Albrecht is now at the Department of Psychology, Yale University.

0028-3932/$ – see front matter. Published by Elsevier Ltd.
doi:10.1016/j.neuropsychologia.2011.04.003

et al., 1996; Tipper & Behrmann, 1996). Neglect can manifest in objects with canonical orientations, like a clockface (Marshall & Halligan, 1993a), or when objects are aligned such that they appear to "point" in a particular direction (Driver et al., 1994). In such cases, the part of the stimulus that is neglected is defined by the principal axes, or assumed upright orientations of the objects, as opposed to their positions in viewer-based space. For example, the contralesional side of an object could be neglected whether it is presented contralesionally or ipsilesionally in viewer-based coordinates. This class of impairments is referred to as object-based neglect because the reference frame for neglect is centered on the space defined within the object.

Object-based modulations of attention have also been demonstrated in healthy individuals. For example, a classic study by Duncan (1984) demonstrated that reporting two features from one object was superior to reporting two features from two different (albeit spatially overlapping) objects. Another hallmark study revealing the influence of objects on attention was introduced by Egly, Driver and Rafal (1994) using a variant of a standard cueing method (Posner, 1980). In Egly et al.'s study, two parallel rectangles (objects) were presented on either side of a fixation (either horizontally- or vertically-oriented). On each trial one end of one of the rectangles was cued followed by a target either at the cued location, at the opposite end of the cued object, or at an equidistant position in the uncued object. In addition to faster response times (RTs) to targets at cued positions, RTs to targets at uncued positions were faster when the target appeared within the cued object than when it appeared within the uncued object.

In addition to the seminal observation that objects affect the distribution of spatial attention in healthy individuals, Egly, Driver et al. (1994) used the same approach to examine object-based attention in patients with posterior parietal injury. They found a normal pattern of object-based orienting in a group of eight right hemisphere injured (RHI) patients, but abnormal object-based orienting in a group of five left hemisphere injured (LHI) patients. LHI patients showed an abnormally large object-based effect contralesionally (in the right visual field; VF), and no object-based effect ipsilesionally (in the left VF). Their results were supported by data from a split-brain patient (Egly, Rafal, Driver & Starrveveld, 1994), who showed normal object-based orienting effects in the right VF, which were absent in the left VF. Together, the studies suggest that intact left posterior parietal areas are necessary for typical patterns of object-based orienting to emerge.

As noted above, lateralized information is asymmetrically processed by unilaterally-brain injured individuals. If cues are used to manipulate attention, then presenting cues at lateralized positions may result in disparate effectiveness of the attentional manipulation in each visual field (e.g., Vivas, Humphreys & Fuentes, 2006). When presented with lateralized cues, patients may be less, or less often, aware of a cue's presence, or even when aware, may be unable to fully use its predictive value when presented in the contralesional visual field. Contributing even further to this processing asymmetry is the tendency for neglect patients to be hyperattentive to the ipsilesional side of space (i.e., disengage deficit; Losier & Klein, 2001; Olk, Hildebrandt & Kingstone, 2010; Posner, Walker, Friedrich & Rafal, 1987; Rastelli, Funes, Lupiañez, Duret & Bartolomeo, 2008). It is therefore likely that the findings of Egly, Driver et al. (1994) reflect the contributions of both asymmetric cue and asymmetric target processing deficits. In the present study, we re-examined the influence of object- and viewer-based reference frames on attention using a design that presented cues at midline, a relatively unaffected position. Adopting this approach enabled a more transparent measure of the influence of object- and viewer-based reference frames on shifts of attention after unilateral brain injury.

2. Experimental

2.1. Methods

2.1.1. Participants

This study had IRB approval from both VA NCHCS as well as the Committee for Protection of Human Subjects at the University of California Berkeley. Twenty-nine patients were recruited from the Bay Area, CA community (details reported in Table 1). All patients were at least three months post injury at the time of testing (average delay median = 2.01, mean = 2.38, *SD* = 1.86 years). All provided informed consent prior to participation and were financially compensated $12/h for their participation. Inclusion criteria were: Single unilateral lesion, full visual fields in both eyes (tested via confrontation), and willingness to volunteer. Exclusion criteria were: Recent history of substance abuse (within three years), co-existing neurological diseases, and need for an English language interpreter. Thirteen patients had LHI and sixteen patients had RHI (Fig. 1 shows the lesion overlap from 21 patients in whom brain scans were available). The LHI and RHI patient groups did not differ in age, lesion volume,[2] delay since injury or gender.

2.1.2. Apparatus

Presentation software (NeuroBehavioral Systems, www.neurobs.com) was used to present stimuli and record responses. Patients were given a mouse for responses, and experimenters used an external keypad for input.

Visual stimuli were presented on a 21 × 33 cm laptop LCD screen. The refresh rate was 60 Hz and a resolution of 1280 × 768 × 32 was used. Sounds were presented through the laptop speakers.

2.1.3. Stimuli

Fig. 2 illustrates the visual stimuli used. All stimuli were displayed on a light gray background, and all line widths were fixed at 0.2°. The central fixation consisted of two intersecting perpendicular 0.4° black lines, oriented vertically and horizontally. Two rectangles were oriented obliquely at ±45° from vertical, equally distanced from fixation (similar to Jordan & Tipper, 1999). The outer edges of the rectangles were 9.1° apart. Each middle gray rectangle outline was 2.4° × 9.1°. Black 45°-rotated square outlines subtending 2.6° × 2.6° served as cues. Cues outlined the rectangle ends. Cues were presented only on the vertical meridian, centered 4.7° above or below fixation (center-to-center), always centered at the end of one of the two rectangles. Filled blue 1.6° × 1.6° 45°-rotated square targets were presented centered at either end of either rectangle, ±4.7° vertically or horizontally from fixation (center-to-center). Targets were positioned within the rectangle boundaries. All targets and cues were equidistant from fixation, and all lateralized targets were equidistant from the cues.

The 500-ms alerting beep was a 700-Hz tone, which ramped on and off over 20 ms, presented at approximately 60 dB SPL.

2.1.4. Procedure

All patients were seated approximately 60 cm from the screen with their vertical body midline aligned to the vertical midline of the screen. Patients responded by pressing the left mouse button using their dominant hand.

At the beginning of the experiment, instructions were presented on the monitor, which the experimenter read aloud. Patients were asked to fixate the center of the screen. They were informed that a black cue would indicate the most likely position of the target. They were instructed to respond as quickly as possible when they detected a blue target, regardless of where the target appeared and to withhold responses when no target appeared. The experimenter then demonstrated two sample trials (one cued and one uncued trial, described below), indicating the fixation, the cue and the target. When it was clear that the patient understood the instructions, the experimenter began the 24-trial practice block. Four experimental blocks followed, each with 120 randomized trials. Patients were given breaks between blocks.

Trials began with a 500-ms alerting beep. After 100 ms of auditory stimulation, the fixation display (the fixation and two rectangles) was presented for 600 ms. A cue was then presented for 100 ms. After another 500 ms of the fixation display, on target-present trials, a target appeared for 130 ms. Patients were given up to 1880 ms to respond. Responses or timeouts ended the trial. An 800-ms blank and silent inter-trial interval elapsed between trials (Fig. 2).

During the experiment, the experimenter monitored patients' eye position for fixation. If an eye movement away from the fixation was detected, the experimenter marked the trial with a key press (to be discarded from analysis).

2.1.5. Design

The factors that were manipulated included cue position (top, bottom), target position (top, bottom, left, right, none), and rectangle orientation (±45° from vertical). Target conditions were coded relative to the cue preceding it (Fig. 2, inset). Of the target-present trials, 64% were presented at the cued position. The remaining

[2] For those 21 patients in whom we do have lesion volume estimates, no volume difference was found between LHI and RHI patients, $|t|(19) < 1$.