A Hierarchical Model for Evaluation and Treatment of Visual Perceptual Dysfunction in Adult Acquired Brain Injury, Part 1

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A developmental framework for evaluation and treatment of visual perceptual deficits in adults with acquired brain injury is presented. The framework is based on a review of research conducted on post-cerebrovascular accident subjects and subjects with traumatic brain injuries. Visual perceptual skill is conceptualized as a hierarchy of skill levels that interact and subserve each other. Higher level skills evolve from integration of lower level skills and are subsequently affected by disruption of lower level skills. Oculomotor control, visual field, and acuity form the foundation skills, followed by visual attention, scanning, pattern recognition, memory, and visual cognition. Brain injury can affect the integrity and interaction of each skill level and affect daily living function. Application of this framework dictates a bottom-up approach to evaluation and treatment, emphasizing identification and remediation of deficits in lower level skills to allow normal integration of higher level skill.

Visual perceptual dysfunction is a major treatment focus of occupational therapists working with adults who have acquired brain injuries, yet it is one of the least understood areas of evaluation and treatment. Little consensus exists regarding the most appropriate assessment tools to identify deficits in visual perception or the most effective treatment approach. Few definitive guides have been written to direct the clinician in evaluation and treatment.

Confusion exists, in part, because of the model chosen by therapists to guide evaluation and treatment of visual perceptual dysfunction. Traditionally, for most areas of dysfunction, the developmental framework is the predominant treatment model. This framework emphasizes acquisition and integration of basic skills as a foundation for the development of higher level function. It serves, for example, as the basis for most muscle reeducation theory and dictates that evaluation and treatment begin with the patient gaining control of the proximal musculature before working on finger dexterity. It also serves as the basis for self-care training, directing that a dressing program begin with the patient learning to put on underwear before learning to tie a necktie. In the area of visual perceptual dysfunction, however, the bottom-up developmental model has been bypassed in favor of an approach that Gianutsos and Matheson (1987) described as “top down.” This approach emphasizes the final product, visual perception. Evaluation and treatment are concentrated on this highest level of visual integration. Little emphasis is placed on the basic visual skills that form the foundation for visual perception. Use of this top-down approach has given therapists an impressive vocabulary of words to describe various visual perceptual skills, such as figure-ground, spatial analysis, and visual closure, but little understanding of the cause of dysfunction in these skills. Without knowledge of where the deficit is located in the visual hierarchy (Figure 1), it is difficult to design appropriate evaluation or treatment strategies.

The purpose of this paper is to present a developmental framework for evaluation and treatment of visual perceptual dysfunction in adults with acquired brain injuries. The framework is based on research conducted on adult subjects experiencing cerebrovascular accident (CVA) or traumatic brain injuries. An overview of a hierarchical framework for visual perceptual skill development within the central nervous system (CNS) is provided in Part 1, followed by a discussion of the effect of brain injury on the integration of each skill level in the hierarchy. Part 2 of the paper presents a rationale for selecting appropriate evaluation and treatment methods based on an understanding of visual perceptual skill development.

Hierarchy of Visual Perceptual Skill Within the Nervous System

Visual perceptual function can be conceptualized as a hierarchy of skill levels (see Figure 1). As in all hierar-
Figure 1. Hierarchy of visual perceptual skill development in the central nervous system. Drawing courtesy of Josephine C. Moore, PhD, OTR

chies, skills at the bottom form the foundation for each successive level. Higher level skills evolve from the foundation skills and depend on complete integration of lower level skills for their development. To clearly illustrate the principle of the hierarchy, it is best to begin at the top with the highest level of perceptual skill and then show how each descending level depends on and is supported by the levels below it.

The highest order visual perception skill is visual cognition. Visual cognition can be defined as the ability to mentally manipulate visual information and integrate it with other sensory information to solve problems, formulate plans, and make decisions. It is the most complex ability for visually analyzing the world. As such, it is the foundation for all academic endeavors, such as reading, writing, and solving mathematics problems, and for many vocations, such as artist, engineer, surgeon, architect, and scientist.

Below visual cognition in the hierarchy, and subservient to it, is visual memory. Mental manipulation of a visual stimulus requires the ability to retain a picture of it in the mind's eye (Ratcliff, 1987). In addition to being able to recall the image immediately, one must be able to store it in memory and retrieve it later (Sergent, 1990). For example, successful resolution of a particular visual illusion requires access to memories of the shapes of a goose and a hawk (see Figure 2). Adults and older children can easily resolve this illusion, but toddlers cannot, because they have not yet stored memories of the shapes of these birds.

The ability to store a visual image in memory and recall it later depends on pattern recognition, which involves identification of the salient features of an object (Julesz, 1981, 1985). It is composed of the abilities to identify (a) the configural and holistic aspects of an object (shape, contour, general features, etc.), and (b) the specific features of an object (details of color, shading, texture, etc.) (Cotman & McGaugh, 1980; Delis, Robertson, & Balliet, 1983; Julesz, 1985). Both aspects of recognition must occur for accurate object identification. For example, identification of three letters in a design (see Figure 3) requires attention to both the global configuration of the design and the detail of the components making up the design.

Pattern recognition is dependent on organized, thorough scanning of the visual environment. The retina must record all of the detail in a scene systematically. According to Noton and Stark (1971) and others (Chedru, Leblanc, & Lhermitte, 1973; Festinger, 1971; Tyler, 1969; Yarbus, 1967), the eyes follow a specific route as they record visual information. The route taken is known as a scanpath (Noton & Stark, 1971). The scanpath consists of a series of foveal fixations executed in an orderly, sequential fashion designed to extract information critical to pattern recognition. Viewing a scene, the eyes selectively...
fixate on elements in the design that are critical to making a correct identification while ignoring unessential elements (Yarbus, 1967). The eyes glean information by executing a series of broad sweeping cycles in which the most important details are re-examined several times to ensure identification.

The thoroughness and organization of the scanpath depends on engagement of visual attention. According to Posner and Rafal (1987), visual attention is shifted between visual stimuli by a three-step cognitive process. The first step is a disengaging operation, in which the eye ceases to focus on the object under study. This step is followed by a moving operation, in which focus is shifted to a new object, and finally by a comparing operation, in which the previous object is compared with the new one for similarities and differences. Visual attention is a specific skill that can be influenced strongly by global attention. Global attention to the environment is controlled by the arousal sequence mediated through the brainstem reticular formation (Posner & Rafal, 1987). This sequence was described by Moore (1991) as the four As: asleep, awake, alert, and attending. Progression through the sequence is under both tonic and phasic nervous system control (Posner & Rafal, 1987). Tonic control is mediated through the sleep and wake cycle dictated by the body’s circadian rhythm and follows a natural course of excitation and depression throughout the day. Phasic control is triggered by an event occurring in the environment, such as an unexpected flash of light, or by anticipation of an event, such as approaching a busy intersection. The nervous system responds to the event with increased arousal that engages selective visual attention.

Visual attention and the higher skills in the hierarchy are controlled by three primary visual skills that form the foundation for all visual functions. These foundation skills are: oculomotor control, the visual fields, and visual acuity. Oculomotor control enables efficient conjugate eye movements and ensures that the scanpath is quickly and accurately completed. The visual fields register the visual scene and ensure that the CNS receives complete visual information. Visual acuity ensures that the visual information sent to the CNS is accurate. Without these basic skills, the image generated is inadequate and prevents engagement of higher visual functions.

Skill levels within the hierarchy function as a single entity and provide a unified structure for visual perceptual ability. Each skill level depends on the integration of those before it and cannot function effectively without the assistance of its predecessors. Thus visual cognition cannot maintain its integrity without the support provided by visual memory, scanning, attention, and so on. Brain injury or disease can affect learning and adaptation through the visual channels by disrupting integration of vision at any one of the skill levels. Because of the unity of the hierarchy, skill function cannot be disrupted at one level without an adverse affect on the function of the total structure. If brain injury disrupts a lower level skill, the skills above it will also be compromised. A patient may present with what appears to be a deficit in a higher skill level when the actual deficit occurred at a much lower level in the hierarchy. For example, what appears to be a deficit in a visual cognitive skill, such as figure-ground ability, may actually be due to inaccurate pattern recognition caused by an asymmetrical scanning pattern that results from visual inattention compounded by a visual field deficit. Treatment of the higher level skill (figure-ground imperception) would not be effective unless the underlying deficits in visual attention and visual field losses were addressed first. Determining the cause of a deficit requires an understanding of how brain injury affects the integration of vision at each skill level and how the skill levels interact to produce visual perception.

**Visual Dysfunction After Brain Injury**

**Visual Field Deficits**

Visual field deficits are common after both CVA and traumatic brain injuries. Homonymous hemianopsia (loss of visual field in the corresponding right or left half of each eye) has been identified as a frequent sequela to CVA (Leigh & Zee, 1983), whereas in head injury, the predominant loss is in the superior horizontal visual fields (Uzzell, Dolinskas, & Langhitt, 1988). The presence of visual field loss has been directly associated with the disruption of a variety of daily functional activities including dressing, driving, and return to work (Groswasser, Cohen, & Blankstein, 1990; Hier, Mondlock, & Caplan, 1983; Johnson & Kelner, 1983; Warren, 1981). Academic skills such as reading can also be affected. For example, Gianutsos, Glosser, Elbaum, and Vroman (1983) documented the relationship between central field deficits and the tendency of patients with brain injuries to commit errors in reading. Other research studies have reported a relationship between the presence of visual field deficits and unilateral spatial neglect and other perceptual deficits in post-CVA patients. (Albert, 1973; Bisiach, Luzzatti, & Perani, 1979; DeRenzi, Colombo, Faglioni, & Gibertoni, 1982; Gianutsos et al., 1983; Hier et al., 1983; Rossi, Solomon, & Reding, 1990; Warren, 1981).

Whether or not various types of visual training can improve visual field deficits is controversial. Homonymous hemianopic field deficits have been regarded as unchangeable after onset, but the research of Zihl (1980, 1981), Zihl and Von Cramon (1979a, 1979b, 1982, 1985, 1986), and others (Blythe, Kennard, & Ruddock, 1987; Corbetta, Marzi, Tassinari, & Aglioti, 1990; Marshall & Halligan, 1988; Perenin & Jeannerod, 1975; Poppel, Held, & Frost, 1973; Weiskrantz, 1987; Weiskrantz, Warrington, Sanders, & Marshall, 1974) suggests that it may be possible to decrease the size of the visual field deficit through stimulation of the blind hemifield. Although some of these studies have been criticized for their poor method-
ology and control (Campion, Latto, & Smith, 1983), re-
search continues to be published supporting recovery of
some vision in the blind hemifields (Corbetta et al., 1990).
Bosley et al. (1987) reported that patients who experi-
enced spontaneous degrees of recovery from visual field
loss after CNS lesions had lesions that were located pri-
marily outside the occipital lobe, whereas those without
improvement had lesions confined primarily to the oc-
cipital lobe.

Other research has shown that training can be effec-
tive in increasing a person's ability to compensate for
the visual field deficit (Gianutsos & Matheson, 1987; Rossi et
al., 1990). Pommerenke and Markowitsch (1989) pro-
vided intensive training to subjects who had chronic field
deficits ranging in duration from 8 weeks to 4.7 years.
Extensive perimetric tests to quantify the extent of the
visual field deficits were done before and after training.
Although the size of the field deficit did not decrease as a
result of training, significant improvement was observed
in the efficiency, accuracy, and scope of the visual search
pattern executed by the subjects. Improvement occurred
even in subjects who had failed to adopt more efficient
strategies for more than 3 years after lesion. The patient's
ability to compensate for loss is affected by the contour of
the boundary between the seeing and nonseeing portion
of the field (Gianutsos & Matheson, 1987). If the bound-
ary is abrupt, spontaneous compensation is less likely to
occur than if the boundary is less severe and includes
more areas of reduced visual acuity rather than complete
loss.

**Deficits in Visual Acuity**

Whereas visual field integrity affects the quantity of visual
stimulation reaching the central nervous system, visual
acuity affects the quality of stimulation the CNS receives.
Both quantity and quality are necessary for accurate inte-
gration of visual information. Traditionally visual acuity is
measured clinically with a Snellen letter chart or similar
acuity test. These tests measure acuity by determining the
smallest high contrast detail, presented at high luminous
intensity, that a person can perceive at a given distance.
Because small amounts of refractive error in the lens of
the eye yield predictable decrements in performance on
these tests, they have served as the standard for prescrib-
ing corrective lenses (Scheiber, 1988). However, tradi-
tional measures of visual acuity do not fully describe the
visual capability of a person. Research has shown that
visual acuity varies as a function of target size, contrast,
and illumination (Owsley, Sekuler, & Seimsen, 1983;
Scheiber, 1988). Traditional tests measure acuity within a
severely restricted range of these variables that does not
necessarily correspond to the person's visual experiences
with the environment. The typical environment is com-
posed of objects of varying degrees of contrast, size, and
luminosity. Much of a person's day is spent in suboptimal
lighting conditions. A standard acuity test only measures
the ability to see a black car against a white snowbank at
midday. It does not measure the ability to see a gray car
against a concrete building under cloudy conditions or to
pick a face out of a crowd of people who are of the same
race.

Contrast sensitivity function testing offers a way to
measure a person's ability to resolve spatial properties
across a range of spatial frequencies and levels of contrast
(Scheiber, 1988). A series of sine wave gratings is present-
ted to the viewer (see Figure 4). The circular gratings vary
in spatial frequency, contrast, and orientation. Spatial fre-
cuency is represented by the width of the bars in the
grating and varies from a low frequency presentation (few
bars per grating) to a high frequency presentation (several
bars per grating). Contrast is represented by the differ-
ce in intensity between the bars and varies from high
intensity (alternating black and white bars) to low intensity
(alternating shades of gray bars). Orientation is repre-
sented by the tilt of the bars within the grating.

When the test is performed, a sine wave grating of a
certain spatial frequency is presented. The contrast of the
grating is then reduced until barely discernible. The less
contrast needed to detect the orientation of the grating,
the greater the visual acuity of the observer. On this test,
gratings are presented over a range of spatial frequencies
covering low, intermediate, and high frequency ranges. A
person's ability to resolve contrast is plotted along a con-
trast sensitivity function curve (see Figure 5). The upside-
down U shape of the curve is due to the interaction of
optical and neural properties of the eye (Scheiber, 1988).
Because neural processing is completed independently at
each frequency, performance at one frequency level can-
not be used to predict performance at another (Bodis-
Wollner, 1972; Bodis-Wollner & Diamond, 1976; Bulens,
Meerwaldt, Van Der Wildt, & Keemink, 1989; Campbell,

![Figure 4. Example of test stimuli used for the contrast sen-
sitivity function test. Reprinted by permission from Vistech
Consultants, Inc., Dayton, Ohio.](image)
Figure 5. Graph used to plot test scores on the contrast sensitivity function test. Shaded area depicts normal adult range for test performance. Reprinted with permission from Vistech Consultants, Inc., Dayton, Ohio.
A person may, for example, exhibit normal acuity at a high frequency and reduced acuity at a lower frequency. This person may experience a dulling of vision and express the feeling that his or her vision is not quite right, yet may score within normal limits on a standard acuity test. By measuring acuity over a range of frequencies, contrast sensitivity function testing provides a more comprehensive assessment of the person's visual capacity (Bodis-Wollner & Diamond, 1976; Bulens et al., 1989; Campbell, 1983; Hyvarinen, 1982; Scheiber, 1988; Sekuler, 1980; Sergent, 1984).

Research has shown that patients with cerebral lesions may exhibit deficits in contrast sensitivity (Bodis-Wollner, 1972; Bodis-Wollner & Diamond, 1976; Regan et al., 1981). Bulens et al. (1989) reported that 62% of their subjects with ischemic brain lesions affecting the posterior visual pathways (geniculocalcarine tracts) demonstrated abnormal contrast sensitivity function. Losses in the medium to high frequency ranges were associated with occipital and occipitotemporal lobe lesions. Low spatial frequency losses were associated with temporal and parietal lobe lesions, yet visual acuity as measured by a Snellen refraction test was within normal limits for each of the 16 subjects. According to Bodis-Wollner and Diamond (1976), the decrease in contrast sensitivity observed in cerebral lesions is due to the destruction of neurons in the cortical areas receiving visual information and to decreased sensitivity in the surviving neurons because of disrupted neuronal interaction. Decreases in contrast sensitivity function have also been shown to be associated with visual field deficits (Bulens et al., 1989; Hess & Pointer, 1989) and with age (Derefeldt, Lennerstrand, & Lundh, 1979; Sekuler, 1980).

**Oculomotor Dysfunction**

Disruption of oculomotor control occurs through two basic mechanisms after brain injury, disruption of cranial nerve function or disruption of central neural control. The pattern of oculomotor dysfunction depends on the areas of the brain injured and the nature of the injury. Disruption of eye movements secondary to damage to central neural control areas differs in quality compared with those associated with damage to the cranial nerves (Leigh & Zee, 1983).

Cranial nerve injury has been identified as a frequent sequela to head trauma (Gianutsos, Perks, Mazeronle, & Trem, 1989; Gianutsos, Ramsey & Perlin, 1988; Grosfasser et al., 1990; Leigh & Zee, 1983; Neger, 1989). Paralysis of the extraocular muscles innervated by the cranial nerves causes acute paralytic strabismus, the major symptom of which is diplopia or double vision. The presence of diplopia has been identified as one of a family of symptoms composing a condition known as post traumatic vision syndrome (PTVS). The term PTVS was coined by Padula (1988) to describe a syndrome of visual deficits unique to persons with traumatic brain injuries. According to Padula, major characteristics include exotropia, accommodative dysfunction, convergence insufficiency, low blink rate, spatial disorientation, poor fixation, irregular eye pursuit movements, and unstable ambient vision. These characteristics are manifested by various behavioral symptoms including diplopia, the illusion that objects are moving in the environment, poor concentration and attention, staring behavior, poor visual memory, asthenopic symptoms (eye pain), and neuromotor difficulties affecting balance, coordination, and postural control. The patient may exhibit one or several of these behavioral symptoms. However, unless there is noticeable deviation of the eyes, the symptoms are frequently attributed to cognitive, perceptual, or motor deficits and not identified as related to oculomotor dysfunction.

Eye movements are under a complex combination of cortical and subcortical control. Major central structures involved in oculomotor control include the midbrain superior colliculi, frontal eye fields, parietal and temporal lobes, the reticular system, and the cerebellum (Bruce & Goldberg, 1984; Cotman & McGaugh, 1980; Gours, 1985; Kandel, 1985; Leigh & Zee, 1983; Morrow & Sharpe, 1990; Nagel-Leiby, Buchtel, & Welch, 1990; Pierrot-Deseilligny, Gray, & Brunet, 1986). Injury to any one of these structures or their associated pathways can affect both involuntary and voluntary direction of gaze. Lesions of the cerebellum disrupt the direction, extent, force muscle tone, and timing of eye movements (Moore, 1991). Saccadic dysmetria, which causes the eyes to overshoot or undershoot targets, is observed. Abnormalities in pursuit gain may be noted that interfere with tracking moving objects. Stabilization of gaze may be affected through disruption of the vestibulo-ocular and optokinetic reflexes (Leigh & Zee, 1983). Injury to the parietal lobe can result in increased latency in initiating saccades toward the contralateral hemispace secondary to attentional deficits (DeKewa, 1982). Morrow and Sharpe (1990) have shown that patients with unilateral cerebral hemisphere lesions demonstrate a reduction of smooth pursuit gain in tracking objects bidirectionally and especially toward the side of lesion. The frontal eye fields, located in the premotor area of the cortex, direct voluntary visual search of a scene based on anticipation of where critical visual stimuli will be found in the environment. Damage to this area results in reduced monitoring of the environment and in the initiation of saccades toward the side contralateral to the lesion (Bruce & Goldberg, 1984; Gours, 1985; Leigh & Zee, 1983). The superior colliculi of the midbrain monitor the visual periphery and automatically direct gaze toward any unanticipated or novel stimuli in the environment (Kandel, 1985; Leigh & Zee, 1983). The rostral portion of the brainstem serves as the outlet for the control centers for horizontal and vertical

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gaze, as well as for all ascending and descending neural pathways between higher and lower CNS levels, including the reticular activating system. Damage in this area, as commonly occurs in head trauma, can result in difficulty in initiating eye movements (Leigh & Zee, 1983). All of these central neural structures have been shown to be vulnerable to injury from both trauma and vascular insult (Cohen, Groswater, Barchadski, & Appel, 1989; Gianutos et al., 1989; Gianutos et al., 1988; Leigh & Zee, 1983; Neger, 1989; Stanworth, 1974).

Visual fields, acuity, and oculomotor control form the foundation for the development and integration of all higher level visual skills because they control the quality and quantity of visual input. Any disruption of these basic skills will affect all judgments that are based on visual information. Research has shown these skills to be vulnerable to injuries affecting a wide variety of neural structures. The deficits are often subtle and may be overlooked without thorough, specific assessment of the foundation skills. An effective treatment program cannot be established unless these areas are addressed first.

Deficits in Visual Attention and Scanning

Visual attention operates under a complex network of intrahemispherical and interhemispherical control. Visual information is simultaneously processed in several locations within and between the hemispheres and then integrated to provide the CNS with a continuously updated picture of the environment. Visual attention is directed on the basis of this composite picture of the environment (Mesulam, 1981).

Visual input entering each hemisphere is refined as it travels through the lateral geniculate nucleus on to the occipital cortex. From the occipital cortex, the refined visual information is sent in two directions (Kelly, 1985; Mishkin & Appenzeller, 1987; Mishkin, Ungerleider, & Macko, 1983; Rafal & Posner, 1987; Ratcliff, 1987). Some impulses follow a superior route through the posterior parietal lobe where visual spatial processing occurs. Other impulses take an inferior route through the temporal lobe where visual object processing takes place. In the parietal lobe, vision is integrated with additional sensory information and transformed into a general, holistic representation of objects in the environment coming from the contralateral hemispace (Mesulam, 1981; Mishkin et al., 1983). The parietal lobe focuses on the location of objects and their relationships to each other. In contrast, visual information sent to the temporal lobe is analyzed for the specific details of color, form, and size needed for accurate object identification. The temporal lobe focuses on pattern recognition and detail and remembers the qualities of objects. Information between the two lobes is shared to produce a detailed map of the contralateral environment. According to Mesulam (1981), this map is used to direct visual attention toward objects and to identify these objects in space. Without the contribution of each lobe, the map would be lacking either in configural aspects or in details.

Lesions along the parietal route, especially in the right hemisphere, result in inattention to the location of objects in space and classic neglect syndrome. Lesions along the temporal route result in difficulty identifying objects once located and retaining a memory of the object for later use (Heilman & Valenstein, 1979; Mishkin et al., 1983; Moore, 1991).

Communication between the two hemispheres is critical, as each contributes a different aspect of directed attention. Research has shown that the left hemisphere has mechanisms for directing attention only toward the right hemifield, whereas the right hemisphere has mechanisms for directing attention toward both the right and left hemifield (Caplan, 1985; Heilman & Van Den Abel, 1980; Palmer & Tzeng, 1980; Spier et al., 1990; Weintraub & Mesulam, 1988). If a lesion occurs in the left hemisphere, attention may be diminished toward the right hemifield but some attentional capability is still present because of the intact right hemisphere. If the lesion occurs in the right hemisphere, the capacity for directed attention toward the left hemifield is lost. According to Heilman and Valenstein (1979), this asymmetry in the direction of visual attention may explain the consistently documented finding that hemi-inattention or visual neglect is associated with right hemisphere lesions and rarely with left hemisphere lesions.

Recent research suggests that the hemispheres also differ in the strategy employed to focus attention. According to Palmer and Tzeng (1990) and others (Bergen & Julesz, 1983; Pring, 1981; Rapcsak, Verfaelle, Fleet, & Heilman, 1989; Reuter-Lorenz & Kinsbourne, 1990; Sagi & Julesz, 1985), the left hemisphere employs a strict sequential item-by-item strategy in searching the environment. This strategy may give it an advantage in discriminating the minute differences in objects needed for detailed identification (Delis et al., 1983; Pring, 1981). The left hemisphere can be described as the one that sees the trees in a picture. Because of the focal nature of the strategy, only a limited number of items can be processed at a time. In contrast, the right hemisphere employs a less spatially selective strategy, breaking down a stimulus array into groups of items for processing (Palmer & Tzeng, 1990). This more versatile strategy enables the hemisphere to simultaneously process several items and gives it an advantage for configural processing (Delis et al., 1983). It can be described as the hemisphere that sees the forest in the picture.

Contributions from each hemisphere are needed for complete and efficient visual processing or to see both the forest and the trees (see Figure 3). From a treatment perspective, it is important to understand that because both contribute to the overall process, damage to either
Deficits will be observed in the visual skills subserved by the hemisphere will affect engagement of visual attention. Deficits will be observed in the visual skills subserved by visual attention, specifically visual scanning and pattern recognition.

Visual scanning entails movement of the eyes from object to object in the environment. Research has shown that in noninjured adults, scanning is completed in an organized, systematic, and efficient pattern using saccadic eye movements (Chedru et al., 1973; Festinger, 1971; Posner & Rafal, 1987; Warren, 1990; Yarbus, 1967). Saccades are rapidly executed eye movements designed to locate an object and focus it on the fovea of each eye. They either occur automatically when a novel or important stimulus appears in the peripheral field or are consciously executed to search for an object in the environment (Leigh & Zee, 1983). Control of saccadic eye movements can be disrupted after damage to either hemisphere. Saccadic deficits associated with brain injury include (a) failure to initiate saccades toward the field contralateral to the side of the lesion, (b) increased latency period in initiating saccades toward the contralateral field on the involved side, (c) decreased saccadic accuracy in the involved hemifield, (d) inability to fixate gaze in the contralateral field, (e) tendency to fixate first on the most peripheral visual stimuli in the hemifield on the sound side, and (f) tendency to be distracted by peripherally occurring stimuli in the sound hemifield (Belleza, Rapaport, Hopkins, & Hall, 1979; Chedru et al., 1973; DeRenzi, 1982; DeRenzi et al., 1982; DeRenzi, Gentilini, Faglioni, & Barbieri, 1989; Yocher & Bigelow, 1983; Posner & Rafal, 1987).

The visual scanning deficits associated with visual inattention may result in use of an ineffective visual search pattern to explore the environment. Chedru et al. (1973) studied the scanning patterns of 36 noninjured subjects and 115 subjects with brain injuries. They found that noninjured subjects who were asked to locate a specific figure hidden among others projected on a screen consistently employed a systematic scanning pattern to search for the figure. Most of the noninjured subjects employed a circular clockwise or counterclockwise scanning pattern, beginning in the upper left-hand quadrant. Most subjects spent an equal amount of time exploring each half of the visual field and an equal amount of time studying each figure until the correct one was located. In contrast, few of the subjects with brain injuries demonstrated a systematic search pattern. Most began exploring visual space in the hemifields on the sound side. Subjects with right hemisphere lesions spent a greater amount of time scanning in the right half of the visual field. Saccadic excursions into the left half of the visual field were delayed and brief. As a whole, the group with brain injuries scanned more slowly, fixated longer, and was less accurate locating the correct form. Warren (1990) reported similar results finding that 48% of 23 post-CVA subjects demonstrated a disorganized search pattern on a scanning test compared with 9% of the control group of noninjured subjects.

Tyler (1969), studying the visual scanning patterns of post-CVA patients with aphasia, found that patients with significant expressive and receptive aphasia incompletely scanned pictures for detail, which resulted in a simplistic interpretation of the content of the picture. The more complex the scene, the more the aphasic subjects’ eyes seemed to tire and fail to search for additional information in the picture. Tyler concluded that the defect in visual exploration interfered with the cognitive processes of visual perception, thus reducing the subjects’ ability to think about and interact with the environment. According to Tyler, certain types of aphasia cannot be solely explained by concepts limited to speech and language. Severe deficits in visual scanning may contribute to the language deficits observed in some aphasias by preventing the patient from gathering sufficient information about a scene or object to verbally interpret what is seen.

Deficient visual scanning has been associated with poor performance in reading, accident proneness, and dependence in self-care after CVA. Diller and Weinberg (1970) found that post-CVA persons who demonstrated deficient scanning performance on a letter cancellation task also demonstrated an increased rate of accidents during transfers and off-therapy hours related to inattention of the environment. Hier et al. (1983) observed a relationship between several factors reflecting inattention to the environment including dressing apraxia, neglect, extinction, lack of persistence, and denial.

Deficits in Pattern Recognition and Memory

Pattern recognition depends on the ability to extract minute detail in viewing an object. The process begins at the retina. The retina breaks down the visual array into individual spatial components of frequency, contrast, contour, orientation, and intensity and transmits this information to various neural areas for analysis (Corman & McGaugh, 1980; Sergent, 1984). The retina simultaneously provides the CNS with several varying descriptions of the object under study. This redundancy in visual input to the CNS enables precise comparison of the differences and similarities between objects and facilitates efficient visual object recognition (Sergent, 1984).

Sergent (1984) suggested that the hemispheres may not have equal ability to resolve the visual detail sent from the retina. She cited evidence that the right hemisphere has superior capability to process sensory information of low contrast and frequency and information having greater visual distortion. It can resolve fuzzy images and tune into the low frequency spectral components of an image or scene. Because of this advantage, the right hemisphere may be responsible for completing the initial processing of spatial information: identifying general contours and
gradations of objects in the environment and alerting the CNS to their presence. This capability is consistent with the previously cited research on the right hemisphere's advantage in directing visual attention on a global, less spatially selective basis. The left hemisphere, according to Sergent, is better at resolving detail of the visual array and carries out the fine processing needed to extract differences between objects. To complete this function, the left hemisphere requires visual input to be of greater clarity and redundancy. The two hemispheres function together to provide efficient pattern recognition. The right hemisphere completes the initial visual processing, alerts the CNS to the presence of an object in the field, and focuses the object on the foveas of the eyes. The left hemisphere then uses the high-quality visual information received through the foveas to extract minute details regarding the critical features of the object. The advantages of both hemispheres are needed to ensure accurate identification of the object. If the right hemisphere is damaged, the CNS is not alerted to the presence of an object and the focal attention of the left hemisphere is not adequately engaged. The condition of visual spatial neglect is identified clinically. If the left hemisphere is damaged, the CNS tunes into the presence of objects but is unable to make discrete comparisons (e.g., this is a letter but how does it differ from the letter next to it?). Deficits in visual cognitive skills, such as figure–ground and visual closure, may result. The quality of pattern recognition has been shown to be affected by deficits in visual scanning. Belleza et al. (1979), using a design copy test, compared subjects with and without brain injuries to determine whether patterns of visual exploration influenced performance on drawing tasks. All subjects with brain injuries with drawing impairment on the design copy test demonstrated “abnormal scanning patterns” (p. 30). Compared with noninjured subjects, the subjects with brain injuries had more fixations but shorter fixation durations, spent less time studying the most informative areas of the design, and demonstrated an asymmetrical scanning strategy restricting exploration of the design to the sound half of the visual field. Belleza et al. suggested that ambient vision enables the person to detect salient visual information peripheral to the area of fixation, which in turn engages visual attention mechanisms and causes focal inspection for detail. When the visual scanning pattern is disrupted, focal inspection is incomplete or absent; this makes it difficult for the CNS to construct an internal representation or perception of the object and formulate the correct spatial judgment. Posner and Rafal (1987) found similar results in their study on persons with visual neglect syndromes. These subjects were slower to disengage a stimulus and shift their eyes toward the contralateral field. Subjects with right brain lesions were slower moving from right to left than from left to right regardless of the visual hemifields being explored. They were also less likely to re-engage and explore an area that had been previously inspected, resulting in incomplete perception of the area under exploration.

Conclusions derived from this research indicate that for accurate pattern recognition, the CNS must receive information on both the configural aspects and the details of an object. If not, the brain is deprived of critical information needed to generate an accurate visual representation (Delis et al., 1983; Sergent, 1984). This deprivation in turn adversely affects visual memory and the quality of learning through the visual channels.

There appear to be three requirements for efficient object recognition and storage (Ratcliff, 1981; Sergent, 1990). First, the person must be able to construct a three-dimensional model or description of the object from the two-dimensional image falling on the retina. Second, the person must have access to an organized store of models held in memory. Third, the person must be able to associate the new models with those in storage. Deficits in visual attention and scanning may result in failure to construct an accurate visual model. Gianutsos et al. (1983) identified a form of visual spatial imperception which they labeled focal imperception. This condition is characterized by visual inattention to the lateral aspect of any object within the person's span of focus. It is associated more often with right brain injury and results in inattention to the left lateral aspect of the object under inspection. When a person reads, focal imperception increases the tendency to make paralexic mistakes in which the person misreads the first letter or letters of words. For example, the word delicacy may be read as licacy or the word Eight may be misread as Fight. In the first example, the CNS would dismiss the word as a nonsense word and not store it in memory. In the second example, misreading of the word would change the context of the sentence and create confusion and decreased comprehension. In either case, the accuracy of the visual model is compromised, affecting the quality of subsequent visual manipulations of that model.

**Deficits in Visual Cognition**

Visual cognition represents the highest level of visual skill integration within the nervous system. Deficits in visual cognition result in difficulties in identification of the spatial properties of objects and subsequently the mental manipulation of these properties in thought. Terms such as agnosia, alexia, disorders of spatial analysis, visual closure, figure–ground, and position in space are used to describe deficits in visual cognition. These skills are largely learned and are related to intelligence and experience, with wide variance between and within species (Gibson, 1976).

As with all higher level skill, visual cognition is susceptible to the influence of the skills subservient to it in the hierarchy. Recent research suggests that one of the
most crucial of these skills is visual attention. Rapesak et al. (1989) and others (Delis et al., 1983; Gianutsos et al., 1983; Rafal & Posner, 1987; Weinberg, Piasetsky, Diller, & Gordon, 1982; Weintraub & Mesulam, 1988) have shown that persons with brain injury have difficulty using selective visual attention to meet the demands of complex visual tasks. According to Julesz (1985), visual attention can be categorized as either attention or preattentive. Preattentive vision is ambient, instantaneous, effortless, and expansive. It occurs automatically and largely without consciousness. Attentive vision relies on serial processing and entails an effortful stimulus-by-stimulus scanning of the visual array. This serial search becomes increasingly difficult as the number of distracters in the array increases (e.g., finding a specific person in a class picture with 10 students versus finding the person in a picture with 100 students) or if the distracters are difficult to discriminate from the target (e.g., locating a specific person in a crowd where everyone is dressed identically). Studies on noninjured adults have shown that this kind of visual processing is limited by the attentional capacity of the person and requires both effort and vigilance (Rapesak et al., 1989).

Research has shown that persons with brain injuries demonstrate defined patterns of breakdown in attentive vision. Ambient scanning and preattentive abilities are generally intact, permitting adequate orientation to space and attention to the general features of an object or scene (Rapesak et al., 1989; Weinberg et al., 1982). Additionally, these persons adequately scan tasks that are highly structured or require only simple discrimination. Breakdown occurs as the demands of the task increase in terms of either stimulus array or complexity. Under these conditions, persons with brain injuries display an inability to attend to the critical features and variables between objects, a tendency to restrict scanning to the ipsilateral (sound) side of objects, and an inability to impose structure on an unstructured stimulus array (Dels et al., 1983; Rapesak et al., 1989; Weinberg et al., 1982; Weintraub & Mesulam, 1988). The erratic search pattern created by the breakdown in attentive vision causes persons to commit errors in viewing and manipulating complex visual input. Locher and Bigelow (1983) studied performance on the Motor-free Visual Perception Test, a test of complex visual perception. They found that subjects with brain injuries demonstrated unsystematic and irregular scanning strategies and exhibited significantly fewer fixations than noninjured subjects, with a resultant decrease in test performance.

According to Delis et al. (1983), whether and how much a deficit in selective attention will affect performance of daily living skills depends on the severity of the disruption and the nature of the person's vocation or lifestyle. Persons with disorders at this level may appear to adapt without difficulty in our highly verbal society. However, they will experience limitations in certain areas that require complex visual processing, such as driving, doing academic work, and reading, and in certain vocations, such as interior design, surgery, or engineering.

Summary

Visual perception can be conceptualized as consisting of a hierarchy of skill levels that interface with one another to integrate visual information efficiently. Consistent with other developmental frameworks, skills at the bottom of the visual perceptual hierarchy are thought to form the foundation for those at the highest levels. Each skill level in the hierarchy evolves from the one that precedes it and cannot maintain its integrity without the support provided by integration of the lower level skills. Research has shown that each skill level is vulnerable to injury as a result of trauma or disease. When brain injury occurs, the unity of the framework is disrupted and the integration of skill levels ceases. If disruption occurs at a lower skill level, all of the skills above it will be disrupted as well. To be effective, evaluation and treatment must be directed toward identification and remediation of the deficit in the lower level skill.

Part 1 of this paper has presented a review of the literature supporting this concept of a visual hierarchy. One of the limitations of this review is the lack of research linking the visual perceptual deficits identified to dysfunctional performance of daily living activities. The relevance of visual perceptual deficits to functional performance is a serious issue that must be addressed to establish the efficacy of our treatment approach in this area. The effect of gross visual deficits on performance is easily observed and documented in the clinic. But do mild deficits in visual attention, scanning, oculomotor control, and so on affect performance or does the ability of our central nervous system to adapt to sensory information negate the influence of more subtle dysfunction? If these deficits do affect functional performance, what is the most effective approach to treatment? These questions have not been answered yet, in part, because our profession has not had a logical framework to guide therapists in clinical research.

The purpose of this article has been to provide that research needed to justify our treatment of this area, which has long been considered crucial to the successful rehabilitation of our patients. Although the validity of evaluation and treatment has not undergone extensive scrutiny in the literature, limited research exists that indicates the direction to be taken operating from the framework of the visual perceptual hierarchy. Part 2 of this paper presents a rationale for evaluation and treatment based on the hierarchical concept.
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References


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