Line Bisection and Visual Orienting Within and Beyond Arm's Reach In Patients with Visuospatial Neglect.

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List of Signs, Symbols and Abbreviations (Abb.)

Sign/Symbol/Abb.	Meaning
%	Percent
95% CI	95% Confidence Interval
B	Bisection Bias
c	caudate nucleus
cd/m^2	candle-meter squared (luminosity)
cm	centimeter
CT-	negative CT scan
D	Disengage Operation Deficit
f	female
F	Frontal lobe
FA	False Alarm
HD	Hemifield Deficit
Hz	hertz
m	male
ME	Main Effect
ms	milliseconds
n	neutral
na	not applicable
N(+)	Manifesting signs of Visuospatial Neglect
N(-)	Not manifesting signs of Visuospatial Neglect
O	Occipital lobe
P	Parietal lobe
r	Pearson Correlation Product
RT	Reaction Time
sd	standard deviation
sec.	seconds
SOA	Stimulus Onset Asynchrony
T	Temporal lobe
th	thalamus
v	valid
VFD	Visual Field Defect
wm	white matter

Abstract

Line bisection and covert orienting were explored in patients with neglect using stimuli presented within (peripersonal space) and beyond (extrapersonal space) arm's reach. METHODS: Forty-three young subjects, 9 older subjects and 13 individuals with right-hemisphere damage, seven of whom were classified as showing left neglect, participated in the study. In one task, subjects used a hand-held device to remotely bisect computer-generated horizontally and vertically oriented lines that were placed centrally or away from center (above, below, center for horizontal lines; to the left, right of center for vertical lines). To direct the subject's attention, the bisecting cursor that was controlled by the subject was initially presented near the center of the line or towards one or the other end. In a second task, subjects detected the presentation of a target presented in one of 4 quadrants (top left; top right; bottom left; bottom right) following informative peripheral cues designed to elicit covert orienting of visual attention. All stimuli were presented at distances of 28 cm (peripersonal space) and 224 (extrapersonal space) cm. RESULTS: Line Bisection In patients with neglect a significant rightward bias (i.e., >10%) on horizontal lines was noted, as expected. Interestingly, cuing the left end of the horizontal line significantly reduced the rightward bias to near normal level, while cuing the middle or right end of the line resulted in the expected significant rightward deviations. In contrast, vertical lines yielded a non-significant downward bias and the bisection cursor starting position did not significantly alter the bias. Viewing distances did not significantly alter bisection biases for either horizontal or vertical lines. In normal controls, the bisecting cursor significantly altered the bias in the direction of its initial starting position on both horizontal (left-right ends of lines) and vertical lines (top-bottom ends of lines). As well, a viewing distance by line location interaction was obtained for horizontal lines only. The direction of the bias differed significantly between lines displayed above and below eye levels in peripersonal space, but it did not in extrapersonal space. Visual Orienting All groups responded more rapidly to targets presented at the cued location (valid cuing condition) than to targets at uncued locations (invalid cuing condition). Patients with neglect manifested a disengage deficit between hemifields, as expected, wherein the reaction time delay on an invalid trial was much greater for targets presented in the neglected hemifield following cues in the non-neglected hemifield, than vice versa. However, evidence of a within field disengage deficit in the contralesional hemifield was not substantiated here. Moreover, following the presentation of a cue within the contralesional hemifield, patients with or without neglect responded equally quickly to poor field targets at the cued and uncued locations. Viewing distance did not alter the manifestation of the disengage deficit pattern in patients with neglect. In normal controls, detection of the cued target was fastest to the lower field in peripersonal space than at any other location or viewing distance. Finally, a correlational analysis performed on the entire sample of patients with right-hemisphere damage suggested a relationship between rightward deviations on line bisection and the disengage. Conclusion: The outcome of these studies provides partial support of Previc's (1990) model of upper and lower visual field specialization.

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cheers,

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PART 1: VISUOSPATIAL NEGLECT - BACKGROUND

A common neurological concomitant of posterior right-hemisphere lesions is visuospatial neglect. Visuospatial neglect's cardinal feature is an impaired ability to attend to events occurring on the contralateral side of the body or space (Brain, 1941; Roth 1949; Denny-Brown et al, 1952; Critchley, 1953; Hecean et al, 1956). This inability to attend to contralateral stimuli has been noted following left-hemisphere parietal lesions (Denny-Brown & Banker, 1954) as well, but it is reportedly both less frequent and severe (see Ogden, 1985). Bisiach, Luzzatti and Perani (1979) and Bisiach, Capitani, Luzzatti, and Perani (1981) found that the right temporo-parieto-occipital junction was the region most frequently affected in patients exhibiting neglect (for review see Vallar and Perani, 1987). While the most frequent anatomical correlate of neglect is the inferior parietal region of the right-hemisphere, neglect has also been reported following either right anterior (pre-Rolandic) damage (see Vallar and Perani, 1987; p.238), left anterior (Damasio et al, 1980), or thalamic (Watson and Heilman, 1981) damage, as well as with lesions of the basal ganglia (Healton et al, 1982) or white matter (Masson et al, 1983; Cambier et al, 1983) involvement has also been reported. Neglect can be defined as a syndrome in which damage to several cortical and sub-cortical areas results in a processing impairment of events or stimuli occurring in space (see Mesulam, 1981, 1990 for review).

If the patient is approached from the left side and addressed from that side, he or she may either not respond at all or else react to the query by orienting incorrectly to the right side (i.e., visual allesthesia). Other examples of behavioral manifestations of neglect include grooming only the right half of the body, eating food only on the right-side of the plate and moving along a trajectory, such as an arc, that implies a strong rightward bias (Heilman, 1995). Individuals with neglect behave as if only the right half of the world exists (Grusser, 1982). The previous examples described some of the *visual* deficits that accompany visuospatial neglect; however, in addition, neglect may be expressed in other modalities such as touch or vibration (somatic neglect). Somatic neglect often includes various forms of awareness deficit, such as denying upper limb paralysis (i.e., anosagnosia). In some cases, the individual firmly believes that the paralysis of the contralesional limb is the consequence of an undue heaviness of a third overlying limb (sometimes described as a phantom limb). Moreover, the patient may be convinced that the additional weight bearing limb belongs to someone else, or even that the phantom limb may have been resected from a cadaver and attached to their body (personal communication Dr. S. E. Black). The validity or plausibility of such a procedure is neither questioned nor challenged by the patient. If the lesion includes parts of the adjacent temporal lobe, neglect may also be observed in the auditory domain (Heilman & Valenstein, 1972). Similarly, in motor functions, patients with neglect may be impaired in the initiation of movements towards the left half of space (Heilman et al, 1979). The inability to move towards the contralesional side is not due to a deterioration of muscle power, since both limbs are affected. Heilman and colleagues have suggested that this type of neglect may be described as an intentional deficit, rather than a perceptual/attentional deficit. Thus, damage to various cortical areas and related system(s) results in a pattern of behavioral deficits specific to the affected attentional processes (for reviews see Mesulam, 1981, 1990).

As decades of research have shown (e.g., Holmes, 1903, Brain, 1941), visuospatial neglect cannot be conceived as an all-or-nothing phenomenon. A diagnosis is commonly based on a variety of standard tests. The most common of these involve tasks in which patients cancel out letters or symbols, bisect lines, or read words, sentences or short paragraphs. Also, patients may be asked to draw a figure from a model or memory; one of the most commonly depicted (and cited) exemplars is copying a daisy (Heilman, 1979). Almost invariably patients with neglect copy the right side of the daisy (egocentric frame of reference), but fail to draw part or all of the left side of the flower. Asymmetry in the patient's performance between left and right halves of space (i.e., misidentification or cancellation of the left part of the stimulus or array of stimuli) is taken as evidence of left-sided neglect. In more recent times much emphasis has been placed on the possibility that neglect may also be expressed in varying degrees of severity (i.e., mild, moderate and severe neglect), as clinical experience and the literature on neglect suggest that impairments may be manifested in different modalities or levels of severity (Pizzamiglio et al, 1992). Although no single task has achieved universal acceptance for measurement of the severity of neglect, such measures as the number of omissions on cancellation tasks, the magnitude of the rightward deviation on line bisection, and/or the number of tasks on which neglect is manifested have been used to assess the degree of impairment.

It is now well established that neglect can be distinghished from simple sensory and motor deficits, as classical behaviors associated with this condition are dissociable from sensori-motor deficits (Halligan et al, 1990) or cannot be explained by them. As argued by Mesulam (1985), the lack of awareness of stimulation in a particular spatial sector (i.e., left-hemispace) does not translate directly in manual exploration, searching or seeing impairments. Most researchers' views of neglect reach beyond the earlier models of sensory (e.g., Sensory Defect Hypothesis; Denny-Brown et al, 1952) and motor (Defective Exploration Hypothesis; Schott et al, 1966) impairments, although their contributions were seminal in establishing contemporary theories of neglect. Currently, two main streams predominate. One theory emphasizes impairments in attention as a failure in arousal or distribution of attention, while the other attributes impairments of neglect to faulty representation of stimuli (or space). The above mentioned models of neglect are described briefly below.

Cognitive Models of Neglect

Kinsbourne (1970, 1987) proposed that the cerebral hemispheres shared the control of directed attention to extra-corporal space. He elaborated on this assumption by suggesting that, like head and eye movements, attentional shifts were guided to the left- or right-hemispace by the contra-lateral hemisphere. Under these conditions, Kinsbourne proposed that the allocation of attention in space is the result of a continuous competition between left-and right-hemispheres. For instance, he hypothesized that in patients with neglect, the contralateral attention bias of the intact hemisphere is no longer opposed by the damaged hemisphere, resulting in an exaggerated rightward bias. Thus, left neglect was proposed as a concomitant of the right-hemisphere's inability to counteract the left-hemisphere's rightward orienting tendency. Later, in an attempt to explain the differential incidence of left and right neglect, Kinsbourne (1974) revised his proposal by adding that the rightward orienting tendency of the left-hemisphere was considerably stronger than that of the right-hemisphere. Several studies, including Reuter-Lorenz et al (1990), have provided independent empirical evidence in support of his model.

Alternatively, Heilman and van den Abell (1980) suggested that allocation of attention was asymmetrically represented between the hemispheres, rather than the result of inter-hemispheric competition as proposed by Kinsbourne. Heilman and colleagues have proposed that the right-hemisphere is dominant in the deployment of directed attention and that directed attention can be dispensed from it in both the right and left halves of space. Additionally, according to these authors, this hemispheric specialization accounts for the greater incidence of left-sided neglect. Of note, in recent years with the advent of functional neuroimaging, Corbetta et al (1991), provided support for this model by demonstrating increased blood flow to the right parietal area following stimulation from either halves of space, while an increase in regional flow in the left parietal area occurred only after stimulation originating from the right half of space. Issues of laterality aside, both of these models hypothesized that attention is a central cognitive process which functions as a facilitatory mechanism to specific sensory or motor operations (Butter, 1987; Rizzolatti and Berti, 1990). Thus, according to this view, damage to attentional processes results in a pattern of behavioral deficits specific to the operations under investigation, left-sided neglect on cancellation or line bisection tasks.

In contrast to the attentional model of Heilman and Kinsbourne, Bisiach and colleagues (e.g., Bisiach et al, 1979; Bisiach & Berti, 1990) argued that the impairment observed in patients with neglect is neither the consequence of faulty perceptual nor attentional processes, but resides in a defective representation of the world (or object). In one clever study, Bisiach and colleagues demonstrated that neglect could be elicited in the absence of tangible stimuli. Two patients were asked to describe a familiar scene (i.e., Piazza del Duomo) from memory. Although they could describe accurately the right hand side of the scene, these individuals failed entirely to mention the left side of the scene, regardless of their point of reference. Also, Bisiach et al (1983) demonstrated that the magnitude of rightward bisection increased with the length of lines in a line bisection task, and they suggested that this varying deficit provided further support to their representational model. Other support for the model stemmed from a forced-choice experiment in which patients with neglect chose an intact stimulus (e.g., burning vs. non-burning house; broken vs. intact glass) over another without conscious awareness of the left side of the object (Bisiach & Rusconi, 1990; Marshall & Halligan, 1988), and from studies of the else described objects scanned through a vertical slit at midsagittal plane (Bisiach et al, 1979). Bisiach argued that neglect impaired the visual interaction of both right and left halves of a represented engram (whether visual or otherwise). As such, it is the transposition between the observed and the represented which is reportedly defective according to their model.

In addition to the attentionally or representationally based models, other conceptualizations of neglect exist. Heilman and colleagues have refined their position and suggested that neglect is a deficit in the initiation of movement towards the contralesional side (see Heilman et al 1995; Watson et al, 1978). These authors noted longer motoric reaction time to stimuli presented in the contralesional space and on that basis suggested that these individuals were not "unwilling" but "disinclined" to cross the midsagittal plane with their ipsilesional limb (i.e., right arm). This observation has been supported independently in other paradigms, including cancellation (e.g., Tegner & Lavender, 1991) and line bisection (Heilman et la, 1985) tasks, and also paradigms in which the motor and visual components of the tasks have been decoupled (e.g., Heilman et al, 1990).

However, other researchers, including Halligan and Marshall (1989) and more recently Mijovic (1991), have contested the validity of decoupling motor and visual domains.

Each of the aforementioned models implies that neglect is a unitary cognitive process, which is relegated to an anatomical locus (i.e. right-hemisphere) or cognitive domain (e.g., attentional, motor or representational). If this is the case, then it could be argued that interruption of that particular centre or system, whether directly or indirectly (i.e., diaschisis), would yield equivalent deficits. However, it is well documented that lesions occurring in different cortical or subcortical regions result in an assortment of attentional impairments distinct from simple sensory and motor deficits associated with that region, suggesting that none of the brain areas damaged are purely attentional but may be part of a distributed attentional system. Mesulam (1981, 1990) presented a model of a large scale network of the distribution of directed attention, a model which accounted for the diversity of impairments following damage to various cortical regions. In this model, neglect behavior is subdivided into perceptual, motor, and limbic components. This parceling of neglect behavior was based on a review of the animal and human literature, in which attentional deficits were found following damage in at least one of the following cortical and subcortical areas: dorso-lateral posterior parietal lobe, dorso-lateral pre-motor/pre-frontal cortex, cingulate gyrus, superior colliculus, thalamus, and/or basal ganglia. According to Mesulam, this multiplicity of neglect-causing lesions was not the reflection of chaotic or diffuse cerebral organization, but, instead, reflected the existence of a highly organized network. He argued that it was not necessary to have areas of the brain devoted singly to attentional mechanisms, but that attentional neurons intermixed with sensory or motor neurons could form attentional circuits.

Overall, these various models suggest that a precise understanding of visuospatial neglect necessitates the identification of the underlying processes whose disturbance leads to this disorder. As such, whether neglect reflects a disturbance in the allocation of directed attention in space independent of primary sensory or motor deficits (Heilman et al, 1985) or in the representation of stimulus or space, it would seem critical that the tasks or paradigm designed to study the impairment reflect the spatial aspect of the disorder. However, several limitations are inherent to the tasks utilized in the assessment of visuospatial neglect. Primarily, they provide information that is restricted to a narrow region of visual space, typically centered about 30 cm from the patient. Second, a paper and pencil format of the tasks is generally used, thereby introducing a potential confound of motor movement or initiation characteristics (i.e., measurement inaccuracies or inconsistencies). Finally, these tasks are typically presented on a table top. As such, they provide little information about the extent of the disorder from an ecological point of view. That is, visuospatial neglect is conceived as a spatial disorder, whereby patients have difficulty orienting or localizing objects in contralateral space. Space itself is not a unidimensional entity, but rather a complex three-dimensional construct. This aspect of the disorder is not captured in the current paper and pencil forms of assessment.

An Expanded View Of Visuospatial Neglect

The approach employed in this thesis sought to address the issue of ecological validity in the assessment of visuospatial neglect by expansion of the dimensions in visual space along which it is measured. In addition to the traditional measurement of visuospatial neglect in the horizontal plane (i.e., azimuth), measurements were made in both the vertical plane as well as in depth. As such, these additional tests allow for the possibility that the deficits may vary in different dimensions of visual space with the implication that these dimensions are represented separately in the brain or else involve different mechanisms that are affected to varying extents by the lesion. Only recently have efforts been directed towards a better understanding of the extent of neglect in three-dimensional space. These studies are discussed further in Part 3: Line Bisection. Most have lacked theoretical support to direct their empirical efforts to study of the deficits in three-dimensions. It should be noted that an equal, if not greater, impetus was generated in the primate literature. Brain (1941) was the first to emphasize the importance of attention directed within the "grasping space" region, a region that spans an area approximately 30-40 cm extending from and surrounding the body. Several decades later a small number of primate studies provided support for Brain's original supposition and an increasing amount of evidence suggests that distinct brain areas are implicated in the organization of behavior within and outside of grasping space (e.g., Mountcastle et al, 1975; Lynch et al, 1977; Sakata et al, 1985; Sakata et al, 1980). The evidence gathered has relied on the documentation of behavioral deficits following ablation of specific cortical areas, specifically the parietal and striate cortex (Pandya and Kupers, 1969; Jones et al, 1978: Matelli et al, 1986), or anterior structures such as the frontal eye fields and Area 6 (e.g., Rizzolatti et al, 1983), or else correlational studies that report increased neuronal activity in these same regions by use of electrophysiological methods (Leionen et al, 1979). In fact, Rizzolatti and colleagues (for review see Rizzolatti and Gallese, 1988) provided the first series of empirically driven research into different regions of space. Their efforts led to increased interest in mapping the characteristics of cortical areas responsible for the deployment of attention to various spatial sectors and the physiological characteristics of neurons in areas responsible for the behavior (e.g., Godschalk et al, 1981; Godschalk and Lemon, 1989; Gentilucci et al, 1983; Gentilucci et al, 1989; Lynch and McLaren, 1989). In parallel with these physiological studies, interest in developing a human equivalent model has increased in recent years (see below).

Models of Attention in Three-Dimensional Space

Several models of attention in three-dimensional space exist. Earlier researchers defined space in term of movements, as in the case of Grusser (1983; also see Jeannerod, 1988 and Paillard, 1982). In recent times, more sophisticated models like that of Cutting and Vishton (1995) defined space along a three-tiered continuum of personal (within 2 m), action (up to 30 m) and vista (furthest distance resolved by the viewer) components. The latest model proposed by Previc (Previc, in press) suggests that, although space is primarily partitioned into the realms of peripersonal (within arm's reach) and extrapersonal (outside arm's reach) domains (Previc, 1990), the extrapersonal realm can be further subdivided into focal, action and ambient sections, each subserving specific perceptuo-motor functions. This notion is predicated on the fact that we generally view objects in relation to other objects, so objects which are closer to the horizon, and hence farther away, appear in our field of view to be above those which are closer to us.

From a neuropsychological perspective, Previc's (1990) model may be better suited to the development of a paradigm of visual attention in three dimensions for patients with visuospatial neglect. Previc posited that the specialization of upper and lower visual fields may be responsible for certain patterns of behavior in three-dimensional space. He further argued that ecological factors, such as enhanced visuo-manipulatory skills and increased visual effectiveness, led to this specialization of visual hemifields. Furthermore, because these evolutionary specializations involved disparate forms of behaviors, each visual field attended to visual information from different spatial sectors. The upper visual field attends to visual information from far distances or extrapersonal space, while the lower visual fields attends to visual information introduced near the body or peripersonal space.

In support of his upper visual field/extrapersonal and lower visual field/peripersonal dichotomy, Previc linked neurophysiological characteristics of the dorsal (parietal) and the ventral (temporal) visual system neurons to the visual processing capacity of the two hemifields. Previc suggested that the information processing characteristics of parietal neurons corresponded well with the visual control of reaching and other manipulations occurring in peripersonal space, while the information processing characteristics of temporal (inferotemporal) neurons correlated well with the search for and recognition of objects in extrapersonal space.

Assessment of Visuospatial Neglect in Three-Dimensional Space

Evidence from the human neuropsychological literature (see Part 3: Line Bisection;

Halligan & Marshall, 1991; Shelton et al, 1990; Mennemier et al, 1991) suggests that there may exist separate attentional "maps" specialized for near (i.e., peripersonal) and far (i.e., extrapersonal) space. However, in these studies the near and far spaces were defined as relative distances both falling within the peripersonal spatial dimension, as defined in this thesis. As a means to extend this line of research, this dissertation set out to investigate patterns of attentional biases in peripersonal and extrapersonal space as defined by Previc (1990).

The choice of measure is critical in highlighting the potential variation in peripersonal and extrapersonal space and its characteristics should be independent of the effects of the experimental manipulations. One such metric is the line bisection task. Line bisection is a paper and pencil test which was introduced by Axenfeld (1894) to assess spatial perceptual asymmetries in hemianopic patients. Over the past century, line bisection has gained popularity in the assessment of visuospatial neglect and indeed, most studies that have examined the performance of subjects to stimuli in near and far space have used line bisection (see Part 3 - Line Bisection for more details). There are a number of reasons for the choice of line bisection over other measures of neglect including the physical characteristics of lines which allow for both continual measurements and multiple orientations of the display. As well, the magnitude of the deficit can also be measured objectively over repeated presentations, because the length of the line can be varied, thereby preventing the subject from adopting a response set without affecting the nature of the task (Riddoch and Humphreys, 1983). Thus, by varying the line's orientation, position and length bisection deficits can be "mapped" reliably in three-dimensional space.

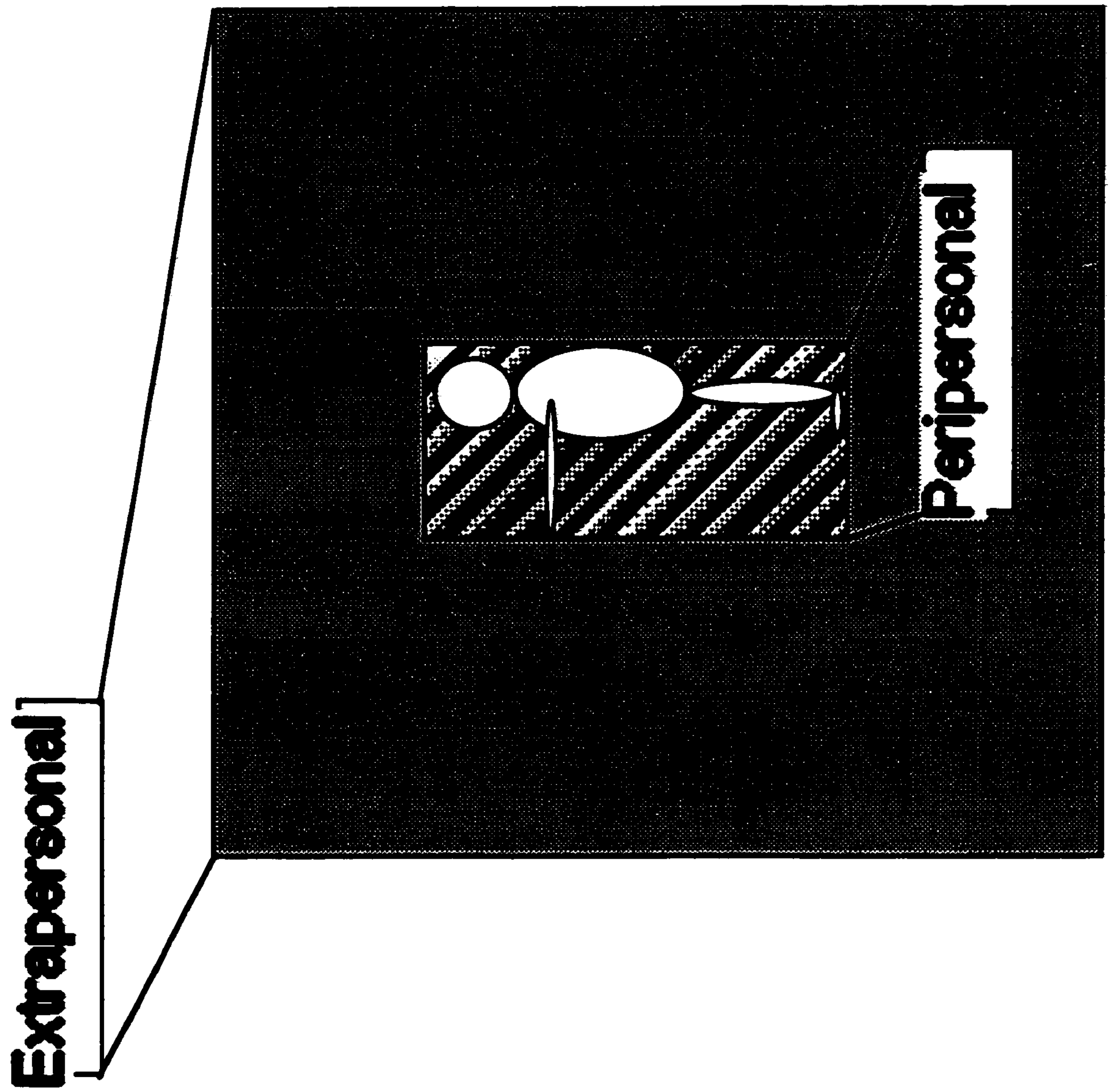

Figure 1
A schematic depiction of the peripersonal and extrapersonal Viewing distances.

A second task was proposed, namely, visual orienting (Posner et al ,1981), for the purpose of exploring possible cognitive mechanisms of line bisection deficits. One fundamental element of visual orienting is the selective character of directed attention. When we attend selectively to a location in space, the result is more efficient detection of stimuli occurring in the attended location. As such, orienting bears similar malleable characteristics to line bisection. That is, displays that are typically employed in orienting research can be modified to accommodate responses above and below eye level, to the left and right of the midsagittal plane, without compromising the task itself. In this regard, these two tasks, lend themselves well to between-task performance comparisons. In light of this connection, a third objective is proposed in the current study. This objective is based on the knowledge that patients with neglect display a distinct deficit on the orienting task: a disengage deficit, which translates into an increase in response latency to an invalidly cued target in the neglected half of space when compared to the non-neglected half of space. As such, I asked "Do the line bisection and visual orienting tasks share a common attentional component?".

PART 2: GENERAL EXPERIMENTAL METHODS

Subjects

Data were obtained from 65 subjects, 34 females and 31 males. The participants comprised three groups; patients with right-hemisphere[1] lesions, young and older normals.

Patients with Right-Hemisphere Damage: A total of 13 patients with right-hemisphere damage took part in the current experiment (See Appendix E for sketches of lesions). Six males and 7 females participated. The average age of male subjects was 61.5 years (sd 4.9; range 60-79), while that for the female subjects was 67.9 years (sd 7.3; range 55-82). Participants were recruited from stroke units at hospitals in the Halifax, Nova Scotia region. Because partial to complete recovery from visuospatial neglect occurs within a period of 6 months (Campbell and Oxbury, 1976; Hier et al, 1983), all patients were contacted within that post-stroke period.

Inclusion in the study was based on a single, right-hemisphere stroke, documented in 9/13 cases by Computerized Tomography (CT) scan or Magnetic Resonance Imaging (MRI). Although right-handedness was stressed, one left-handed individual, who met the inclusion criteria, was included. Volunteers were recruited if they were less than 85 years of age with optically-corrected visual acuity of 20/40 or above, and free from any of a documented history of psychiatric or neurologic (other than the presenting unilateral lesion) illnesses, an extended history (3+ years) of alcohol or narcotic abuse, severe verbal and written speech comprehension difficulties (i.e., global aphasics), and dementia.

Ethical approval was obtained from each hospital in which subjects were recruited. Patient participants were recruited retrospectively and prospectively. Several retrospective searches were performed with the approval of the Medical Records Department at the Victoria General Hospital (VGH) and the Nova Scotia Rehabilitation Centre (NSRC) to

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[1] The selection of patients with right-hemisphere damage was based on the following reasons; 1)-it is the site of damage most frequently reported for neglect and 2)-the possibility of language disturbance confounding (comprehension) the task is lessen in comparison to patients with left-hemisphere lesions to the temporo-parietal area.

search for the names of patients fulfilling the research criteria from the admissions' pool at various time between December 1994 to July 1995. This form of recruitment did not yield any participants. The prospective approach involved contacting staff physicians and medical residents from stroke units at the Victoria General Hospital (VGH), Nova Scotia Rehabilitation Centre (NSRC) and the Camp Hill Medical Centre (CHMC) regarding potential recruitment of research participants who fulfilled the research criteria.
Once identified, potential participants were contacted by the physician (or resident) responsible for their care while at the VGH, NSRC, or CHMC. The physician, through either verbal or written correspondence, solicited the patient's permission for the experimenter (BJWL) to contact them regarding the experiment. An initial informed consent was released to the attending physician by the patient, allowing the experimenter to contact him or her regarding potential participation in the study[2]. Following the contact process, participants were assessed for neglect and extinction (see Tables 1 & 2 below for details). This resulted in the division of the original sample into two groups, with one group of individuals that manifested signs of neglect or extinction, while those in the other group did not.

Young adults: A total of 43 individuals made up this group, which was comprised of 19 men and 24 women between the ages of 18 and 34 years. The majority of subjects were recruited from an introductory psychology class, five individuals were graduate students and two were close acquaintances of the experimenter. All subjects were naive to the purpose or aim of the studies. The average age for male and female subjects was respectively, 23.1 years (sd 3.7; range 18-26) and 23.8 years (sd 5.4; range 18-34). Informed consent was obtained from each subject; individuals enrolled in the introductory class received two credit points towards their final grade for their participation.

Older adults: Older adults were arbitrarily defined as individuals 45 years of age

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2 A $15.00 participation fee was provided, as well as transportation via taxicab was provided, if needed.

and older. A total of 9 individuals were enrolled in the experiment, 5 males and 4 females. Subjects were recruited through public announcements posted on the Dalhousie University campus, at senior's citizen clubs, in local hospitals and by word of mouth. The average age of male and female subjects was respectively, 55.2 (3.4; range 54 to 60) and 49.0 (3.4; range 47 to 54). All subjects were right-handed by self-report. Informed consent was obtained from each participant. Subjects did not receive any type of remuneration for their participation.

Visuospatial Neglect Assessment

The assessment of visuospatial neglect proceeded in three steps. These steps included assessment of the visual fields followed by the administration of a cancellation task and finally an examination for evidence of visual extinction. The inclusion of visual extinction in the classification of neglect is predicated on the assumption that it represents a milder form of the disorder. Support of this assumption resides in the evidence that neglect frequently resolves into double simultaneous extinction, therefore it has been suggested that they probably lie on opposite extremes of an attentional deficit continuum[3] (Robertson, 1992). Thus my sample of patients with right-hemisphere damage was divided into two groups, one with neglect or extinction (N+) and one with neither (N-), see Table 2, where the first 7 patients are classified as N+ and the last 6 are classififed as N-.

Visual field deficits (VFD): Visual field defects were assessed by the experimenter using visual confrontation. Seated at about arm's length from the patient with the eyes of both examiner and patient aligned along the vertical meridian, the visual field of each eye was tested individually. The examiner closed the eye opposite to the patient's covered eye, then the patient was instructed to fixate the examiner's opened eye. The monocular fields of both individuals should now have been superimposed, allowing for a direct comparison

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[3] Controversy exists with regards to this claim, as either condition can be assessed in the absence of the other. However, methodoligical issues continue to obscure an unequivocal resolution. As such, in this monograph, both conditions are deemed comparable.

of the patient's fields with those of the examiner's. The examiner's finger was moved on a plane mid-way between the examiner and the patient. Each of the four visual field quadrants was examined systematically. The finger was brought towards the centre of gaze (fixation point) along lines at 45 degree[4] to the vertical and horizontal axes. The patient was instructed to verbally inform the examiner when they saw the finger. Any eye movements by the patient was corrected by reminding them to maintain fixation with the examiner's eye. If an eye movement occurred, the trial was aborted and replaced with a new one.

Of note, this assessment did not rule out the presence of a visual field deficit, as a number of patients did manifest defects on hospital admission (see Table 1). However, it did provide a fairly accurate evaluation of the extent of the intact field of vision at the time of their participation in the study. As such, it was crucial that an existing visual field cut did not affect the perception of stimuli within the display area, which subtended approximately 12 degrees of visual angle and corresponded approximately to the width of their shoulders. The confrontation procedure revealed that all patients could detect stimuli (i.e., examiner's finger) accurately within that visual scope.

Star Cancellation: Patient with right-hemisphere damage were administered a star cancellation task (Halligan et al, 1991). The star cancellation test's sensitivity in diagnosing patients with visuospatial neglect has been previously demonstrated (Halligan et al, 1989). The test consists of an array of 131 stimuli comprised of 52 large stars and 53 small stars. Complimentary stimuli include randomly dispersed letters and short words (See copy in Appendices). The star cancellation test was placed in front of the patient on a table top at a distance approximating 30 cm. An arrow head centred on the bottom edge of the page was aligned with the patient's midsagittal plane. The patient was then given a lead

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[4] An angle that allowed a direct evaluation of potential deficit above and below eye level (i.e., superior or inferior quandrantanopias). This is an important aspect of the visual field appraisal, as stimuli were dispensed above and below eye level.

pencil (or red pen) and was instructed to cross out (or circle) all the small stars on the page. No restriction was imposed on head or eye movements, but patients were informed of a time limit of 3 minutes to completion. Performance was measured by the number of small star omission(s) on either the left or right side of the page.

A number of studies have shown that normal healthy controls make 2 errors or less on cancellation tasks (e.g., Black et al, 1990; Albert, 1973). A recent report by Halligan et al (1992) reported that normal elderly adults (age range = 50 to 75 years) on average omitted 1-2 stars. Therefore, in the present study, a classification of neglect required at least 3 omissions, and at least 2 more omissions from the contralesional half of the array than from the ipsilesional half.

Table 1
Patients with Right-Hemisphere lesion: Sample Neurological Characteristics. See page xiv for list of abbreviations.

Patients	Age/Sex	Lesion Loc	VFD[5]	Hemiplegia	Time post-onset*
A.C.	61/m	F,T,P,wm	Yes	Yes	3
B.M.	60/m	na	na	Yes	3
I.P.	82,f	P,O,wm	Yes	No	1
M.H.	75/f	negative	Yes	Yes	14
M.L.	55/f	F,P,wm	Yes	Yes	6
P.T.	68/f	F,T,P,wm	No	Yes	5
V.L.	79/m	P,wm	Yes	No	4
S.F.	51/m	F,T	No	Yes	3
I.D.	62/m	th,c, wm	No	Yes	4
M.W.	62/f	na	na	Yes	5
J.J.	57/m	na	na	No	6
K.M.	61/m	O,wm	Yes	No	12
A.O.	65/f	na	na	Yes	3

* in months

[5] This is based on the chart review and represents deficits at the time of admission. Visual confrontation at the time of the experiment indicated that, if a VFD was present, it never fell (or encroach upon the area) within the scope of the displays.

Visual Extinction A second measure was administered to assess visual extinction. As in visual confrontation, the examiner was seated at about arm's length from the patient with the eyes of both examiner and patient aligned. Unlike visual confrontation, neither the examiner nor the patient closed their eyes. However, the patient was asked to focus on the examiner's nose (i.e., root of the nose) to monitor spontaneous eye movements. The examiner's index fingers were presented approximately 20 cm to the left and right of the patient's midsagittal plane at eye level and well within their visual field (as determined by the visual confrontation task). Twenty trials of unilateral (i.e., 5 trials moving the right index finger, 5 trials moving the left index finger) and bilateral (i.e., 10 bilateral trials; moving both index fingers simultaneously) visual stimulation were administered. Extinction was defined by a 50% or greater failure rate during the bilateral stimulation condition (see Table 2). Patients had to verbally report the moving index finger(s).

Apparatus

The apparatus consisted of three main components that serve to generate, and project the stimuli as well as record the subject's responses. The apparatus employed for the projection of the stimuli consisted of a flexible Cineplex™ rear-view projection screen (40 cm^2), a wooden frame (50 cm^2), an EIKI™ high intensity over-head projector, and a TELEX™ MX1 datapad (i.e., computer image projection system). A rear-view flexible screen was fastened onto the wooden frame, which in turn was set into two wooden anchors that stabilized the frame. The clearance between the bottom of the frame and the floor was sufficient to provide adequate legroom for the subjects, including those seated in a wheelchair, when close observation distances were required. A TELEX™ MX1 datapad was positioned directly above the light source of the EIKI™ high intensity over-head projector. The datapad was linked to a Macintosh LC630 through reciprocal monitor ports, using a video cable. The video functions on the datapad were set on the default mode, which generated the best picture quality and resolution. This setting also insured

Table 2

Patients with Right-Hemisphere Lesion: Performance on Star Cancellation and Extinction Screen

	Star Cancellation		Neglect	Extinction
	Left Omissions	Right Omissions	(L minus R)	
A.C.	26	8	Yes	No
B.M.	5	1	Yes	No
I.P.	4	1	Yes	Yes
M.H.	0	0	0	Yes
M.L.	26	15	Yes	No
P.T.	3	1	Yes	No
V.L.	1	0	1	Yes
S.F.	0	0	0	No
I.D.	0	0	0	No
M.W.	0	1	1	No
J.J.	2	0	2	No
K.M.	1	0	1	No
A.O.	11	10	1	No

consistency in picture attributes (e.g., tint, brightness, etc.) across subjects during data collection.

The hardware responsible for the generation of the stimuli consisted of an Apple™ Macintosh LC630 computer. The apparatus used in responding to the stimuli consisted of a ten foot (mouse cable) extension and a modified Apple™ computer mouse. The mouse was mounted and affixed to a 15 cm X 7 cm X 7 cm metal/wooden box. A rotary knob activated the tracking ball. Activating the press button resulted in the response being recorded.

Procedure

Viewing distances: All stimuli were presented at two different Viewing distances, namely at 28 and 224 cms, as shown in Figure 2 The more distant observation distance lay within extrapersonal space as defined by Previc (1990), while the nearer one fell within peripersonal space. Procedural details for each experiment are provided in the sections titled Line Bisection (Part 3) and Visual Orienting (Part 4).

Statistical Analyses

Data management: A database was setup using ClarisWorks™ spreadsheet and SimpleText™ word processing packages. The data set contained anonymously coded patient information (e.g., neglect classification, sex, age, handedness, and/or education), CT scan/MRI localization data, and line bisection and visual orientation scores.

Statistical Analyses: The SuperANOVA™ statistical package was used to conduct the analyses of variance (mixed and within-subject designs). Additional analyses, such as Pearson Coefficient Moment Correlations and t-Test analyses, were performed using the StatVIEW™ statistical package.

Figure 2
A schematic view of the apparatus components and layout at both the peripersonal and extrapersonal Viewing distances. Component a) depicts the computer (hardware and software), b) depicts the projection units, and c) depicts the rearview projection screen setup. See text for details.

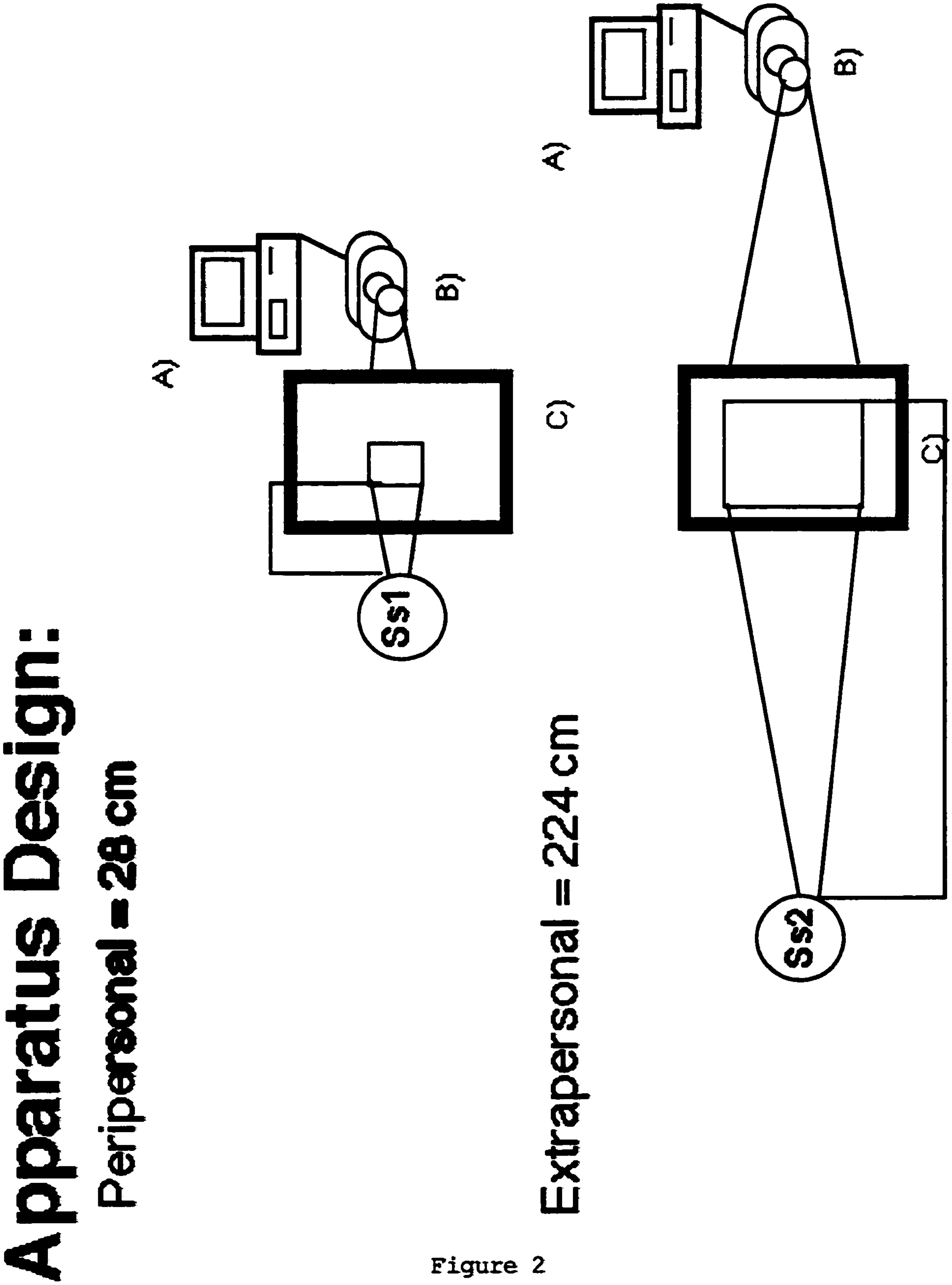
Apparatus Design:
Peripersonal = 28 cm
Extrapersonal = 224 cm
A)
B)
C)
Ss1
A)
B)
C)
Ss2

Figure 2

PART 3: LINE BISECTION

NORMAL CONTROL

Background

Horizontal Line

Despite a growing body of evidence contributing to our understanding of bisection bias in neurological patients (e.g., Axenfeld, 1894 and Liepmann & Kalmus, 1900[6]; Columbo et al 1976; Schenkenberg et al, 1980; Riddoch & Humphreys, 1983; Halligan & Marshall, 1989; Marshall & Halligan, 1990; Cowey et al, 1994), until the past decade, relatively little research had been dedicated to the examination of the bisection performance of normal individuals. In fact, Bruyer (1983, p.231) stated "..., nothing is reported (perhaps nothing is known) about line bisection in normal subjects." He further cautioned that in many fields of clinical neuropsychological research, the [false] presumption is that normal individuals will perform flawlessly. Given this cautionary statement, the current state of knowledge of line bisection performance in normal subjects is reviewed below.

Bisection Bias at Midsagittal Plane[7]

A number of studies have examined directional bisection biases of normal individuals on horizontal rods or lines positioned in the midsagittal plane. Bradshaw et al (1985), investigating bisection biases of 24 normal right-handed individuals on horizontal rods, reported that a leftward bias was consistently observed. This finding has also been observed using college age subjects (e.g., Scarsbrick et al, 1987), in older subjects (e.g., Fukatsu et al, 1990), and in the elderly (e.g., van Deussen, 1983). Currently, as shown in Table 3, 15 studies have provided support for a leftward bias on the bisection of horizontal

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[6] These references are cited in Werth (1993).
[7] It should be noted that the review of bisection performance in normals is detailed and presented in a logical progression; as such, it is important to note that chronologically the effects of line position were investigated prior to midsagittal investigation. This was partly in response to the current neurological investigations of that time, which investigated the effects of line position on bisection biases of neurologically impaired individuals and compared them to controls.

lines in normals (e.g., Bisiach et al, 1976; Scarsbrick et al, 1987), while 15 investigators reported rightward bias (e.g., Schenkenberg et al, 1980; Manning et al, 1990). Only two studies, not shown in the Table 3, reported no significant rightward or leftward biases (e.g., Heilman et al, 1984; Werth & Poppel, 1988).

The effects of Hemispace on Bisection

Hemispace is defined as the external space to the left or right of a subject's midsagittal plane (i.e., viewer centered frame of reference). The effects of varying the stimuli across hemispace on a bisection task in normals was first investigated by Bowers and Heilman (1980); who reported greater leftward bisection bias at the midsagittal and right-hemispace position, while a rightward bisection bias was observed in left hemispace. In contrast, Schenkenberg et al (1980) found that normal controls displayed a non-significant leftward bias on horizontal lines in left-hemispace, but displayed significant rightward displacements at centre and right-hemispace. A number of studies have re-examined the influence of varying the position of horizontal segments from left- to right-hemispace on the bisection bias. Currently, as shown in Table 4, only a small number of studies have provided support for Bowers' original findings (e.g., Bradshaw et al, 1983; Schenkenberg et al, 1980), while most investigators reported an increasing rightward bias from left to right hemispace (e.g., Ishiai et al, 1994; Mennemier et al, 1997). Interestingly, one study presented a pattern opposite to that reported by Bowers (Butter et al, 1988), while another reported a consistent leftward bias across hemispace (Chatterjee et al, 1994). Based on the current sample of studies, it would appear that the effects of hemispace on the bisection bias remain equivocal.

Table 3
Mean percentage displacements from midpoint in horizontal line bisection by non-neurological samples. A positive value indicates a rightward bias, while a negative value indicates a leftward bias.

Study	# Ss	Judgment
Bradshaw & H. '80	24	2.7
Bradshaw '85	24	-1.6
Bradshaw '87	12	-1.6
Bisiach et al '90	10	-0.8
Black et al '90	20	-0.8
Burnett-Stuart '91	18	0.2
Butter et al, '90	8	4.0
Columbo et al, '76	50	0.7
Chatterjee et al, '94	5	-0.03
Chieffi '96	12	-1.3
Chokron & I, '96	60	0.4
Fuji et al '91	10	2.2
Halligan & M '89	20	-0.8
Halligan & M '89	10	-0.1
Halligan et al '90	20	0.2
Harvey et al '95	12	0.1
Ishiai et al, '89	10	0.5
Kashmere & Kirk, '97	30	0.3
Manning et al '90	22	0.17
Marshall & H '89	20	-0.7
Marshall & H '90	10	-1.4
Mattingley et al '93	6	-0.8
Mennemier et al, '97	10	0.33
Milner et al,'92	12	0.7
Nichelli et al, '89	10	0.13
Reuter-L. & P, 90	9	-0.1
Scarsbrick et al,'87	30	-0.7
Schenkenberg et al, '80	20	0.73
Toth & Kirk '96	34	-0.5
Van Deusen '93	93	-0.59

Table 4
Mean percent displacement of line bisection judgments as a function of line position in non-neurological samples. A positive value indicates a rightward bias, while a negative value indicates a leftward bias.

Study	# Subjects		Line Position	
		Left	Middle	Right
Bowers & H '80	24	-1.5	2.7	3.4
Bradshaw et al '83	24	-4.0	N/A	3.9
Butter et al '88	5	1.4	N/A	-0.04
Chatterjee et al '94	5	-0.08	-0.03	-0.03
Coslett et al. '90	5	0.1	N/A	0.5
Ishiai et al '94	10	0.4	0.5	0.6
Mennemier et al '97	10	0.5	0.33	1.03
Milner et al,'92	12	0.4	0.7	1.4
Nichelli et al '89	10	0.4	0.13	0.5
Shenkenberg et al '80	20	-0.6	0.73	1.73

The Effects of Unilateral Cuing on Bisection

Six studies have reported on the effect of cuing on bisection judgments in normal subjects (see Table 5). With the exception of the study of Nichelli et al (1989), most investigators have reported an overall leftward displacement with the presentation of a left unilateral cue. Likewise, the presentation of a right cue led to either a rightward bias in most studies, or else a reduction of the existing leftward bias (e.g., Milner et al, 1992).

Conclusions

Three main conclusions can be drawn from Tables 3,4, and 5. First, individuals with a right-hand preference tend to bisect single horizontal segments fairly accurately (B = 0.05%; Table 3) when presented at the midsagittal plane. Second, the position of horizontal segments (i.e., rod/line) to the left and right of the midsagittal plane appears to affect the judgment of the displacement, but the outcome based on the current sample of studies is unclear. Finally, unilateral cuing of lines centered in the subjects' midsagittal plane resulted in a bisection bias in the direction of the unilateral cue; that is, the response was in the direction of the cue.

Table 5
Mean percent displacements of horizontal line bisection judgments as a function of left and right unilateral cues in non-neurological samples. A positive value indicates a rightward bias, while a negative value indicates a leftward bias.

Study	# of Subjects	Left Cue	Right Cue
Chatterjee et al, '94	5	-0.9	-0.8
Fischer, '94	10	-0.08	0.40
Mattingley et al '93	6	-0.6	0.5
Milner et al '92	12	-1.5	-0.6
Nichelli et al '89	10	0.1	1.2
Reuter-Lorenz	9	-1.4	0.9

Vertical Lines

Bisection Bias at Midsagittal Plane

Although limited in comparison to the knowledge gathered on horizontal segments, researchers have also examined bisection displacements from midpoint using vertical segments in normals (see Table 6). Bradshaw et al (1985), investigating the bisection performance of twenty-four right-handed normal individuals on vertically oriented rods, reported non-significant bisection judgments above the midpoint. In a similar experiment, Scarsbrick et al (1987) demonstrated that 30 normal right-handed individuals bisected vertical lines significantly above midpoint, when using their right-hand. A finding recently supported by Kashmere and Kirk (1997). In contrast, Rapsack et al (1988) reported that normal control subjects (4 right-handers and 1 left-hander) bisected vertically oriented rods (non-significantly) below midpoint.

Table 6
Mean percentage displacements from midpoint in vertical line in non-neurological samples. A positive value indicates a upward bias, while a negative value indicates a downward bias.

Study	Subjects	Judgment
Bradshaw et al '85	24	0.4
Butter '89	12	3.8
Kashmere & Kirk '97	30	1.3
Rapsack '88	5	-0.05
Scarsbrick '87	30	1.4
Shuren et al '94	10	2.0

The Effect of Line Location on Bisection

Only three studies to date have reported the effects of varying the position of line presentation in space on vertical biases in normal individuals (see Table 7). In Butter et al's (1987) study, normal controls bisected vertically oriented rods placed above, below eye level, or at eye level at a distance of 30 cm. Although subjects bisected rods significantly above the midpoint, bisection biases did not vary significantly from each other at any of the placements. In contrast, a recent study by Shuren et al (1994) reported a significant effect of line position on the upward bias, as the upward judgment decreased when the line was positioned below as opposed to above eye level. Similarly, Shelton examined bisection biases of vertical lines presented at six locations along the vertical axis, ranging from 15 cm above to 60 cm below eye level at a distance of 30 cm. Analyses of displacements from midpoint revealed that vertical lines were bisected below midpoint in 12 hospital controls. Additionally, the magnitude of the displacement from midpoint was significantly less when the lines were presented below than above eye level. In contrast, Drain and Reuter-Lorenz (1996) reported that perception of an upward bias increased as the lines were moved from above to below eye levels. These findings, based on the current sample of studies, are contradictory and uninformative with regards to the effects of line position on bisection biases. Methodological differences (see Drain and Reuter-Lorenz, 1996) may, in part, be responsible for this observation.

Table 7
Mean percent displacement of vertical line bisection judgments as a function of position in non-neurological samples. A positive value indicates a rightward bias, while a negative value suggests a leftward bias.

Study	Subjects	Line Position		
		Below	At Centre	Above
Butter '89	12	2.9	3.8	3.5
Shelton et al '90	12	-2.3	-	-0.4
Shuren et al '94	10	0.6	2.0	3.1

The Effects of Unilateral Cuing on Bisection

To date, the only study that has examined the effects of unilateral cues on vertical bisection biases (Drain & Reuter-Lorenz, 1996) reported that line pre-bisected either above or below veridical midpoint were precieved as bisected accurately when presented with a unilateral cue in the opposite direction. In this case, the cue appeared to have a correction factor on the perception of the line length and determiniation of its centre point. Given the efficacy of such a procedure for horizontal line biases, further investigation on vertical lines biases seems warranted.

Conclusions

Two main conclusions can be drawn from Tables 6 and 7. First, individuals with right-hand preference tend to bisect single vertical segments above (B = 1.5%; see Table 6) the veridical midpoint, when presented at the midsagittal plane. Second, based on conflicting outcomes and a very small sample, effects of line position on vertical biases are inconclusive. The various outcomes of the aforementioned studies may rest with the use of different modalities (e.g., Bradshaw et al, 1985; Scarsbrick et al, 1987). Another possibility may be related to the distance at which the bisections were performed. In the Bradshaw et al (1985) and Scarsbrick et al (1987) studies, bisections of vertical lines were performed in far peripersonal space at a distance of 45 cm, while in Rapsack et al (1988) employed a closer observation distance of 30 cm.

A number of issues are raised by this review. For example, we have no knowledge of bisection displacement biases when lines are moved along a plane orthogonal to their orientation (i.e., horizontal lines presented above and below eye level). This may be a critical consideration, as indicated in Previc's (1990) ecological model of visual field specialization. Additionally, because of physical limitations imposed by the paper and pencil task, investigations of line bisection outside of arm's reach are lacking. As a consequence our knowledge of bisection biases appears to be limited within a three-dimensional framework. The study eliminated limitations set by the use of paper and pencil tasks by using a computer generated line bisection task.

Predictions

NORMALS

Neurologically intact subjects were run, in part, to provide one kind of baseline (control) data.

1)BISECTION JUDGMENT-

Horizontal Lines Based on the meta-analytical outcome of no significant bias on horizontal lines presented at midsagittal plane (see Table 3), a prediction is reserved.

Vertical Lines Although a theoretical explanation is still lacking, the literature suggest that an upward bias is typically observed. As such, an upward bias is predicted in this study.

2)VIEWING DISTANCE BY LINE LOCATIONS- Previc's main assumption implies an interaction of upper and lower visual field specialization, their neuroanatomical correlates and Viewing distance, as such bisection judgments will differ within and between Viewing distance. Specific predictions for each line orientation are provided below:

Horizontal Lines In keeping with Previc upper and lower visual field specialization, in peripersonal space lines presented below eye level will result in greater leftward bisection displacements than those presented above eye level, while in extrapersonal space lines presented below eye level will lead to smaller leftward bisection displacement than those presented above eye level.

Vertical Lines In keeping with Previc's model, in peripersonal space the lower field is preferentially processed, hence the bottom portion of the line is preferentially processed leading to a greater downward bias; conversely, in extrapersonal space the upper field is preferentially processed, hence bisection will be biased toward the top.

3) EFFECTS OF CURSOR STARTING LOCATION-Generally speaking, initial cursor location, via its control over visual attention in space, will bias bisection judgments in the direction of the "cue". This bias will modify judgments symmetrically around the bisection position when the cursor starts in a central (neutral location).

4) VIEWING DISTANCE BY CURSOR STARTING LOCATIONS- Based on Previc's main assumptions, predictions for each cursor start are provided below:

Horizontal Lines In keeping with Previc upper and lower visual field specialization, "cues" will have a greater effect on lines presented below and above eye level in peripersonal and extrapersonal space, respectively, when compared to the other line position at that Viewing distance.

Vertical Lines According to Previc's model the lower and upper fields are preferentially processed in peripersonal and extrapersonal fields, respectively. Hence, in peripersonal space a greater effect will follow the bottom versus top "cue", while in extrapersonal space a greater effect for the top than bottom "cue" will be observed.

PATIENTS WITH NEGLECT

In clinical practice, the most commonly used screening tool in the assessment of visuospatial neglect (hereafter referred to as neglect) is the line bisection test. Recent evidence has indicated that line bisection is a sensitive test for the detection of visuospatial neglect (see Schenkenberg et al, 1980; Ferro et al, 1987; Black et al, 1990; Monaghan & Shillcock, 1998). A horizontal line drawn on a piece of paper, which is centered to the patient's midsagittal plane, is presented on a table top. The patient is then asked to bisect the line into two equal halves. Because the half of space opposite to their lesion is neglected, patients significantly misbisect horizontal lines toward the non-neglected half of space, producing a rightward displacement from the veridical midpoint of the line.

Horizontal Lines

A number of investigators (e.g., Axenfeld, 1898: Patterson & Zangwill, 1944; Bisiach et al, 1976) have reported on the behavior of patients on line bisection, but no systematic investigation had been carried out until the study of Schenkenberg et al (1980). These researchers investigated the patterns of line bisection deviations in patients with left- or right-hemisphere damage, diffuse brain damage, and in hospital controls. Each column was comprised of lines varying in lengths from 10 to 20 cm in 2 cm step increments. The number of lines left un-bisected and the magnitude of deviations away from the objective midpoint measured in millimetres were compared across the experimental groups. Statistical analyses revealed that right-hemisphere damaged patients with neglect significantly omitted more lines than any other patients. Furthermore, in this group the magnitude of deviations from the midpoint were significantly greater than those from other experimental groups on left and centre columns, but not on the right column. Because patients with neglect omitted more lines than other control groups and significantly misbisected the lines on the side opposite to the lesion, the authors concluded that line bisection was a useful tool to differentiate between brain damaged groups with and without neglect.

Since the findings reported by Schenkenberg et al (1980), several other research groups have studied the bisecting performance of patients with neglect (e.g., Bisiach et al, 1983; Halsband et al, 1985; Halligan and Marshall, 1988; Marshall and Halligan, 1990;

Halligan and Marshall, 1991; Ishiai et al, 1989), as shown in Table 8. In an attempt to explain the ipsilateral displacement during bisection, some authors have suggested that patients with neglect tend to overestimate the length of the line on the ipsilesional side, which leads to significant lateral displacements from midpoint (e.g., Heilman, 1985). Other researchers have attributed the systematic displacements to defective leftward visual search leading to an underestimation of the contralesional line length, leading to a false subjective representation of the true line length (Ishiai et al, 1992; Ishiai et al, 1989). Notwithstanding these complementary theories of bisection judgments, the regularity of this phenomenon has led to the notion that areas of the brain subserving spatial attention, and to some extent the control of human behavior, may be organized along a left-right spatial continuum (Heilman et al, 1990). Recent evidence has shown that this left-right dichotomy may be only one of three spatial dichotomies, which include altitudinal and radial (i.e., depth) dichotomies as well (see Rapsack et al, 1988 & Mennemier et al, 1992).

The Effects of Hemispace on Bisection Bias

Five studies have examined the effects of hemispace (left-half *versus* right-half) on bisection biases in patients with neglect (Schenkenberg et al, 1980; Heilman and Valenstein, 1979; Riddoch and Humphreys, 1983; Milner et al, 1993; Ishiai et al, 1994). Although absolute bisection displacements varied from study to study, all showed similar bisection patterns across hemispace (see Table 9). When horizontal lines were presented completely to the left of the patient's midsagittal plane, the rightward displacement

Table 8

Mean percentage displacements from midpoint in horizontal line bisection judgments in patients with left-neglect. A positive value indicates a rightward bias, while a negative value indicates a leftward bias.

Study	# Patients	Judgments
Bisiach et al '83	12	10.0
Bisiach et al '90	15	15.0
Black et al '90	71	12.8
Burnett-Stuart '1991	6	11.4
Butter et al, '90	18	43.0
Cermack '91	5	12.8
Columbo et al, '76	53	38.0
Ferro et al ('87)	10	46.0
Fujii et al ('91)	10	25.5
Halligan & M '91	1	34.7
Halligan & M '92	5	5.0
Halligan et al '90	4	5.0
Halligan et al '93	3	13.7
Harvey et al, '95	8	16.8
Hjaltason ('92)	6	52.1
Hjalston & Tegner,'97	12	18.8
Ishai et al ('89)	8	24.4
Lin et al, 1996	13	35.0
Marshall & H, '89	1	10.0
Marshall & H, '90	3	25.5

significantly increased in comparison to that observed at midsagittal plane or in the right half of space. In turn, the magnitude of rightward displacement when lines were presented to the right of the patient's midsagittal plane was less than that observed at the midsagittal plane. Thus, it appears from these studies that moving the line along the horizontal meridian from the neglected to the non-neglected half of space reduced significantly the magnitude of the rightward displacement typically observed on horizontal lines.

Table 9
Mean percent displacement of horizontal line bisection judgments as a function of position in patients with left-neglect. A positive value indicates a rightward bias, while a negative value indicates a leftward bias.

Study	# Subjects	Line Position		
		Left	Middle	Right
Milner et al '93	3	10.2	7.7	2.9
Heilman & V '79	6	8.8	5.0	2.5
Ishiai et al '94	10	13.7	10.8	5.8
Riddoch & H '83	5	17.2	13.8	9.3
Schenkenberg '80	20	12.5	9.5	1.9

The effects of Lateral Cuing on Bisection Bias

To date, four studies have reported on the effects of unilateral cuing during line bisection in patients with visuospatial neglect (e.g., Heilman and Valenstein, 1979; Riddoch and Humphreys, 1983; Reuter-Lorenz and Posner, 1991; Hjalston and Tegner, 1997). All, with the exception of Heilman and Valenstein (1979), have reported significant attenuation of rightward displacement with the presentation of a left cue when compared with the displacement following the right cue (see Table 10). Methodological differences between Heilman and Valenstein and others may have been responsible for the discrepant findings. While in the other three studies cues were presented unilaterally, in Heilman and Valenstein's study cues were presented bilaterally and subjects were instructed to attend to them unilaterally. Given that patients with neglect tend to favor the ispilesional half of space, the saliency of a left end cue may have been diminished by the constant presence of a right end cue on each line presentation (see Mattingley et al, 1993 for effect of non-visible cuing). Lastly, among these studies, only Reuter-Lorenz and Posner (1991) attempted to measure the magnitude of cuing by comparing bisection displacement under left and right cuing with bisection displacement without cuing.

Table 10
Mean percent displacement of horizontal line bisection judgments as a function of unilateral cues in patients with left neglect. A positive value indicates a rightward bias, while a negative value indicates a leftward bias.

Study	# Subjects	Left Cue	Right Cue
Heilman & V. '79	6	5.1	5.8
Hjalston & Tegner,'97	12	1.8	16.9
Reuter-L.& P. '90	9	0	4.6
Riddoch & H. '83	5	8.2	17.8

Other forms of cuing have included varying lateral hand positioning prior to bisection. A study by Halligan, Manning and Marshall (1991) demonstrated the variation of bisection judgments contingent upon initial hand position. Hand position to the left-most end of the line resulted in a significant reduction in the rightward deviation as compared to that observed with either a neutral start position or with the hand placed initially at the right end of the line. Whether using a static or dynamic cue, it appears that the cue facilitates the orientation of attention to the neglected side, as observed in the reduction of rightward bias.

The effect of Viewing distance on the Bisection Bias

To my knowledge, only three[8] studies have investigated the effects of Viewing distance on the performance of patients with neglect on line bisection and they have reported conflicting outcomes (see Table 11). Presenting horizontal lines in peripersonal and extrapersonal space, Halligan and Marshall's (1990) study of a patient with parietal lobe area damage revealed bisection deficits restricted to the peripersonal space area. Conversely, Cowey et al (1994) compared bisection biases in peripersonal and extrapersonal space in 5 patients with neglect, using identical methodology to Halligan and Marshall (1991). They reported that the direction of the bisection bias remained the same in

[8]Shelton et al (1990) and Mennemier et al (1992) are not included, as they reported findings from patients with bilateral lesions and used radial lines to measure the effects of near and far peripersonal space.

the two spatial domains and that the magnitude of the bias increased significantly in extrapersonal space. Tegner and Levander's (1991) investigation of the performance of right-hemispheric lesion patients on a line bisection task under near and far extrapersonal space conditions, using binoculars to change the perceived depth of the stimuli (i.e., Task 4, p884), supported that outcome. The directional bias for the medium and long horizontal lines under normal and reversed binocular viewing conditions remained the same and was not significantly different in magnitude. Based on these studies, there appears to be no clear consensus on the possible dissociation of near (peripersonal) and far extrapersonal space in patients with neglect. This may be secondary to methodological factors including the heterogeneity of samples in terms of lesion site, severity (i.e., mild, moderate and severe), and type of neglect (i.e., motor versus perceptual). Additionally, an apparent lack of consensus on the operational definitions of peripersonal and extrapersonal space may, in part, account for the current findings. Thus, the assertion that peripersonal and extrapersonal neglect are dissociable remains provisional.

Two other studies by Pizzamiglio et al (1989) and Coslett et al (1991), using the Wundt-Jastrow Illusion[9] perceptual task, have also reported an absence of a dissociation between near and far extrapersonal space in patients with neglect. It should be noted that spatial dissociations are not restricted to the peripersonal and extrapersonal realms. Another level of representation includes that between personal (i.e., autotopagnosia) and peripersonal space. Bisiach et al (1986) described the performance of a patient who manifested signs of left-sided personal neglect (assessed by upper limb-identifying commands), while manifesting no impairment on the extrapersonal (peripersonal) tasks. This phenomenon has been reported independently by Guariglia and Antonucci (1992), using a battery of tests specifically designed to assess personal neglect (e.g., finger recognition, body schema). It appears that, although each types of deficits can occur in the

[9]The illusion is created by having two semi-circular fans of identical size and shape displayed slightly off centre from one another, resulting in the displaced fan appearing smaller than its counterpart.

absence of the other, extrapersonal (as defined by these authors) space neglect is the most prominent.

Table 11
Mean percent displacement of horizontal line bisection judgments as a function of Viewing distance in patients with left neglect. A positive value indicates a rightward bias, while a negative value indicates a leftward bias.

Study	**# Subjects**	**Peripersonal**	**Extrapersonal**
Cowey et al '94	5	10.3	13.3
Halligan & M '90	1	37.1	-0.5
Tegner& Levander '91	2	14.8	18.3

Vertical Lines

The earliest reports of neglect in the vertical plane came from two abstracts (Morris et al, 1985; Mark and Heilman, 1988), which reported that some patients with neglect omitted significantly more lines in the lower than upper contralesional quadrant on a line cancellation task. This finding was supported by Halligan and Marshall (1989a) in a subset of their sample of patients with neglect, on a modified version of the Albert line cancellation task (Albert, 1973). Since the pattern of deficit was not present in all patients with neglect, it was suggested that in addition to the commonly observed and documented left- versus right-half of space disparity, an upper- versus lower-space deficit was also present in some patients exhibiting signs of neglect. The number of studies investigating the bisection bias at midsagittal plane is small, as shown in Table 12.

Table 12
Mean percentage displacement of vertical line bisection judgments as a function of position in patients with left neglect. A positive value indicates a rightward bias, while a negative value indicates a leftward bias.

Study	**Subjects**	**Bias**
Burnett-Stuart'91	1	2.7
Rapsack et al '88	1	2.6

The effects of Line Location on Bisection Bias

Evidence in support of vertical visuospatial neglect using line bisection is modest in comparison to horizontal neglect. As illustrated in Table 12, a small number of single case studies have demonstrated that, following bilateral damage to the parietal area, patients tend to bisect vertical lines significantly above midpoint in peripersonal space (e.g., Rapsack et al, 1988), while other studies have examined the effect of displacing the line along the horizontal meridian (e.g., Butter et al, 1989; Mennemier et al, 1992 - see Table 13). One single case study demonstrated the opposite effect; that is, a downward bias (e.g., Shelton et al, 1990).

Few of the traditional theories concerning the distribution of attention in left- and right-halves of space (e.g., Heilman and van den Abell, 1981; Kinsbourne, 1987; Rizzolatti and Gallese, 1988) address line bisection errors in the upper vs. lower half of space or in extrapersonal vs. peripersonal space. In the present proposal, hypotheses regarding line bisection performance were derived from the predictions of Previc's (1990) model of visual field specialization. This model stipulates that the deployment of attention is a complex interaction of stimuli location and Viewing distance. Previc maintains that a close relationship between the upper visual field and extrapersonal space exists, while the lower visual field is associated with activity in peripersonal space. Moreover, he linked the perceptual processing capabilities of the upper and lower visual field with the ventral (i.e., temporal) and dorsal (i.e., parietal) visual streams, respectively. Thus, given the visual field specialization and its concurrent neural correlates, specific impairments in bisection judgments can be predicted based on site of damage.

Table 13
Mean displacement of vertical line bisection judgments as a function of position in patients with left neglect.

Study	**Subjects**		**Line Locations**	
		Below	**At Centre**	**Above**
Butter et al '89	1	6.8	2.8	0.5
Mennemeier et al '92	1	7.8	7.8	7.7

Predictions

1)BISECTION JUDGMENT-Bisection judgments in this sample of patients with neglect are expected to follow the pattern observed in the literature for both horizontally and vertically oriented lines.

Horizontal Lines A significant rightward overall bisection judgments is expected in patients manifesting signs of neglect.

Vertical Lines A significant upward overall bisection judgment is expected in patients manifesting signs of neglect.

2) VIEWING DISTANCE BY LINE POSITION- Previc's main assumption purports an interaction of upper and lower visual field specialization, their neuroanatomical correlates and Viewing distance, such that bisection judgment will differ within and between Viewing distance.

Horizontal Lines In patients manifesting neglect following parietal involvement the rightward bisection judgments on horizontal lines below eye level will be greater (relative magnitude) than those observed above eye level in peripersonal space, while no significant differences across line position are expected in extrapersonal space.

Vertical Lines Bisection judgments on vertical lines, assuming a significant upward bias, will be greater in peripersonal than extrapersonal space and restricted to lines located left of the midsagittal plane.

3) EFFECTS OF CUE-Because the direction of attention affects what we see, and attentional misdirection is a primary cause of the displacement from veridical midpoint the unilateral cursor start position will bias the judgments in its direction, while the central cursor start will result in a rightward judgment intermediary between the left and right cursor start.

Horizontal Lines As such, the rightward bisection judgment observed in patients with neglect should be significantly reduced (if not eliminated) following the left cursor start and exaggerated following the right cursor start. The middle cursor start should occupy an intermediary position.

Vertical Lines The upward bias observed in patients with neglect should be exacerbated following the top cursor start, while a bottom cursor start should reduce (if not eliminate) the upward bias.

4) VIEWING DISTANCE BY CURSOR STARTING LOCATIONS- Based on Previc's main assumptions predictions for each cursor start are provided below:

Horizontal Lines In keeping with Previc's postulates, bisection biases will not differ qualitatively at the two Viewing distances, given that the impact of parietal damage should be most prominent in peripersonal space. Thus, displacements from veridical midpoint following the redirection of attention by "cues" will be significantly less to lines below eye level than to "cues" to lines presented above eye level.

Vertical Lines In keeping with Previc's postulates and the impact of parietal damage in peripersonal space, the redirection of the bisection judgment following the bottom "cue" will not differ between Viewing distances, while the displacement from veridical midpoint after the top "cue" will be greater in extrapersonal than peripersonal space. The middle "cue" should have an intermediate bias relative to the unilateral "cues" at both Viewing distances.

BETWEEN GROUP PREDICTIONS

Although there exists performance evidence to support a general slowing in response time in older subjects (e.g., Plude et al, 1994), there is no evidence that performance accuracy should suffer as well. It is expected that brain damage will result in a significant alteration of bisection accuracy or bias on horizontal and vertical lines.

Predictions

1)-The group of patients with neglect will differ significantly in overall performance from the other three groups.

2)-Because it is hypothesized that neglect is responsible for the misdirection of attention and subsequently the perception of the line, the group of patients who do not manifest neglect will not differ significantly from the two groups of normal individuals.

3)-The young and older samples of normal individuals will not differ significantly from each other.

Methods

Apparatus-Software: A computer program written in PASCAL controlled the 1)-number of trials, 2)-number of conditions, 3)-line thickness, 4) line length, 5) line position along the horizontal and vertical meridians, and 6) intial bisecting cursor starting location (referred to hereafter as 'cue'). The computer program recorded the position of each individual bisection, as well as the time to complete the bisection in seconds, and generated a summary output.

Stimulus characteristics: The thickness of the lines subtended 0.5^0 of visual angle in peripersonal and extrapersonal space. Two line lengths were generated and these subtended 7^0 and 14^0 of visual angle. Varying line length was proposed by Riddoch and Humphreys (1983, p.592) as a means to prevent the participants from developing a response set specific to a line. On any given trial, the cue appeared either at the left (or top for vertical lines) end, right (or bottom for vertical lines) end or randomly along the middle third of the line with each location occurring on one third of the trials (see Figure 3 for schematic of display). Adjustment of the bisection along the horizontal/vertical axis was achieved by clockwise or counter-clockwise rotation of the rotary knob from the modified computer mouse (described in the Methods section; Apparatus, Hardware). As well, horizontal lines were presented at one of three positions: top, middle or bottom. Similarly, vertical lines were presented at one of three positions; left, middle or right. The order of line orientation, length, position and cursor position were completely randomized.

Scoring of Bisection Bias: The program assigned a value ranging from 0 to 100 percent to each line. In the case of the horizontal line, 0 corresponded to the left most end of the line and 100 to the right most end of the line. A value of 50 demarcated the veridical midpoint of the line. Given this scheme, a value less than 50 indicated a leftward bias and a value greater than 50 indicated a rightward bias. Similarly, for vertical lines, the 0 value corresponded to the bottom most end of the line, while 100 corresponded to the top most end of the line. As such, a downward bias was denoted by a value less than 50, while a value greater than 50 reflected an upward bias.

Design: The design of this study was a 3 X 3 X 2 repeated measures. Three independent variables were manipulated for both horizontally and vertically oriented lines: line position (left/top, middle/middle, right/bottom), cue position (left/top start, middle/middle start, right/bottom start), and line location (extrapersonal, peripersonal). The primary dependent variable was the percent deviation from midline, defined as the displacement from midpoint subtracted from the true half divided by true half multiplied by 100 (Schenkenberg et al, 1980). Computationally, the formula is:

$$\text{Percent Deviation} = \frac{\text{measured deviation} - 50}{50} \times 100$$

Although response times (sec.) to complete bisection were recorded and analyzed, they were not presented in the main body of the text and are found in the Appendices. Each line presentation was repeated twice for each condition and orientation, totaling 72 trials.

Figure 3
A schematic representation of horizontal (A) and vertical (B) lines positions and intial cue locations. The marker (*) highlights the range in which the cue occurred for the middle cue condition.

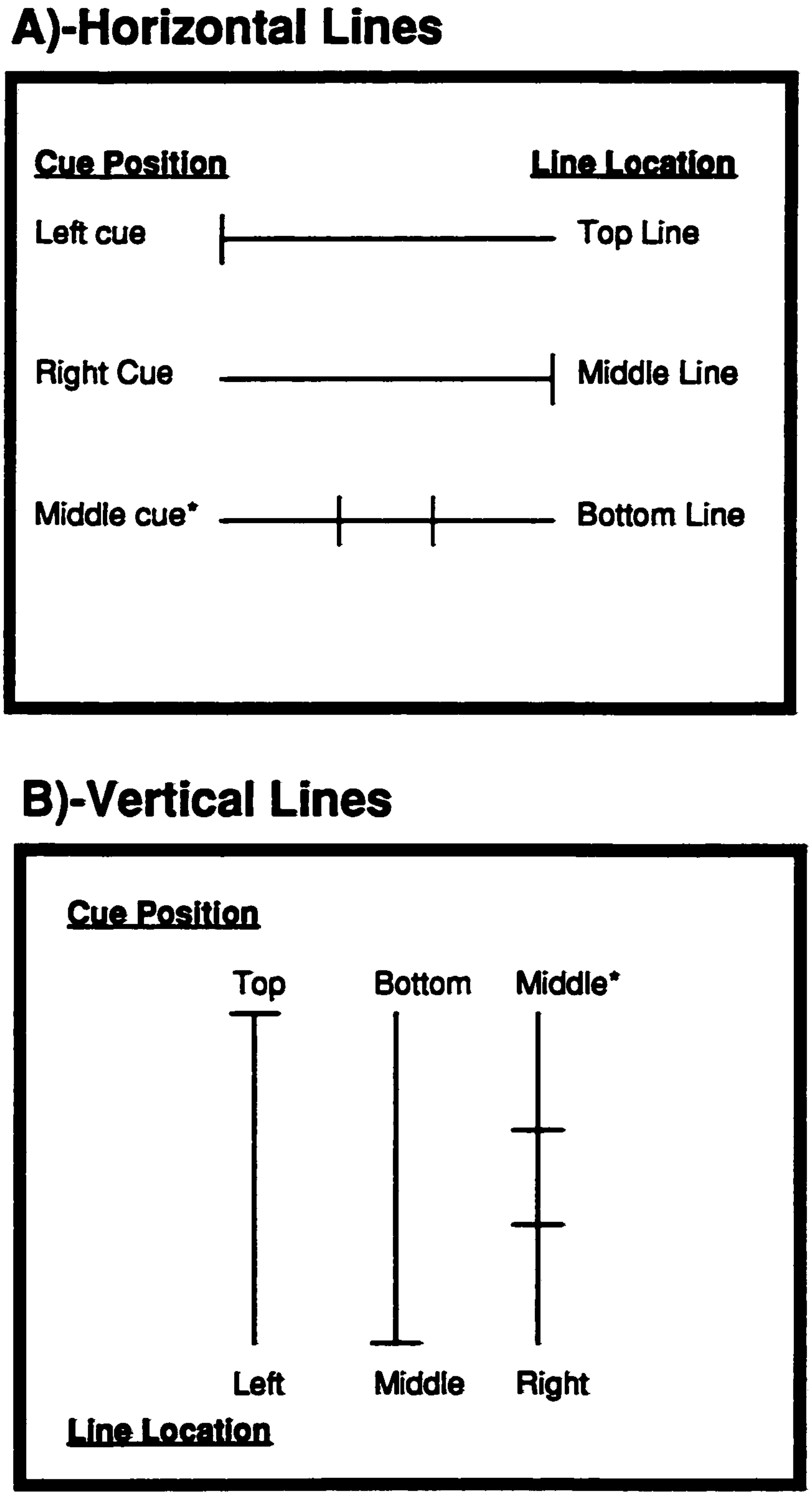

A)-Horizontal Lines
Cue Position
Line Location
Left cue
Top Line
Right Cue
Middle Line
Middle cue*
Bottom Line
B)-Vertical Lines
Cue Position
Top
Bottom
Middle*
Left
Middle
Right
Line Location

Figure 3

Procedure: Once the subject was seated, a chin rest was fastened to the chair and adjusted. Subjects were centred to the screen, using a computer generated (ClarisWorks™) centering cross (7^0 x 7^0) projected onto the Cineplex™ screen. First, the centering cross was centered at the middle of the screen. Next, the subject's midsagittal plane was aligned with the vertical segment of the cross. Then, the horizontal segment of the centering cross was either raised or lowered until it was aligned with the root of the subject's nose. Of note, the centering cross' position corresponded with the position of the middle horizontal and vertical lines, thus assuring as accurate an alignment of the subject and the stimuli as possible.

The subject was instructed to locate without deliberation the midpoint of each line presentation, using a modified computer mouse with the right (or ipsilesional) hand. The modified computer mouse was positioned along the subject's midsagittal plane, below the chin rest, at a distance approximating 15 cm away from the body. This was done to minimize the contribution of spatial compatibility. A practice block (consisting of 12 lines) was followed by an experimental (i.e., 72 lines) block . Given the simplicity of the task, the practice block was only offered in the leading Viewing distance (i.e., peripersonal or extrapersonal, not both). A minimum of 156 lines were bisected by each participant. Patients with right-hemisphere damage were subjected to two extra experimental blocks at each Viewing distance, because of the variability in their performance. Eye movements were not restricted during this task.

Statistical analyses: A descriptive evaluation of overall bisection (i.e., collapsed across Viewing distance, line position and bisecting cursor starting location) judgment was performed across group designation. Of note, only the longer line length was utilized in the analyses presented here, as this length is representative of that more commonly reported in the literature and that which provides the more robust findings. This visual inspection of the data was then followed by four repeated measures analyses, one for each group. In addition, several single sample t-Test analyses were performed to determine if subset bisection judgments were significantly different from zero, using the middle line biases in peripersonal space. The choice of the middle line in peripersonal space seemed appropriate, given that it is the most commonly reported condition.

Results

Between Group Evaluation

Horizontal and Vertical Lines

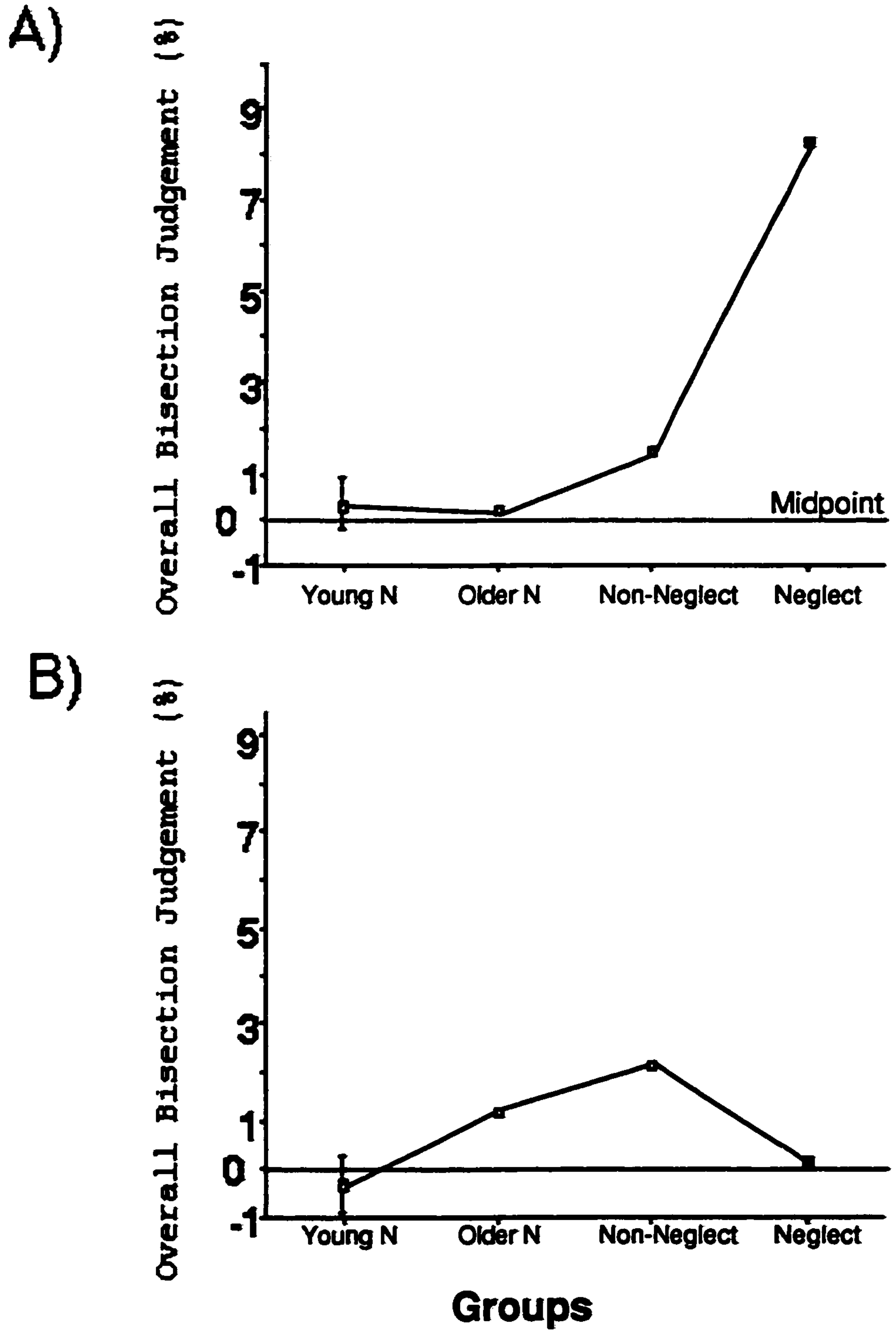
The overall bisection judgments for horizontal and vertical lines are presented across the four groups in Figure 4a and 4b, respectively. The most notable outcome in the horizontal lines data is the sizeable rightward bias in patients with neglect. The magnitude of the effect is several times that observed in young (i.e., 24 times) and older (i.e., 40 times) normal, and right-hemisphere patients without neglect (i.e., 8 times). This pattern of results was not substantiated with vertical lines, as the patients' judgments fell within the range of that found in the young normals. In fact, patients with neglect exhibited the smallest upward bias relative to the group of patients with right-hemisphere lesion and older normals. Lastly, the group of young normals manifested a downward bias. A breakdown of bisection biases for horizontal and vertical lines across Viewing distance, line position, and cue for all four groups is presented in table format in Appendix A.

Within-Group Analyses

In the section that follows, outcomes are presented on a group by group basis. Unless stated otherwise this represents a repeated measures design with three factors: Viewing distance, line position and cue.

Normal Controls (Young Sample)

As the starting position of each subject was counter balanced between peripersonal and extrapersonal space, an analysis of variance using initial Viewing distance as a



Figures 4a &4b
Mean overall bisection judgment from horizontal (A) and vertical (B) lines across the young normals (Young N), older normals (Older N), patients with right-hemisphere lesions with and without neglect. The error bar assigned to the young normals is the group's 95%CI. A positive value depicts a rightward (horizontal lines) or upward (vertical lines), while a negative value depicts a leftward (horizontal lines) or downward (vertical lines) deviation.

Horizontal Lines

The overall bisection bias on horizontal lines did not deviate significantly from the veridical midpoint (Bias = 0.06%; $t_{1,42}$ = 0.47, p = 0.64). Next, an analysis of variance revealed that there were significant main effects of Viewing distance ($F_{1,42}$=4.8; p= 0.03) and Cue ($F_{1,42}$=49.9; p = 0.0001). While a leftward judgment (i.e., -0.2%) was observed in peripersonal space, a rightward judgement was noted in extrapersonal (i.e., 0.4%) space. A leftward bisection judgment (i.e., -1.0) following the left cue was significantly different from the rightward judgment following the middle (i.e., 0.2%; F=28.4; p= 0.0001) cue; as well the right cue led to a rightward judgment (i.e., 1.0%) that was significantly greater than that observed following the middle cue (F=14.4; p = 0.0003). The Viewing distance by Cue interaction was significant ($F_{2,84}$=15.9; p = 0.0001 - see Figure 5b), while the Viewing distance by Location interaction was not significant. The effect of the left (F=46.5; p=0.0001) cue was most prominent in peripersonal (i.e., -1.7%) than extrapersonal (i.e., -0.1) space. The effects of middle and right cues were qualitatively similar at both Viewing distances.

Vertical Lines

The overall bisection bias on vertical lines deviated significantly below the veridical midpoint (Bias = -0.8%; $t_{1,42}$ =-4.8, p = 0.0001). Next, the analysis of variance suggested that there were significant main effects of Viewing distance ($F_{1,42}$=44.9; p = 0.0001) and Cue ($F_{1,42}$=19.5; p= 0.05). Overall (i.e., collapsed across

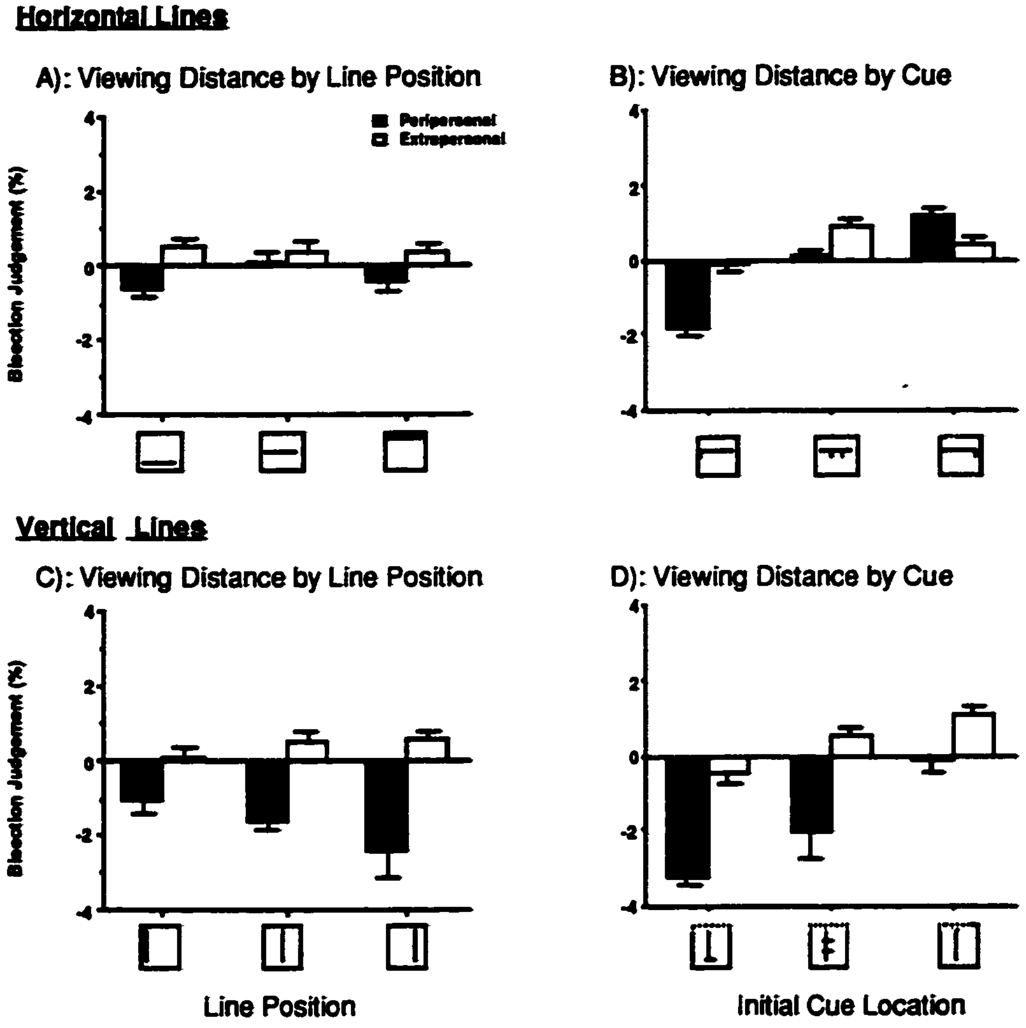


Figure 5

Mean bisection judgment in young normals according to line position and Viewing distance in horizontal (a) and vertical (c) lines, and mean bisection judgment according to initial cue location and Viewing distance in horizontal (b) and vertical (d) lines. A positive value represents a rightward (horizontal lines) or upward (vertical lines), while a negative value represents a leftward (horizontal lines) or downward (vertical lines) deviation.

cursor start and line position) bisection judgment in peripersonal space exhibited adownward bias (i.e., -1.6%), while in extrapersonal space an upward bias was noted (i.e., 0.4%). The downward bisection judgment following the bottom (i.e., -1.8%) cue was significantly different from the downward judgment following the middle (i.e., -0.7%) cue (F=7.4; p= 0.008), the judgment of the middle cue was also significantly different from that of the upward judgment following top cue (i.e., 0.6%; F=12.4; p = 0.0007). Significant 2-way interactions were noted between Viewing distance and Cue ($F_{2,84}$=3.5;p = 0.03 - see Figure 5d) and the Viewing distance and Line Location ($F_{2,84}$ = 3.6; p = 0.03 - see Figure 5c). A significant difference in the direction of bisection judgments between peripersonal (i.e., downward) and extrapersonal (i.e., upward) space was observed for bottom (F=29.5; p=0.0001), middle (F=24.4; p=0.0004) cues, and top (F=3.8; p=0.05) cues (see Figure 5d). Similarly, a significant difference in the direction of bisection judgments between peripersonal (i.e., downward) and extrapersonal (i.e., upward) space was observed for left (F=7.2; p=0.009), middle (F=21.5; p=0.0001), and right (F=42.2; p=0.0001) lines (see Figure 5d).

Normal Controls (Older Sample)

Horizontal Lines

The overall bisection bias on horizontal lines did not deviate significantly to the right of the veridical midpoint (Bias = 0.08%; $t_{1,8}$ = 0.11, p = 0.91). Next, the analysis of variance revealed a significant main effect of Cue ($F_{2,16}$=3.7; p = 0.05). Although the right (i.e., 1.0%) and left (i.e., -0.4%) cues did not differ significantly from the middle (i.e., 0.0%) cue, left and right cue differed significantly from each other (F=7.1; p=0.02). No other MEs or interactions were significant (see Figures 6a & 6b).

Vertical Lines

The overall upward bisection bias on vertical lines did not deviate significantly from the veridical midpoint (Bias = 1.0%; $t_{1,8} = 0.93$, $p = 0.38$). Next, the analysis of variance suggested that there were no significant main effects of Viewing distance, Line Position, or Cue. However, a significant 2-way interaction was noted between Viewing distance and Cue ($F_{2,16}=3.62$; $p = 0.05$ - see Figure 6d). Although the patterns of response following bottom and middle cues were similar at both Viewing distance, the top cue resulted in a significant twofold reduction in the upward bias in extrapersonal compared to the bias in peripersonal space ($F=6.7$; $p=0.02$). No other interactions were significant (see Figure 6c).

Patients With Right-Hemisphere Who Do Not Manifest Neglect

Horizontal Lines

The overall bisection bias on horizontal lines did not deviate significantly to the right of the veridical midpoint (Bias = 1.91; $t_{1,6} = 1.0$, $p = 0.34$). The analysis of variance revealed a significant main effect of Cue ($F_{2,12}=4.5$; $p = 0.04$). Planned contrasts suggest that, although they did not differ significantly from the middle (i.e., 1.8%) cue, the left (i.e., -0.3%) and right (i.e., 3.0%) cues differed significantly from each other ($F=8.7$; $p=0.01$). No other ME or interaction was significant (see Figures 7a & 7b).

Vertical Lines

The overall downward bisection bias on vertical lines did not deviate significantly from the veridical midpoint (Bias = -0.88; $t_{1,6} = -0.39$, $p = 0.71$). The analysis of variance revealed a significant main effect of Line Position ($F_{2,12}=4.2$; $p= 0.04$). Bisection judgments from left (i.e., 2.6%) lines differed significantly from the middle (i.e., 0.8%; $F=5.6$; $p = 0.04$) and right (i.e., 0.9%; $F=7.0$; $p = 0.02$) line, while left and right lines did not differ from each other. No other ME or interaction was significant (see Figures 7c & 7d).

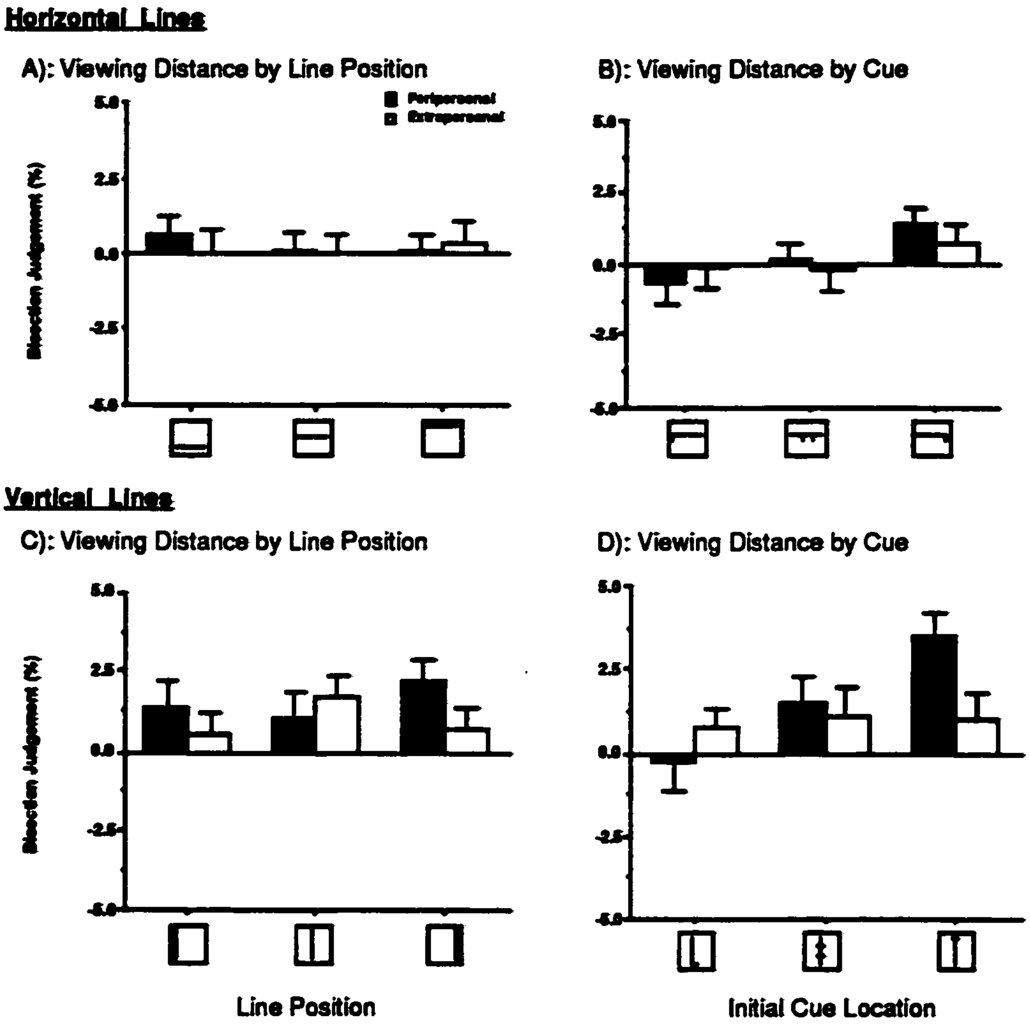


Figure 6
Mean bisection judgment lines in older normals according to line position and Viewing distance in horizontal (a) and vertical (c) lines, and mean bisection judgment according to initial cue location and Viewing distance in horizontal (b) and vertical (d). A positive value represents a rightward (horizontal lines) or upward (vertical lines), while a negative value represents a leftward (horizontal lines) or downward (vertical lines) deviation.

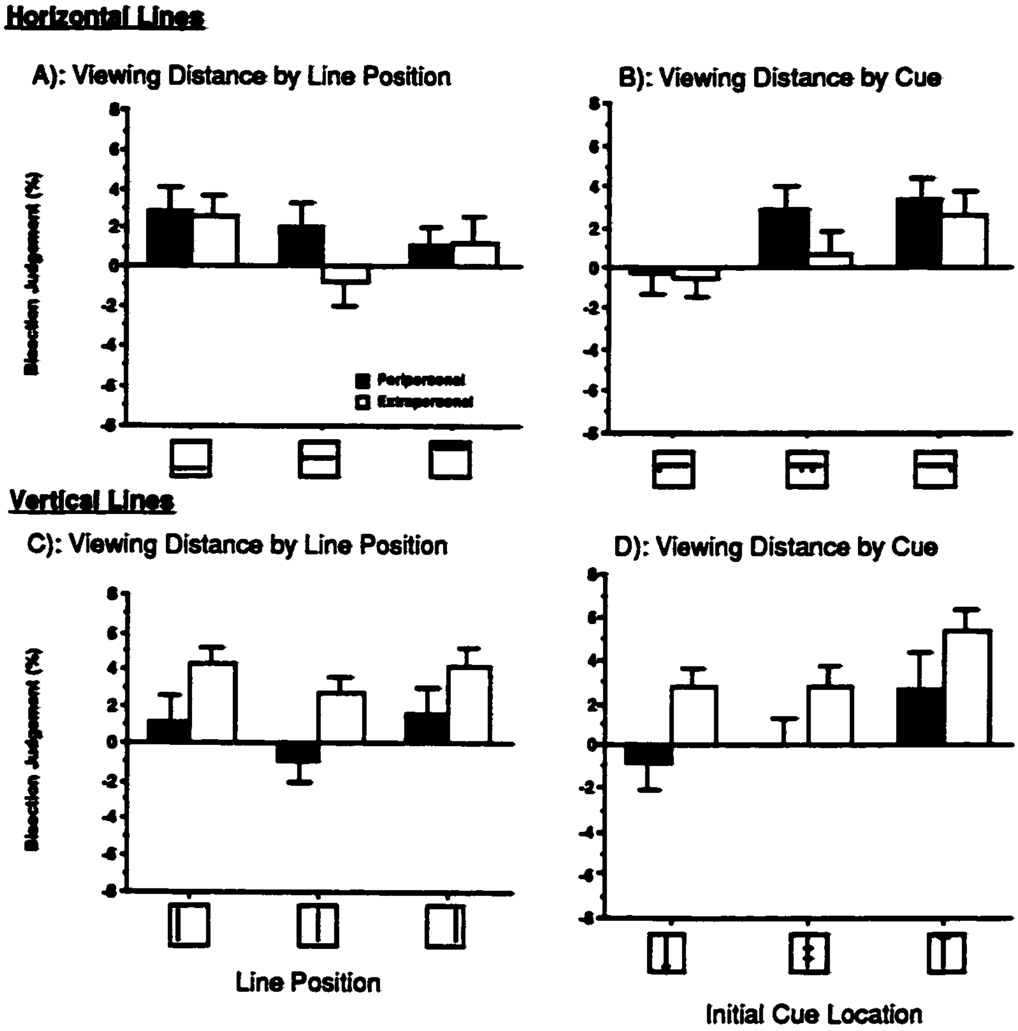


Figure 7
Mean bisection judgment in patients with right-hemisphere lesions, who did not manifest neglect, according to line position and Viewing distance in horizontal (a) and vertical (c) lines, and mean bisection judgment according to initial cue location and Viewing distance in horizontal (b) and vertical (d) lines. A positive value represents a rightward (horizontal lines) or upward (vertical lines), while a negative value represents a leftward (horizontal lines) or downward (vertical lines) deviation.

Patients with Neglect

Horizontal Lines

The overall rightward bisection bias on horizontal lines deviated significantly from the veridical midpoint (Bias = 9.8; $t_{1,6}$ = 2.6, p = 0.04). Next, the analysis of variance suggested that there was a significant main effect of Cue ($F_{2,12}$=6.2; p = 0.01). Although they did not differ significantly from each other, the middle (i.e., 14.8%; F12.1, p = 0. 005) and right (i.e., 9.7%; F12.1, p = 0. 005) cues differed significantly from the left (i.e., 0.9%) cue. No other ME or interaction was significant. Of particular interest was the reversal in the magnitude of rightward bisection judgments across line location and Viewing distance. As seen in Figure 8a, the bottom lines exhibited the greatest rightward deviation in peripersonal space, while in extrapersonal space the top line exhibited the greatest rightward deviation. This observation proved significant (F=4.65, p=0.05) using planned contrast comparing the combined bottom and middle line locations to the top line location across viewing distance[10]. Lastly, the effects of unilateral cues, shown in Figure 8b, were more visible in peripersonal than in extrapersonal Viewing distance, as a unilateral left cue resulted in a leftward bias in peripersonal space.

Vertical Lines

The overall downward bisection bias on vertical lines did not deviate significantly from the veridical midpoint (Bias = -1.1; $t_{1,6}$ = -0.32, p = 0.76). Next, the analysis of variance suggested that none of the ME or interactions were statistically significant (see Figures 8c & 8d).

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[10] The contrast is the following [(PB + PM)-(EB +EM) vs. (PT + PE)], where P is peripersonal, E is extrapersonal, B is bottom, M is middle and T is top line location.

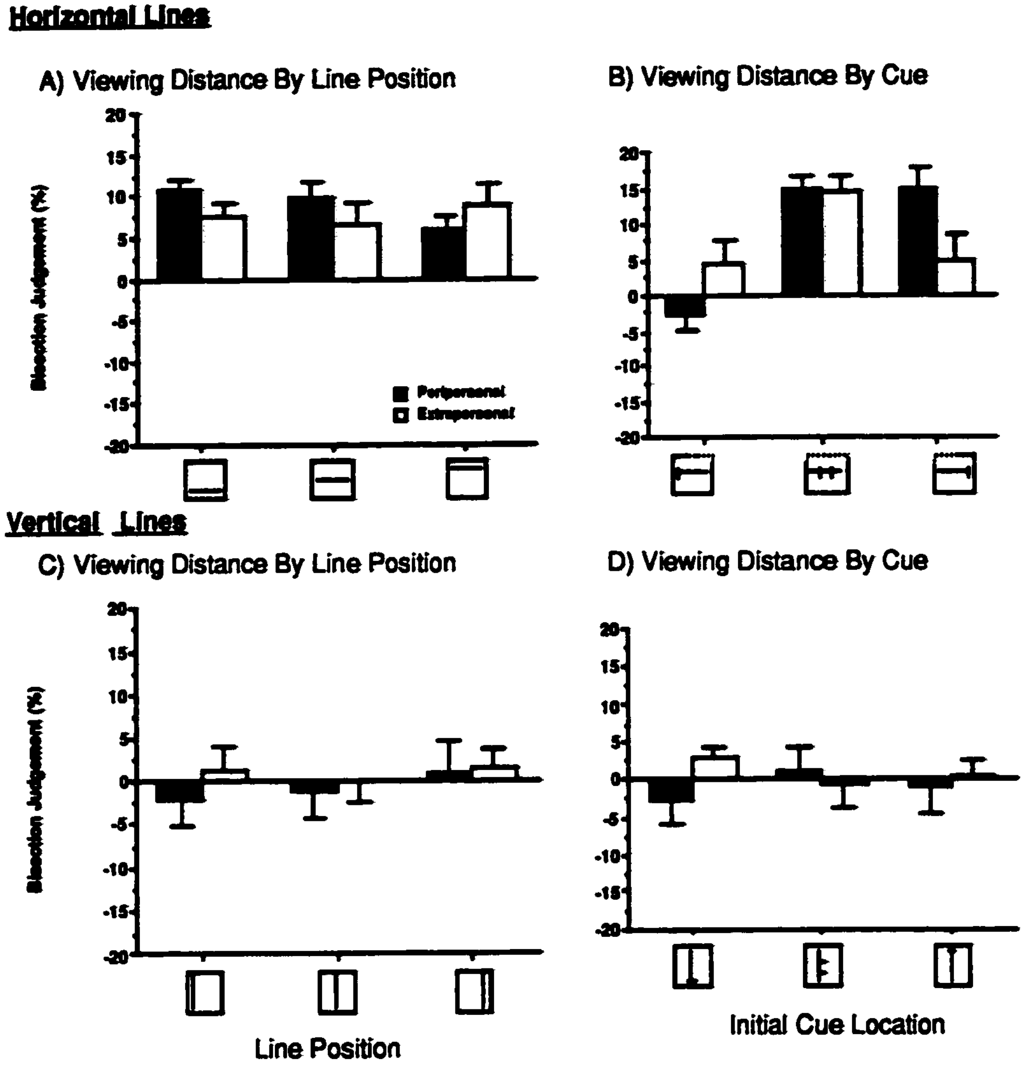

Figure 8
Mean bisection judgment lines in patients with neglect according to line position and Viewing distance in horizontal (a) and vertical (c) lines, and mean bisection judgment according to initial cue location and Viewing distance in horizontal (b) and vertical (d). A positive value represents a rightward (horizontal lines) or upward (vertical lines), while a negative value represents a leftward (horizontal lines) or downward (vertical lines) deviation.

Discussion

The findings are presented by the type of analysis and their possible interpretation in light of the current status of the literature.

Section A: Between-Group

The major purpose of this analysis was to corroborate previous reports of greater bisection deficits in patients with right-hemisphere lesions manifesting neglect (e.g., Heilman et al, 1995, Gainotti et al, 1972; Albert, 1973; Costa et al, 1968) when compared to either neurological non-neglect patients or normal controls. As such, the findings from horizontal lines supported previous findings that patients with neglect misbisect lines significantly to the right of midpoint, while current results from vertical lines bisection displacements did not support a significant deviation from the veridical midline.

Section B: Within-Group

Normal Individuals

Overall Bias

The current findings suggested that young (B= 0.06%) and older (B=0.08%) normal subjects tended to bisect horizontal line fairly accurately. This finding is interesting in light of Bruyer's (1983) comment regarding the flawlessness of normal subjects performance on line bisection (see p. 23). This outcome suggests that, in a large sample of right-handed individuals, normal individuals do perform to near flawlessness. A finding not previously reported. Perhaps, the fact that previous research was conducted on smaller samples may, in part, account for the discrepancy. A group of investigators have suggested the composition (and size) of the sample under investigation may be biased by an inherent propensity to scan lines in one direction over the other leading to a classification of "left-shifters" and "right-shifters" (Manning et al, 1990). The scanning behavior apparently dictated the direction of the bisection bias. However, in her sample participants bisected a greater number of lines per condition than those in the current sample. As such, this explanation is therefore not applicable to the outcome presented here, as fewer lines were bisected per participants. Alternatively, Bradshaw and colleagues (e.g., Bradshaw et al, 1983) suggested through a series of bisection experiments that subjects tend to overestimate the left segment of the line (or rod), which presumes that the true length of the right segment is underestimated leading to the leftward bias and supported a representational imbalance in processing efficiency between hemispheres. A logical extension would suggest that a rightward bias reflects an overestimation of the right segment combined with an underestimation of the left segment of the line, while the left-hemisphere is activated to a greater degree than the right-hemisphere (hence hemispheric imbalance or asymmetry). Following Bradshaw's logic, the current outcome suggests that neither left nor right-hemisphere were preferentially activated. Another possibility, and perhaps complimentary, resides in methodological differences across studies. Line bisection is a complex visuo-motor-perceptual task. In the studies presented in Table 3, methodological differences were restricted primarily to the number of lines per page (e.g., Fischer, 1994 vs. Kim et al, 1997), line length (e.g., Black et al, 1990 vs. Manning et al, 1990), and number of trials per condition (e.g., Bower & Heilman, 1983 vs. Halligan et al, 1990), while all lines were bisected manually. However, even when methodological parameters are controlled biases still vary (see Table 3, Halligan et al, 1990 vs. Halligan and Marshall, 1989). As such, the bisection behavior (i.e., motoric) may in fact be critical in determining the resulting bias and not the physical parameters of the line, which is the main argument presented by the proponents of hemispherical activation hypotheses (e.g., Kinsbourne, 1993). As such, in these studies the bisection is not a simple response, but a complex action that results in selectively activating specific hemispheric regions; frontal and parietal (see Roland et al, 1980 for study of cortical activation during voluntary movements in extra-corporal space). The effects of asymmetrical hemispheric activation on perceptual performance are documented in normal individuals (e.g., Reuter-Lorenz et al, 1990; Bradshaw et al, 1985) and brain damaged individuals (e.g., Robertson & North, 1993).

The current study differs methodologically in that bisection of lines was accomplished using a rotary knob on a modified mouse (minimizing lateral motor movement), while in the above mentioned studies intricate arm-vision movements were required (e.g., arm moving within and across hemispaces under visual guidance). In that case the bias reported here may be a direct consequence of reducing the motoric contribution (i.e., asymmetrical hemispheric activation secondary to arm movement resulting in the preferential activation of one hemisphere over the other). Thus, the bisection bias (or more accurately lack thereof) reported here reflects a reduction from the influence of motor or spatial factors and may have led to a more representative and accurate (not confounded) assessment of line bisection behavior and performance.

Patients with right-hemisphere lesions, who do not manifest signs of neglect, tended to bisect the line to the right (Bias = 1.91%) of the veridical midpoint. The magnitude of the deviation was greater than that observed in normal (who showed none), but it was significantly less than that found in patients with neglect. As predicted, patients manifesting neglect displayed the greatest rightward bias. This is in agreement with a number of previous investigators (e.g., Schenkenberg et al, 1980; Halligan & Marshall, 1989; Milner et al, 1993), who have consistently shown this result on horizontal line bisection. Moreover, upon closer inspection of the rightward biases observed in the literature, the magnitude of the judgment (B= 9.8%), using the current line length, is consistent with those reported (see Table 8).

Line Position

It appears that the position of horizontal lines along the vertical meridian does affect the overall bisection biases of normal young, but not older subjects[11], individuals. This finding was not predicted. Notwithstanding, it appears critical to note, at the very least, the variation of the rightward bisection bias, which was greatest on lines presented below eye

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[11]The small number of subjects and consequently low statistical power may be partially responsible for this null finding.

level compared to those presented above eye level. Previous studies demonstrated that in normal dextral subjects bisection biases vary from left to right of midpoint contingent upon the position of the line along the left-right axis continuum (e.g., Bowers and Heilman, 1980). However, no previous study had investigated the bisection biases on horizontal lines along the vertical meridian. In the sample of right-hemisphere patients without neglect, a non-significant overall rightward bias was observed. However, when the biases were broken down across line location, the bias appeared to be largest below eye level and reduced at the middle and top line positions. Similarly, in patients with neglect the bias varied in a similar fashion, but the magnitude of the displacement exceeded that of the non-neglecters. This pattern appears to be an exaggeration of the pattern observed in younger normal controls (see above). These findings suggest that attention is also organized and biased along a top-bottom axis continuum, which is apparently independent of line orientation.

Cuing Effects

The current findings supported the prediction of a significant effect of unilateral (i.e., left and right) cue on the bisection judgment of young and older individuals, which corroborated the effects of static cuing previously reported (e.g. Reuter-Lorenz & Posner, 1990). It has been suggested that the manipulation of cue location reflects the subject's attentional bias secondary to a hemispheric activation imbalance (e.g., Reuter-Lorenz et al, 1990). As such, the unilateral cuing would exert its effect in activating the contralateral hemisphere; in turn, an asymmetrical activation of the hemisphere results in the overestimation and underestimation of the contralateral and ipsilateral segments of the line, respectively. Of note, more recently the attentional theory has been challenged by a perceptual hypothesis (Fischer, 1994). Fischer suggested that an absence of order effect on reporting the identity of bilaterally placed letters combined with unilateral cue presentation supported a perceptual and not an attentional factor in the bias. However, difficulty in dissociating the confound of attention in his "perceptual grouping" hypothesis minimized the impact of the findings. Given that the cue was an integral part of the line and not a separate entity in previous studies (e.g., Riddoch & Humphreys, 1983), including Fischer's (1994), my study provides unequivocal support for an attentional component.

Similarly, the effects of cue were significant for right-hemisphere patients, who did not manifest neglect. The similarities between the younger sample and this group are not surprising and have been reported before (Milner et al, 1993). However, the effect of the cursor start was stronger in patients with neglect than the other two groups. The current findings are in agreement with previous findings (e.g., Lin et al, 1996; Milner et al, 1993; Marshall & Halligan, 1991). Additionally, given the minimal motoric involvement in the bisection performance, the current outcome provides indirect evidence in support of attentional mechanisms and against other factors, including the arm of the investigator (see Reuter-Lorenz & Posner, 1990), a motoric contribution to the bisection (see, Marshall and Halligan, 1990), or a perceptual component (see Fischer, 1994). Moreover, of particular interest is the near "normalization"[12] of the left unilateral cue condition on the bisection biases of patients with neglect.

Previc's Model

The line location interaction by Viewing distance was not supported in any of the groups under investigation. However, visual inspection of the Viewing distance and line location interaction revealed an opposing trend in bisection performance. In patients with neglect bisection judgments of bottom and middle line resulted in greater rightward deviations in peripersonal space, while in extrapersonal space the top line generated a greater rightward displacement (see Figure 8a). In contrast, although variable bisection judgments to unilateral cues across Viewing distance were noted in the group of young normals, the interaction appeared to be restricted to the variable effects of the left cue in peripersonal (i.e., leftward bias) and extrapersonal (i.e., rightward bias) space. As such, it

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[12]Approaching the range of bisection judgment found in young normal participants.

did not provide support for Previc's assumptions. This interaction was not supported statistically in either the older normals or the patients without neglect.

Vertical Lines:

Normal Individuals

Overall Bias

The prediction of an upward bias on vertical lines was not supported in this study. The group of young normals displayed a significant downward bias. To my knowledge only one other study reported a similar finding (Rapsack et al, 1988. Theories of left-right distribution of attention (e.g., Kinsbourne, 1987) cannot provide any substantial guidance in the elucidation of the top-bottom dimension. Given the relatively small number of studies investigating vertical biases, empirical data is equally sparse in providing guidance in the interpretation of the finding. In contrast, a non-significant upward bias was observed in the older sample. The latter is consistent with a number of previous reports supporting an upward bias (Scarsbrick et al, 1987; Butter et al, 1989; Shelton et al, 1990; Mennemier et al, 1992). Again, issues of scanning and sample composition may partly explain the discrepancies among current findings. As in the discussion of the outcome from horizontal lines methodological considerations may also be a critical factor .

An unanticipated finding was the overall downward bias observed in patients with neglect. This is in contrast to the reported upward bias observed in patients with neglect. In addition, it appears to be counter-intuitive based on the findings of greater rightward biases on bottom than top horizontal lines. However, altitudinal neglect is dissociable from lateral neglect (Marshall & Halligan, 1994).

Line Position

The bisection judgment remained stable across the horizontal meridian for the younger and older normals. For both patients with and without neglect displacement from veridical centre varied at the middle line location, but not for the left or right lines. This finding is difficult to interpret, as there are, to my knowledge, no available studies with which to contrast the current findings. Additionally, one might have expected that the variability observed in bisection displacements in horizontal lines moved along the vertical meridian might also hold for the vertical lines being moved across the horizontal meridian. That is, given the finding of greater leftward biases in left hemispace, compared to middle and right hemispace locations, an attenuation of the downward bias as lines were moved to the right was expected. This was not the case in the current sample of patients with neglect. No explanation is provided for this outcome.

Cuing Effects

As predicted, unilateral cuing significantly affected the bisection judgments in young normals, such that the downward bias was attenuated or exacerbated by top and bottom unilateral cues, respectively. This is the first study of its kind to report on the effects of cuing on a computerized version of vertical line bisection. The hemisphere activation theory cannot account for this top-bottom distinction. An alternative explanation to this theory might suggest that, instead of attentional resources being deployed according to an environment centred (i.e., left-right) framework, attentional resources may be activated through the psychophysical properties of the stimuli itself. Under this assumption, there would be no spatially driven dimensional feature to the deployment of attention, but an activation of attentional units based on the physical features of the stimuli (i.e., object centered: see Farah et al, 1990; Feldman, 1985), as one segment of the line might attract attention more strongly than another region of the line, as there are fewer units activated.

As far as the right-hemisphere group is concerned, the outcome of the analyses was perplexing. Bisection judgments were affected by the unilateral positioning of the cue in patients who did not manifest neglect but not in patients with neglect. There are no other studies with which to compare this outcome and interpret its meaning. Most studies (e.g., Butter et al, 1987) investigated the effects of vertical displacement on bisection judgments, but not cuing.

Viewing distance

Interestingly, in young normals overall bisection judgments did vary at the two Viewing distances, as a downward bias was observed in peripersonal space (Bias =-1.4) and an upward bias in extrapersonal space (Bias = 0.4). This may reflect a difference in the scanning proposed by Manning et al (1990). Moreover, under this conceptualization, the current findings suggest that vertical lines in peripersonal space are scanned from bottom to top, while lines in extrapersonal space are scanned top to bottom. This provides support for Previc's (1990) visual field specialization model, as the differential allocation of attention in peripersonal and extrapersonal space leads to biases below and above eye levels, respectively.

A significant effect of varying Viewing distance on the overall bisection judgments was absent for the other three groups.

Previc's Model

In contrast to the horizontal lines, the outcome of vertical line bisection may support a contribution of an attentional component, as only the Viewing distance by cue interaction reached statistical significance. Moreover, this finding is restricted to the younger adults, as the outcome originating from the older sample is more difficult to interpret. In the younger sample, the effects of unilateral (i.e., bottom) cuing resulted in a downward bias in peripersonal while unilateral (i.e., top) cuing resulted in an upward bias in extrapersonal space. As predicted by Previc (1990), this finding indicated that the deployment of attention in peripersonal and extrapersonal space appears biased to the lower and upper fields, respectively. This finding is not supported by the performance of patients who do not manifest signs of neglect, as the extrapersonal Viewing distance appeared to magnify the effects of line location and cuing. A previous report by Mattingley et al (1993) suggested that moving the location of lines in the radial plane leads to a magnification of the effects observed within grasping space. The group of patients demonstrating signs of neglect did not support any of these interactions.

The findings with normal subjects' bisections of horizontal and vertical lines are mixed. One possibility for the varied outcomes may reside in the small number of observations, consequently, increasing variability and obscuring effects that may have been present (i.e., statistical power).

PART 4: VISUAL ORIENTING

The experimental paradigm which has generated the most coherent set of findings on visual orienting in neglect is Posner's cuing paradigm (for a review, see Losier & Klein, submitted). In this paradigm, subjects are asked to make a simple manual response once a target has been detected. Prior to detection, the location of the anticipated target is uncertain. However, a cue preceding the target may serve as an indicator of the likely target location. When the cues are informative about target location, the likelihood of the target appearing in the cued location is greater than in an uncued location. Trials on which the target appears at the cued location are referred to as valid, and trials on which the target appears at an uncued location are referred to as invalid. Finally, a cue indicating that the appearance of a target is equally likely at all possible locations is typically known as neutral[13].

It has been consistently demonstrated that reaction time to a target is faster on valid than on invalid trials, while the neutral cuing condition usually occupies an intermediate position between valid and invalid response times (e.g. Posner et al, 1980). Differences between the valid and neutral conditions are defined as a benefit, while differences between the neutral and invalid conditions are defined as a cost. Analyses of costs and benefits provide us with valuable information regarding the attentional allocations of the visual system along various spatial dimensions.

Two types of visual orienting responses exist: overt and covert. In overt orienting the selection of attention is achieved by turning the head and/or eyes to the point of interest. On the other hand, covert orienting is described as the shifting of mental attention mechanisms to the source of interest. The emphasis of this thesis is on covert visual orienting, which can be accomplished in either a reflexive or a controlled manner. That is, we can either respond to an event in the environment following a sudden change in its

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[13]A neutral cue might be the presentation of a plus sign at fixation or the brightening of the display background (see Petersen et al, 1989), or a brightening near each possible target location.

composition or we can voluntarily deploy our attention in one direction. Typically, reflexive or exogenous (i.e., originating outside the organism) orienting is examined using peripheral visual cues to draw attention to a specific spatial location. In contrast, under controlled or endogenous (i.e., originating within the organism) orienting an arrow, or other arbitrary symbol is displayed, usually at fixation, to indicate the likely location of the upcoming target. The possible importance of these various orienting protocols is reviewed elsewhere (Klein et al, 1992).

Covert Orienting in Normal Individuals

The majority of studies investigating attentional shifts typically used displays in which the possible target locations were to the left or right of fixation (e.g., Posner et al, 1980). Evidence exists to support the notion that precuing facilitates the detection of a subsequent target when it corresponds with the cued location, the valid condition, and hinders the response when it does not correspond with the cue, the invalid condition (e.g. Posner, 1980; LaBerge, 1983; Duncan, 1984; Gawryszewski et al, 1987). In recent years, some interest has extended into the examination of the ability to deploy attention in 2 and 3-dimensional space.

From a series of three experiments, Gawryszewski et al (1987), reported a directional bias in both horizontal and vertical conditions. Specifically, they reported that subjects responded more quickly to stimuli in the right half of space under the valid and invalid conditions, and subjects responded more quickly to stimuli below the horizontal meridian under all cuing conditions (valid, invalid, and neutral). These findings indicate that normal subjects display a natural tendency to detect stimuli faster below than above the horizontal meridian and to the right. This evidence in part supports Previc's model, which predicts faster response below than above eye level in peripersonal space.

In the mid- to late-1980s there was a growing interest in the study of attention in depth. Downing and Pinker (1985) required subjects to attend to the central fixation position within an array of lights in a 3-dimensional scene. Two rows of lights were placed parallel to each other. One row was positioned in front of the central fixation (at a distance of 101 cm from the subject), while the other was positioned behind it (at a distance of 171 cm from the subjects). Because the two rows occupied different positions retinotopically, great care was taken to maintain identical visual angles within and between the two rows. A cue presented at the central location indicated the visual direction in which the target stimulus might appear. Responses were slower for targets positioned farther away than for closer targets. In addition, the cost of attending farther targets in the invalid condition was greater than that for the closer targets. Finally, the cost of attending to farther targets increased with retinal eccentricity. In light of these findings, the authors concluded that a mental representation underlying visual attention existed, in which depth and visual angle[14] were critical.

As well, Gawryszewski et al (1987) investigated the movement of attention in the radial plane within a 57 cm range. Subjects were presented with a central stimulus, positioned at a distance of 38 cm from the eyes, that cued the subject to attend to a position along the same visual direction that was either closer (19 cm away) or farther away (57 cm) from the subject. A response target was presented at either of these two Viewing distances. As expected, mean reaction times were greater for invalid cues than for valid cues. Costs for invalidly cued positions were greater for far than for near targets, suggesting that the subjects could not attend to targets positioned at different Viewing distances simultaneously and could disengage faster from near than from far locations.

The data from previous visual orienting studies (e.g., Eriksen and Hoffman, 1972; Posner et al, 1980; Posner, 1980; LaBerge & Buchsbaum, 1990; Duncan, 1984); coming specifically, from Downing and Pinker (1985) and Gawryszewski et al (1987), have suggested that movement of attention may be biased within a three-dimensional framework.

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[14] Of note, evidence suggesting increased costs with greater retinal eccentricity, however, has been contested (Posner et al, 1981; Hoffman, 1996)

Although the evidence is clear with regard to the effects of cued and uncued conditions on the ability to respond to targets along horizontal displays (i.e., fixation flanked by left and right target locations), the evidence from vertical displays (i.e., target located above or below fixation) is not as abundant nor as clear. Additionally, only two studies have reported on the deployment of attention in near and far space, utilizing two distinct sets of Viewing distance parameters (i.e., 57 vs 170 cm). It seems that the investigation of visual attention (i.e., orienting) is lacking a theoretical framework within which to examine systematically the effects of Viewing distance. Previc's (1990) visual field specialization model provides a theoretical framework from which predictions along the horizontal and vertical dimensions can be made, while the model further suggests that an interaction between these dimensions and Viewing distance should exist. Responses to targets following informative and peripheral cues were analyzed in examining this possibility.

Predictions

Neurologically intact subjects were run, in part, to provide one kind of baseline (control) data.

Reaction Time

1)-Responses to validly cued targets will be faster than those to invalidly cued targets.

2)-Based on Previc's Model, response times in peripersonal space are expected to be faster to targets appearing below eye level than above eye level, while in extrapersonal space the response time to targets appearing above eye level should be faster than those observed below eye level.

Accuracies (Percent Correct)

No discrepancies in response accuracies (i.e., hits) are expected in this sample of individuals, because their ability to detect stimuli is not impaired or affected by neurological factors (e.g., visual field deficits, visuospatial neglect).

Visual Orienting in Patients with Hemispheric Damage

Posner (Posner & Cohen, 1984) proposed three elementary operations involved in attentional shifts: the disengage, move, and engage components of attention. These shifts are closely linked to the theoretical elements of the cost-benefit paradigm. For instance, Posner argues that in the valid condition, since the cue signifies the likely position of the target, following the cue and prior to the appearance of the target, one disengages attention from fixation, moves attention, and engages attention where the target is later likely to be presented. Similarly, when no cue is provided for the impending location of the target, as in the neutral condition, the appearance of the target will result first in attention disengaging from fixation, moving to the target and, then, engaging it. The increase in response latency between neutrally and validly cued targets rests with the equiprobability of target location in the former cuing condition; that is, there are at least two possibilities to monitor in typical horizontal displays under the neutral cuing condition. Finally, if attention is directed incorrectly and the target appears in an unattended location, as in the invalid condition, after being misoriented attention must then disengage from the invalidly cued location, move to the new location, and then engage the target. Given that attention must disengage, move and engage on neutral trials, the usual difference between invalid and neutral trials must be due to a longer time to disengage from the miscued peripheral location or to move the longer distance. This type of appraisal corroborates the findings reported of the performance under the various cue conditions, which demonstrates reliably that validly cued targets are responded to the fastest followed by the neutrally and invalidly cued targets.

Of the three elementary attentional operations, the disengage operation has been investigated the most. Evidence for the disengage operation stems from investigations of patients with visuospatial neglect. Current research efforts employing the visual cuing paradigm have independently shown that these patients, like neurologically intact individuals, respond more quickly to targets under valid than invalid conditions, but display a dramatic interaction between target location and cue type (see Figure 9). Although valid condition responses to targets presented in ipsilesional and contralesional halves of space appear relatively comparable, invalid condition responses to targets are significantly slower in the contralesional than ipsilesional half of space. In light of this finding, Posner (Posner et al. 1984, p.1874)) wrote, "These symmetric benefits of valid cues can be contrasted with the marked differences in reaction time to ipsilesional and contralesional targets following an invalid peripheral, central, or neutral cue. All three of these conditions produce a markedly greater reaction time on the contralesional side, particularly at short intervals. ... The main difference appears to be that target detection in the invalid and neutral trials first requires that attention be disengaged from a location other than the target." The increased cost (typically defined as the difference in response time between invalidly and neutrally cued targets) for contralesional targets following ipsilesional cues has been referred to as a "Disengage Operation Deficit", as if patients with neglect are impaired in disengaging attention from ipsilesional space in order to re-orient toward objects in contralesional space.

Many years have passed since the original reports by Posner. In a chapter from a recent book dedicated to advances in visuospatial neglect research, Robertson and Eglin (1993, p.171) wrote "... Patients with parietal lobe damage detect the asterisk nearly as well in the contralesional and ipsilesional sides of space when it occurs in the cued location (nearly equal ability to move and engage attention to cued locations). However, the delay in responding to the asterisk is increased substantially when it occurs in the neglected field.

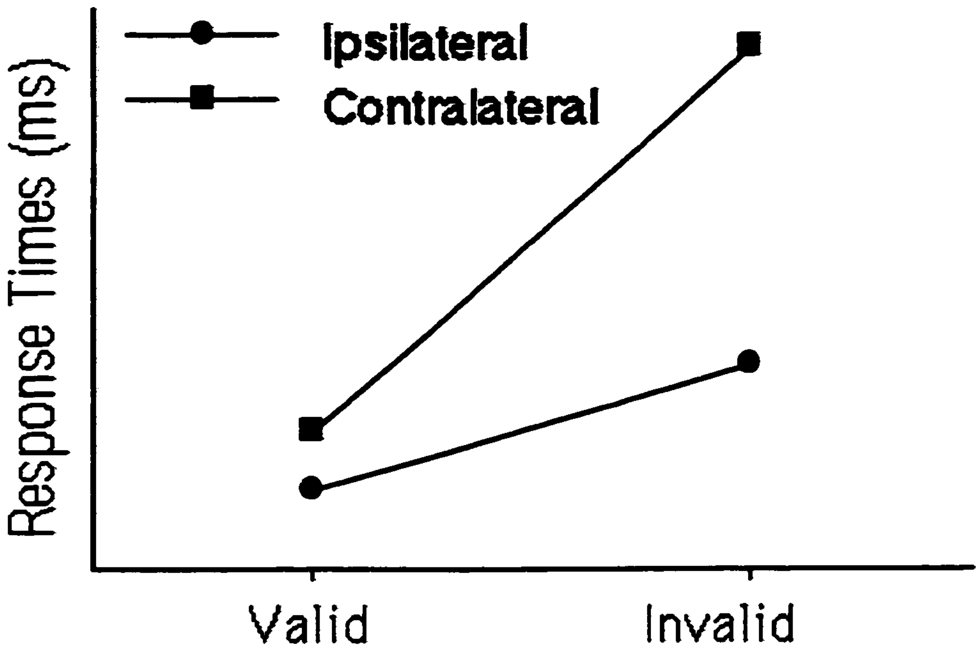

Figure 9
A schematic depiction of the disengage operation, as illustrated by the increased cost in responding to invalid targets in the contralesional hemispace compared to the response observed in ipsilesional hemispace, observed in patients with left-sided neglect.

Patients with parietal lobe damage show an abnormal contralesional delay. When attention must be disengaged from a location on the intact side, there is an abnormal delay...". As such, the disengage operation deficit represents an abnormally long response to invalidly cued targets in the contralesional half of space.

The majority of studies investigating the Disengage Operation Deficit have used variants of an exogenous-endogenous (i.e., hybrid) mode of orienting (Posner et al, 1987; Baynes et al, 1986; Morrow & Ratcliff, 1988; Petersen et al, 1989; Verfaillie et al, 1990; D'Erme et al, 1992; Egly et al, 1994). To my knowledge, only a few studies have employed pure forms of exogenous or endogenous orienting. Farah et al (1989) and Ladavas et al (1994) investigated the orienting capacities of patients with visuospatial neglect using uninformative peripheral cues (purely exogenous orienting). In contrast, two studies have used central cues (purely endogenous orienting) to orient an individual's attentional resources. This was done by Nagel-Lieby et al (1990), and by Posner et al (1984) in a subset of 3 patients (C. W., R. S., & L. M). A disengage operation was supported by Posner's three patients[15], while it was not by the patients reported in Nagel-Lieby's sample. As such, the disengage operation deficit appears more robust under exogenous orienting.

Looking at deficits across ipsilesional and contralesional halves of space provides only partial understanding of the Disengage Operation Deficit. If this deficit represents an inability to disengage from the current focus of attention and move to another, then the Disengage Operation Deficit should be present within as well as between halves of space. Baynes et al (1986) provided (partial) evidence in support of the preceding assumption. They reported a disengage deficit within the contralesional but not ipsilesional field (good field RT: valid=494, invalid = 566; poor field RT: valid = 467, invalid = 673). However, no data were collected between fields (with attention crossing the vertical midline) in their

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[15]Of note, C.W. sustained a left-hemisphere, while the other two patients sustained right-hemisphere lesions.

study. Posner et al (1987) also investigated this possibility both within and across hemifields, and they demonstrated that the disengage phenomenon was the consequence of relative positioning of the cue-target relationship and not the consequence of moving from the ipsilesional to contralesional field. Although it appears that along the horizontal plane a disengage deficit is the consequence of a directional bias (i.e., ipsilesional), evidence regarding a disengage deficit along the vertical plane (which is not confounded by movements towards the contralesional field) is still sparse. As such, it is difficult to know if these two variants of the disengage phenomenon are identical in nature or separate entities.

Early results suggested that lesions to the parietal area, specifically the superior parietal lobules (Posner et al, 1984), were responsible for the deficit. Naturally occurring lesions are rarely, if ever, circumscribed to a particular region, nor are they fixed in size. Nevertheless, the parietal lobes have been the common denominator in this equation. Moreover, there seems to be an asymmetry in the magnitude of the deficit, where right-hemisphere lesions lead to greater deficits than left-hemisphere lesions (see Posner et al, 1984; Morrow & Ratcliff, 1988). As well, it appears that the deficit is sensitive to the interval between cue and target (e.g., Posner et al, 1982, 1984; Morrow & Ratcliff, 1988; Farah et al, 1989; Petersen et al, 1989). Independently, these studies have shown that the Disengage Operation Deficit is greater in magnitude (i.e., response time discrepancies between halves of space under invalid cuing conditions) at shorter SOAs, typically 150 msec. or less than at longer SOAs (i.e. > 150 ms).

Allocation of attention along two or more spatial dimensions

As detailed above, most studies investigating the Disengage Operation Deficit have compared response latencies to targets presented in ipsilesional and contralesional halves of space along the horizontal meridian (Posner et al, 1982, 1984; Morrow & Ratcliff, 1988; Petersen et al, 1989; D'Erme et al, 1992; and Egly et al, 1994) with the exception of Baynes et al (1986), who looked at performances within vertical hemifields (i.e., upper vs lower). Moreover, in the majority of studies of visual orienting, stimulus displays are typically presented at a distance which corresponds to the junction (i.e., boundary) between peripersonal and extrapersonal space. The distance at which the displays were presented varied within a narrow range of depth: 50 cm (Baynes et al, 1986) to 80 cm (Morrow & Ratcliff, 1988). Thus, we do not know if the disengage operation deficit, which is reportedly a consequence of parietal lobe damage, will differ within and between fields or when the display is moved within (peripersonal space) or outside of reach (extrapersonal space) of the patient. Again, according to Previc's model, the relationship between parietal lobe function and Viewing distance suggests that deficits should be more prominent in the lower field than the upper field and that this performance pattern should be more prominent in peripersonal than extrapersonal space.

Predictions:

It should be noted that all patients with right-hemisphere damage may display similar patterns of performance. However, it is predicted that patients with neglect will be affected more severely by some of the manipulations of this study than their non-neglecting counterparts. As such, the following predictions are formulated for patients manifesting signs of neglect only The performance of patients who do not manifest signs of neglect are expected to fall within normal range.

<u>Reaction Time</u>

1)-As reported in the literature, responses to targets, when collapsed across position and Viewing distance, will be faster under valid cuing than under invalid cuing.

2)-Given the propensity of patients with neglect to omit (or fail to respond to) stimuli in the neglected (contralesional) field, responses to targets in the ipsilesional hemifield will be faster than those observed in the contralesional hemifield.

3)-According to Previc, under neutral conditions and as a consequence of parietal damage, responses to targets in the contralesional half of space should be faster above than below eye level in peripersonal space and no significant differences between upper and lower visual fields are expected in extrapersonal space. Response latencies to targets are expected to be greater in the contralesional than ipsilesional half of space.

4)-Because independent evidence exists to support both between and within fields disengage deficits following parietal damage, it is expected that under the current orienting protocol the two types of disengage deficits should be evident in the same individuals.

5)-Given the anatomical and functional findings of Posner and colleagues, as well Previc's assumption of visual field specialization,

i)-When responses to cued targets are collapsed across upper and lower halves of space, the between field disengage operation deficit should be significantly greater in peripersonal than extrapersonal space.

ii)-Reorienting of attention to the lower visual field following the presentation of an invalid cue in the upper field will lead to longer response times than when attention is reoriented to the upper visual field following a lower visual field invalid cue. This response pattern should be greater in the contralesional than ipsilesional field Also, in keeping with Previc's model, this pattern should be more prominent in peripersonal than extrapersonal space.

<u>Miss Rates</u>

1)-Miss rates will be greater in contralesional than ipsilesional space.

2)-Based on the predictions made by Previc's model, it is expected that miss rates will be greater in the lower field in peripersonal space while fewer in the upper field of extrapersonal space.

METHODS

<u>Apparatus-Software and Stimuli:</u> Stimulus presentation was controlled by a PASCAL program. The program controlled three main operations of the paradigm: 1)-

number of trials, 2)-number of conditions and 3)-stimulus thickness (i.e., 1^{o} of visual angle). In addition, the program allowed for the manipulation of five parameters: 1)-cue position, 2)-target position, 3)-stimulus onset asynchrony, 4)-target duration and 5)-target identity. Figure 10 depicts the physical characteristics of the cue and target.

Display and stimulus characteristics: A quadrant display was utilized (see McCormick & Klein, 1990; see Figure 10). Three types of trials were generated using various combinations of cue and target: cued, neutral, and catch. Cued trials were further subdivided into valid and invalid cuing conditions. In the valid condition the cue and target location were congruent, while under the invalid condition the cue and target location were incongruent. In contrast, in the neutral condition the cue appeared at the center and provided no indication of the likely location of the impending target. A catch trial was characterized by a cue followed by a predetermined 'no-response' target (the digit 5). The stimuli were white on a black background. The cue and target were presented at a distance of 11^{0} of visual angle from fixation and subtended 1° of visual angle. The luminosity of the display at the central area of the screen was measured at approximately 7.0 cd/m^2.

The composition of the various trials is presented in Table 14. The trials were presented randomly. Cue validity, excluding catch trials (13% of all trials), was 62.5% for valid and 12.5% for each possible invalidly cued location. Neutral cues occurred on approximately 10% of trials.

A practice block, consisting of 54 trials, preceded the experimental block, which consisted of 232 trials. One experimental block was presented at each Viewing distance. Thus, each subject responded to a total of 518 trials.

Table 14

Number of trials for each cue-target combination at the four locations.

	Cue				
Target	**Down Left**	**Up Left**	**Down Right**	**Up Right**	**Neutral**
Down Left	30	6	6	6	5
Down Right	6	30	6	6	5
Up Right	6	6	30	6	5
UP Left	6	6	6	30	5
Catch Trial[16]	5	5	5	5	0

<u>Time course of events (see Figure 11):</u> A computer generated tone (44 Hz) initiated each trial. Following the tone, three parallel, horizontal lines appeared on the screen at one of five possible locations (top left, top right, bottom left, bottom right or centre) and served as the cue to the upcoming target. The cue remained present for the entire duration of the trial. Next, a 120 msec interstimulus interval (ISI) separated the onset of the cue and the appearance of the target. Then, the target (the digit 2) appeared and remained on screen until the subject responded or for a maximum period of 3000 ms. If a response was not made during this time on a target trial, the target was considered to have been missed. Each trial was separated by a 1000 ms. intertrial interval.

Procedure

The session began with a 10 minute period of dark adaptation. During this time, the experimenter seated and aligned the subject to the apparatus (see Procedure; Part 2: Line Bisection for details), while providing experimental instructions. The subject was asked to maintain fixation on the centrally located cross during each trial. He/she was told that following a tone three parallel bars would appear on the screen at one of five possible

[16] The number of trials per cell was 4 instead of 5 for the patients with right-hemisphere damage, as the experimental block had to be partitioned into two equal halves.

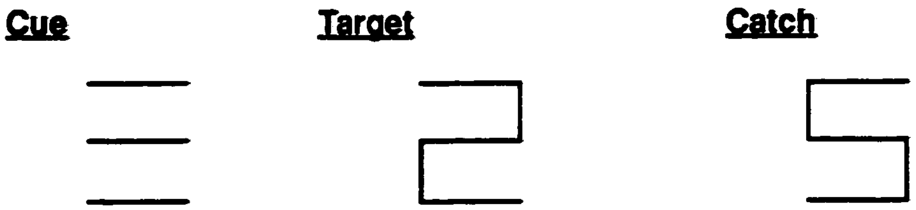
positions. Shortly following the appearance of the three parallel bars, on most trials, the digit two (2) or five (5) would appear at that position. However, on some trials, the digit two (2) or five (5) might appear elsewhere. The subjects were instructed to respond as quickly and accurately as possible to the detected target (the digit 2) by pressing the mouse button, as it rested in the patient's midsagittal plane at a distance approximating 15 cm, while maintaining fixation on the centre cross. By placing the response apparatus directly in front of the subject confounding effects of spatial compatibility are minimized. All stimuli were presented well within the scope of the patients' visual fields.

This 'go-no go' paradigm is a departure from the simple detection of the asterisk (or other symbol) reported in the literature. However, the choice of this paradigm allows the experimenter to control for indiscriminate responding, as measured by false alarms, and verify the nature of the speeded response (speed-accuracy trade off), as measured by the percentage of correct responses. Under previous simple detection protocols, this aspect of the subjects' or patients' performance was difficult to ascertain.

Eye movements: Healthy individuals were instructed to maintained fixation on the centre cross during each trial. Although patients with neglect received similar instruction, their eye position was monitored visually for movements during each trial by the experimenter.

Design

Design: The design of this study was a 2 X 3 X 4 repeated measures design. Three independent variables were examined: Viewing distance (peripersonal, extrapersonal), cue type (valid, invalid, and neutral), and the target stimulus position (upper left, upper right, lower left, lower right). The dependent variables were the response time to each target presentation in milliseconds (msec.) and accuracy (percent correct).



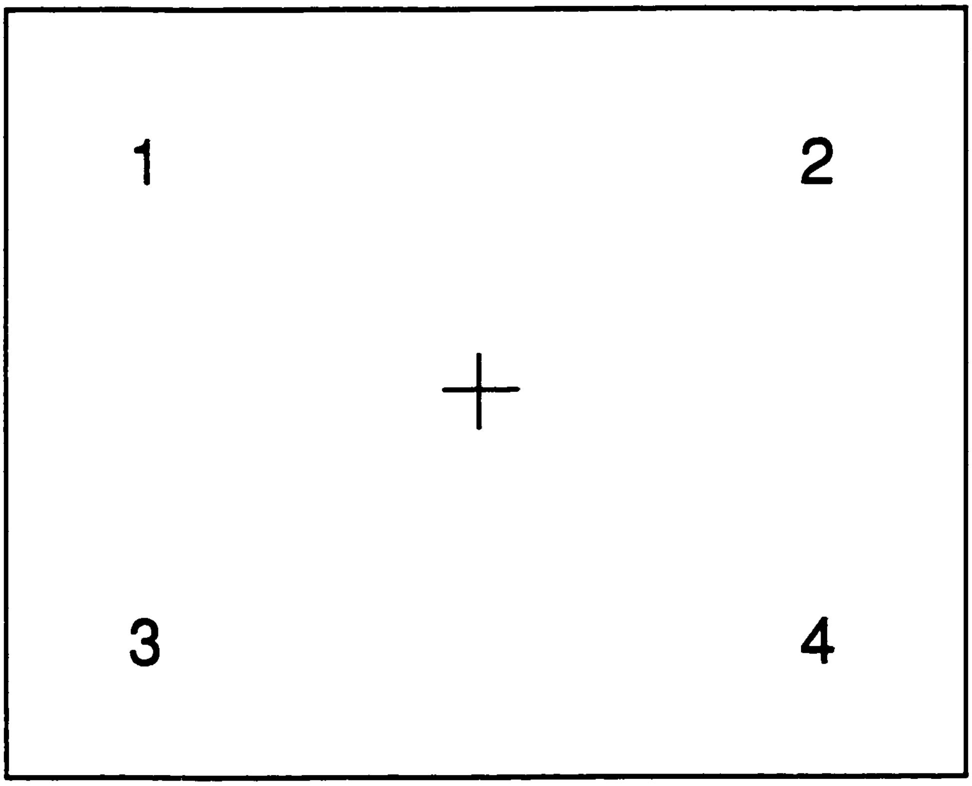


Figure 10
A) A schematic of the cue, target and catch stimuli characteristics. B) The potential target locations.

Statistical Analyses

Data management: This database included identical subject demographics as that described in the Line Bisection section, unless stated otherwise. Response times shorter than 150 ms were considered anticipatory and were discarded.

Statistical analyses: Statistical analyses proceeded in three phases. In the first phase, response latencies, measured in milliseconds, were analyzed according to type of cue (valid, invalid and neutral), target hemifield (upper left, upper right, lower left, lower right), which is divided into lateral and vertical hemifield to ease the potential differentiation of responses along the two planes, and Viewing distance (peripersonal and extrapersonal timing of cue and target apparitions expressed in milliseconds (ms).space). The initial analysis examined the effects of cue on targets across hemifield and Viewing distance. In the second phase of the analyses, participants' response patterns under neutral conditions were examined to provide a pure measure of responding to various targets locations (i.e., responses to quadrants). The final set of analyses examines response times to targets as a function of target hemifield and cue-target relation (see Figure 12). Under this scheme, invalid trials were sorted into categories defined by the spatial relation between the cue and target. The invalid - LR (same side) category refers to trials wherein the cue and target were on the same side (left or right) of space but in different locations. The Invalid - UD category refers to trials wherein the cue and target were on at the same height (upper or lower field) but in different locations. The invalid - OP (opposite) category refers to trials wherein the cue and target were on diagonally opposite corners of the display. The analysis using these 3 invalid categories, which also included Valid and Neutral, addressed the issue of the disengage operation within and between fields in patients with right-hemisphere damage. Finally, errors of omission (e.g., misses) and percent correct of responses were also analyzed for each group, using the repeated measure design described above.

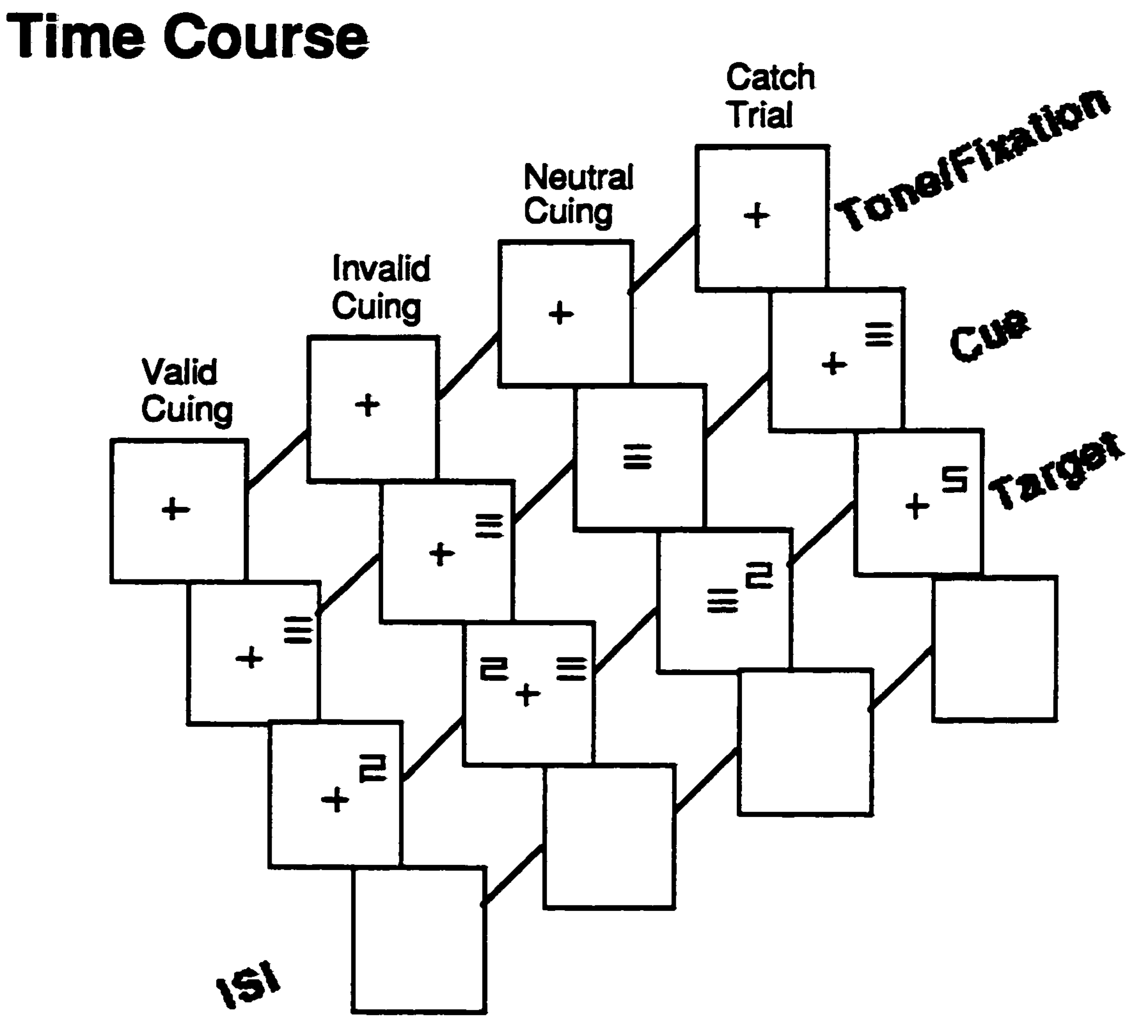


Figure 11

A schematic of the time course of events. A visual depiction of the four types of events illustrating valid, invalid, neutral and catch conditions.

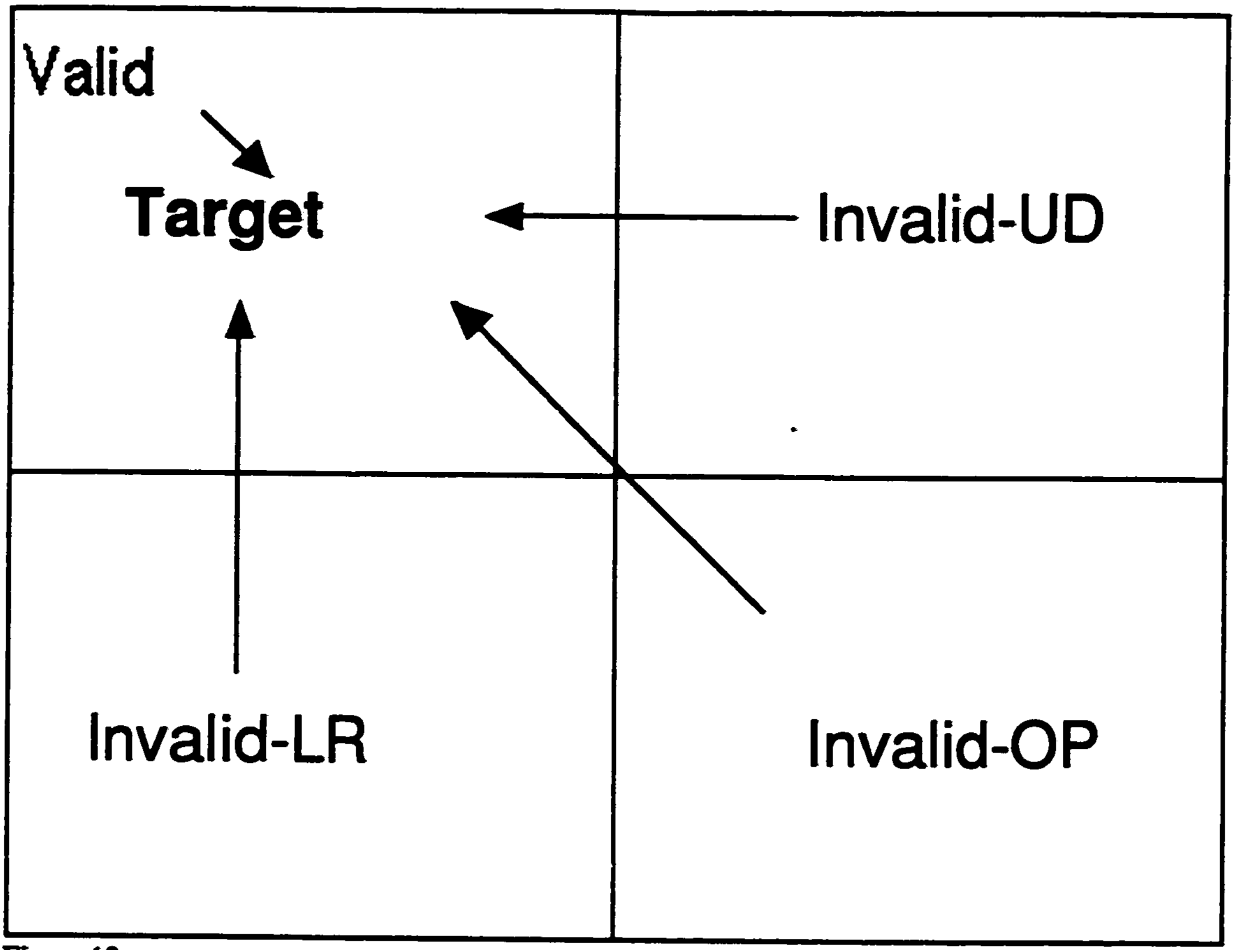


Figure 12
A schematic representation of the within (Invalid-LR) and between (invalid-UD & OP) field cue-target relations. See text for details.

RESULTS

Anticipatory responses occurred in less than 3% of all trials in young normals, while they were absent in the remaining three groups. The data generated from anticipatory responses were removed. This procedure resulted in one empty data cell, which was replaced by the group's arithmetic mean response time for that cell.

Between-Group Analyses

Costs + benefits (C+B, which is the difference between Invalid and Valid reaction times) are presented across the four groups in Figure 13. The most notable outcome depicted in this graphical presentation of the data is the greater C+B in patients with neglect. The magnitude of the effect is fourfold that observed in young normals and twice that seen in the group who did not manifest neglect.

Within-Group Analyses

In this section, reaction time and false alarm data are presented on a group by group basis. For the sample of patients with neglect, accuracy (i.e., percent correct) data are also reported. Three main analyses are described: 1) Target Detection, investigating the overall response patterns to targets at both Viewing distances; 2) Quadrant Analyses, examining potential lateral or/and altitudinal biases under uncued (neutral) conditions; and 3) Within and Between Field Cuing Analyses, appraising the response patterns within and between fields. The pertinence of this latter analysis becomes clearer in the investigation of performance patterns in patients with neglect.

YOUNG CONTROLS

Target Detection

As the Viewing distance was counterbalanced between peripersonal and extrapersonal space, all analyses presented below were initially executed using the starting distance as a between-group factor to investigate any potential effects of starting distance on performance. The starting order interacted with Viewing distance, which is essentially a

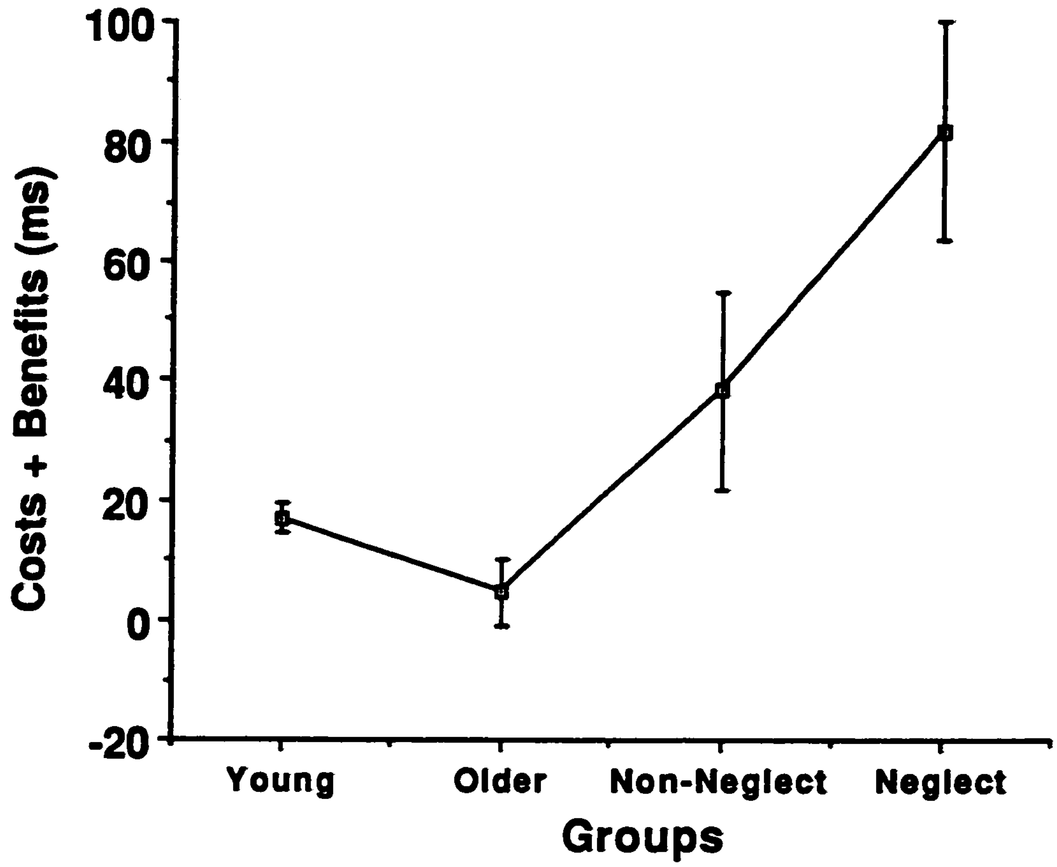


Figure 13

Mean costs + benefits (collapsed across cue condition, quadrant and Viewing distance) and standard errors of young normals, older normals, patients with right-hemisphere lesions and patients with neglect expressed in milliseconds (ms). The bars represent 95% CI.

main effect of practice. Participant's responses to targets, in general, were faster with time[17] on task. This variable did not interact significantly with any other critical parameters such as Hemifield or Cuing and therefore order was not used further in the analyses.

A Viewing distance by Lateral Hemifield (i.e., Left vs. Right) by Vertical Hemifield (i.e. Lower vs. Upper) by Cue Condition (i.e., Valid and Invalid only) repeated measures analysis of variance was performed. Response times to cued targets along the various spatial coordinates are found in Table 15. Significant main effects of cue condition ($F_{1,49}$; = 26.1, p =0.0001) and Vertical Hemifield ($F_{1,49}$; = 4.1, p =0.04) were revealed. Responses to valid (RT = 437 ms) targets were faster than responses to invalid (RT = 456 ms) targets, while responses to the upper field (RT = 449 ms) were slower than those observed in the lower field (RT = 444 ms). The interaction between cue condition by vertical hemifield ($F_{1,49}$; 7.4, p =0.009) was also significant. Planned contrasts demonstrated that response times to validly cued targets in the lower field (RT = 432 ms) were significantly faster (F =11.5, p =0.001) than those recorded in the upper field (RT = 442 ms), while response times to invalidly cued targets were not significantly different in lower (RT = 457 ms) and upper (RT = 455 ms) fields. The Viewing distance by vertical hemifield by cue condition ($F_{1,49}$; = 6.4, p =0.01) proved significant, and the source of variance was isolated to faster responses in peripersonal (RT = 422 ms) than extrapersonal (RT = 442 ms) space to validly cued target in the lower field. No other main effects or interactions proved significant beyond the 0.05 level of statistical significance.

[17] Given that subjects tended to respond more quickly in time, this is a welcome finding, as vigilance remained high (possibly increased) throughout the protocol.

Table 15
Mean reaction times (sd) expressed in ms to validly and invalidly cued targets to quadrants across Viewing distance in young normals.

		Peripersonal		Extrapersonal	
Quadrants		**Cue Type**		**Cue Type**	
of Target		Valid	Invalid	Valid	Invalid
Left	Upper	442(10)	455(11)	445(12)	455(15)
	Lower	422(9)	449(12)	442(14)	455(16)
Right	Upper	438(12)	447(11)	443(13)	465(14)
	Lower	421(9)	458(12)	442(14)	464(15)

The rate of false alarms was also examined. Table 16 displays the breakdown across Viewing distance and hemifields. A Viewing distance by Lateral Hemifield (i.e., right vs. left only) by Vertical Hemifield (i.e., upper vs. lower field only) repeated measures analysis of variance was performed. Significant main effects of Viewing distance ($F_{1,49}$; = 5.4, p =0.02) and lateral hemifield ($F_{1,49}$; = 5.3, p =0.02) were revealed. The false alarm rate was lower in peripersonal (FA = 2.6%) than extrapersonal (FA = 3.7%) space, while the rates were greater in left (FA = 3.8%) than right (FA = 2.5%) hemifield. No other main effects or interactions proved significant beyond the 0.05 level of statistical significance.

Table 16
Breakdown of percent false alarms to cued targets in ipsilesional and contralesional halves of space across the Viewing distance in young normal.

	Peripersonal		Extrapersonal	
Target Location	**Left**	**Right**	**Left**	**Right**
Upper	3.5	2.5	5.3	2.8
Lower	2.6	1.8	3.8	2.8

Quadrant Analyses

A Viewing distance by Quadrant (i.e., upper left, upper right, lower left, and lower right) repeated measures analysis of variance was performed on the data from the neutral condition. None of the main effects or interactions proved significant beyond the 0.05

level of statistical significance (see Table 17).

Table 17
Mean reaction times (sd) expressed in ms to targets under the neutral cuing condition in peripersonal and extrapersonal space across horizontal and vertical meridians in young normals.

	Peripersonal		**Extrapersonal**	
	Upper	**Lower**	**Upper**	**Lower**
Right	468(16)	466(17)	475(16)	456(15)
Left	469(15)	455(17)	471(16)	462(17)

Within and Between Field Cuing Analyses

A Hemifield by Cue-Target Relation (Valid, Invalid-LR, Invalid-UD, Invalid-OP, Neutral) repeated measures analysis of variance was performed. A main effect of Cue-Target Relation was significant ($F_{4,196}$= 8.2; p=0.0001). This effect was reported above and will not be described any further here. No other main effect or interactions proved significant beyond the 0.05 level of significance (see Table 18).

Table 18
Mean reaction time (sd) expressed in ms to combined cued targets in left-right hemifield across Viewing distance in young normals.

Cue Condition	**Left Side**	**Right Side**
Valid	438(11)	436(11)
Invalid-LR*	460(14)	462(13)
Invalid-UD*	444(11)	451(12)
Invalid-OP*	459(13)	461(12)
Neutral[18]	464(14)	467(14)

* See text for explanation of combinations

[18] Previous research (e.g., Posner, 1980) has consistently shown that the neutral cuing condition occupies an intermediate position between valid and invalid responses. However, the data from some quadrant display experiments appears to challenge this organization in attentional deployment (this experiment, and Ladavas et al., 1994, p.1200 Fig.2.).

OLDER CONTROLS

Orienting Performance

Analysis of the responses to targets under various cuing condition for this group found no significant effect (i.e., main effects or interactions). The reader is referred to the Appendices for a summary table of the response time performances.

PATIENTS WITH RIGHT-HEMISPHERE LESIONS WHO DO NOT MANIFEST NEGLECT

Target Detection

A Viewing distance by Lateral Hemifield (i.e., right vs. left only) by Vertical Hemifield (i.e., upper vs. lower field only) by Cue Condition (i.e., Valid and Invalid only) repeated measures analysis of variance was performed. A main effect of Viewing distance indicated that response times to targets were significantly faster ($F_{1,5}$; = 13.7; p =0.01) in peripersonal (RT = 520 ms) than extrapersonal (RT = 585 ms) space. Although it did not reach statistical significance ($F_{1,5}$; = 4.2; p =0.09), responses were faster to targets in the ipsilesional (RT = 504 ms) than contralesional (RT = 601 ms) half of space, as noted in Table 19. No other main effects or interactions proved significant beyond the 0.05 level of statistical significance.

Table 19
Mean reaction times (sd) expressed in ms to validly and invalidly cued targets to quadrants across Viewing distance in patients with right-hemisphere lesions.

		Peripersonal		**Extrapersonal**	
Quadrants		**Cue Type**		**Cue Type**	
of Target		**Valid**	**Invalid**	**Valid**	**Invalid**
Contralesional	Upper	538(52)	605(74)	614(79)	647(65)
	Lower	530(40)	597(86)	576(40)	699(118)
Ipsilesional	Upper	468(28)	477(26)	538(15)	542(31)
	Lower	471(23)	471(29)	530(17)	533(22)

The rate of false alarms was also examined (Table 20). Because of the large number of zero entries no inferential statistics were performed, instead a descriptive analysis of the distribution of false alarm is presented. The most striking observation is the paucity of false alarms in contralesional space, while rates in the ipsilesional half of space appear more stable.

Table 20
Breakdown of percent false alarms to cued targets in ipsilesional and contralesional halves of space across the Viewing distance in patients with right-hemisphere lesions.

	Peripersonal		Extrapersonal	
Cue Type	**Contralesional**	**Ipsilesional**	**Contralesional**	**Ipsilesional**
Upper	0.8	1.7	0.00	2.1
Lower	0	1.7	0.00	1.7

Quadrant Analyses

A Viewing distance by Quadrant repeated measures analysis of variance was performed. The main effect of Viewing distance was significant ($F_{1,5}$=5.9, p=0.02), where response times were faster in peripersonal (RT = 536) than extrapersonal (RT = 633) space. Although no other main effect or interactions proved significant beyond the 0.05 level of statistical significance, based on the predictions and the data it seemed that some planned contrasts were justifiable (see Table 21). Planned contrast comparisons revealed that responses to targets in contralesional hemifield were significantly (F=7.3, p=0.01) slower than those observed in ipsilesional hemifield. A significant outcome was not supported when contrasting upper and lower field responses, nor did any other comparison prove significant beyond the 0.05 level of significance.

Table 21
Mean reaction times (sd) expressed in ms to targets under the neutral cuing condition in peripersonal and extrapersonal space across horizontal and vertical meridians in patients with right-hemisphere lesions.

	Peripersonal		Extrapersonal	
	Upper	**Lower**	**Upper**	**Lower**
Ipsilesional	524(32)	481(31)	571(38)	549(20)
Contralesional	567(83)	572(39)	751(127)	662(80)

Within and Between Field Cuing Analyses

A Hemifield by Cue-Target Relation repeated measures analysis of variance was performed. Although none of the main effects proved significant (see Table 22), the interaction was significant ($F_{4,20}$; = 3.2; p =0.04). The analysis revealed that responses to invalid UD (F=16.6, p=0.0006) or invalid OP (F=20.0, p=0.0002) and neutral (F=5.7, p=0.03) targets were significantly slower in contralesional space, when compared to their homologous ipsilesional responses. Of interest was the absence of a cuing effect in either fields when the valid response times were compared to the invalid LR's (i.e., within field comparison). Comparing the valid response with the remaining invalid responses also yielded non-significant outcomes. The faster response times to invalidly-LR than validly cued targets in contralesional space were perplexing.

Table 22
Mean reaction time (sd) expressed in ms to combined cued targets in Ipsilesional and Contralesional halves of space in patients with right-hemisphere lesions who do not manifest neglect.

Cue Condition	Ipsilesional	Contralesional
Valid	502(18)	564(48)
Invalid-LR	537(34)	548(49)
Invalid-UD	487(17)	668(104)
Invalid-OP	494(17)	694(109)
Neutral	531(24)	633(74)

PATIENTS WITH NEGLECT

Target Detection

A Viewing distance by Lateral Hemifield (i.e., right vs. left only) by Vertical Hemifield (i.e., upper vs. lower field only) by Cue Condition (i.e., Valid and Invalid only) repeated measures analysis of variance was performed (see Table 23). A main effect of lateral hemifield indicated that response times to targets were significantly faster ($F_{1,6}$; = 8.5; p =0.02) in the ipsilesional (RT = 646 ms) than contralesional (RT = 1001 ms) half of space, while a significant main effect of cue ($F_{1,6}$; = 21.3; p =0.004) supported faster responses to validly (RT = 783 ms) than invalidly (RT = 865 ms) cued targets. There was a significant 2-way interactions between Viewing distance by Lateral Hemifield ($F_{1,6}$; = 6.9, p =0.04) and a marginal interaction between Lateral Hemifield by Cue ($F_{1,6}$; = 4.9, p =0.06). Response to targets were slowest in the contralesional half of extrapersonal space (Ipsilesional RT = 969 ms, Contralesional RT = 1034 ms; F = 13.4, p = 0.01), while responses to targets in the ipsilesional half of space were identical at both Viewing distances. Collapsed across Viewing distance, the Disengage Operation Deficit is highlighted by the larger cuing effect in the contralesional half of space (Invalid RT - ValidRT = 130 ms) compared to the same condition in ipsilesional space (Invalid RT - ValidRT = 34 ms). No other main effects or interactions proved significant beyond the 0.05 level of statistical significance.

Table 23
Mean reaction times (sd) expressed in ms to validly and invalidly cued targets to quadrants across Viewing distance in patients with neglect.

		Peripersonal		Extrapersonal	
Quadrants		Cue Type		Cue Type	
of Targets		Valid	Invalid	Valid	Invalid
Contralesional	Upper	895(137)	1006(121)	871(134)	998(130)
	Lower	919(148)	1054(146)	1061(180)	1207(180)
Ipsilesional	Upper	628(54)	641(52)	620(48)	675(55)
	Lower	629(42)	689(51)	640(49)	648(59)

A Viewing distance by Target Hemifield (i.e., Ipsilesional and Contralesional) by Cue Condition (i.e., Valid and Invalid only) repeated measures analysis of variance was performed on accuracy measures (% correct response). None of the main effects or interactions proved significant beyond the 0.05 level of statistical significance. However, inspection of Table 24, reveals that patients with neglect missed a greater number of targets in contralesional than ipsilesional space. Viewing distance did not affect this pattern of response.

Table 24
Probability of response in percent to cued targets in ipsilesional and contralesional halves of space across the Viewing distance in patients with neglect.

	Peripersonal		Extrapersonal	
Cue Type	**Ipsilesional**	**Contralesional**	**Ipsilesional**	**Contralesional**
Valid	98	87	98	84
Invalid	100	80	97	79

The rate of false alarms was also examined. A Viewing distance by Lateral Hemifield (i.e., right vs. left only) by Vertical Hemifield (i.e., upper vs. lower field only) repeated measures analysis of variance was performed. Table 25 displays the breakdown across Viewing distance and hemifields. Although a reversal of false alarm patterns occured at both Viewing distance,with a greater rate in the upper than lower field in peripersonal space and vice versa in extrapersonal space, the analysis yielded a statistically non-significant outcomes.

Table 25
Breakdown of percent false alarms to cued targets in ipsilesional and contralesional halves of space across the Viewing distance in patients with neglect.

	Peripersonal		Extrapersonal	
Cue Type	**Contralesional**	**Ipsilesional**	**Contralesional**	**Ipsilesional**
Upper	1.4	0.7	0.7	0.0
Lower	0.0	0.7	1.4	1.4

Quadrant Analyses

A Viewing distance by Quadrant repeated measures analysis of variance was performed. The main effect of quadrant was significant ($F_{3,15}$; = 8.8; p =0.0008), where response times, upon inspection of Table 26, were slower to targets in the contralesional half of space at both Viewing distances. Planned contrast comparisons, collapsing across Viewing distance, suggested that the primary source of variance stemmed from the lower quadrant (F_1 = 14.1; p =0.001), where responses were slowest. Of note, a planned contrast comparing responses to the upper left quadrant vs upper and lower right also yielded a significant outcome ($F_1 = 11.1$; $p = 0.004$). No other main effects, interactions or simple effects proved significant beyond the 0.05 level of statistical significance.

Table 26
Mean reaction times (sd) expressed in ms to targets under the neutral cuing condition in peripersonal and extrapersonal space across horizontal and vertical meridians in patients with neglect.

	Peripersonal		**Extrapersonal**	
	Upper	**Lower**	**Upper**	**Lower**
Ipsilesional	648(70)	678(57)	671(78)	754(72)
Contralesional	869(103)	1044(132)	1097(146)	1173(203)

Within and Between Field Cuing Analyses

A Hemifield by Cue-Target Relation repeated measures analysis of variance was performed (see Table 27). Main effects of Hemifield ($F_{4,24}=11.1$; $p=0.02$) and Cue ($F_{4,24}=6.7$; $p=0.0009$) were significant and have been addressed above. Of particular interest, however, was the significant Hemifield by Cuing ($F_{4,24}=7.5$; $p=0.0005$) interaction. In particular, there was no cuing effect in the contralesional half of space when the valid response times were compared to the invalid (i.e., within field comparison), whereas comparing the valid response with the remaining invalid responses yielded a significant outcome ($F_1=28.4$; $p=0.0001$).

Table 27
Mean reaction time (sd) expressed in ms to combined cued targets in Ipsilesional and Contralesional halves of space in patients with neglect.

Cue Condition	**Ipsilesional**	**Contralesional**
Valid	629(32)	937(100)
Invalid-LR	684(35)	887(93)
Invalid-UD	648(36)	1134(115)
Invalid-OP	658(42)	1194(108)
Neutral	688(41)	1058(95)

Discussion

The findings of the current study are discussed separately for each group, namely normals and patients with right-hemisphere damage (i.e., patients without and with neglect).

Normals

The current study supported the hypothesis of faster response times to validly cued targets relative to invalidly cued targets. This effect is robust and has been reported consistently in studies of attention (e.g., Posner, 1980). In the current study, the cuing effect was relatively small, 17 ms, compared to previous reports. A potential explanation for the small magnitude of the cuing effect reported here may reside in the physical parameters of the stimulus display. Most studies of visual attention have used a horizontal display in which two potential target locations flank a central fixation point. However, in the current study attention was allocated to a larger number of potential locations (i.e., 4 vs. 2). I suspect that the difference in cuing effects observed in this study is primarily accounted for by slowed valid responses. Although participants were informed that four locations were possible, no markers were available prior to target appearance. Thus, with no visible marker and an increased number of potential locations, valid responses would be slowed, yielding a small difference in the cost-benefit (Invalid-Valid) computation. Other factors including event probability, stimulus onset asynchrony (Posner & Cohen, 1984: Posner, 1978), or the go-no go nature of the discrimination task may have contributed to the current observation.

In the current study, a trend towards faster responses to targets in the left relative to those in the right half was noted, but the difference was negligible (i.e., approx. 10 ms). Of particular interest was the faster reaction time to the detection of targets appearing below eye level. This finding was not anticipated, but it is consistent with trends reported in previous reports (e.g., Gawryszewski et al, 1987; Rizzolatti et al, 1987). Additionally, the cuing effect was similar in magnitude (i.e., 5 ms) to that reported by Gawryszewski et al

(1987).

Perhaps the most interesting findings rest with the significant interaction of Viewing distance, vertical hemifield and cuing condition. This outcome provide unequivocal support for one component of Previc's (1990) postulate. Overall, the fastest response time to targets, validly cued, occurred in peripersonal space below eye level. If the purpose of allocating attentional resources is to facilitate information processing (Posner, 1978), then the ecological tenet suggests that the spatial sector in need of acute and sensitive response would most likely occur below eye level, an area that will necessitate a manual response (e.g., reaching, manipulating, pressing a button). There is a suggestion that our ability to reconstruct visual detail from memory may also show a lower field bias (see Previc & Intraub, 1997). In contemporary times, the need to process information below eye level has increased with new levels of technology, such as utensils, or, in more recent times computer keyboards and monitors. As such, our orienting abilities in this spatial sector ought to be fine tuned (or biased relative to above eye level) when a motoric response is required. The absence of the opposite pattern of responding in extrapersonal space may be a consequence of a limitation in motoric movement involved in this task.

In normal subjects shifts of attention within and between hemifields yielded roughly equivalent cuing effects. That is, contrary to some reports suggesting that attentional resources are affected by inter/intrafield distances, comparing responses to invalidly cued targets within and between fields did not yield any evidence to support hemifield activation (Hughes & Zimba, 1985) or attentional gradient hypotheses (Downing & Pinker, 1985). Although, my findings might appear to be at odds with Klein and McCormick (1989) who found the slowest RTs when attention had to shift from a cued location in one field to a diagonally opposite target location in the other, there are so many differences between their study and mine that the discrepancy could mean any of a number of things. For example, in the Klein and McCormick study, a simple luminosity detection task was used, targets were cued endogenously and location was marked and a longer SOA was used.

Right-Hemisphere Groups

First and foremost, it should be noted that the findings suggest similar patterns of behavioral performances between the two groups of right-hemisphere patients. However, it is the magnitude of the deficits that differentiates them. The descriptions that follow address the statistical outcomes of each groups separately.

Patients Without Neglect

Although not statistically significant, patients with right-hemisphere damage responded to validly cued targets more quickly than to invalidly cued ones. The cuing effect was 25 ms, which is small relative to that previously reported in non neglecting samples (validity = 40-50 ms; see D'Erme et al 1993), but about the same as that observed in young normals (i.e., 17 ms). Other studies have reported variable performance patterns, from marginal costs (e.g., Posner et al, 1984) to large benefits (e.g., Baynes et al, 1986). The composition of the current sample of patients without neglect may in part be responsible for the observation. The effects of lesion size, location, etiology and time since insult on performance are well documented (e.g., Andersen et al, 1986). As well, a small sample size and variability in lesion size and composition may account for the current outcome.

It has been demonstrated that individuals sustaining brain damage produce slowed responses on timed tasks relative to a non brain-damaged control group (Birch et al, 1967). However, the typical pattern of performance is one in which a general slowing is observed, as witnessed by psychometric evaluations (i.e., mental control, Digit Symbol-WAIS-R, etc.) supporting a decline in attention and concentration indexes (Ben-Yishai et al, 1987). This profile is typical of subcortical (Heilman et al, 1978.) or brainstem (Watson et al, 1974) damage, affecting arousal systems (e.g., reticular formation). In the current data set, the impairment on the orienting task is not global, but specific to the events occurring within the contralesional half of space, seemingly reflecting the laterality of the damage. Targets in the ipsilesional half of space were responded to relatively faster than those in the contralesional half (i.e., a difference of 79 ms). Additionally, the current sample of individuals responded more quickly to targets presented above than below eye level (a difference of 35 ms). This finding was not predicted, nor has it been previously reported to my knowledge.

A few possibilities exist for the interpretation of the aforementioned findings. The current sample of patients with right-hemisphere damage manifested a mild form of visuospatial neglect, undetectable using a cancellation task or line bisection. A recent report (Pizzamiglio et al, 1995), stemming from collaborative efforts between Italian and British research groups, confirmed that 1) various forms of neglect exist, and 2) that in many cases little correlation exists between paper and pencil tasks (that is, evidence of neglect on one task may have been absent on another). Blanton and Gouvier (1987), selecting a group of individuals with right-hemisphere damage on the basis of a negative diagnosis of neglect (based on a paper and pencil task), demonstrated reliable and consistent contralesional impairment on what they considered more sensitive tasks, including timed tasks (e.g., simple detection). More recently, Koyama et al (1997) provided additional evidence that the degree of impairment on attentional tasks was positively correlated with the severity of neglect in patients with right-hemisphere damage.

Anatomical characteristics of the sample may also have contributed to the current outcome. The deployment of attention is a function orchestrated by a widespread neuronal network that involves various structures including parietal, cingulate, frontal cortices, as well as various subcortical structures like the thalamus and superior colliculi (Mesulam, 1981, 1990). As such, the heterogeneity of lesions, which extended from the rostral to the caudal pole of the hemisphere and included subcortical areas (e.g., thalamic), within the sample may, in part, explain the pattern of results.

When assessing responses to invalid targets separately, the analyses failed to reject the null hypothesis in this sample of patients with right-hemisphere damage. This lack of difference is primarily accountable by the similar reaction times between the collapsed invalid reaction times. Not surprisingly, the prediction of equivalent overall reaction time performances across the two Viewing distances, peripersonal and extrapersonal space, was supported. As well, the response pattern to cued targets was identical at both Viewing distances. Additionally, the anticipated interaction between upper/lower visual fields and the peripersonal/extrapersonal space was not supported.

Patients with Neglect

As previously reported (Posner et al, 1984), patients with lesions restricted to the posterior right-hemisphere, including the parietal area, respond overall to cued targets in a similar fashion to other neurological or non-neurological controls; that is, they show an overall faster response time to validly than invalidly cued targets. Other researchers have documented this observation (Baynes et al, 1986; Posner et al, 1987; Morrow & Ratcliff, 1988; Farah et al, 1989; D'Erme et al, 1992). However, the validity effect reported in this sample, 109 ms, is small relative to previous studies, which reports values ranging from 200 to 350 ms (e.g., Posner et al, 1984; D'Erme et al, 1992). A potential explanation for the discrepancy in the magnitude of the validity effect may reside in the severity of neglect itself. D'Erme et al's (1992) contrast of patients manifesting severe and mild forms of neglect supports this possibility. As well, Morrow and Ratcliff (1988) demonstrated in a subsample of their participants that as the neglect resolved the disengage deficit diminished correspondingly.

As expected, an ipsilesional advantage in response times over the contralesional half of space was found under both cued (Contralesional - Ipsilesional = 358 ms) and neutral (Contralesional - Ipsilesional = 368 ms) conditions. The resulting spatial bias also accounts for the Disengage Operation Deficit observed. As such, an imbalance in the orienting system leading to processing of information in the ipsilesional field more effectively and expediently resulted in a quantifiable (accuracy or RT) delay in responding to stimuli presented to the contralesional half of space (see Riddoch & Humphreys, 1987). Kinsbourne's model (Kinsbourne, 1970; 1974; 1977; 1987) also accounts for the data discussed. In his model, the asymmetrical deployment of attentional resource is a direct consequence of the attraction of the ipsilesional half of space combined with an inadequate exploration of the contralesional half of space.

The prediction of discrepant performance patterns between the peripersonal and extrapersonal Viewing distances was not supported statistically, despite an absolute difference of 50 ms. Additionally, the outcome was counter to Previc's prediction, as responses were faster in peripersonal than extrapersonal space. As such, this result does not appear to be a methodological aberration (e.g., visual angles maintained between Viewing distances, task specific). In fact, it could be argued that distance may have had a slight magnifying effect. This observation has been reported by Cowey et al (1993), who reported a greater bisection bias in extrapersonal than peripersonal space. Another possibility for the current outcome is fatigue. Although the starting position was counterbalanced for all right-hemisphere patients, it was not counterbalanced according to diagnosis. In the current sample 5 individuals started at the peripersonal viewing position[19].

In terms of the deployment of attention across the horizontal meridian, like their non-neglecting counterparts, patients with neglect responded more quickly to targets presented above than below eye level. However, the difference in response time was 91 ms, which is a threefold increase from the non-neglecting sample. This behavioral pattern has been reported previously using various protocols, including a cancellation task (e.g., Halligan & Marshall, 1989), modified cancellation tasks (e.g., Pitzalis et al, 1997), or vertical line bisection (e.g., Rapsack et al, 1988).

Most, if not all, current models of attention are ill-equipped to explain or predict deficits outside the left-right continuum, as they rely heavily on the notion that the central nervous system is organized in a criss-crossing manner (i.e., decussations; e.g., see

[19] One possibility would be to perform an analysis comparing those patients who began in peripersonal space to those who began the task in extrapersonal space.

Kinsbourne, 1987). Specifically, they postulate that the representational organization of the hemispheres primarily mirrors that of the outside world (body- and environment-centered) along the horizontal plane. However, this left-right dichotomy (right-hemisphere processes left-sided information) leaves little room for the other spatial coordinates. Presumably, altitudinal and radial planes are processed independently (i.e., area specific) or co-jointly by the hemisphere (i.e., homologous areas), which may be mediated through the corpus callosum. This possibility is entertained in the following section.

Within Field Absence of Cuing (WFAC):

As the disengage deficit for targets and cues within the poor field was smaller than predicted or obtained in previous studies (Baynes et al, 1986), it is highlighted here in a separate section. Descriptively, the data suggested an absence of cuing effect within the contralesional field in patients with right-hemisphere lesions. That is, in patients with neglect, when compared to the ipsilesional field, in which a strong benefit existed (cost-benefit = +55 ms), in the contralesional field an equivalently strong cost was noted (cost-benefit of -50 ms). Thus, it would seem that performance (detection) in the contralesional field was not affected by the nature of the cue, valid or invalid. In fact, there appeared to be an advantage in responding to invalidly cued targets.

Kinsbourne's model of interhemispheric inhibition (for review Kinsbourne, 1993) may provide an explanation for the lack of cuing effect within the contralateral halve of space. The model stipulates that the hemispheres actively inhibit each other, such that under conditions of equivalent hemispheric activation (i.e., rest) a zero attentional bias exists. However, under conditions in which an imbalance in hemispheric activation exists, an orienting bias contralateral to the stimulated hemisphere ensues. This argument is supported by faster response times to the ipsilesional than contralesional targets in patients with neglect. How then can I explain the within-field results observed here?

Collective evidence suggests that visuospatial neglect is a consequence of a disruption in the 'normal' representation of the three-dimensional environment (e.g., Bisiach et al, 1979, 1983; Rizzolatti et al, 1987; Halligan & Marshall, 1991). I propose that the disengage operation deficit, either across or within a hemifield, is an exemplar of a disruption in three dimensional representation. Figure 14 provides a depiction of how space may be represented in the intact human parietal lobes. This organization is based on previous electrophysiological recording (i.e., Heilman & van den Abell, 1980), neuroimaging data (Corbetta et al, 1990) and computer modeling (Cohen et al, 1994). Each hemisphere is equipped with attentional units that contain an attentional module receiving varying gradients of information from both halves of space, as well as excitatory (depicted by a + sign) and inhibitory (depicted by a - sign) inputs. Input units channel information from the dorsal visual pathway, as proposed by Mishkin and colleagues (Mishkin et al, 1983). In this proposal, the left hemisphere contains one attentional unit, while the right hemisphere contains two (see Heilman & van den Abdell, 1980; Mesulam & Wintraub, 1987; Corbetta et al, 1990). These units are contained within the parietal lobe neuronal structure. All three units converge onto a response unit, which may or may not be structurally related to the parietal lobes. Alternatively, these response units may be related structurally to the neuronal network responsible for the behavior (i.e., manual response vs. orienting). The right-hemisphere's attentional module responsible for the left half of space representation has a stronger input to the response unit than the right half representation. However, the combined inputs from the right half of space representation from both left- and right-hemisphere equal that of the right-hemisphere's left half of space. Finally, as suggested by the computer model of Cohen and colleagues (Cohen et al, 1994), as well as by Kinsbourne (1987), in a resting state the excitatory and inhibitory inputs in the system equal zero excitation, resulting in no directional attentional bias.

Following right parietal damage and destruction of the left greater than right attentional unit, an imbalance in the allocation of attention is created. Thus, in the covert orienting paradigm, because attentional units representing left space are damaged, response to targets in that spatial sector are impaired. The impairment is likely a combination of processing inefficiency, as a function of reduced neuronal resources, and competition of opposing (i.e., ipsilesional) stimulation (through inhibitory connection) of the cue by the intact attentional units representing the right half of space. Consequently, responses to the right are faster under the valid cuing condition because the intact attentional units are activated, and responses to ispilesionally and invalidly cued targets are also fast because the processing of the target takes precedence over that of the cue originating in the contralesional field; as such it mimics simple detection. The absence of cuing within the contralesional hemifield is a concomitant of the following activity. Simply, when both events occur within the same field, in this case the neglected field, the inhibitory impact of the opposing (in this case the intact left-hemisphere) hemisphere on the attentional bias is absent. Thus, the damaged hemisphere, although with limited attentional resources, processes all information in its corresponding spatial sector, equally albeit crudely, given its poor localizing abilities. Wilson et al (1997), in a patient with bilateral parietal damage, reported a similar difficulty in localizing individual stimulus within an array.

Somewhat puzzling and counterintuitive were the faster responses to invalidly than validly cued targets in the contralesional field. However, this may be explained in terms of a hemispheric activation process, as well. In this case, I am referring specifically to intra-hemispheric activation. That is, while validly cued targets involve a single event (cue and targets overlap), invalidly cued targets involved two static, non-contiguous events (cue and target do not overlap). Under these conditions, the invalid event in theory provides greater overall stimulation to the damaged hemisphere, theoretically resulting in a faster response time. A positive correlation between degree of hemispheric activation and a skewed attentional bias has been demonstrated before (e.g., Robertson & North, 1992; Halligan & Marshall, 1989; Kinsbourne, 1974).

<u>Figure 14</u>

A schematic representation of a unidimensional model of attention, which is based in part by the works of Cohen et al (1994) and Heilman & van den Abdell (1980). The model is comprised of several levels; input, attentional, and response modules. Additionally, several connections exist within and between the right and left hemisphere modules, as represented by excitatory (+) and inhibitory (-) inputs. Left-H, left-hemisphere; Right-H, right-hemisphere. See text for more details.

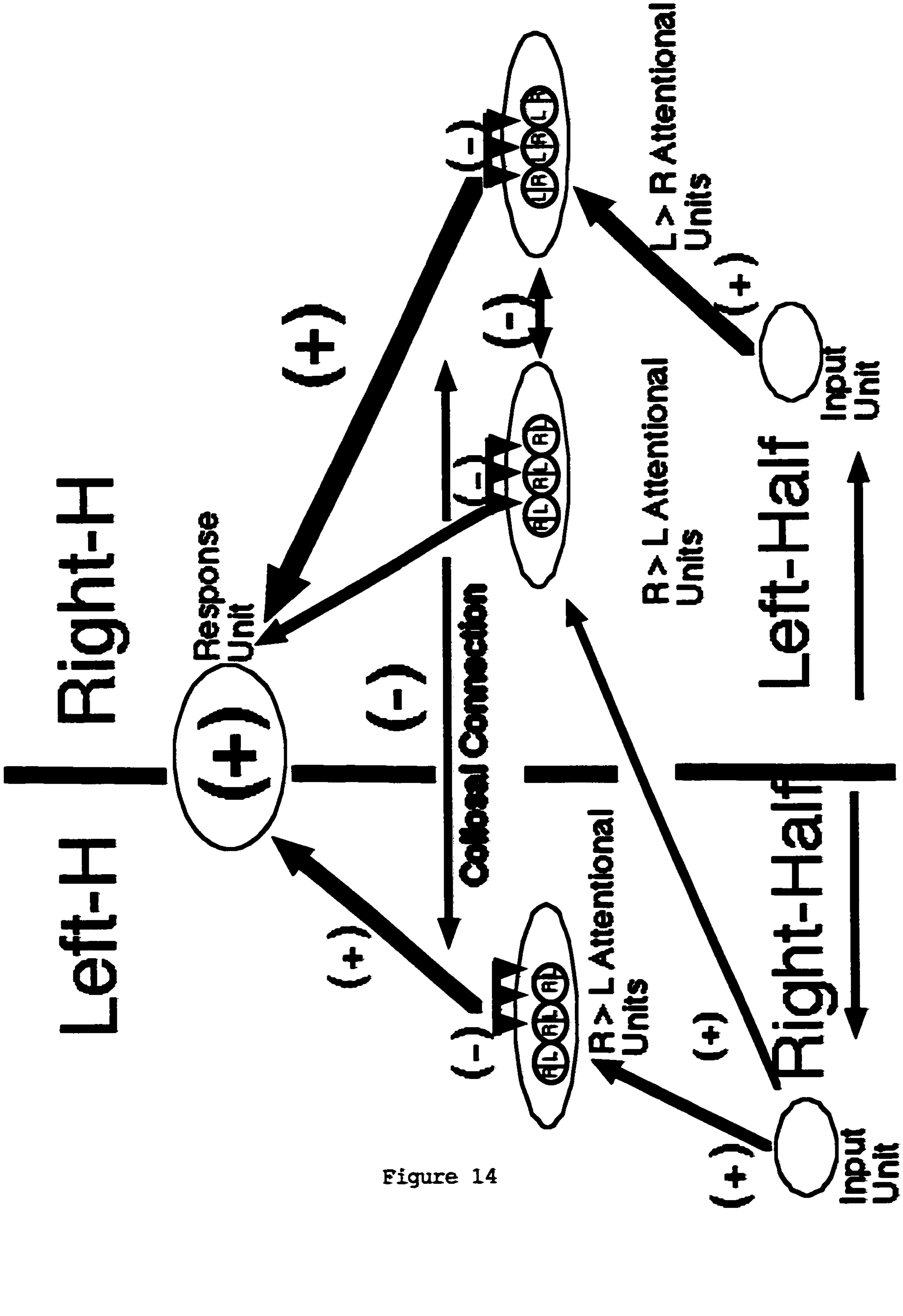

Left-H
Right-H
Response Unit
(+)
(-)
Collosal Connection
R > L Attentional Units
L > R Attentional Units
Input Unit
Input Unit
Right-Half
Left-Half

Figure 14

In the other two dimensions, vertical and radial (depth), data from the current study permits some predictions along the vertical axis, while it reserves predictions along the radial dimension, given the effects of vertical hemifields and Viewing distance on orienting performances in patients with neglect.

PART 5: DISENGAGING: A HYPOTHESIS FOR LINE BISECTION

As stated earlier, three elementary operations exist in Posner's general cognitive-anatomical theory of orienting of visuospatial attention, which suggests that attention **disengages** from its current focus, when an event occurs at a separate location from gaze, **moves** to the new location, and **engages** at the new location in space. Moreover, neurobehavioral research has repeatedly shown that distinct anatomical areas of the brain are involved independently in the execution of these attentional operations (Posner et al, 1982; Posner et al, 1984) and several studies (Baynes et al, 1986; Morrow & Ratcliff, 1988; Petersen et al, 1989; Farah et al, 1989), and a recent meta-analytic review of the phenomenon (Losier & Klein, submitted) suggest that a disengage operation is associated with the parietal lobes.

After right parietal damage, patients' ability to orient to the contralesional targets following an ipsilesional cue is impaired, as evidenced by increased latencies. That is, given the propensity to orient towards the ipsilesional half of space (e.g., Chedru, 1976; Ladavas et al, 1990), information presented at that location takes precedence over information located within (towards) the contralesional half of space. Similarly, performance on line bisection is marked by significant rightward displacements from midpoint. Eye monitoring findings suggest that this deficit is due, in part, to the fact that only the right half of the line appears to be engaging attention (Ishiai et al, 1992), as indicated by fewer eye movements towards the contralesional (i.e., left) half of the line and the resultant misperception of the entire line length. Line bisection studies, where the attentional focus is redirected to the contralesional half of space, have demonstrated diminished rightward biases (see Reuter-Lorenz & Posner, 1990). Corroborating evidence is also found in the outcomes of modified cancellation tasks. A reduction in ipsilesional competition for attentional resources, accomplished by removing stimuli in that sector, results in a significant improvement in patient's cancellation performance in the contralesional space (e.g., Mark et al, 1988). Thus, a deficient disengage mechanism appears responsible for the observed cancellation performances and, perhaps, line bisection errors. If this is the case, then the magnitude of the rightward displacement should correlate positively with the disengage operation deficit. In this section I asked the following question: "Is there a positive relationship between the magnitude of the rightward bias and the disengage operation?"

Methods

Subjects:

This sample was comprised of 13 patients who survived a right-hemisphere stroke. Given that a behavioral criterion (i.e., disengage deficit) appeared critical in the analysis and the potential for a larger sample, a diagnosis of neglect was not considered critical for the current correlational analyses. Patient characteristics are detailed in the general methods section (p.17).

Procedure:

Five variables were utilized in this section. These were obtained from the line bisection (p.43), visual orienting (p. 77) and Star Cancellation (p. 16) tasks described in previous method sections. The reader is referred to those sections for clarification.

Disengage Metric:

Reaction Time (RT) - Based on the orienting findings in Section IV, the data from peripersonal and extrapersonal Viewing distances were collapsed. Then, the upper and lower field responses were averaged within their corresponding hemifields for valid and invalid reaction times. Once those values were derived, the valid and invalid response times for targets in each hemifield were subtracted from each other (Invalid-Valid), producing a cuing effect score. Finally, the disengage deficit metric was obtained by calculating the difference between contralesional and ipsilesional cuing effects.

Computationally, the latter is expressed as follows:

$$D=[(invalid_i - valid_i) - (invalid_c - valid_c)]$$

where D is the disengage metric, c denotes responses originating in the contralesional half of space, and i denotes responses originating in the ipsilesional half of space.

Misses - This measure was restricted to the misses. It was generated by subtracting the proportion correct measure (PC) from 1. Otherwise it was identical to the procedure described above in generating the disengage metric.

RT/PC-This measure is identical to the RT measure with the exception that accuracy measures were incorporated in the computation. This performance measure is considered a more representative measure of the deficit, as the reaction times are partially weighted by the individual's ability to detect target presentations at that location. Thus, valid and invalid mean reaction times were divided by their corresponding accuracies (e.g., ipsilesional valid RT/ipsilesional valid proportion correct). The division yielded a measure of response efficiency. Again, cuing effects (i.e., Invalid - Valid) were calculated and a disengage metric was generated using the computational formula described above.

<u>Hemifield Deficit (HD)</u>

Reaction Time (RT) - The field deficit is based on the responses to validly cued targets. The data were collapsed across the two Viewing distances. Again, the upper and lower quadrants of each half of space were collapsed, yielding a contralesional and an ipsilesional value (expressed in ms). Next, the hemifield deficit was generated by subtracting the contralesional valid responses from the ipsilesional valid responses. This process was repeated using the response times to neutrally cued targets. It has been proposed that the magnitude of the hemifield deficit, as defined by the neutral condition, might be also be a good indicator of the disengage deficit, as the subject has to disengage attention from fixation and relocate to the target.

Misses - Hemifield deficits were generated using the miss rates of valid responses observed in contralesional and ispilesional space. This procedure was repeated for the neutral data.

RT/PC - Hemifield deficits were obtained by dividing the reaction time to valid (and neutral) targets by their corresponding accuracies in contralesional and ipsilesional space.

Star Cancellation:

The array of stimuli (letters, stars, etc.) was divided into a left (or contralesional) and right (or ipsilesional) half, using the central small star as the midpoint (viewer centred frame of reference), resulting in 26 small stars in each half of the display. Then, the number of small star omissions (not canceled) was tabulated for each half. Next, the omissions on the right (ipsilesional) were subtracted from omissions committed on the left (contralesional) half, generating a single value of the deficit.

Line Bisection (MIDDLE CUE):

The bisection biases of horizontal lines following middle cues were averaged across top, middle and bottom locations. Next, the veridical midpoint, which had been assigned a value of 50 (Note: the extent of all lines from left to right ranged from 0 to 100), was subtracted from the averaged middle cue bias. This generated a middle cue (bias) value. As such, a rightward (or ipsilesional) bias would yield a positive value, while a leftward (or contralesional) bias would yield a negative value.

Data Management

A dataset was constructed containing all 5 variables and their corresponding metrics (i.e., RT, misses and RT/PC). Using the STATView (4.01) statistical software package, Pearson Product Moment Correlations were calculated and three correlation matrices generated (see Table 28). Of note, the Hemifield deficit based on valid response (HDv) and disengage deficit were not correlated, because the valid response is a component of the disengage computation.

Results

A number of significant correlations emerged from this analysis of just 13 patients. Star Cancellation and Line Bisection (r=0.80) yielded a positive correlation, suggesting that the numbers of omissions were proportional to the magnitude of rightward deviation. This outcome merely reflected the generally poorer (visual) information processing abilities observed in the contralesional hemifield relative to the ipsilesional hemifield. Correlations between Star Cancellation and HDv-PC (r=0.55) and HDn-PC (r=0.58) proved significant, suggesting that the greater number of cancellation omissions covaried positively with the increased number of validly and neutrally cued target misses (see Table 28b). As expected given the difficulty processing contralesional information, HDv and HDn correlated positively and significantly under all metrics considered (i.e., RT, Misses, & RT/PC). Finally, an important finding is the positive correlation (r=0.92; see Table c) between the hemifield deficit, as defined by the neutral condition, and the disengage operation.

Of particular interest in this correlational analysis is the relation between the classical measures of neglect and the disengage operation deficit. Outcomes amongst Line Bisection, Star Cancellation and the disengage phenomenon are mixed across the three metrics. An observation of the correlation matrices found in Tables 28a to c indicates that only the correlation between the Disengage efficiency metric and Star Cancellation (r=0.57) and Disengage efficiency metric and HDn (r=0.92) supported a statistically significant relationship. Thus, the greater the number of omissions on cancellation the greater the disengage operation value. Although it did not reach statistical significance, the relation between line bisection and the disengage operation was notable (r=0.49). As such, it appears that a modest amount of covariance exists between rightward deviation on line bisection and the magnitude of the disengage deficit (at least R^2=24%).

Discussion

Although the current analysis generated a number of interesting outcomes, only the line bisection, disengage and hemifield deficits findings are discussed in detail. The assumption of a relationship between the rightward bias on line bisection and the disengage phenomenon was not supported statistically. However, the correlation was nonetheless moderate (r=0.49) and suggestive. What are some of the considerations that might explain this result? The first is a lack of statistical power. However, given the other significant outcomes (e.g., Star Cancellation vs. Line Bisection), this is unlikely. One possibility for the lack of statistical significance may be inherent to the assessment of the behavior itself. That is, the number of trials sampling the orienting behavior exceeded that of the line bisection by a factor of two. As such, there would be more variability in the measurement of the bisection behavior, thereby masking a potential effect or relationship when compared to a more stable (less variable) measure. Alternatively, the current finding may, in part, be a function of simple physical and temporal characteristics of stimuli. The events occurring in the orienting paradigm are discrete (temporally, but not spatially, contiguous), while a line is a continuous (spatially, but not temporally contiguous) entity. Stated differently, visual orienting involves a sequence of events, occurring one after the other, and it requires a speeded response, while in line bisection the stimulus is present continuously and the response is not speeded, but deliberate. The validity of the physical characteristics is further strengthened by the positive and significant correlation between Star Cancellation

Table 28

Correlation Matrix of Star Cancellation, Line Bisection, Field Deficit-Valid, Field Deficit-Neutral and the Disengage metrics for reaction time (a), misses (b) and efficiency scores (c) in the sample of patients with right-hemisphere lesions. Asterisks indicate that correlations significantly differ from zero.

a) RT

	Star Canc.	L. Bisection	HDv	HDn	Disengage
Star Canc.	1	0.80*	0.28	0.48	0.44
L. Bisection	-	1	0.38	0.50	0.41
HD-v	-	-	1	0.93*	-
FHD-n	-	-	-	1	0.35
Disengage	-	-	-	-	1

b) Misses

	Star Canc.	L. Bisection	HDv	HDn	Disengage
Star Canc.	1	-	0.55*	0.58*	-0.18
L. Bisection	-	1	0.37	0.48	-0.28
HD-v	-	-	1	0.98*	-
HD-n	-	-	-	1	0.16
Disengage	-	-	-	-	1

c) RT/PC

	Star Canc.	L. Bisection	HD-v	HD-n	Disengage
Star Canc.	1	-	0.58*	0.56*	0.57*
L. Bisection	-	1	0.46	0.39	0.49
HD-v	-	-	1	0.94*	-
HD-n	-	-	-	1	0.92*
Disengage	-	-	-	-	1

(i.e., discrete and timed) and the Disengage variables (see response efficiency; RT/PC). Thus, it may be these various physical characteristics of the stimuli that account for the current findings between covert orienting and line bisection.

A complementary explanation may reside in the neglect impairment itself and in the manner in which the information is represented allocentrically. Bennet and Kinsbourne

(1990), argue that in neglect the 'representing' need not resemble the 'represented'. Kinsbourne (1993) further argues that in neglect the representing is the experience and that it, the experience, is biased to the right half of space. This conceptualization of visuospatial neglect was shared by DeRenzi et al (1989, p 232), who spoke of a "magnetic attraction" to the ipsilesional side of space relative to the contralesional half of space following right parietal damage. The patients' bisection performance suggest that only the right extent of the line 'perceived' matters (e.g., Kim et al, 1997; Ishiai et al, 1992 & 1989). Again, the representing need not resemble the represented. In my study, the "magnetic attraction" was implicitly extrapolated from the magnitude of the disengage deficit. Thus, I argued that the right segment of the line and the ipsilesional invalid cue serve to draw attention and impair performance directed toward the contralesional hemispace in both line bisection and orienting tasks, respectively. As such, the rightward displacement on line bisection is not conceived as an all or nothing phenomenon, but the deficit is understood as a graded difficulty in reorienting from right to left (see Eglin et al, 1994; Grabowecky et al, 1993; Ladavas et al, 1990; Weintraub & Mesulam, 1987; Gianotti and Tacci, 1971),which according to the current analysis is partly, if not statistically, accountable by a difficulty in disengaging from the right segment of the line.

The correlation between the hemifield deficit, using target responses to the neutral condition and the disengage operation is an important and new finding. A recent review of the disengage operation (Losier & Klein, submitted) made reference to this possibility. However, given that most studies reviewed had not reported or utilized the neutral condition, only a narrative review, and not quantitative, meta-analysis could be provided. The current orienting protocol was able to address this issue and the correlational analysis suggests that the magnitude of the disengage operation deficit can also be gauged from the severity of the hemifield deficit, as defined by the neutral condition.

The results of the current analysis are encouraging, given the positive correlation between line bisection deviation, the cancellation task and the disengage deficit. More research, using variants of the current protocol or new measures, is needed to further elucidate the possible mechanisms of line bisection impairments in patients with neglect.

PART 6:GENERAL CONCLUSIONS

Line Bisection

Normal Controls:

The following description is based on the data obtained from young and older samples of normal individuals, unless stated otherwise. Outcomes generated from horizontal lines supported an absence of a significant directional bias. This is an important finding, as the use of a computerized version of the line bisection task appears to have reduced the contribution of motoric or spatial (i.e., hemispheric activation, see Bradshaw et al, 1985; Kinsbourne, 1993) factors in the bisection performance. The effects of unilateral cues on bisection biases were in the expected direction and provided further corroboration on the reliability of the computerized version in the measurement of this behavior[20]. Finally, the effects of Viewing distance varied between the young and older normals, and may have reflected issues of statistical power (older normals constituted a smaller sample). In young normals, the bisection bias varied between a significant leftward and a rightward deviation in peripersonal and deviation in extrapersonal space, respectively. Moreover, the discrepancy in bisection bias direction between Viewing distance appears to be accounted for primarily by the greater effect of the left cue in peripersonal than extrapersonal space. Although Previc's model does not directly address performance along the left-right continuum, it does address the issue of object identification and localization. Previc argues that in peripersonal space an object's spatial location is critical, while in extrapersonal space an object's identification is paramount. From an ecological point of view, once an object is in close proximity, the necessity to identify it is superceded by the need to localize and respond to it. Thus, in the context of deploying attentional resources in object localization, greater effects of unilateral cuing in peripersonal than extrapersonal space appear appropriate. Lastly, the greater effects of the left unilateral cue than right or middle cues in

[20]The effects of cuing were the same as that observed on the paper and pencil version (see Milner et al, 1992).

peripersonal space may simply reflect the supported notion of right-hemisphere dominance in attention (e.g., Corbetta et al, 1990; Weintraub & Mesulam, 1987; Heilman and van den Abdell, 1980). In the absence of competing stimuli, an imbalance in the deployment of attention may occur in the sector of the left cue, enhancing the bias of the bisection in that direction.

Interestingly, the observed downward bias on vertical line in the current sample of young normals is contrast to that most frequently reported in the literature, where an upward bias is reported. Again, in reducing motoric and spatial factors, the computerized version of this task may reflect a more accurate assessment of this behavior. Interestingly, the young normals manifested opposing biases in peripersonal (downward) and extrapersonal (upward) space. This is likely a reflection of the effects of cue on the bias, as evidenced by the significant interaction between Viewing distance and cue in this group. Although the location of the line appeared to matter as well, the direction of the bisection bias remained at the two Viewing distances. The interaction of Viewing distance and cue is important in supporting Previc's model. That is, the opposing biases observed suggest that in peripersonal space attention is concentrated toward the lower segment of the line and vice versa in extrapersonal space.

These findings suggest that attentional deployment in normals does vary in space; specifically, it appears to be influenced by line orientation and Viewing distance. Additionally, although much evidence has been provided in support of a left-right continuum (e.g., Bowers & Heilman, 1980), the current findings provide additional (e.g., Drain & Reuter-Lorenz, submitted) evidence in support of a top-down continuum. Moreover, the outcomes observed suggest that biases along these continua vary contingent upon Viewing distance. The summary of the findings is illustrated in Figure 15 a and b.

<u>Figure 15</u>
Summary of line bisection findings across young normals, patients with right-hemisphere lesions with and without neglect. Horizontal (A) and vertical (B) lines location and cue placement are depicted at both Viewing distances (i.e., peripersonal and extrapersonal space). Arrows indicate location of the cue (initial bisecting cursor start). As such, on horizontal lines, leftward and rightward pointing arrows depict left and right cues, respectively, while on vertical lines the upward and downward pointing arrows depict top and bottom cues, respectively. The arrowless tick represent bisection resulting from the middle starting cursor (middle cue) for both line orientation. The oval structure represents the veridical midpoint of the line.

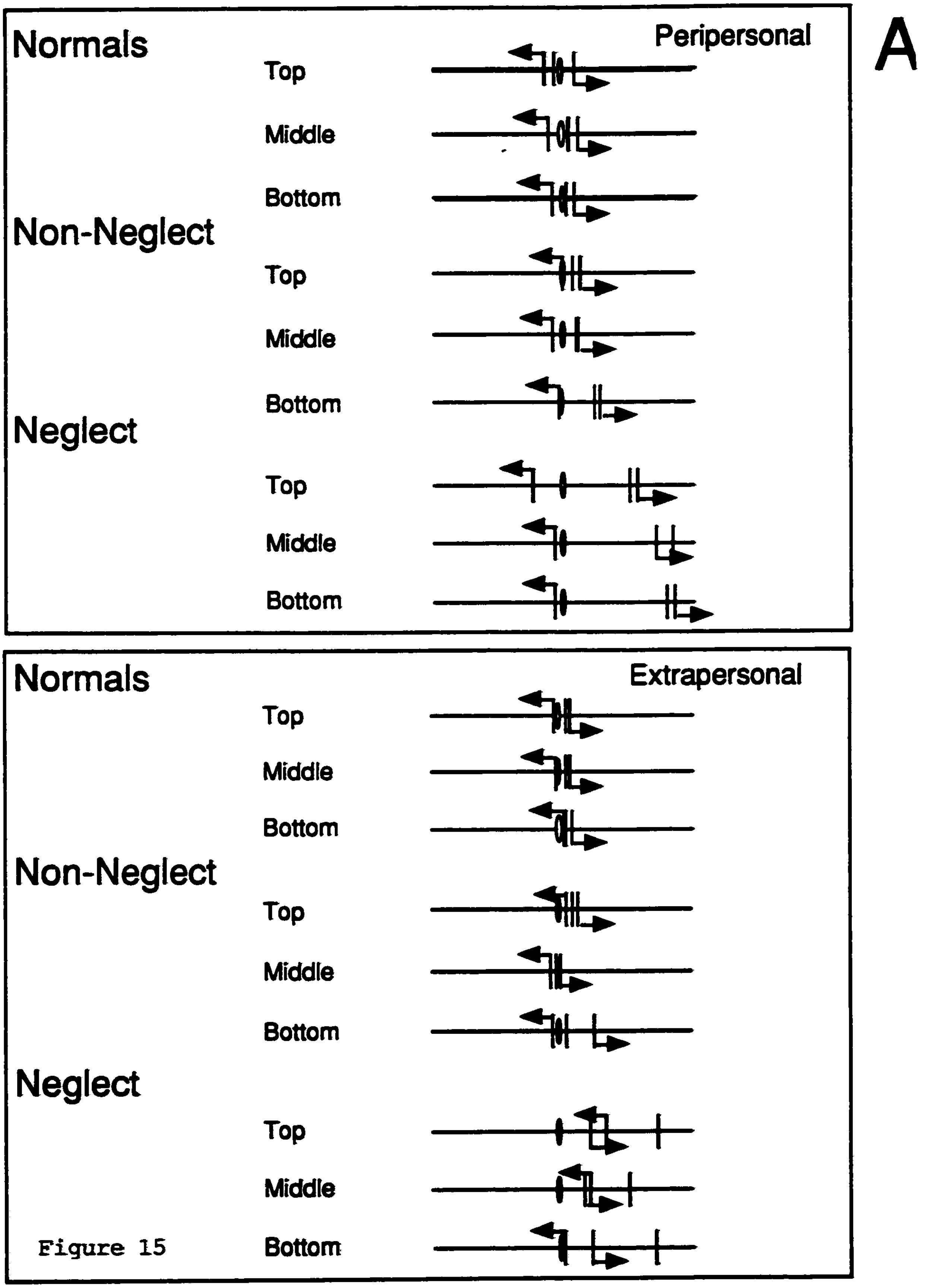
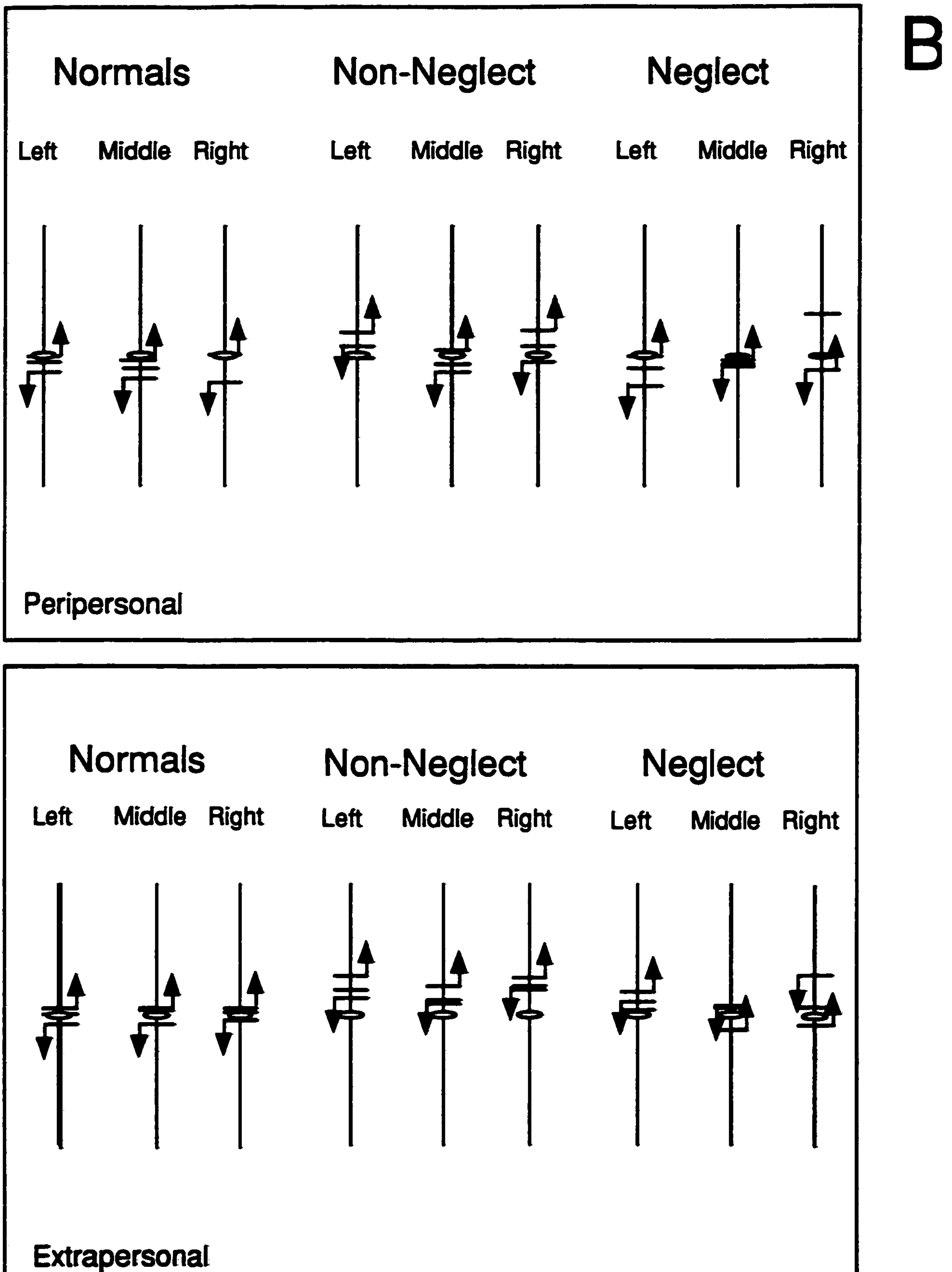

A
Peripersonal
Normals
Top
Middle
Bottom
Non-Neglect
Top
Middle
Bottom
Neglect
Top
Middle
Bottom
Extrapersonal
Normals
Top
Middle
Bottom
Non-Neglect
Top
Middle
Bottom
Neglect
Top
Middle
Bottom

Figure 15


B
Normals
Non-Neglect
Neglect
Left
Middle
Right
Left
Middle
Right
Left
Middle
Right
Peripersonal
Normals
Non-Neglect
Neglect
Left
Middle
Right
Left
Middle
Right
Left
Middle
Right
Extrapersonal
Figure 15

Right-Hemisphere Damaged Patients:

Results from the group of patients who did not manifest neglect supported a non-significant rightward bias, which was unaffected by line location or Viewing distance manipulations. The effect of cue was similar to that observed in young normals with the exception that rightward deviations were on average three times larger. In contrast, the group of patients with neglect displayed an overall rightward bias that exceeded that observed from the other two groups and was in keeping with that most frequently reported in the literature (i.e., greater than 10%). Unilateral cues modified the biases observed under the no-cue condition. In particular, the presentation of the left unilateral cue led to a significant reduction of the rightward bias in patients with neglect and in some cases the bias was reduced to the normal range. Also, when the bias is examined across the three locations for the horizontal lines, a greater rightward deviation is observed at the bottom location than the top location, suggesting that the impairment varied along the vertical dimension (see Halligan and Marshall, 1989). A comparison of performance between Viewing distances revealed that for patients with neglect, the overall (when collapsed across all three cuing conditions) bisection bias was magnified in extrapersonal space. This is readily observed when considering the greater range in bisection biases following the cues in peripersonal space compared to that found in extrapersonal space (see Figure 15A Extrapersonal Neglect). Cowey et al (1994) noted a magnification of bias in their group of patients with neglect, when comparing bisection biases in peripersonal and extrapersonal space. Of particular interest in this study was the trend observed on varying bisection biases across Viewing distance and line location. The larger rightward deviation observed in the comparison of bottom and top lines in peripersonal space, although it was less conspicuous in extrapersonal space, lends partial credence to Previc's assumptions. In Previc's model damage to the parietal area should produce a deficit in the lower field in peripersonal space. The greater rightward deviation found on lines located below rather than above eye level (bottom line) is supportive of this assumption.

In large part, outcomes generated from vertical line bisection tended to be non-significant for both groups. One exception was noted in the group of patients without neglect where the upward bias increased significantly from the right to the left positioned line. This result suggests that on the contralesional side there was a tendency to omit a larger portion of the vertical line when compared to the performance on the right lines. These data do not provide any further elucidation on Previc's model. A summary of the findings is found in Figure 15a and b.

Orienting

Normal Controls:

The performance of the young sample corroborated that reported by previous investigators (e.g., Klein et al, 1992; Posner, 1980): validly cued targets were responded to more quickly than invalidly (collapsed across location) cued targets (see Table 15). Moreover, and perhaps more critical to the objective of this study, responses varied according to target location and Viewing distance, as denoted by faster reaction time to validly cued targets in the lower field in peripersonal space than elsewhere (see Young Normal, Figure 16c & d). This response pattern supported by Previc's model. That is, information presented in extrapersonal space requires identification (temporal lobe object identification) and information presented in peripersonal space requires a localization (parietal lobe object localization). Thus, a faster response time in peripersonal space and below eye level is predicted and was found. Since this is a localization task, it could be argued that the subject also had to discriminate between targets (digit 2) and foils (digit 5), which might have led to an opposite set of predictions and outcomes; that is, faster response times above eye level in extrapersonal space. However, a potential explanation for the absence of this effect may reside in the repetitive presentation of the stimuli. The unchanging characteristics of a task has been shown to lower the demand on information processing capacity, thereby facilitating the transition from a nonautomatic (controlled) to an automatic mode of information processing (Shiffrin & Schneider, 1977; Shiffrin, 1988). Thus, discriminating targets (digit 2) from foils (digit 5) after a great number of trials may be no longer as taxing cognitively as localizing the target, hence the faster responses in peripersonal than extrapersonal space.

Patients with Right-Hemisphere Damage:

In agreement with previous reports, response time of patients manifesting neglect were significantly slower than their non-neglecting counterparts or normal controls (e.g., D'Erme et al, 1993; for review see Heilman et al, 1995). The group of patients who did not manifest neglect responded to targets in the lower visual field more slowly (see Non-Neglect, Figure 16k,o & l,p) than those above eye level (see Non-Neglect, Figure 16i,m & j,n). As well, they manifested smaller disengage deficits between hemifields and within hemifields when compared to that observed in patients with neglect (see Figure 16i-q, k-s & m-v). Interestingly, Viewing distance did not significantly alter this pattern of response (see Figure 16). Of particular interest in the group of patients with neglect is the discovery of the absence of cuing (i.e., invalid minus valid responses) effects for shifts of attention within the contralesional half of space (see Neglect, Figure 16q, s & w). Only one study had previously investigated this possibility (Baynes et al, 1986) and reported the presence of a cuing effect. However, methodological differences might account for the discrepancies observed. In their study, Baynes et al presented responses to fields in blocks (i.e., ipsilesional and contralesional), resulting in no competition between fields. Also, their target locations were marked by outlines of boxes that remain on for the duration of the trial, whereas in my study there were no physical markers. Finally, their cue and target symbols were not comparable in visual angles (X vs 1), so masking of the target by the cue might have ensued resulting in longer response times under invalid cuing conditions and more so in contralesional (impaired) space.

How can I then explain the absence of a within field disengage deficit? In Part 4, I suggested that a representational disruption underlies the phenomenon described. In essence, an inadequate coordinate system to guide behavior within the contralesional field disabled the system responsible for responding to targets in the expected manner (i.e., cuing effect). As such, I proposed that faster responses to the invalidly cued targets were conceived as the result of greater perceptual activation than that assumed for the validly cued targets. At the very least, studies aimed supporting or refuting this possibility should be sufficient impetus to generate more research. Importantly, should this finding of an absence of cuing effect prevail, it will lead to some re-conceptualizing of the disengage deficit per se.

Lastly, the absence of a Viewing distance effect may provide some support to Previc's model, when considering the faster response times in peripersonal space in younger normals. That is, damage to parietal lobes combined with poor information processing capacity in peripersonal space made the distinction in performance between the two Viewing distances less conspicuous.

Of note, an inherent difficulty exists with the summary figures described above. That is, an absence of cuing when comparing valid and invalid responses under certain condition (e.g., Patients with Negelct panel Q) is misleading. This is primarily a consequence of an absence of cuing observed primarily within the contralesional half of space for both groups. Conversely, the absence of cuing under certain invalid conditions (i.e., same height or diagonally opposite) in the group of patients who do not manifest neglect is perplexing and not as easily explained. That is, why should the responses under different invalid conditions vary? The position of the cue (location) may be responsible. However, there is no evidence that placement of other stimuli (e.g., target or foil) in identical position affect their responses in a similar fashion (here the target would be responded to significantly more slowly - see Table 19). In Ladavas et al (1994) study, normal subjects responses to validly cued targets were slower than those to invalidly cued targets (p.1200, Fig. 2). Perhaps, the physical characteristics of the display are critical, as a quadrant display have been used in Ladavas and this study. The pattern reflecting a more objective cuing effect is found in Tables 19 & 23 for patients without and with negelct, respectively.

Line Bisection: A Deficit in Disengagement of Attention

The outcome of the correlational analyses in Part 5 is interesting and encouraging. Despite not reaching a level of statistical significance, the comparison between line bisection and the disengage operation nonetheless suggests shared variance in performance behavior. As such, the argument is made that the rightward bias in patients with neglect represents, at least in part, a difficulty in disengaging from the right segment of the line. Neglect has been previously defined as a consequence of a reduced ability of objects (stimuli) in the contralesional hemifield to attract attention. Evidence in support of this notion comes from visual search studies (e.g., Grabowecky et al, 1993), which demonstrated that a reduction in the number of ipsilateral items resulted in improvement in visual search of objects in the contralateral hemifield. Thus, it is presumed that attention being biased to the ipsilesional hemifield, movement towards the contralesional hemifield is impeded. In the absence of visual search manipulations, it is conceivable that the patient with neglect may become "stuck" on the ipsilesional hemifield, or in this study experienced difficulty in disengaging from the right segment of the line and behaved accordingly.

<u>Figure 16</u>

Summary of visual orienting response time to validly and invalidly cued target locations across young normals, patients without and with neglect. Cue-target findings are presented by quadrant (see insert for cue location) and Viewing distance (peripersonal and extrapersonal space). A,I,Q) Upper Left (Contralesional) Quadrant Peripersonal Space; B,J,R) Upper Right (Ipsilesional) Quadrant Peripersonal Space; C,K,S) Lower Left (Contralesional) Quadrant Peripersonal Space; D,L,T) Lower Right (Ipsilesional) Quadrant Peripersonal Space; E,M,V) Upper Left (Contralesional) Quadrant Extrapersonal Space; F,N,V) Upper Right (Ipsilesional) Quadrant Extrapersonal Space; G,O,W) Lower Left (Contralesional) Quadrant Extrapersonal Space; and H,P,X) Lower Right (Ipsilesional) Quadrant Extrapersonal Space. The legend in the upper right corner depicts the origin of the cue under invalid condition: 1 upper left, 2 upper right, 3 lower left, and 4 lower right. Note that reaction time scales vary across groups in order to highlight response patterns.

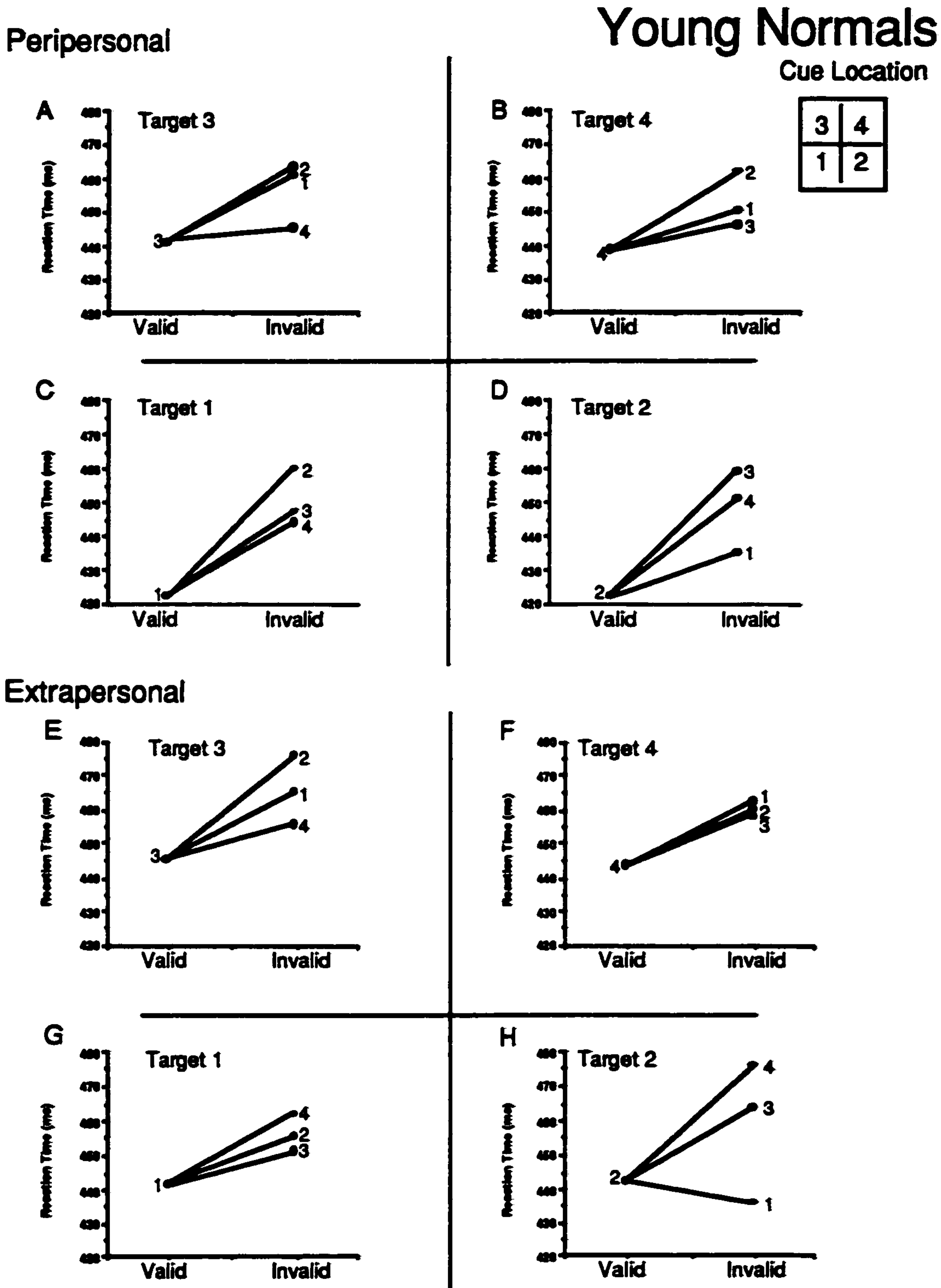

Young Normals
Cue Location
3 4
1 2
Peripersonal
A
Target 3
Valid
Invalid
B
Target 4
Valid
Invalid
C
Target 1
Valid
Invalid
D
Target 2
Valid
Invalid
Extrapersonal
E
Target 3
Valid
Invalid
F
Target 4
Valid
Invalid
G
Target 1
Valid
Invalid
H
Target 2
Valid
Invalid

Figure 16

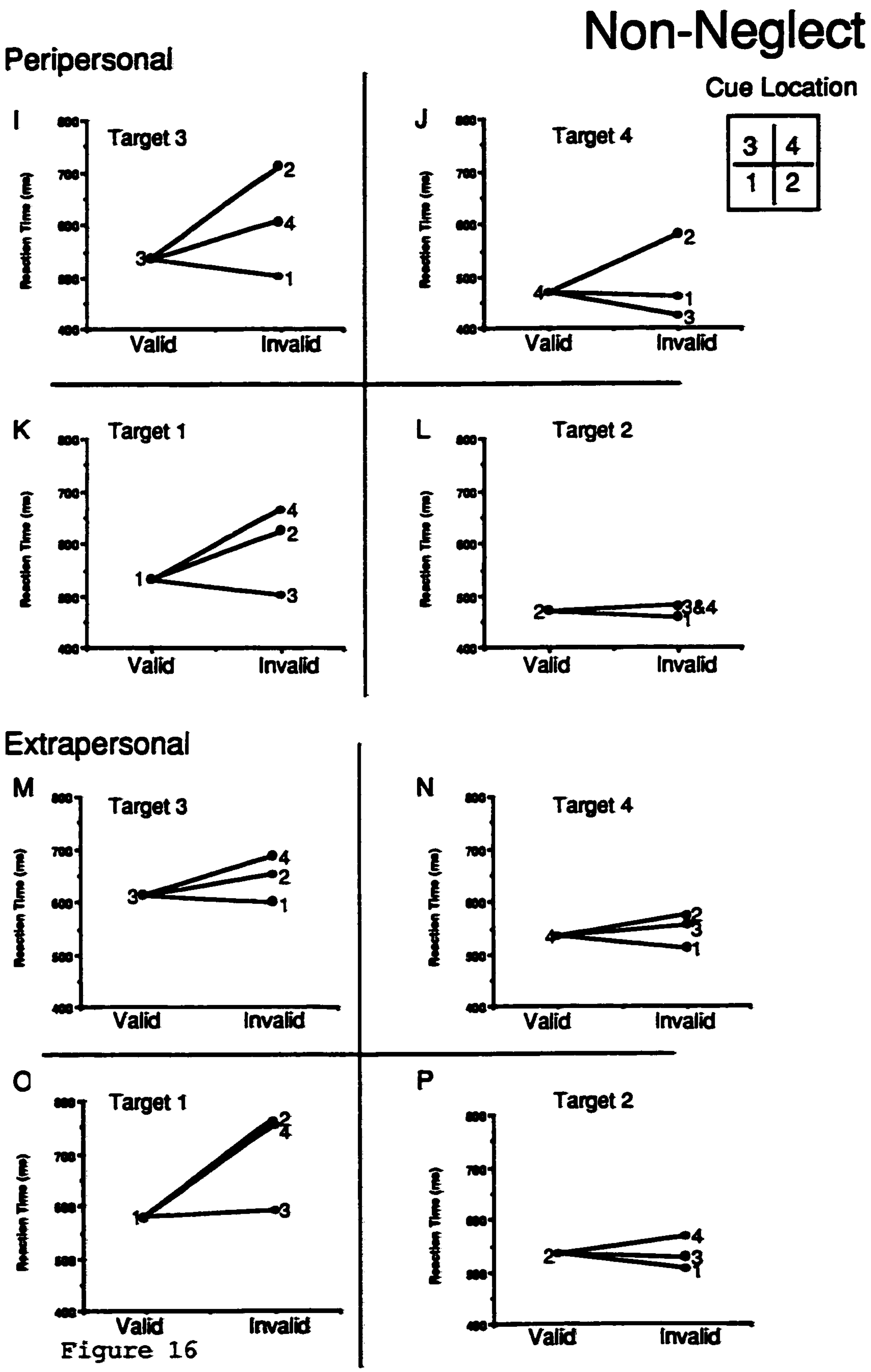

Non-Neglect
Cue Location
3 4
1 2
Peripersonal
I
Target 3
J
Target 4
K
Target 1
L
Target 2
Extrapersonal
M
Target 3
N
Target 4
O
Target 1
P
Target 2
Reaction Time (ms)
Valid
Invalid
3&4

Figure 16

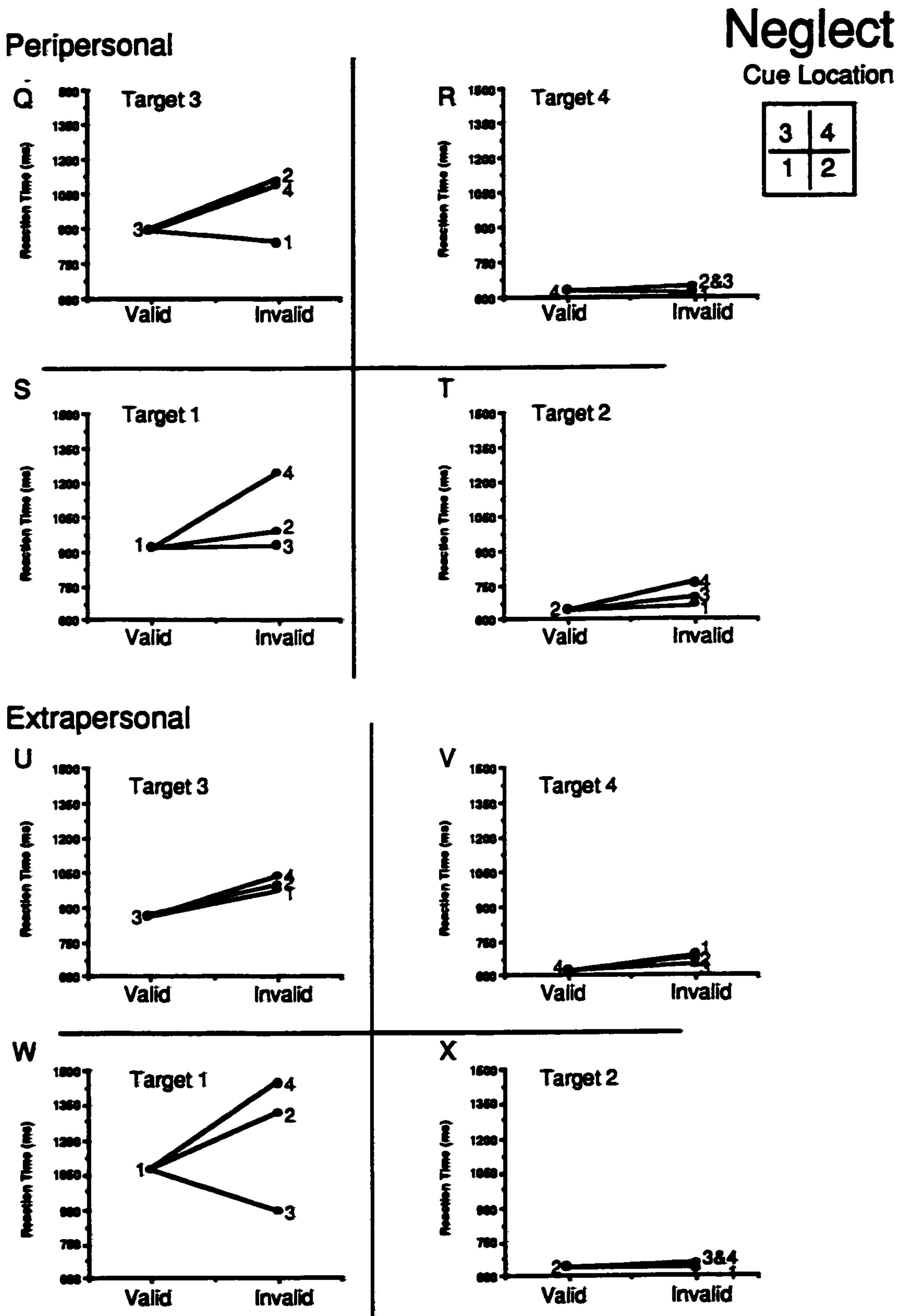

Neglect
Cue Location
3
4
1
2
Peripersonal
Q
Target 3
R
Target 4
S
Target 1
T
Target 2
Extrapersonal
U
Target 3
V
Target 4
W
Target 1
X
Target 2
Reaction Time (ms)
Valid
Invalid
2&3
3&4

Figure 16

Uninformative cues and the disengage deficit

A significant correlation between the response to neutral targets and the disengage deficit suggests that the hemifield difference may be a reliable indicator of the disengage deficit. Additionally, it purports that the neglect deficit can in part be conceptualized as a difficulty in disengaging from the ipsilateral hemifield and orienting towards the contralateral hemifield. As such, in patients with neglect, it appears that their attentional/representational resources are 'anchored' in ipsilateral hemifield. This concept of neglect has been suggested previously by Ladavas (1993), where she introduced the term of ipsilateral "hyper-attention". Whether the disorder is characterized by magnetic draw to the ipsilesional hemifield (DeRenzi et al, 1989), disengage deficit (Morrow & Ratcliff, 1988) or hyper-attention (Ladavas, 1993), neglect translates into a deficit of responding to information presented in the contralateral hemifield.

What do the results suggest?

The current study has provided some answers to the initial questions found in the INTRODUCTION. As such, "Are near and far space represented independently in the brain?". The group of young normals consistently demonstrated a preferential ability to process stimuli presented in peripersonal space and below eye level (Table 15). In contrast, the performance of patients with neglect remains stable across both Viewing distances, except that the magnitude of the lower field deficit appeared greater in extrapersonal than peripersonal space. As such, the difference in performance is quantitative not qualitative. Thus, given these patterns of performances, near and far space appear to be represented differently, not independently, in the brain, as illustrated in Figures 17 a (Young Normals) and b (Patients with Neglect). From a two-dimensional perspective; "Are the horizontal and vertical dimensions represented by the same cognitive/neural substrate?". The answer to this question is not as evident, but may hinge on what is represented and/or responded to along these dimensions; that is, the orientation of the stimulus itself (e.g., horizontal or vertical lines), or the plane along which the stimuli are located (i.e., horizontal lines above or below eye level). In this thesis, the dimension construct is predicated by the orientation on which the response is executed. As such, the stimulus is the criterion. On line bisection, young normals did not demonstrate a bias on either horizontal or vertical lines. Patients with neglect, however, displayed a significant bisecting impairment on horizontal lines (rightward), but not on vertical lines. On visual orienting, the horizontal and vertical dimensions are arbitrary. The quadrant display is collapsed according to dimension; that is, bottom and top locations are averaged for the left and right halves for the horizontal dimension, while the left and right halves are averaged for the vertical dimension. Interestingly, young normals manifested a preference along the vertical and not the horizontal dimension, while patients with neglect manifested significant difficulties along the horizontal (crossing from ipsilesional to contralesional space) but not the vertical plane. The performance of patients with neglect is consistent across both tasks, while that of the young normals is not. Based on neurological damage, the evidence suggests that the horizontal and vertical dimensions are subserved by different neural substrates. The answer to the final question, "Do the line bisection and visual orienting task share a common attentional elementary function?", is inconclusive based on the statistical outcome of the Pearson Moment Correlation coefficient between line bisection and the disengage deficit. However, there is some indication that the deficit on line bisection may be partly accountable by a disengage operation deficit.

Two other findings are noteworthy. The first is the absence of cuing observed in the contralesional field in the orienting paradigm. This provides additional support for the idea that patients with neglect are poor at localizing (e.g., Wilson et al, 1997). The other finding is the significant relationship between the field deficit, as defined by the neutral (uninformative to the pending location of the target) cuing condition and the disengage operation deficit. This finding is new and the shared variance between the two measures purports and support a practical predictive value from this outcome, as the field deficit is easier to compute than the disengage deficit.

None of the current outcomes provided unequivocal corroboration for Previc's model. Isolation of results in either young normals (e.g., cued target in lower field in peripersonal space) or patients with neglect (e.g., rightward bias trend between bottom and top lines in peripersonal space) provided partial support only. Two possibilities exist, but cannot be addressed in the context of the current data set. The first is simply that Previc's (1990) model is not empirically sound. The other resides in the choice of task utilized to assess the model. Thus, a lack of support for the model may be intrinsic to the tasks used to evaluate the behavior in each spatial domain, as the tasks should reflect the behavior expected to occur in the spatial domain under investigation. In Previc's model emphasis is placed on the nature of the task and the spatial domain (Viewing distance) in which it occurs. He postulated that in extrapersonal space the identification of an object was paramount, while in peripersonal space its location was critical in effecting a response.

By way of illustration, one might think of the processes underlying the search for a box of Kellogg's Corn Flakes at the local supermarket. As you walk down the cereal aisle, you engage in visual exploration until a match is found. Once the item is identified, you engage it by moving closer. As you approach the section of the aisle containing the Corn Flakes, the necessity for its identification is replaced by the need to localize and reach for the nearest box. This description assumes reciprocal feedback between cognitive processes underlying behavior in each spatial domain. However, in order to better understand the mechanism operating at each Viewing distance, we must isolate components of the said behavior in a manner that allows us to compare and contrast it with that of other spatial domains. In this context, issues of ecological validity prevail and tasks in peripersonal and extrapersonal space should reflect the assessment of (expected) reaching/grasping and visual exploration behavior, respectively. Under such a revised scheme, the denoted peripersonal and extrapersonal tasks would be evaluated in their respective and alternate

Viewing distance domains. This would lead to between and within Viewing distance comparison between the two tasks. One could imagine that outcomes would vary across Viewing distance for each task, while both task would vary from one another within a Viewing distance.

The ecological validity argument presented here may shed further light into the current outcome. Task employed in this thesis may have inadvertently tapped into cognitive processes (e.g., attentional/localizing) that subserved one Viewing distance over the other. Because of the repetitive nature of the tasks themselves, the necessity to continually identify the object as a line or cue-target may have lessened. This in contrast to continually monitoring the changing location and orientation of the line or target location. Under these parameters, varying patterns of performance should be more evident in peripersonal than extrapersonal space, which is the outcome of this thesis. The young normals' preferential processing of orienting information in the lower field combined with a greater effect of cue on line bisection in peripersonal support it. The similarity in performance patterns observed at the two Viewing distance in patients with neglect support it, as well. For the patients, damage to the parietal area masked any potential variations in performance across Viewing distance.

Study Strengths and Weaknesses

Strengths

In this study, line bisection and visual orienting data were obtained by using a common pool of participants for all factors examined. This is the first study of its kind to collect such a comprehensive set of spatial performance data in patients with neglect. Additionally, it is the first study of patients with neglect to make predictions based on a model of three-dimensional attention (Previc, 1990). Consequently, within each spatial sector the design allowed for the collection of data above and below eye level, in addition to the typically reported left-right dichotomy. Given the perceptual nature of both tasks, efforts were made to limit the contribution of motoric factors (i.e., lateral arm movements), especially in line bisection, by utilizing a rotary knob and a simple button press to record responses. On line bisection, the unilateral (and middle) cues were contiguous with the line, a characteristic missing in previous investigations (see Marshall and Halligan, 1994). The current thesis also provided some relatively unexplored comparison (i.e., near vs. far; top vs. bottom) with each task in normals. Finally, as stimulus generation and recording were performed by the computer, human error in measurement (e.g., Halligan and Marshall, 1991; Cowey et al, 1993) was lessened.

Limitations

One of the potential confounding factors in the interpreatation of the current results are visual field defects. Although the visual confrontation assessment of field defects was accurate, it is limited in its ability to precisely map the range or type (island of cuts) of impairment. Perimetry assessment may have been more favorable in determining their field cut status. Notwithstanding this possibility, I am confident that the current research outcomes are valid, as the neglect was present within the intact field of vision (see Walker et al, 1990 for similar outcome and recommendations).

Issues of motivation are also relevant, as participants were asked to take part in the experiment(s) amidst an already busy rehabilitative program. That is, all individuals, with the exception of M.H., were seen between demanding rehabilitative sessions (e.g., O.T.) at various times of day (i.e., early morning to late afternoon). Fatigue (Mark et al, 1988) and variable levels of arousal (Ben-Yishay et al, 1987; Fleet & Heilman, 1986) may have had an impact on their performance. Also, although the tasks were completed within each visit, multiple visits were scheduled for each participant. As such intervisit variability cannot be assessed beyond the measurement of neglect at each visit.

Finally, eye movements were not systematically monitored. On the one hand, during the line bisection, eye movement was not restricted and may have contributed to the lack of statistical significance as it pertains to the Viewing Dstance by Line Position in patients with neglect. By restricting the eye movement (fixation to the centre of screen), effects of line position (above or below eye level) across viewing distance may have been more readily observed. Lastly, from a statistical perspective there always exist concerns associated with smaller sample sizes (i.e., power, type II errors; Keppel, 1992).

Future Directions

In light of the knowledge regarding the various forms of neglect manifestation (i.e., perceptual, motoric, intentional, representational, personal, extrapersonal, etc.), the measurement of deficits in peripersonal and extrapersonal space may be further highlighted by utilizing tasks specific to the expected behavior in the spatial domain investigated. That is, instead of comparing performance across Viewing distance, the evaluation of near-far space should also confine itself to the task performed within each spatial domains. Under this scheme, a dissociation between Viewing distance and task would be sought. As mentioned earlier, tasks reflective of grasp or prehension and visual exploration would be preferable in highlighting the potential dissociations. Given Previc's (in press) recent extension of his upper and lower visual field specialization model, it appears that this approach is warranted. This would allow us to sample more thoroughly and systematically the extent of visuospatial neglect in three-dimensional space.

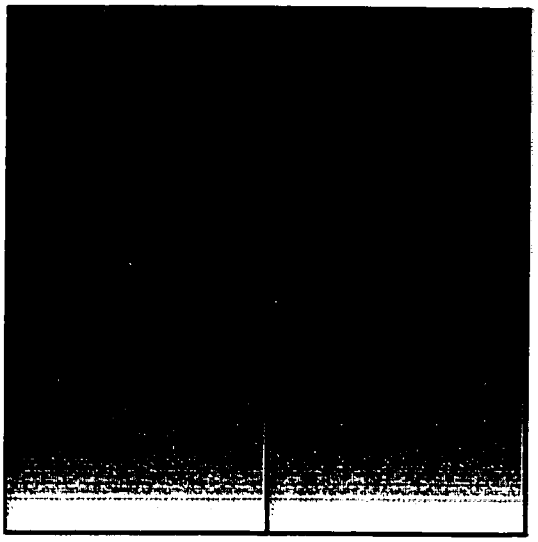
Given some of the current study's limitations, it appears imperative to investigate a larger sample of patients, increasing the statistical power of the various analyses. Additionally, comparison groups (i.e., between-subject or within-subject protocols) might include individuals in the acute versus chronic or recovery stages. Such investigation would also allows us to determine the stability of various components of the deficit in the three-dimensional realm. From a rehabilitative point of view, this type of information

Figure 17

A schematic representation of the patterns of performance across Viewing distance (peripersonal and extrapersonal) in young normals (A) and patients with neglect (B). Each square represents the two dimensional (horizontal and vertical meridian provided) layout at each Viewing distance. The shaded areas represent locations in which the processing of visual information is either impaired (i.e., patients with neglect) or inefficient (i.e., young normals).

A

Young Normals



Peripersonal

Summary of Supportive Findings:

1) Benefit to valid targets appearing in lower vs. upper field.

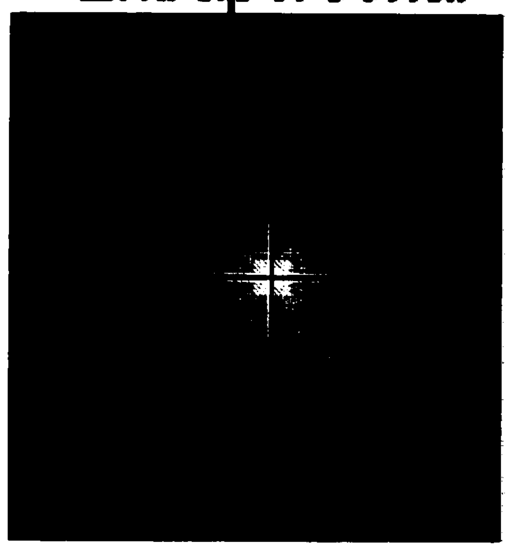
2) Bisection biases do vary across line locations where greater bias on bottom than top lines.

3) Effect of cue (left) greater in peripersonal than extrapersonal space.

4) Downward bias on vertical lines.

CONCLUSION: Information processing is more effective below eye level and in peripersonal space.

Extrapersonal



Summary of Supportive Findings:

1) No benefit of cued or uncued targets appearing in lower vs. upper field.

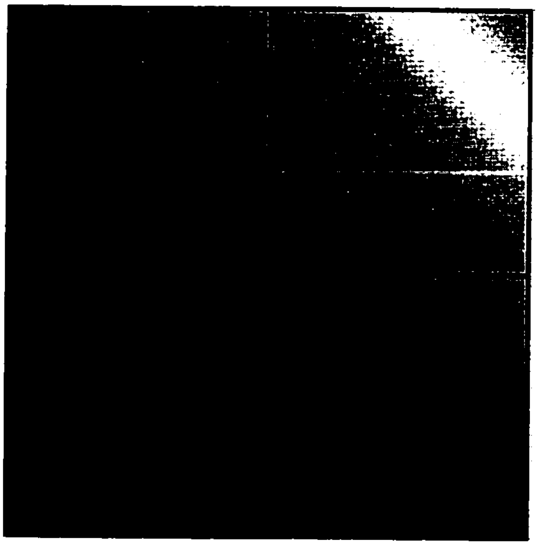
2) Bisection bias does not vary significantly across line locations.

3) Effect of cue (left) is less in extrapersonal than peripesonal.

Figure 17

B

Patients with Neglect



Summary of Supportive Findings:

1) Significant costs to targets appearing in lower contralesional field.

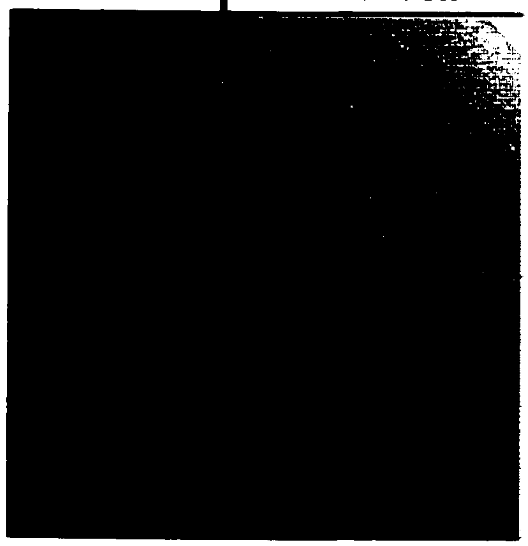
2) Bisection biases do vary across line locations where greater rightward bias on bottom than top lines.

3) Effect of cue (left) greater at the top than bottom location.

CONCLUSION: Deficit appears to be focussed to the lower contralesional quadrant.

Peripersonal

Extrapersonal



Summary of Supportive Findings:

1) Greater cost to lower contralesional field in extrapersonal than peripersonal.

2) Greater overall rightward bias in extrapersonal than peripersonal space.

3) Effect of cue (left) is greater in peripersonal than extrapersonal space.

4) Bias on vertical lines equivalent at both viewing distance.

CONCLUSION: Magnification of deficit in extrapersonal space compared to peripersonal space.

Figure 17

could prove valuable in the planning of behavioral management programs.

Given some of the known characteristics of this neurological disorder, it would seem appropriate to investigate patients manifesting mild versus more severe forms of neglect. An index of severity may be a critical factor in determining the three-dimensional extent of neglect. In keeping with this line of inquiry, as well as the current clinico-anatomical knowledge (Mesulam, 1990; Vallar & Perani, 1987), it would seem appropriate to compare and contrast groups of patients following frontal and parietal area damage (see Rizzolatti and Gallese, 1988).

Given the propensity for ipsilesional eye deviation in these patients (Ishiai et al, 1989, 1991; Chedru et al, 1973), a systematized and fully automated eye monitoring procedure would allow a better assessment of the contribution of eye movements in the investigation of three-dimensional neglect, when measuring performance on line bisection and other commonly used tasks.

In conclusion, as stated above, a number of interesting findings were generated in this study. Perhaps, the most intriguing and fascinating has been the absence of cuing effects (i.e., orienting) within the contralesional field. Unlocking the mechanisms underlying this performance behavior may shed further light in our understanding of this very complex neurological disorder. With the expansion of our knowledge in the deployment of attention in space (e.g., Previc, 1998) and the concurrent elegance of the tools involved in its appraisal (i.e., computerized paper and pencil tasks, orienting tasks, etc.), the key(s) to unlocking the mechanisms of visuospatial neglect is becoming more accessible. As such, more research investigating the performance of patients with neglect within and between field, as well as along the complimentary vertical and depth planes, is necessary.

PART 7: APPENDICES

A)-Breakdown of Line Bisection data by Group Classification

Horizontal Lines

Space	Location	Cue	Younger	Older	R-Hemi	Neglect
Periperso	Bottom	Left	-1.2	-0.7	-1.2	-1.1
		Middle	0.1	0.8	4.0	16.4
		Right	0.9	1.7	5.2	17.5
	Middle	Left	-1.6	0.2	0.4	-1.6
		Middle	0.5	-1.0	2.8	17.0
		Right	1.4	0.8	2.6	14.2
	Top	Left	-2.2	-1.8	0.6	-5.0
		Middle	-0.4	0.6	1.0	11.6
		Right	1.2	1.3	2.2	12.2
Extraperso	Bottom	Left	0.4	0.2	0.5	1.1
		Middle	0.2	-0.5	1.7	15.8
		Right	1.0	0.2	5.6	5.5
	Middle	Left	-0.2	-1.0	-1.9	4.4
		Middle	0.5	0.2	-0.8	11.2
		Right	0.9	0.6	0.2	3.6
	Top	Left	-0.4	0.2	0.2	7.6
		Middle	0.5	-0.5	1.2	16.2
		Right	0.9	1.3	2.0	4.5

Vertical Lines

Space	Location	Cue	Younger	Older	R-Hemi	Neglect
Periperso	Left	Bottom	-2.8	0.2	0.6	-4.1
		Middle	-0.8	1.1	-0.6	-2.6
		Top	0.1	2.8	3.0	0.2
	Middle	Bottom	-3.2	-1.8	-2.4	-1.6
		Middle	-1.5	0.8	-1.5	-1.2
		Top	-0.1	4.0	1.1	-0.6
	Right	Bottom	-3.8	0.6	-1.0	-2.6
		Middle	-3.8	2.4	2.2	7.4
		Top	0.3	3.4	3.6	-2.6
Extraperso	Left	Bottom	-0.8	1.2	2.7	1.4
		Middle	0.1	-0.6	2.8	0.2
		Top	0.9	0.6	6.1	3.0
	Middle	Bottom	-0.5	0.8	2.3	1.2
		Middle	0.7	2.0	1.5	0.9
		Top	1.2	2.2	4.4	-2.5
	Right	Bottom	-0.1	0.2	3.6	6.2
		Middle	0.6	1.7	3.0	1.0
		Top	1.0	0.2	5.4	-2.2

B- Line Bisection Reaction Time Data

The section that follows displays tables containing data from the study which was not presented in the main body of the. The Tables contain data obtained from short line bisection, including bisection bias and reaction time. Of note, all participants were included (right and left handers). Also, some Tables differ in the total number of participants. Some of the participants data was either lost or not available for that particular database.

Short line - Bisection bias, Horizontal

Table 1, Young Normal Individual bisection biases across space, location and cursor

	Count	Mean	Std. Dev.	Std. Error
Peripersonal, Bottom, Left start	50	49.880	1.466	.207
Peripersonal, Bottom, Right start	50	51.740	1.614	.228
Peripersonal, Bottom, Middle start	50	50.700	1.594	.225
Peripersonal, Middle, Left start	50	49.780	1.607	.227
Peripersonal, Middle, Right start	50	51.900	1.446	.205
Peripersonal, Middle, Middle start	50	50.640	1.723	.244
Peripersonal, Top, Left start	50	49.680	1.347	.190
Peripersonal, Top, Right start	50	51.880	1.480	.209
Peripersonal, Top, Middle start	50	51.000	1.414	.200
Extrapersonal, Bottom, Left start	50	49.700	1.568	.222
Extrapersonal, Bottom, Right start	50	51.000	1.385	.196
Extrapersonal, Bottom, Middle start	50	50.520	.995	.141
Extrapersonal, Middle, Left start	50	49.680	1.362	.193
Extrapersonal, Middle, Right start	50	51.100	1.529	.216
Extrapersonal, Middle, Middle start	50	50.460	1.265	.179
Extrapersonal, Top, Left start	50	49.920	1.368	.193
Extrapersonal, Top, Right start	50	51.180	1.380	.195
Extrapersonal, Top, Middle start	50	50.480	1.111	.157

Summary Table of ANOVA

Source	df	F	p
Space	1, 49	7.6	0.0083
Location	2, 98	n.s.	
Cursor	2, 98	117.4	0.0001
S x C	2, 98	7.6	0.0009
L x C	2, 98	n.s.	
S x L x C	2, 98	n.s.	

Space; Peripersonal, Extrapersonal, Location; Top, Middle, Bottom
Cursor; Left, Middle, Right

Table 2

Older Normal Individual bisection biases across space, location and cursor

	Count	Mean	Std. Dev.	Std. Error
Peripersonal, Bottom, Left start	9	49.778	.972	.324
Peripersonal, Bottom, Right start	9	51.778	2.863	.954
Peripersonal, Bottom, Middle start	9	49.778	2.635	.878
Peripersonal, Middle, Left start	9	49.444	1.878	.626
Peripersonal, Middle, Right start	9	51.333	1.732	.577
Peripersonal, Middle, Middle start	9	50.778	.667	.222
Peripersonal, Top, Left start	9	48.778	2.333	.778
Peripersonal, Top, Right start	9	51.000	2.291	.764
Peripersonal, Top, Middle start	9	49.556	1.878	.626
Extrapersonal, Bottom, Left start	9	49.333	1.500	.500
Extrapersonal, Bottom, Right start	9	50.889	2.088	.696
Extrapersonal, Bottom, Middle start	9	49.889	2.088	.696
Extrapersonal, Middle, Left start	9	50.222	1.922	.641
Extrapersonal, Middle, Right start	9	50.000	2.179	.726
Extrapersonal, Middle, Middle start	9	50.000	1.414	.471
Extrapersonal, Top, Left start	9	49.556	1.424	.475
Extrapersonal, Top, Right start	9	51.111	1.453	.484
Extrapersonal, Top, Middle start	9	49.778	1.787	.596

Summary Table of ANOVA

Source	***df***	***F***	***p***
Space	1, 49	n.s.	
Location	2,16	n.s.	
Cursor	2,16	9.5	0.0019
S x C	2,16	4.5	0.03
S x L	2,16	n.s.	
L x C	2,16	n.s.	
S x L x C	4,32	n.s.	

Table 3

Patients with Non-Neglect's bisection biases across space, location and cursor

	Count	Mean	Std. Dev.	Std. Error
Peripersonal, Bottom, Left start	7	48.952	3.217	1.216
Peripersonal, Bottom, Right start	7	49.714	3.302	1.248
Peripersonal, Bottom, Middle start	7	52.643	3.473	1.313
Peripersonal, Middle, Left start	7	49.548	4.040	1.527
Peripersonal, Middle, Right start	7	51.810	4.513	1.706
Peripersonal, Middle, Middle start	7	50.619	2.360	.892
Peripersonal, top, Left start	7	47.643	3.544	1.339
Peripersonal, top, Right start	7	52.548	3.089	1.168
Peripersonal, top, Middle start	7	50.381	2.004	.757
Extrapersonal, Bottom, Left start	7	49.393	4.681	1.769
Extrapersonal, Bottom, Right start	7	50.000	3.109	1.175
Extrapersonal, Bottom, Middle start	7	50.571	1.718	.649
Extrapersonal, Middle, Left start	7	49.964	2.043	.772
Extrapersonal, Middle, Right start	7	49.964	3.203	1.211
Extrapersonal, Middle, Middle start	7	50.964	2.725	1.030
Extrapersonal, top, Left start	7	48.393	4.500	1.701
Extrapersonal, top, Right start	7	50.571	2.878	1.088
Extrapersonal, top, Middle start	7	50.321	3.880	1.467

Summary Table of ANOVA

Source	df	F	p
Space	1, 6	n.s.	
Location	2, 12	n.s.	
Cursor	2, 12	4.9	0.03
S x C	2,12	n.s.	
S x L	2, 12	n.s.	
L x C	4,24	n.s.	
S x L x C	4,24	n.s.	

Table 4

Patients with Neglect bisection biases across space, location and cursor

	Count	Mean	Std. Dev.	Std. Error
Peripersonal, Bottom, Left start	7	46.167	6.979	2.638
Peripersonal, Bottom, Right start	7	50.600	5.558	2.101
Peripersonal, Bottom, Middle start	7	50.556	4.537	1.715
Peripersonal, Middle, Left start	7	44.572	5.288	1.999
Peripersonal, Middle, Right start	7	49.597	6.801	2.570
Peripersonal, Middle, Middle start	7	49.236	2.674	1.011
Peripersonal, Top, Left start	7	45.458	4.251	1.607
Peripersonal, Top, Right start	7	51.528	6.368	2.407
Peripersonal, Top, Middle start	7	49.250	5.031	1.902
Extrapersonal, Bottom, Left start	7	46.095	5.755	2.175
Extrapersonal, Bottom, Right start	7	44.514	6.661	2.517
Extrapersonal, Bottom, Middle start	7	45.452	6.151	2.325
Extrapersonal, Middle, Left start	7	47.690	6.450	2.438
Extrapersonal, Middle, Right start	7	40.286	8.591	3.247
Extrapersonal, Middle, Middle start	7	47.357	8.257	3.121
Extrapersonal, Top, Left start	7	49.833	9.549	3.609
Extrapersonal, Top, Right start	7	41.500	9.965	3.766
Extrapersonal, Top, Middle start	7	51.310	4.719	1.784

Summary Table of ANOVA

Source	df	F	p
Space	1, 6	n.s.	
Location	2, 12	n.s.	
Cursor	2, 12	n.s.	
S x C	2, 12	7.4	0.008
S x L	2, 12	n.s.	
L x C	4, 24	n.s.	
S x L x C	4, 24	n.s.	

Vertical Lines

Table 5

Young Normal Individual bisection biases across space, location and cursor

	Count	Mean	Std. Dev.	Std. Error
Peripersonal, Left, Bottom start	50	48.800	1.539	.218
Peripersonal, Left, Top start	50	51.140	1.773	.251
Peripersonal, Left, Middle start	50	50.260	1.651	.234
Peripersonal, Middle, Bottom start	50	48.720	1.552	.220
Peripersonal, Middle, Top start	50	51.440	1.554	.220
Peripersonal, Middle, Middle start	50	50.020	1.879	.266
Peripersonal, Right, Bottom start	50	48.840	1.811	.256
Peripersonal, Right, Top start	50	51.360	1.747	.247
Peripersonal, Right, Middle start	50	50.500	1.594	.225
Extrapersonal, Left, Bottom start	50	49.440	1.327	.188
Extrapersonal, Left, Top start	50	50.660	1.334	.189
Extrapersonal, Left, Middle start	50	50.020	1.348	.191
Extrapersonal, Middle, Bottom start	50	49.400	1.604	.227
Extrapersonal, Middle, Top start	50	50.440	1.473	.208
Extrapersonal, Middle, Middle start	50	49.960	1.340	.189
Extrapersonal, Right, Bottom start	50	49.500	1.359	.192
Extrapersonal, Right, Top start	50	50.280	1.738	.246
Extrapersonal, Right, Middle start	50	50.140	1.340	.190

Summary Table of ANOVA

Source	df	F	p
Space	1, 49	n.s.	
Location	2, 98	n.s.	
Cursor	2, 98	75.5	0.0001
S x C	2, 98	34.6	0.0001
S x L	2,98	n.s.	
L x C	2, 98	n.s.	
S x L x C	4,196	n.s.	

Space; Peripersonal, Extrapersonal, Location; Left, Middle, Right
Cursor; Top, Middle, Bottom

Table 6

Older Normal Individual bisection biases across space, location and cursor

	Count	Mean	Std. Dev.	Std. Error
Peripersonal, Left, Bottom start	9	49.444	1.509	.503
Peripersonal, Left, Top start	9	52.111	2.205	.735
Peripersonal, Left, Middle start	9	51.222	2.108	.703
Peripersonal, Middle, Bottom start	9	50.222	1.922	.641
Peripersonal, Middle, Top start	9	53.667	1.936	.645
Peripersonal, Middle, Middle start	9	51.444	2.789	.930
Peripersonal, Right, Bottom start	9	49.889	2.147	.716
Peripersonal, Right, Top start	9	52.444	1.590	.530
Peripersonal, Right, Middle start	9	51.333	1.118	.373
Extrapersonal, Left, Bottom start	9	50.889	1.965	.655
Extrapersonal, Left, Top start	9	52.667	3.041	1.014
Extrapersonal, Left, Middle start	9	50.222	1.641	.547
Extrapersonal, Middle, Bottom start	9	50.333	1.658	.553
Extrapersonal, Middle, Top start	9	51.222	2.108	.703
Extrapersonal, Middle, Middle start	9	50.889	1.691	.564
Extrapersonal, Right, Bottom start	9	50.000	1.118	.373
Extrapersonal, Right, Top start	9	51.889	2.421	.807
Extrapersonal, Right, Middle start	9	49.889	1.364	.455

<u>Summary Table of ANOVA</u>

<u>Source</u>	<u>df</u>	<u>F</u>	<u>p</u>
Space	1, 8	n.s.	
Location	2,16	n.s.	
Cursor	2,16	21.4	0.0001
S x C	2,16	4.9	0.02
S x L	2,16	n.s.	
L x C	2,16	n.s.	
S x L x C	4,32	n.s.	

Table 7

Patients with Non-Neglect's bisection biases across space, location and cursor

	Count	Mean	Std. Dev.	Std. Error
Peripersonal, Left, Bottom start	7	51.286	2.870	1.085
Peripersonal, Left, Top start	7	50.929	3.006	1.136
Peripersonal, Left, Middle start	7	53.405	4.718	1.783
Peripersonal, Middle, Bottom start	7	50.476	2.523	.954
Peripersonal, Middle, Top start	7	52.143	2.035	.769
Peripersonal, Middle, Middle start	7	51.810	2.873	1.086
Peripersonal, Right, Bottom start	7	50.500	4.992	1.887
Peripersonal, Right, Top start	7	50.381	3.623	1.369
Peripersonal, Right, Middle start	7	51.238	1.931	.730
Extrapersonal, Left, Bottom start	7	49.321	4.017	1.518
Extrapersonal, Left, Top start	7	52.000	2.309	.873
Extrapersonal, Left, Middle start	7	52.393	1.682	.636
Extrapersonal, Middle, Bottom start	7	51.107	1.632	.617
Extrapersonal, Middle, Top start	7	52.893	3.055	1.155
Extrapersonal, Middle, Middle start	7	52.571	1.618	.612
Extrapersonal, Right, Bottom start	7	50.643	2.688	1.016
Extrapersonal, Right, Top start	7	51.321	2.897	1.095
Extrapersonal, Right, Middle start	7	50.357	1.796	.679

Summary Table of ANOVA

Source	df	F	p
Space	1, 6	n.s.	
Location	2, 12	n.s.	
Cursor	2, 12	n.s.	
S x C	2, 12	n.s.	
S x L	2, 12	n.s.	
L x C	2, 12	n.s.	
S x L x C	4, 24	n.s.	

Table 8

Patients with Neglect's bisection biases across space, location and cursor

	Count	Mean	Std. Dev.	Std. Error
Peripersonal, Left, Bottom start	7	48.476	7.916	2.992
Peripersonal, Left, Top start	7	49.774	7.987	3.019
Peripersonal, Left, Middle start	7	50.607	9.215	3.483
Peripersonal, Middle, Bottom start	7	49.726	3.432	1.297
Peripersonal, Middle, Top start	7	47.631	11.610	4.388
Peripersonal, Middle, Middle start	7	52.690	7.107	2.686
Peripersonal, Right, Bottom start	7	50.095	5.519	2.086
Peripersonal, Right, Top start	7	49.155	4.428	1.673
Peripersonal, Right, Middle start	7	53.667	6.915	2.614
Extrapersonal, Left, Bottom start	7	53.190	3.224	1.218
Extrapersonal, Left, Top start	7	45.786	10.259	3.877
Extrapersonal, Left, Middle start	7	50.762	5.598	2.116
Extrapersonal, Middle, Bottom start	7	53.238	5.697	2.153
Extrapersonal, Middle, Top start	7	46.857	9.560	3.613
Extrapersonal, Middle, Middle start	7	52.429	7.570	2.861
Extrapersonal, Right, Bottom start	7	52.524	6.964	2.632
Extrapersonal, Right, Top start	7	48.357	7.222	2.730
Extrapersonal, Right, Middle start	7	49.881	3.669	1.387

Summary Table of ANOVA

Source	df	F	p
Space	1, 6	n.s.	
Location	2, 12	n.s.	
Cursor	2, 12	n.s.	
S x C	2, 12	4.0	0.04
S x L	2, 12	n.s.	
L x C	4, 24	n.s.	
S x L x C	4, 24	n.s.	

Short line - Reaction Time
Horizontal

Table 9
Young Normal Individual bisection reaction times across space, location and cursor

	Count	Mean	Std. Dev.	Std. Error
Peripersonal, Bottom, Left start	49	3.492	1.326	.189
Peripersonal, Bottom, Right start	49	3.422	1.118	.160
Peripersonal, Bottom, Middle start	49	3.033	1.240	.177
Peripersonal, Middle, Left start	49	3.627	1.519	.217
Peripersonal, Middle, Right start	49	3.453	1.299	.186
Peripersonal, Middle, Middle start	49	2.980	1.150	.164
Peripersonal, Top, Left start	49	3.627	1.617	.231
Peripersonal, Top, Right start	49	3.553	1.461	.209
Peripersonal, Top, Middle start	49	3.141	1.340	.191
Extrapersonal, Bottom, Left start	49	3.888	1.325	.189
Extrapersonal, Bottom, Right start	49	3.741	1.417	.202
Extrapersonal, Bottom, Middle start	49	3.251	1.235	.176
Extrapersonal, Middle, Left start	49	3.773	1.468	.210
Extrapersonal, Middle, Right start	49	3.720	1.421	.203
Extrapersonal, Middle, Middle start	49	3.365	1.253	.179
Extrapersonal, Top, Left start	49	3.916	1.291	.184
Extrapersonal, Top, Right start	49	3.688	1.307	.187
Extrapersonal, Top, Middle start	49	3.269	1.162	.166

Summary Table of ANOVA

Source	df	F	p
Space	1, 49	6.9	0.01
Location	2, 98	n.s.	
Cursor	2, 98	43.1	0.0001
S x C	2, 98	n.s.	0.0009
S x L	2, 98	n.s.	
L x C	4,196	n.s.	
S x L x C	4,196	n.s.	

Table 10

Older Normal Individual bisection reaction times across space, location and cursor

	Count	Mean	Std. Dev.	Std. Error
Peripersonal, Bottom, Left start	9	3.144	1.256	.419
Peripersonal, Bottom, Right start	9	3.167	1.554	.518
Peripersonal, Bottom, Middle start	9	2.878	1.588	.529
Peripersonal, Middle, Left start	9	3.156	1.210	.403
Peripersonal, Middle, Right start	9	3.689	2.075	.692
Peripersonal, Middle, Middle start	9	2.744	1.628	.543
Peripersonal, Top, Left start	9	3.033	1.342	.447
Peripersonal, Top, Right start	9	3.033	1.135	.378
Peripersonal, Top, Middle start	9	2.933	1.568	.523
Extrapersonal, Bottom, Left start	9	3.256	1.122	.374
Extrapersonal, Bottom, Right start	9	3.533	1.377	.459
Extrapersonal, Bottom, Middle start	9	2.844	1.158	.386
Extrapersonal, Middle, Left start	9	3.133	1.323	.441
Extrapersonal, Middle, Right start	9	3.322	1.384	.461
Extrapersonal, Middle, Middle start	9	2.778	1.156	.385
Extrapersonal, Top, Left start	9	3.200	.994	.331
Extrapersonal, Top, Right start	9	3.511	1.685	.562
Extrapersonal, Top, Middle start	9	3.044	1.277	.426

Summary Table of ANOVA

Source	df	F	p
Space	1, 8	n.s.	
Location	2, 16	n.s.	
Cursor	2, 16	8.1	0.004
S x C	2, 16	n.s.	
S x L	2, 16	n.s.	
L x C	4,32	n.s.	
S x L x C	4,32	n.s.	

Table 11

Patients with Non-Neglect's bisection reaction times across space, location and cursor

	Count	Mean	Std. Dev.	Std. Error
Peripersonal, Bottom, Left start	7	5.668	2.480	.937
Peripersonal, Bottom, Right start	7	6.082	3.077	1.163
Peripersonal, Bottom, Middle start	7	5.546	3.128	1.182
Peripersonal, Middle, Left start	7	5.721	3.339	1.262
Peripersonal, Middle, Right start	7	6.118	2.556	.966
Peripersonal, Middle, Middle start	7	4.700	2.327	.880
Peripersonal, Top, Left start	7	5.225	2.205	.834
Peripersonal, Top, Right start	7	6.446	2.735	1.034
Peripersonal, Top, Middle start	7	11.257	16.959	6.410
Extrapersonal, Bottom, Left start	7	4.711	1.784	.674
Extrapersonal, Bottom, Right start	7	5.336	2.286	.864
Extrapersonal, Bottom, Middle start	7	4.118	2.068	.782
Extrapersonal, Middle, Left start	7	5.157	2.701	1.021
Extrapersonal, Middle, Right start	7	5.690	2.143	.810
Extrapersonal, Middle, Middle start	7	3.879	1.651	.624
Extrapersonal, Top, Left start	7	4.718	1.606	.607
Extrapersonal, Top, Right start	7	5.146	2.398	.907
Extrapersonal, Top, Middle start	7	5.543	2.805	1.060

Summary Table of ANOVA

Source	df	F	p
Space	1, 8	n.s.	
Location	2, 16	n.s.	
Cursor	2, 16	n.s.	
S x C	2, 16	n.s.	
S x L	2,16	n.s.	
L x C	4,32	n.s.	
S x L x C	4,32	n.s.	

Table 12

Patients with Neglect's bisection reaction times across space, location and cursor

	Count	Mean	Std. Dev.	Std. Error
Peripersonal, Bottom, Left start	7	7.495	6.086	2.300
Peripersonal, Bottom, Right start	7	5.828	2.358	.891
Peripersonal, Bottom, Middle start	7	6.694	5.094	1.926
Peripersonal, Middle, Left start	7	6.244	3.133	1.184
Peripersonal, Middle, Right start	7	4.845	1.511	.571
Peripersonal, Middle, Middle start	7	5.087	1.681	.635
Peripersonal, top, Left start	7	6.132	3.321	1.255
Peripersonal, top, Right start	7	4.925	1.281	.484
Peripersonal, top, Middle start	7	5.981	3.234	1.222
Extrapersonal, Bottom, Left start	7	7.726	5.096	1.926
Extrapersonal, Bottom, Right start	7	6.377	3.382	1.278
Extrapersonal, Bottom, Middle start	7	5.735	3.723	1.407
Extrapersonal, Middle, Left start	7	7.441	5.033	1.902
Extrapersonal, Middle, Right start	7	6.761	3.332	1.259
Extrapersonal, Middle, Middle start	7	5.593	2.577	.974
Extrapersonal, top, Left start	7	7.629	5.348	2.021
Extrapersonal, top, Right start	7	7.494	5.875	2.221
Extrapersonal, top, Middle start	7	5.595	3.026	1.144

Summary Table of ANOVA

Source	df	F	p
Space	1, 8	n.s.	
Location	2, 16	n.s.	
Cursor	2, 16	n.s.	
S x C	2, 16	n.s.	
S x L	2, 16	n.s.	
L x C	4, 32	n.s.	
S x L x C	4, 32	n.s.	

Vertical Lines

Table 13

Young Normal Individual bisection biases across space, location and cursor

	Count	Mean	Std. Dev.	Std. Error
Peripersonal, Left, Bottom start	50	3.660	1.560	.221
Peripersonal, Left, Top Start	50	3.514	1.241	.176
Peripersonal, Left, Middle start	50	3.246	1.294	.183
Peripersonal, Middle, Bottom start	50	3.598	1.767	.250
Peripersonal, Middle, Top Start	50	3.582	1.443	.204
Peripersonal, Middle, Middle start	50	3.226	1.330	.188
Peripersonal, Right, Bottom start	50	3.514	1.594	.225
Peripersonal, Right, Top Start	50	3.410	1.411	.200
Peripersonal, Right, Middle start	50	3.092	1.306	.185
Extrapersonal, Left, Bottom start	50	3.820	1.470	.208
Extrapersonal, Left, Top Start	50	3.984	1.537	.217
Extrapersonal, Left, Middle start	50	3.118	1.222	.173
Extrapersonal, Middle, Bottom start	50	3.776	1.428	.202
Extrapersonal, Middle, Top Start	50	3.922	1.475	.209
Extrapersonal, Middle, Middle start	50	3.336	1.475	.209
Extrapersonal, Right, Bottom start	50	3.916	1.657	.234
Extrapersonal, Right, Top Start	50	3.834	1.433	.203
Extrapersonal, Right, Middle start	50	3.236	1.222	.173

Summary Table of ANOVA

Source	df	F	p
Space	1, 49	3.8	0.05
Location	2, 98	n.s.	
Cursor	2, 98	36.1	0.0001
S x C	2, 98	4.2	0.02
S x L	2,98	n.s.	
L x C	4, 196	n.s.	
S x L x C	4, 196	n.s.	

Table 14

Older Normal Individual bisection reaction times across space, location and cursor

	Count	Mean	Std. Dev.	Std. Error
Peripersonal, Left, Bottom start	9	3.144	1.256	.419
Peripersonal, Left, Top start	9	3.167	1.554	.518
Peripersonal, Left, Middle start	9	2.878	1.588	.529
Peripersonal, Middle, Bottom start	9	3.156	1.210	.403
Peripersonal, Middle, Top start	9	3.689	2.075	.692
Peripersonal, Middle, Middle start	9	2.744	1.628	.543
Peripersonal, Right, Bottom start	9	3.033	1.342	.447
Peripersonal, Right, Top start	9	3.033	1.135	.378
Peripersonal, Right, Middle start	9	2.933	1.568	.523
Extrapersonal, Left, Bottom start	9	3.256	1.122	.374
Extrapersonal, Left, Top start	9	3.533	1.377	.459
Extrapersonal, Left, Middle start	9	2.844	1.158	.386
Extrapersonal, Middle, Bottom start	9	3.133	1.323	.441
Extrapersonal, Middle, Top start	9	3.322	1.384	.461
Extrapersonal, Middle, Middle start	9	2.778	1.156	.385
Extrapersonal, Right, Bottom start	9	3.200	.994	.331
Extrapersonal, Right, Top start	9	3.511	1.685	.562
Extrapersonal, Right, Middle start	9	3.044	1.277	.426

Summary Table of ANOVA

Source	df	F	p
Space	1, 8	n.s.	
Location	2, 16	n.s.	
Cursor	2, 16	8.1	0.004
S x C	2, 16	n.s.	
S x L	2, 16	n.s.	
L x C	4,32	n.s.	
S x L x C	4,32	n.s.	

Table 15

Patients with Non-Neglect's bisection reaction times across space, location and cursor

	Count	Mean	Std. Dev.	Std. Error
Peripersonal, Left, Bottom start	7	4.836	1.702	.643
Peripersonal, Left, Top start	7	5.605	2.120	.801
Peripersonal, Left, Middle start	7	4.421	1.483	.561
Peripersonal, Middle, Bottom start	7	4.729	1.774	.670
Peripersonal, Middle, Top start	7	5.667	2.456	.928
Peripersonal, Middle, Middle start	7	5.471	2.791	1.055
Peripersonal, Right, Bottom start	7	4.902	1.839	.695
Peripersonal, Right, Top start	7	5.588	2.508	.948
Peripersonal, Right, Middle start	7	4.586	2.409	.911
Extrapersonal, Left, Bottom start	7	5.021	1.580	.597
Extrapersonal, Left, Top start	7	5.943	3.003	1.135
Extrapersonal, Left, Middle start	7	5.261	3.251	1.229
Extrapersonal, Middle, Bottom start	7	4.818	1.325	.501
Extrapersonal, Middle, Top start	7	5.504	2.559	.967
Extrapersonal, Middle, Middle start	7	3.450	1.137	.430
Extrapersonal, Right, Bottom start	7	4.829	1.482	.560
Extrapersonal, Right, Top start	7	4.429	1.207	.456
Extrapersonal, Right, Middle start	7	4.193	1.677	.634

<u>Summary Table of ANOVA</u>

<u>Source</u>	<u>df</u>	<u>F</u>	<u>p</u>
Space	1, 8	5.9	0.05
Location	2, 16	n.s.	
Cursor	2, 16	n.s.	
S x C	2, 16	n.s.	
S x L	2, 16	n.s.	
L x C	4,32	n.s.	
S x L x C	4,32	n.s.	

Table 16

Patients with Neglect's bisection reaction times across space, location and cursor

	Count	Mean	Std. Dev.	Std. Error
Peripersonal, Left, Bottom start	7	8.135	5.145	1.945
Peripersonal, Left, Top start	7	6.417	2.935	1.109
Peripersonal, Left, Middle start	7	6.100	3.591	1.357
Peripersonal, Middle, Bottom start	7	5.710	2.420	.915
Peripersonal, Middle, Top start	7	6.311	3.679	1.390
Peripersonal, Middle, Middle start	7	6.926	5.285	1.997
Peripersonal, Right, Bottom start	7	5.242	2.433	.920
Peripersonal, Right, Top start	7	5.519	2.005	.758
Peripersonal, Right, Middle start	7	5.574	2.864	1.082
Extrapersonal, Left, Bottom start	7	9.712	7.373	2.787
Extrapersonal, Left, Top start	7	8.910	5.999	2.267
Extrapersonal, Left, Middle start	7	7.285	4.459	1.686
Extrapersonal, Middle, Bottom start	7	5.876	2.588	.978
Extrapersonal, Middle, Top start	7	6.150	2.402	.908
Extrapersonal, Middle, Middle start	7	5.579	2.574	.973
Extrapersonal, Right, Bottom start	7	5.860	2.508	.948
Extrapersonal, Right, Top start	7	5.412	2.391	.904
Extrapersonal, Right, Middle start	7	5.679	3.490	1.319

Summary Table of ANOVA

Source	df	F	p
Space	1, 8	n.s.	
Location	2, 16	n.s.	
Cursor	2, 16	n.s.	
S x C	2, 16	n.s.	
S x L	2, 16	n.s.	
L x C	4, 32	n.s.	
S x L x C	4, 32	n.s.	

Long line - Reaction Time

Horizontal

Table 17

Young Normal Individual bisection reaction times across space, location and cursor

	Count	Mean	Std. Dev.	Std. Error
Peripersonal, Bottom, Left start	50	4.044	1.655	.234
Peripersonal, Bottom, Right start	50	4.096	1.439	.204
Peripersonal, Bottom, Middle start	50	3.530	1.486	.210
Peripersonal, Middle, Left start	50	4.026	1.657	.234
Peripersonal, Middle, Right start	50	3.992	1.502	.212
Peripersonal, Middle, Middle start	50	3.466	1.597	.226
Peripersonal, Top, Left start	50	4.014	1.649	.233
Peripersonal, Top, Right start	50	4.146	1.716	.243
Peripersonal, Top, Middle start	50	3.334	1.508	.213
Extrapersonal, Bottom, Left start	50	4.746	1.666	.236
Extrapersonal, Bottom, Right start	50	4.640	1.789	.253
Extrapersonal, Bottom, Middle start	50	3.604	1.292	.183
Extrapersonal, Middle, Left start	50	4.634	1.836	.260
Extrapersonal, Middle, Right start	50	4.418	1.548	.219
Extrapersonal, Middle, Middle start	50	3.746	1.509	.213
Extrapersonal, Top, Left start	50	4.448	1.520	.215
Extrapersonal, Top, Right start	50	4.586	1.583	.224
Extrapersonal, Top, Middle start	50	3.586	1.297	.183

Summary Table of ANOVA

Source	df	F	p
Space	1, 49	10.6	0.0021
Location	2, 98	n.s.	
Cursor	2, 98	94.0	0.0001
S x C	2, 98	5.2	0.007
S x L	2, 98	n.s.	
L x C	2, 98	n.s.	
S x L x C	2, 98	n.s.	

Table 18

Older Normal Individual bisection reaction times across space, location and cursor

	Count	Mean	Std. Dev.	Std. Error
Peripersonal, Bottom, Left start	9	3.478	1.501	.500
Peripersonal, Bottom, Right start	9	3.644	1.716	.572
Peripersonal, Bottom, Middle start	9	3.533	2.531	.844
Peripersonal, Middle, Left start	9	4.056	2.491	.830
Peripersonal, Middle, Right start	9	3.800	1.568	.523
Peripersonal, Middle, Middle start	9	2.911	1.442	.481
Peripersonal, Top, Left start	9	4.067	1.804	.601
Peripersonal, Top, Right start	9	4.311	2.405	.802
Peripersonal, Top, Middle start	9	2.944	1.840	.613
Extrapersonal, Bottom, Left start	9	4.122	1.560	.520
Extrapersonal, Bottom, Right start	9	3.978	1.853	.618
Extrapersonal, Bottom, Middle start	9	3.333	1.626	.542
Extrapersonal, Middle, Left start	9	4.222	2.213	.738
Extrapersonal, Middle, Right start	9	4.056	1.962	.654
Extrapersonal, Middle, Middle start	9	3.122	1.387	.462
Extrapersonal, Top, Left start	9	3.856	1.762	.587
Extrapersonal, Top, Right start	9	4.356	1.761	.587
Extrapersonal, Top, Middle start	9	2.856	.816	.272

Summary Table of ANOVA

Source	df	F	p
Space	1, 8	n.s.	
Location	2, 16	n.s.	
Cursor	2, 16	17.3	0.0001
S x C	2, 16	n.s.	
S x L	2, 16	n.s.	
L x C	4,32	n.s.	
S x L x C	4,32	n.s.	

Table 19

Patients with Neglect's bisection reaction times across space, location and cursor

	Count	Mean	Std. Dev.	Std. Error
Peripersonal, Bottom, Left start	7	5.600	2.644	.999
Peripersonal, Bottom, Right start	7	6.168	3.492	1.320
Peripersonal, Bottom, Middle start	7	5.668	4.193	1.585
Peripersonal, Middle, Left start	7	5.154	1.796	.679
Peripersonal, Middle, Right start	7	5.886	2.631	.995
Peripersonal, Middle, Middle start	7	5.311	3.168	1.198
Peripersonal, Top, Left start	7	5.200	2.049	.775
Peripersonal, Top, Right start	7	5.589	2.124	.803
Peripersonal, Top, Middle start	7	5.418	2.581	.976
Extrapersonal, Bottom, Left start	7	5.521	2.023	.765
Extrapersonal, Bottom, Right start	7	5.639	2.359	.892
Extrapersonal, Bottom, Middle start	7	4.069	1.601	.605
Extrapersonal, Middle, Left start	7	5.832	2.472	.934
Extrapersonal, Middle, Right start	7	5.943	2.020	.763
Extrapersonal, Middle, Middle start	7	4.468	1.983	.750
Extrapersonal, Top, Left start	7	5.768	1.470	.556
Extrapersonal, Top, Right start	7	6.336	2.593	.980
Extrapersonal, Top, Middle start	7	4.704	2.481	.938

Summary Table of ANOVA

Source	df	F	p
Space	1, 8	n.s.	
Location	2, 16	n.s.	
Cursor	2, 16	4.2	0.04
S x C	2, 16	4.7	0.03
S x L	2, 16	n.s.	
L x C	4,32	n.s.	
S x L x C	4,32	n.s.	

Table 20

Patients with Neglect's bisection reaction times across space, location and cursor

	Count	Mean	Std. Dev.	Std. Error
Peripesonal, Bottom, Left start	7	6.814	3.553	1.343
Peripesonal, Bottom, Right start	7	6.481	3.179	1.202
Peripesonal, Bottom, Middle start	7	6.814	4.392	1.660
Peripesonal, Middle, Left start	7	10.051	9.592	3.625
Peripesonal, Middle, Right start	7	5.612	1.732	.655
Peripesonal, Middle, Middle start	7	6.677	3.799	1.436
Peripesonal, Top, Left start	7	9.194	6.882	2.601
Peripesonal, Top, Right start	7	6.124	2.206	.834
Peripesonal, Top, Middle start	7	5.871	3.523	1.332
Extrapresonal, Bottom, Left start	7	9.774	9.100	3.439
Extrapresonal, Bottom, Right start	7	6.879	3.158	1.194
Extrapresonal, Bottom, Middle start	7	6.183	3.527	1.333
Extrapresonal, Middle, Left start	7	12.321	11.903	4.499
Extrapresonal, Middle, Right start	7	7.295	3.784	1.430
Extrapresonal, Middle, Middle start	7	9.002	6.148	2.324
Extrapresonal, Top, Left start	7	10.983	10.410	3.934
Extrapresonal, Top, Right start	7	6.607	3.418	1.292
Extrapresonal, Top, Middle start	7	6.945	3.460	1.308

Summary Table of ANOVA

Source	**df**	**F**	**p**
Space	1, 8	n.s.	
Location	2, 16	3.7	0.05
Cursor	2, 16	n.s.	
S x C	2, 16	n.s.	
S x L	2, 16	n.s.	
L x C	4, 32	n.s.	
S x L x C	4, 32	n.s.	

Vertical Lines

Table 21

Young Normal Individual bisection biases across space, location and cursor

	Count	Mean	Std. Dev.	Std. Error
Peripersonal, Left, Bottom start	50	4.244	1.860	.263
Peripersonal, Left, Top start	50	4.182	1.736	.246
Peripersonal, Left, Middle start	50	3.410	1.525	.216
Peripersonal, Middle, Bottom start	50	4.192	1.629	.230
Peripersonal, Middle, Top start	50	4.100	1.593	.225
Peripersonal, Middle, Middle start	50	3.522	1.680	.238
Peripersonal, Right, Bottom start	50	4.062	1.739	.246
Peripersonal, Right, Top start	50	4.054	1.714	.242
Peripersonal, Right, Middle start	50	3.488	1.730	.245
Extrapersonal, Left, Bottom start	50	4.324	1.377	.195
Extrapersonal, Left, Top start	50	4.634	1.837	.260
Extrapersonal, Left, Middle start	50	3.732	1.510	.213
Extrapersonal, Middle, Bottom start	50	4.574	1.821	.258
Extrapersonal, Middle, Top start	50	4.546	1.711	.242
Extrapersonal, Middle, Middle start	50	3.712	1.543	.218
Extrapersonal, Right, Bottom start	50	4.560	1.643	.232
Extrapersonal, Right, Top start	50	4.688	1.680	.238
Extrapersonal, Right, Middle start	50	3.820	1.866	.264

Summary Table of ANOVA

Source	df	F	p
Space	1, 49	6.0	0.02
Location	2, 98	n.s.	
Cursor	2, 98	56.7	0.0001
S x C	2, 98	n.s.	
S x L	2, 98	n.s.	
L x C	2, 98	n.s.	
S x L x C	2, 98	n.s.	

Table 22

Older Normal Individual bisection biases across space, location and cursor

	Count	Mean	Std. Dev.	Std. Error
Peripersonal, Left, Bottom start	9	3.700	1.950	.650
Peripersonal, Left, Top start	9	3.767	2.068	.689
Peripersonal, Left, Middle start	9	3.367	2.182	.727
Peripersonal, Middle, Bottom start	9	3.689	1.656	.552
Peripersonal, Middle, Top start	9	4.467	2.432	.811
Peripersonal, Middle, Middle start	9	3.078	1.657	.552
Peripersonal, Right, Bottom start	9	3.678	1.570	.523
Peripersonal, Right, Top start	9	3.822	1.802	.601
Peripersonal, Right, Middle start	9	3.011	1.961	.654
Extrapersonal, Left, Bottom start	9	4.522	1.973	.658
Extrapersonal, Left, Top start	9	4.456	2.180	.727
Extrapersonal, Left, Middle start	9	3.067	1.322	.441
Extrapersonal, Middle, Bottom start	9	3.944	1.594	.531
Extrapersonal, Middle, Top start	9	3.222	1.231	.410
Extrapersonal, Middle, Middle start	9	2.944	1.326	.442
Extrapersonal, Right, Bottom start	9	3.911	1.682	.561
Extrapersonal, Right, Top start	9	4.111	1.484	.495
Extrapersonal, Right, Middle start	9	2.900	1.433	.478

Summary Table of ANOVA

Source	df	F	p
Space	1, 8	n.s.	
Location	2, 16	n.s.	
Cursor	2, 16	25.8	0.0001
S x C	2, 16	n.s.	
S x L	2, 16	n.s.	
L x C	4,32	3.5	0.05
S x L x C	4,32	n.s.	

Table 23

Patients with Non-Neglect's bisection reaction times across space, location and cursor

	Count	Mean	Std. Dev.	Std. Error
Peripersonal, Left, Bottom start	7	5.098	2.030	.767
Peripersonal, Left, Top start	7	5.460	2.572	.972
Peripersonal, Left, Middle start	7	5.789	3.568	1.349
Peripersonal, Middle, Bottom start	7	6.774	2.463	.931
Peripersonal, Middle, Top start	7	5.679	2.221	.839
Peripersonal, Middle, Middle start	7	4.834	1.827	.691
Peripersonal, Right, Bottom start	7	5.774	2.754	1.041
Peripersonal, Right, Top start	7	5.883	1.793	.678
Peripersonal, Right, Middle start	7	4.664	2.278	.861
Extrapersonal, Left, Bottom start	7	6.293	2.518	.952
Extrapersonal, Left, Top start	7	5.533	1.841	.696
Extrapersonal, Left, Middle start	7	4.693	2.131	.806
Extrapersonal, Middle, Bottom start	7	5.868	2.003	.757
Extrapersonal, Middle, Top start	7	6.036	2.393	.904
Extrapersonal, Middle, Middle start	7	4.700	1.738	.657
Extrapersonal, Right, Bottom start	7	6.143	2.290	.865
Extrapersonal, Right, Top start	7	6.014	2.141	.809
Extrapersonal, Right, Middle start	7	4.943	2.496	.943

Summary Table of ANOVA

Source	df	F	p
Space	1, 16	n.s.	
Location	2, 16	n.s.	
Cursor	2, 16	4.9	0.02
S x C	2, 16	n.s.	
S x L	2, 16	n.s.	
L x C	4, 32	n.s.	
S x L x C	4, 32	n.s.	

Table 24

Patients with Neglect's bisection reaction times across space, location and cursor

	Count	Mean	Std. Dev.	Std. Error
Peripersonal, Left, Bottom start	7	7.214	3.563	1.347
Peripersonal, Left, Top start	7	8.494	4.385	1.657
Peripersonal, Left, Middle start	7	5.984	2.937	1.110
Peripersonal, Middle, Bottom start	7	6.064	2.452	.927
Peripersonal, Middle, Top start	7	6.356	2.407	.910
Peripersonal, Middle, Middle start	7	5.644	2.284	.863
Peripersonal, Right, Bottom start	7	5.663	1.436	.543
Peripersonal, Right, Top start	7	6.860	1.936	.732
Peripersonal, Right, Middle start	7	5.594	2.457	.929
Extrapersonal, Left, Bottom start	7	9.163	5.346	2.021
Extrapersonal, Left, Top start	7	10.585	6.850	2.589
Extrapersonal, Left, Middle start	7	7.944	4.602	1.739
Extrapersonal, Middle, Bottom start	7	6.906	3.171	1.199
Extrapersonal, Middle, Top start	7	7.433	3.101	1.172
Extrapersonal, Middle, Middle start	7	6.205	2.854	1.079
Extrapersonal, Right, Bottom start	7	6.905	3.189	1.205
Extrapersonal, Right, Top start	7	6.588	2.876	1.087
Extrapersonal, Right, Middle start	7	5.669	2.937	1.110

Summary Table of ANOVA

Source	**df**	**F**	**p**
Space	1, 8	n.s.	
Location	2, 16	5.6	0.02
Cursor	2, 16	6.9	0.01
S x C	2, 16	n.s.	
S x L	2, 16	n.s.	
L x C	4, 32	n.s.	
S x L x C	4, 32	n.s.	

C-Older Normals: Visual Orienting Data

1-Simple Detection

	Count	Mean	Std. Dev.	Std. Error
Peripersonal, Ipsilateral, Valid	9	500.167	57.902	19.301
Peripersonal, Ipsilateral, Invalid	9	505.611	51.917	17.306
Peripersonal, Ipsilateral, Neutral	9	500.833	75.148	25.049
Peripersonal, Contralateral, Valid	9	517.111	75.270	25.090
Peripersonal, Contralateral, Invalid	9	503.222	74.544	24.848
Peripersonal, Contralateral, Neutral	9	511.222	74.592	24.864
Extrapersonal, Ipsilateral, Valid	9	522.500	53.089	17.696
Extrapersonal, Ipsilateral, Invalid	9	524.944	76.098	25.366
Extrapersonal, Ipsilateral, Neutral	9	533.944	72.727	24.242
Extrapersonal, Contralateral, Valid	9	534.833	86.267	28.756
Extrapersonal, Contralateral, Invalid	9	532.889	78.408	26.136
Extrapersonal, Contralateral, Neutral	9	518.167	76.672	25.557

2-Quadrant Analysis

	Count	Mean	Std. Dev.	Std. Error
Peripersonal, Lower left	9	551.889	91.886	30.629
Peripersonal, Lower right	9	531.556	55.651	18.550
Peripersonal, Upper left	9	514.778	77.900	25.967
Peripersonal, Upper right	9	519.000	50.215	16.738
Extrapersonal, Lower left	9	542.111	79.537	26.512
Extrapersonal, Lower right	9	520.778	54.683	18.228
Extrapersonal, Upper left	9	538.778	61.335	20.445
Extrapersonal, Upper right	9	556.222	58.433	19.478

3-Within and Between field Analysis

	Count	Mean	Std. Dev.	Std. Error
Right, Valid	9	511.333	51.571	17.190
Right, Invalid-LR	9	526.944	68.630	22.877
Right, Invalid-UD	9	514.333	61.297	20.432
Right, Invalid-OP	9	510.639	54.318	18.106
Right, Neutral	9	531.889	44.567	14.856
Left, Valid	9	503.722	47.482	15.827
Left, Invalid-LR	9	532.444	86.937	28.979
Left, Invalid-UD	9	523.028	74.287	24.762
Left, Invalid-OP	9	532.694	81.074	27.025
Left, Neutral	9	536.889	66.288	22.096

D-Patients with Neglect: Individual Data

Line Bisection

Horizontal Lines

Table 1

Displays the bisection judgments of individual patients to line position across the two Viewing distances

	Peripersonal			Extrapersonal		
Patients	Bottom	Middle	Top	Bottom	Middle	Top
A.C.	20.6	24.5	8.6	21.4	28.8	30.4
B.M.	10.1	1.6	5.0	4.6	6.6	10.2
I.P.	8.1	7.5	4.6	7.0	-10.8	7.9
M.H.	-1.6	-4.9	-10.2	0.2	9.7	7.6
M.L.	16.6	19.6	16.8	-1.6	-4.9	-10.3
P.T.	11.0	9.8	6.2	1.0	-2.6	1.7
V.L.	11.6	11.2	13.2	19.8	18.8	18.8

Table 2

Displays the bisection judgments of individual patients to cursor start across the two Viewing distances

	Peripersonal			Extrapersonal		
Patients	Left	Middle	Right	Left	Middle	Right
A.C.	-12.8	30.1	36.5	21.4	29.2	30.1
B.M.	12.0	7.4	-2.4	6.8	6.1	8.4
I.P.	1.8	8.8	9.6	-5.0	12.0	-2.8
M.H.	-9.8	5.2	-12.5	-8.0	17.2	8.4
M.L.	-10.2	26.0	37.3	-9.8	5.2	-12.5
P.T.	-2.5	15.0	14.6	5.8	12.0	-17.8
V.L.	4.0	12.6	19.5	19.6	19.6	18.2

Vertical Lines

Table 3

Displays the bisection judgments of individual patients to line position across the two Viewing distances

	Peripersonal			Extrapersonal		
Patients	Left	Middle	Right	Left	Middle	Right
A.C.	1.8	-6.2	0.0	-8.8	-10.0	-5.4
B.M.	-4.1	-5.8	-4.2	2.8	4.3	4.3
I.P.	-11.0	-9.6	-9.0	-0.4	1.4	0.0
M.H.	-9.8	-6.2	-6.2	2.4	-1.3	1.3
M.L.	11.6	14.4	9.0	23.2	13.6	12.2
P.T.	6.7	11.2	22.4	1.4	-2.8	5.4
V.L.	-11.0	-6.0	-5.9	-10.1	-6.0	-5.8

Table 4

Displays the bisection judgments of individual patients to cursor start across the two Viewing distances

	Peripersonal			Extrapersonal		
Patients	Bottom	Middle	Top	Bottom	Middle	Top
A.C	-19.8	1.0	14.3	-8.6	-8.4	-7.6
B.M.	6.0	-10.5	-9.8	2.1	4.0	5.1
I.P.	-12.8	-7.6	-9.4	2.8	2.0	-3.9
M.H.	-11.6	-4.3	-6.2	1.7	-1.0	1.6
M.L.	-4.8	12.5	27.4	10.0	15.0	24.2
P.T.	23.6	27.8	-11.2	12.4	3.4	-11.6
V.L.	0.0	-10.1	-12.0	0.0	-10.1	-12.0

Visual Orienting

Individual Patient Data

Patients with Neglect

Table 1

Mean responses to targets under cued conditions in ipsilesional and contralesional halves of space at the two Viewing distances

	Peri				Extra			
	Ipsi		Contra		Ipsi		Contra	
	Valid	Invali	Valid	Invali	Valid	Invali	Valid	Invali
A.C.	679	686	1556	1671	642	743	1607	1756
B.M.	562	577	690	1112	531	569	803	1179
I.P.	788	839	903	1163	766	829	872	1213
M.H.	750	806	1087	1151	826	845	1245	1573
M.L.	519	524	1039	1343	527	557	1011	1217
P.T.	439	467	506	622	476	475	491	619
V.L.	567	646	648	708	527	631	602	723

Table 2

Probability of response in percent to targets under cued conditions in ipsilesional and contralesional halves of space at the two Viewing distances

	Peri				Extra			
	Ipsi		Contra		Ipsi		Contra	
	Valid	Invali	Valid	Invali	Valid	Invali	Valid	Invali
A.C.	92	100	81	62	100	96	87	79
B.M.	100	100	100	100	97	100	98	100
I.P.	100	100	100	100	100	100	98	92
M.H.	100	100	87	58	89	92	89	52
M.L.	100	100	43	42	98	100	15	29
P.T.	100	100	100	100	100	100	100	100
V.L.	98	100	98	100	100	92	98	100

Table 3

Breakdown of false alarms (# of responses/total number of catch trials) to cued targets in ipsilesional and contralesional halves of space across the Viewing distance

	Peri				Extra			
	Ipsi		Contra		Ipsi		Contra	
	Valid	Invali	Valid	Invali	Valid	Invali	Valid	Invalid
A.C.	0	0	0	0	0	0	0	0
B.M.	0	0	0	0	0	2/4	0	0
I.P.	0	0	0	0	0	0	0	0
M.H.	0	2/4	0	2/4	0	0	0	4/4
M.L.	0	2/4	0	2/4	0	0	0	0
P.T.	0	0	0	0	1/4	1/4	2/4	0
V.L.	0	0	0	0	0	0	0	0

Patients without Neglect

Table 4

Mean responses to targets under cued conditions in ipsilesional and contralesional halves of space at the two Viewing distances

	Peri				Extra			
	Ipsi		Contra		Ipsi		Contra	
	Valid	Invali	Valid	Invali	Valid	Invali	Valid	Invali
S.F.	416	420	435	454	506	494	429	476
I.D.	437	476	479	516	494	476	504	548
M.W.	460	436	616	580	600	612	659	779
J.J.	426	418	436	453	510	482	512	476
K.M.	579	587	690	965	550	547	787	1046
A.O.	499	503	546	634	543	614	675	709

Table 5

Probability of response in percent to targets under cued conditions in ipsilesional and contralesional halves of space at the two Viewing distances

	Peri				Extra			
	Ipsi		Contra		Ipsi		Contra	
	Valid	Invali	Valid	Invali	Valid	Invali	Valid	Invali
S.F.	100	100	100	100	100	100	100	100
I.D.	100	100	100	100	100	100	100	100
M.W.	100	100	100	100	100	100	100	100
J.J.	100	100	100	100	100	100	100	100
K.M.	100	100	100	100	100	100	100	100
A.O.	100	100	100	100	100	100	100	100

Table 6

Breakdown of false alarms (# of responses/total number of catch trials) to cued targets in ipsilesional and contralesional halves of space across the Viewing distance.

	Peri				Extra			
	Ipsi		Contra		Ipsi		Contra	
	Valid	Invali	Valid	Invali	Valid	Invali	Valid	Invali
S.F.	0	0	0	0	0	0	0	0
I.D.	1/4	0	2/4	0	1/4	0	0	0
M.W.	0	0	0	0	0	0	0	0
J.J.	0	0	0	0	0	0	0	0
K.M.	0	0	0	0	1/4	2/4	0	0
A.O.	0	0	0	0	0	0	0	0

E)-Sketches of Right-Hemisphere Lesions

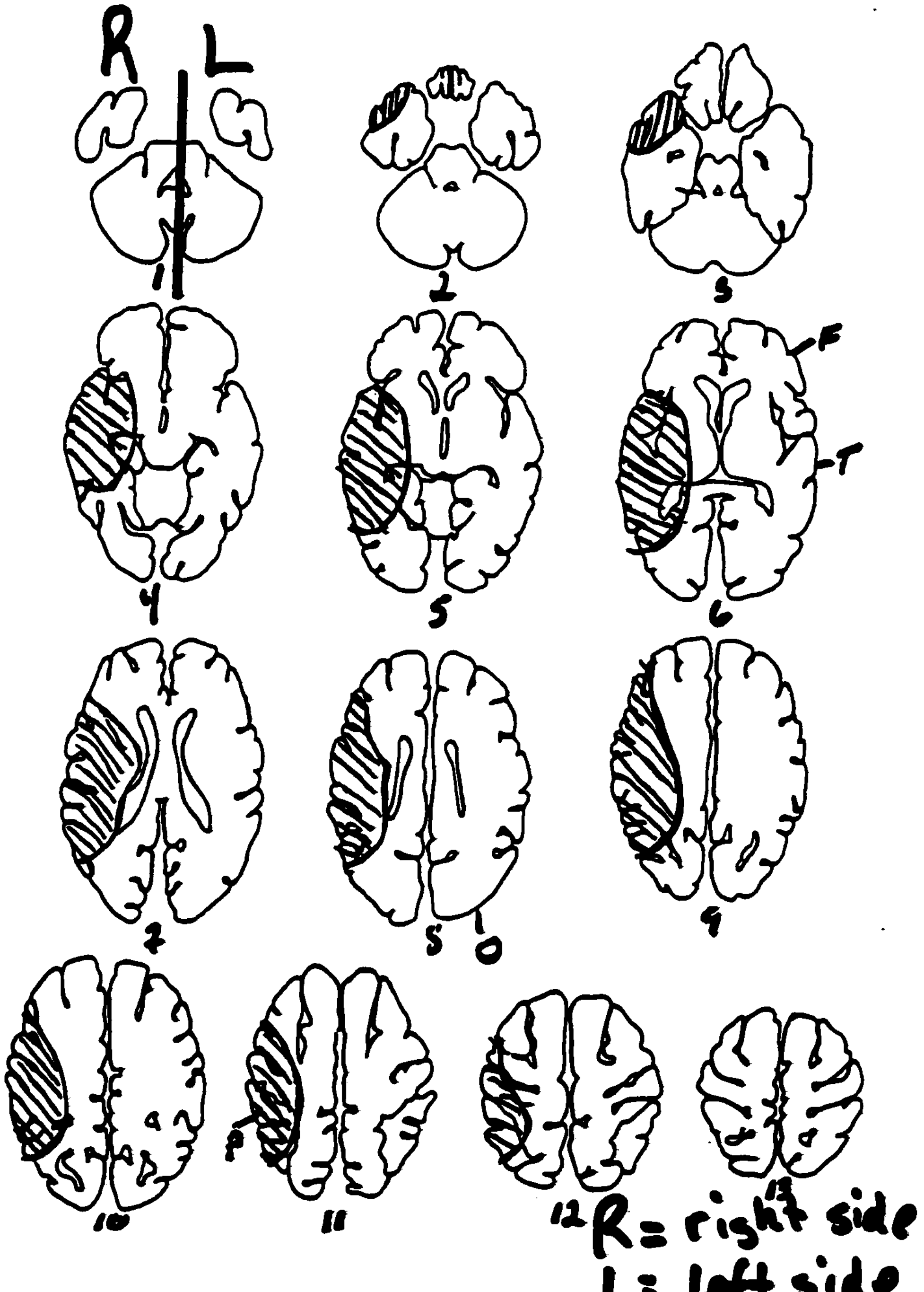
Provided Below are hand sketches of the areas affected by the lesions. These are only approximation of the CT Scan readings, as the templates used to do the sketches and that of the CT scan could not be matched perfectly. Thirteen levels are represented. The first (#1) level is the ventral most section and the last (#13) is the most dorsal section. The labels F, T, P, and O refer to the approximate regions of Frontal, Temporal, Occipital and Parietal lobes. As such, these sketches are intended to complement Table 1. Table 1 has been reproduced below for that purpose. It should be noted that sketches for patients V.L. and K.M. were inadvertently lost at the time of the preparation of this monograph and could not be replaced.

Table 1
Patients with Right-Hemisphere lesion: Sample Neurological Characteristics. See page xiv for list of abbreviations.

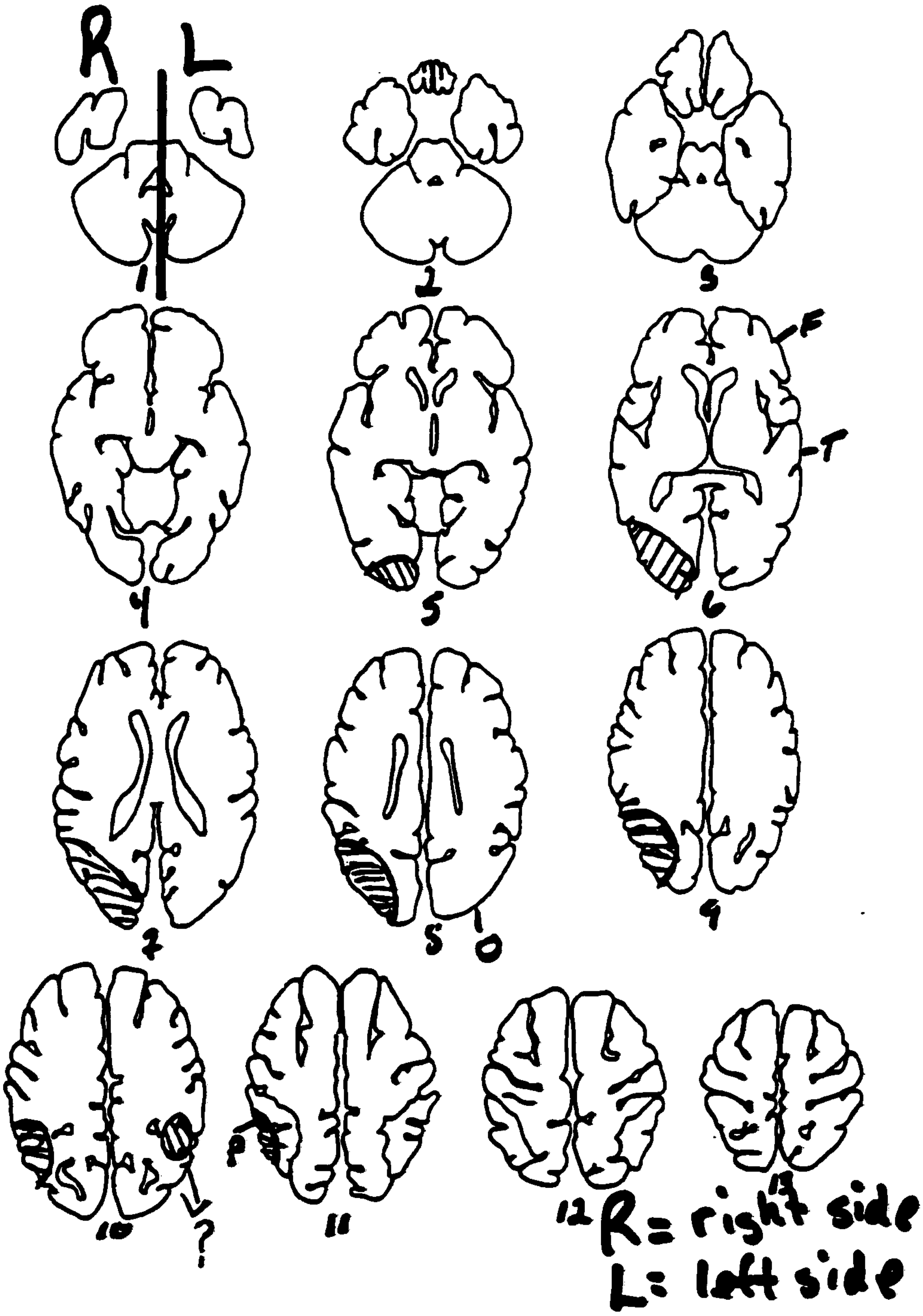
Patients	Age/Sex	Lesion Loc	VFD	Hemiplegia	Time post-onset*
A.C.	61/m	F,T,P,wm	Yes	Yes	3
B.M.	60/m	na	na	Yes	3
I.P.	82,f	P,O,wm	Yes	No	1
M.H.	75/f	negative	Yes	Yes	14
M.L.	55/f	F,P,wm	Yes	Yes	6
P.T.	68/f	F,T,P,wm	No	Yes	5
V.L.	79/m	P,wm	Yes	No	4
S.F.	51/m	F,T	No	Yes	3
I.D.	62/m	th,c, wm	No	Yes	4
M.W.	62/f	na	na	Yes	5
J.J.	57/m	na	na	No	6
K.M.	61/m	O,wm	Yes	No	12
A.O.	65/f	na	na	Yes	3

* in months

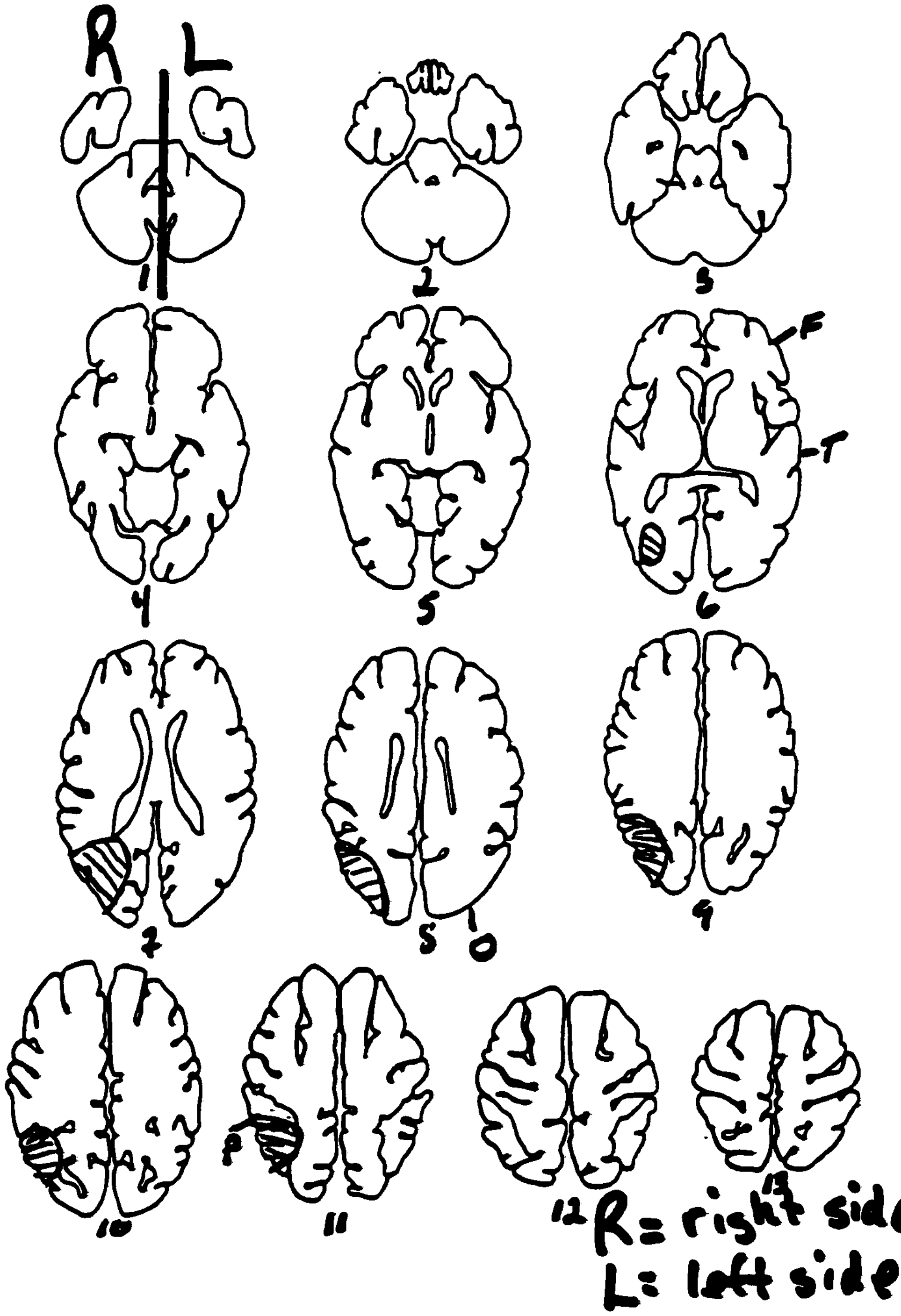
Patient A.C.



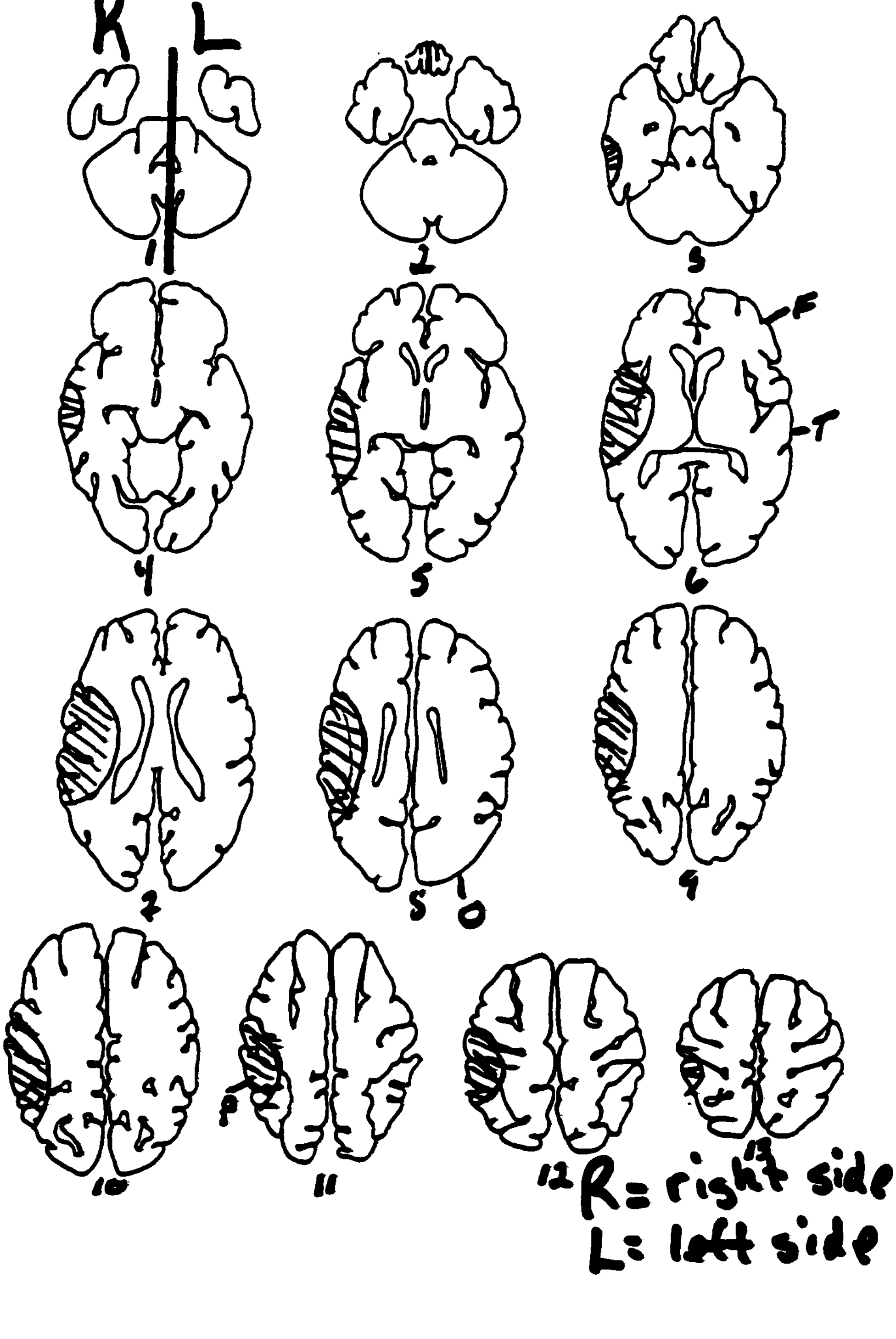
Patient I.P.



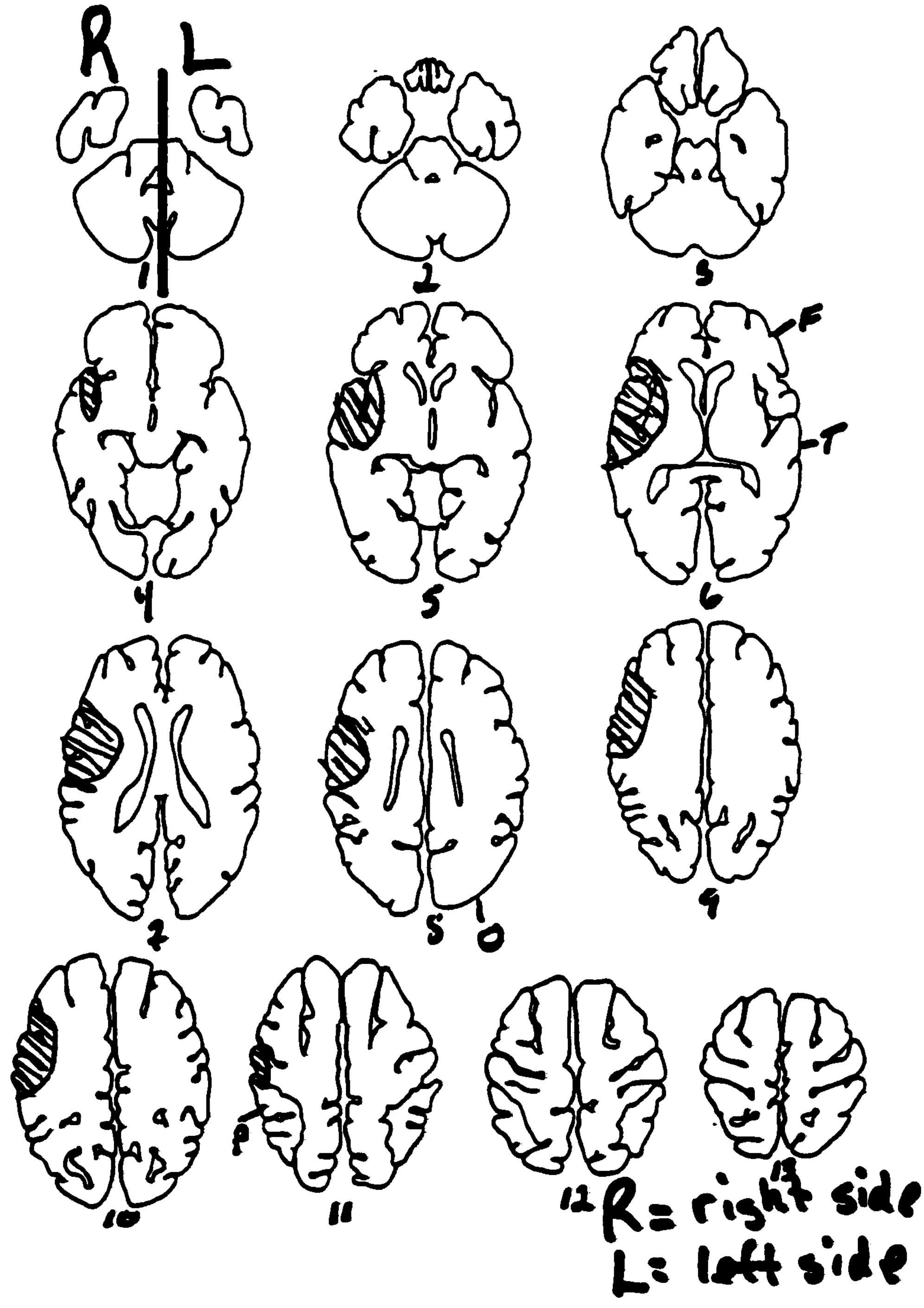
Patient M.L.



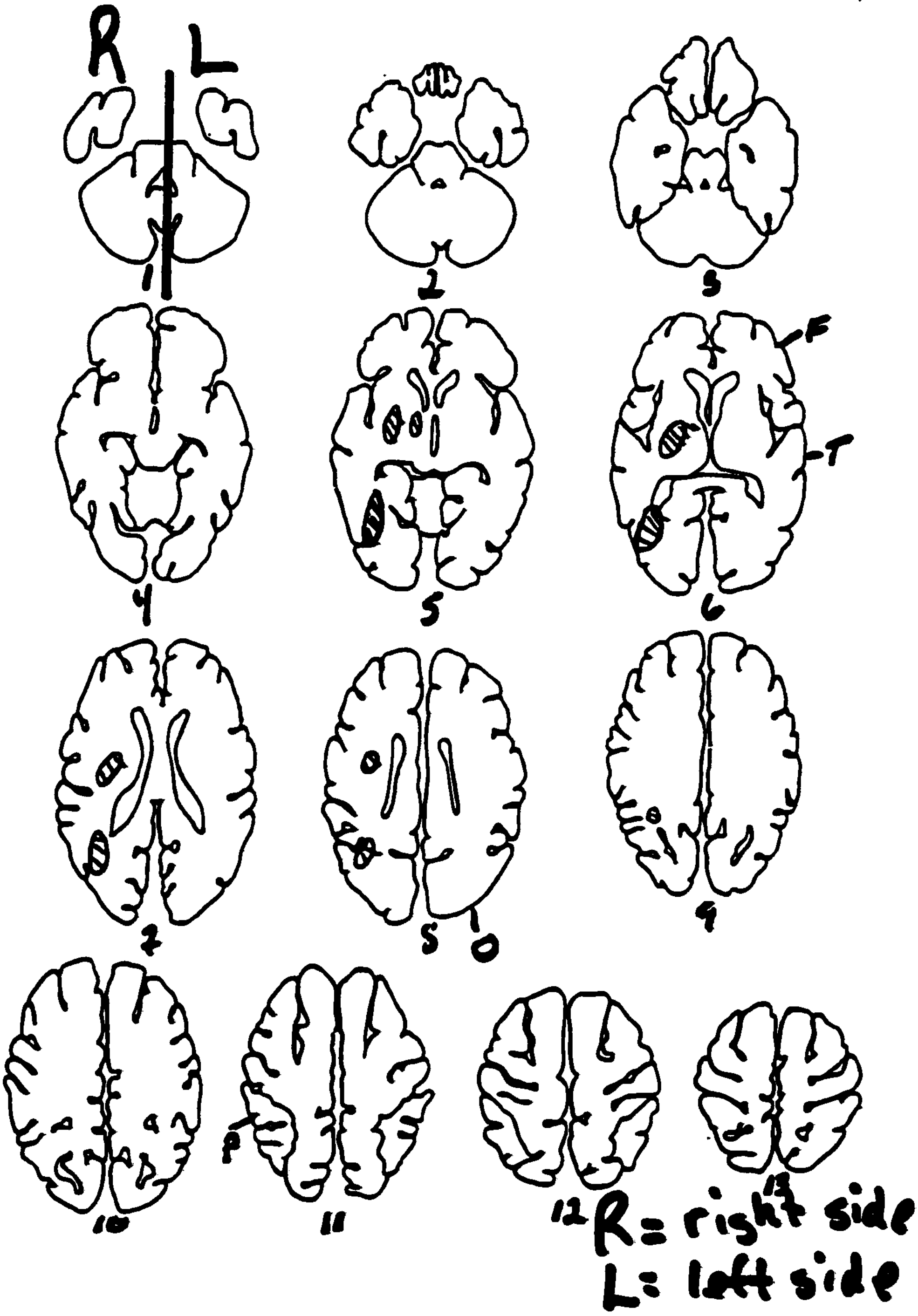
Patient P.T.



Patient S.F.



Patient I.D.



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