Visual Neglect and Mental Representations

Emma Brase

Kansas State University

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Visual neglect is a cognitive condition that is the result of posterior parietal brain damage due to stroke, which causes lack of perception on the side of space contralateral, or opposite side, to the lesion. For example, in an extreme case, a patient with neglect might fail to notice food they have not eaten on the contralesional side of their plate, or accidentally strike contralesional furniture. Most daily functions of individuals with visual neglect are inhibited by lack of complete perception of the world. It is more common for neglect to be found affecting the right hemisphere, causing perception deficits in the left visual field, but there are some noted cases of neglect in the left hemisphere, with deficits in the right visual field, though it does not occur frequently enough to conduct further research on. Neglect related symptoms can range widely in diversity and intensity, making it difficult to pinpoint the exact location associated with the condition, and for consistent ways of treating and addressing patients' specific behaviors of neglect (Adair & Barrett, 2008). Visual neglect is not a type of blindness in the affected visual side (hemianoppia), the difference being that those who are blind will actively move their eyes and head to search for contralateral stimuli, whereas an individual with neglect, hemianopic or not, will fail to do so (Farah, 1997). Visual neglect is also commonly referred to as hemispatial neglect (HSN), unilateral neglect, or visuospatial neglect.

Further, an interesting subcategory of neglect is representational, or imaginal neglect. This type of neglect affects an individual's mental representation of space. Lack of perception on the left side of space can also extend to mental imagery used when performing tasks dealing with numbers, time, spatial awareness, and memory (Bonato, Saj, & Vuilleumier, 2016). This review paper will cover literature that discusses the cause of visual neglect and assessment of its neuropsychological effects, as well as the specific disorders of input it causes.

To begin, patients with visual neglect may unconsciously perceive stimuli, but deny any sort of awareness of said stimuli (Farah, 1197). In her academic review, Farah details three accounts that describe the relationship between neural systems of perception and conscious awareness. Unconscious perception can be related to a disconnection between perceptual systems and the conscious awareness system (CAS). This is explained by Schacter, McAndrews, and Moscovitch's dissociated interactions and conscious experience (DICE) model (1988), which proposes that some CAS brain systems are separate from other brain systems that deal with conscious experiences such as perception, cognition, and action (Farah, 1997). Alternatively, Kinsbourne's integrated field theory (1988) states that conscious awareness is a state in which all brain systems that deal with perception, recollection, current actions, and action plans work together. Damage to or disconnect of the perceptual system disrupts functional brain activity (Farah, 1997). A related theory by Crick and Koch (1990) believe that visual awareness is due to the binding together of the different properties of a stimulus into one mental concept, and that synchronization across visual areas allows for conscious perception of multiple stimuli. Another account done in previous research by Farah and associates found that the processing of stimuli can range in quality of visual perception, and this can affect the degree of the consciousness experience of a stimulus (p. 205). The three main theories presented of certain brain systems, integration of brain activity, and quality of representation and their role in explaining the nature of consciousness are not mutually exclusive, as more than one of these approaches could occur at once.

The nature of consciousness specifically in the case of visual neglect can be closest explained by the account of quality of representation, with neglect resulting in low-quality representations, as well as Kinsbourne's integration account, with both theories addressing damage to perceptual systems found in neglect. Since subjects with neglect are not aware of stimuli on their left side, many subjects tend to deem tasks that ask about stimuli on the left visual side, or about comparing paired stimuli with varying left features, as silly or absurd (as cited in Marshall and Halligan 1988; Volpe, LeDoux, and Gazzaniga 1979) (p. 224).

The purpose of Young's (1983) review is identifying specifically how the right hemisphere is superior on visuospatial tasks. It is generally seen that the right cerebral hemisphere contributes more towards complex and "high level" visuospatial abilities, but both hemispheres deal with relatively simple or "low level" abilities (p. 2). Marr's (1980) theory on different levels of visual representation, including intensity, spatial location of objects from an observer's viewpoint, and object centered representation, is mentioned by Young since it is more precise compared to other theories. However, Marr's theory does not explain how integrated representation of more than one object is constructed (p. 3-4).

The condition of visual neglect is closely related to the nature of how vision works. The left visual hemifield (LVF) projects stimuli to the right cerebral hemisphere, while information from the right visual hemifield (RVF) is projected to the left cerebral hemisphere (p. 5). Those affected by visual neglect are unable to process stimuli presented in the LVF, since damage commonly occurs in the right hemisphere.

Many early studies on the basic perceptual properties of vision in both healthy and neglect subjects had inconsistent results regarding the accuracy of perception of simple stimuli in the LVF and RVF. This is a result of variation in procedural factors, or of no significant measurable difference between hemisphere abilities being found. An exception was with tasks dealing with location and matching, where it was found that right hemisphere damaged patients performed worse than left hemisphere damaged and healthy control patients. This is most likely due to impairment of the right hemisphere having a larger effect on perception (p. 8-13).

In healthy subjects, tasks involving readily named verbal stimuli, such as letters and numbers, object outlines, and simple two-dimension geometric shapes were found to not elicit consistent RVF superiority. However, LVF superiority was noticed in recognition of complex shapes with many points and/or sides. In patients with cerebral lesions, recognition of very complex figures resulted in involvement of the left hemisphere in shape discrimination (Bisiach and Faglioni, 1974; Bisiach et al., 1979 as cited in Young, 1983). The accumulation of studies of healthy and neglect subjects shows that deficits in performance in perception, memory, learning, and complex spatial tasks are a result of right hemisphere damage. This suggests that the right hemisphere is responsible for these specific functions, since these deficits are less likely to occur in left hemisphere damaged patients (Young, 1983).

As explained in Adair and Barrett’s (2008) academic review, visual neglect can be assessed by using cancellation tasks, in which patients are asked to detect and indicate targets from an array of either just targets, or from an array with targets placed among distractor objects. Neglect can also be assessed through tasks such as line bisection tests, which involve marking through the center of a series of horizontal lines, copying simple figures, and drawing figures from memory. Indicators of spatial neglect include failure to cancel contralesional targets, bisecting longer lines further to the right of their midpoints, and errors in the contralesional aspects of drawings. Neglect patients will also tend to begin cancellation tasks on the right side of the array, in contrast to healthy right-handed subjects who tend to begin on the left side of the array. Another indicator of neglect is the misreading of words. The leftward characters of words will often be distorted or partially omitted, for example, the word “reaction” will be read by neglect patients as “action” or “traction.” Leftward omission can even extend to whole paragraphs, with words from the left side of the paragraph being ignored.

Visual neglect has been found to alter visual perception in two ways: egocentric (viewer centered reference frame) neglect, and allocentric (object centered reference frame) neglect. The frame of reference of neglect is evaluated using Ota et al.’s modified cancellation task. Patients with egocentric neglect can identify complete figures and cancel incomplete figures only on the contralesional side of the array, while patients with allocentric neglect can mark figures on both sides of the array, but will misidentify figures lacking left-sided segments as complete figures.

Adair and Barrett also address representational neglect, which will be further covered in the description of other research literature. Representational neglect can be seen in performance on detection tests including assessing map orientation or drawing figures from memory versus copying the figure. When drawing from memory, details on the left side of the item may be left out, but can be drawn more completely when copying.

The introduction of Mort, et al.’s (2003) research paper notes that there is a common consensus among neuroscientists that neglect is associated with right posterior parietal lobe, specifically the area in the temporoparietal junction (TPJ). However, other locations have been found to result in neglect, resulting in dispute over the brain region that most critically causes the condition. In addition to the TPJ, neglect has also been observed following strokes affecting the right inferior frontal lobe. Inferior frontal damage does not need be required or prominent enough to produce neglect, and it is often accompanied by posterior parietal brain damage. Neglect has also been observed in subcortical regions like the thalamus and basal ganglia. These locations are sustained by the middle cerebral artery (MCA), and neglect has also been found to affect regions of the posterior cerebral artery (PCA). However, given the large range of types of damage in patients with neglect, there is no one specific lesion location that can be credited with causing visual neglect. Finding a common affected region among neglect patients would allow the specification of core symptoms of neglect.

In the study conducted by Mort et al., a total of 35 patients, 24 with lesions in right MCA locations and 11 with lesions in the region of the right PCA, had the extent and location of their lesions mapped with MRI into a digital brain image. Spatial normalization was used to make accurate comparisons between neglect and non-neglect patients' lesions, since human brains differ in size and shape from person to person. Persistent cases of neglect are correlated with large lesions, and multiple cognitive functions must be impaired for neglect to be apparent. Mapping of the patients' lesions found that the angular gyrus on the lateral surface of the inferior parietal lobule in the MCA region was the most critical brain region associated with neglect. The specific critical area of neglect was the parahippocampal region, which is important in the transmission of information, including spatial navigation and memory, between the parietal cortex and hippocampus. PCA neglect involves the parahippocampal region, but not the parietal cortex, whereas MCA neglect involves the parietal cortex, but not the parahippocampal region. It is not yet clear what other features distinguish the two types of neglect. Effects of parahippocampal damage could potentially be due to loss of function in the parietal cortex, rather than sole impairment of the parahippocampal region.

Bisiach and Luzzatti's (1978) study focused on the failure by two patients with neglect to describe contralesional scene of the Piazza del Duomo in Milan at each end of the piazza from memory that had been familiar pre-stroke. From both perspectives of the piazza, central and right-sided items were fully described, but only a few left-sided items were less enthusiastically mentioned, almost with annoyance. This study gave an example of how the symptoms of visual neglect also extend to mental images in the form of representational neglect. Bisiach and Luzzatti theorized that mental representation of the environment and visual mental images are possibly split between the left and right hemispheres.

As proposed in Zorzi, Priftis, & Umiltà's (2002) study, patients with hemispatial neglect experience spatial deficit for left-side stimuli in both bisection of physical lines and mental number lines. The study was conducted using four right-brain-damaged patients with persistent left neglect, four right-brain-damaged patients without spatial neglect, and four healthy control subjects. All subjects were tested for and excelled in their numerical and arithmetic skills, and had near-perfect scores in subtraction and number comparison. However, when asked to state the midpoint of the interval of two numbers (ranging in interval size) without making calculations, participants with neglect made a significant amount of errors that were affected by the size of the interval. Errors included left-shifted midpoint answers in short lines and right-shifted in longer lines. Results also showed that reverse presentation of intervals (ex. 9-1) produced the same pattern, showing that mental number lines are widely perceived in a left-to-right manner.

Oliveri, Koch, Salerno, Torriero, Lo Gerfo, and Caltagirone (2009) conducted research that studied whether neural processing in the right posterior parietal cortex (PPC) is critical for spatial-temporal functions and the role of the PPC in the processing of spatial bisections of time intervals. In this study, four total experiments were conducted using time reproduction and line bisection tasks. Each experiment had different patient conditions, the first using repetitive transcranial magnetic stimulation (rTMS) trains to induce inhibition of the PPC in healthy subjects to study directional bias found in neglect patients. The second experiment observed the performance on tasks of right hemisphere damaged subjects with or without neglect. The third experiment was like Experiment 1, but had rTMS trains applied either during the encoding phase or retrieval phase to determine where directional bias occurs in performing the task. The fourth experiment explored the effects on the visual cortex of healthy subjects when rTMS trains are applied during reproduction and bisection of physical line segments.

The findings of these experiments show that directional bias and underestimation in time bisection tasks is associated with right hemisphere damaged subjects with spatial neglect, as well as in healthy subjects with right PPC rTMS. Underestimation was also observed when rTMS trains were applied during the retrieval phase of the bisection task, which involves accessing a mental representation of the interval to bisect it; and underestimation was also found in physical line bisection with rTMS applied. Findings also suggest that the right PPC is critical when timing tasks require the use of spatial processes. Research concluded that spatial distribution affects perception of time intervals, a process influenced by the functions of the right posterior parietal cortex.

Saj, Fuhrman, Vuilleumier, and Boroditsky (2014) studied whether representational neglect causes deficits in representing events in a mental time line, especially events falling to the left, or past, of the time line. Healthy people who read from left to right also perceive time as going from left to right, with past events toward the left and later or future events towards the right, and create a “mental time map” of events. This study had participants remember a series events that were either associated with the past or with the future. Results found that patients with neglect recalled fewer past events that fell to the left of the mental time line than healthy patients. Neglect patients also seemed to “crowd” past events to the right, mislabeling a significant number of past items as taking place in the future. From this study, it can be reasoned that accurate spatial representation is needed for correct temporal representation.

There is increasing evidence from research suggesting that spatial attention plays a role in processing time durations, but it is still unknown if processing also extends to more conceptual aspects of time, or if this ability is impaired by hemispatial neglect. In Bonato, Saj, and Vuilleumier's (2016) study, 14 right hemisphere damaged patients, with and without neglect, were presented with an image of an event from a story they were asked to memorize. Patients were asked to categorize that event as occurring before or after a reference event from the middle of the story. Neglect patients were found to have slower response times in categorizing events that occurred before the temporal reference event, than for events that occurred after the reference. However, there is an insufficient amount of definitive evidence yet to suggest strong correlation between severity of neglect and difficulty in time processing. Additionally, processing of events being altered by neglect could imply issues related to other functions such as the retrieval of episodic memory. The results of this study show that both healthy and neglect patients associate timelines in left to right manner.

Representational neglect occurs when attempting to recall familiar scenes, maps of certain regions, mentally comparing the physical characteristics of objects, mental object rotation tasks, and drawing objects from memory. This type of neglect has complicated conditions, and it is thought to result from impairment of visuospatial working memory (VSWM). VSWM has two subsystems: visual working memory stores information related to the visual aspects of objects or scenes, and spatial working memory stores pathways, spatial orientation, and mental rotation. These systems can be selectively impaired in neglect with either only one, both or neither being affected, and implies the need to differentiate between the visual and spatial properties of tasks.

In Wansard, Meulemans, and Geurten's (2016) study, four different tasks were given to evaluate representational neglect, with two visual tasks: Brooks matrix (a 4x4 matrix of 16 squares), and hand rotation tasks, and two spatial tasks: O'Clock, a task with two different times involving full and half hours (e.g., 9:30 and 11:00) having patients judge which time involved the largest angle between the clock hands with mental comparison of angle size, (occurring on both left and right sides of the clock), and the Animals task (patients mentally represent the ears of specific animals and judge their quality).

Results of the experiment showed that in unilateral neglect, patients' spatial and visual mental imagery abilities can be separated. Furthermore, in both healthy controls and neglect patients, spatial working memory was found to be a more important element of spatial mental imagery abilities, whereas quality of visual memory was found to not to affect neglect patients' ability to complete visual imagery tasks.

Research in neuroscience, and specifically the topic of visual neglect, gained traction in the late 1970s and early 1980s. Earlier research (Bisiach & Luzzatti, 1978; Young, 1983; Farah, 1997) remains relevant, since it describes the basic physical symptoms that can be observed in neglect patients, and the general region of the brain that is affected. However, with increasingly advancing technology, more current research can explore the condition much further and more accurately by using MRI machines in ways that previous technology, such as CT scans, could not. Newer technology has also allowed for researchers to narrow down the exact cerebral area that is affected by neglect (Mort et al., 2003). Bisiach and Luzzatti's 1978 study on representational neglect is commonly cited as one of the first studies to explore the specific subcategory of representational neglect. In more recent years, study on representational neglect has expanded from describing memories of familiar scenes to how other mental representations, such as mental number lines and even how mentally perceive the placing of past and future events (Zorzi et al., 2002; Oliveri et al., 2009; Saj, Vuilleumier, & Boroditsky, 2014; Bonato et al., 2016).

Many of the literature papers that provided information on the standard symptoms of neglect, or collected findings on representational neglect, were in the form of academic reviews of various studies in the field (Young, 1983; Farah, 1997; Adair & Barrett, 2008). Other literature detailed research conducted by experimenters to test hypotheses, with most testing areas of performance associated with representational neglect. Each study had variations on how their hypothesis was tested, either through use of different tasks or by introducing various conditions in each trial of the same task (Bisiach & Luzzatti, 1978; Zorzi et al., 2002; Mort et al., 2003; Oliveri et al., 2009; Saj et al., 2014; Bonato et al., 2016; Wansard et al., 2016).

While there are many characteristics of neglect that research has confirmed, such as how neglect can be assessed in regards to visual impairment experienced by an individual, and the presence of neglect also altering mental representations, there are other aspects involving the nature of neglect that are still debated or that are open to further research. This includes the exact location that causes visuospatial neglect, since many related regions of the brain have been found to cause neglect, as well as how the exact type of reference frame of neglect alters both visual and mental perception. Additionally, there is the question if past personal memories are affected after developing neglect, as well as of the exact relationship between severity of neglect and difficulty in processing the passage of time.

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