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Discussion of unilateral spatial inattention and a proposed new screening method for its detection

Abstract

Unilateral spatial inattention, also known as neglect, is a condition associated with brain injury that results in the patient being unaware of one hemifield, usually contralateral to the side of the lesion. It is commonly the result of traumatic or acquired brain injury (stroke) and it can be quite variable in its presentation and severity. Unilateral spatial inattention typically requires an extensive battery of tests to confirm its presence or absence, and thus is often not identified by individuals working with these patients. This lack of recognition often leaves unilateral spatial inattention patients underserved with their visual needs. In this paper we review some of the common definitions, causes, rates of occurrence and different manifestations of unilateral spatial inattention. We further review some of the classifications of unilateral spatial inattention as well as the more common tests used to detect and diagnose it. An area of much debate, treatment of unilateral spatial inattention, is also examined along with the clinical prognosis for unilateral spatial inattention patients. In this discussion we propose a new testing method to aid in the detection of unilateral spatial inattention. Brain injury patients commonly present with visual perceptual deficits for which The Test of Visual Perceptual Slulls non-motor is commonly administered. This test is frequently used by rehabilitation specialists and optometrists to help identify these deficits. We postulate that patients with unilateral spatial inattention will show more mistakes on those test plates where the correct answer choice falls into the neglected hemi-field. Therefore, it may be possible to uncover and diagnose unilateral spatial inattention solely by analyzing a patient's pattern of errors on the Test of Visual Perceptual Skills. If it were easier to detect unilateral spatial inattention, it would likely lead to better rehabilitative care of unilateral spatial inattention patients.

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DISCUSSION OF UNILATERAL SPATIAL INATTENTION AND A PROPOSED NEW SCREENING METHOD FOR ITS DETECTION

By

GAGGAN BASRA

EMILY MCCART

A thesis submitted to the faculty of the
College of Optometry
Pacific University
Forest Grove, Oregon
for the degree of
Doctor of Optometry
May 2006

Advisor:
Hannu Laukkanen, O.D., MEd, FAAO

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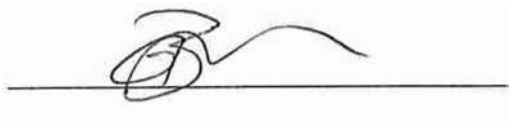

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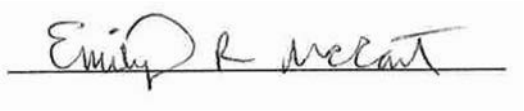

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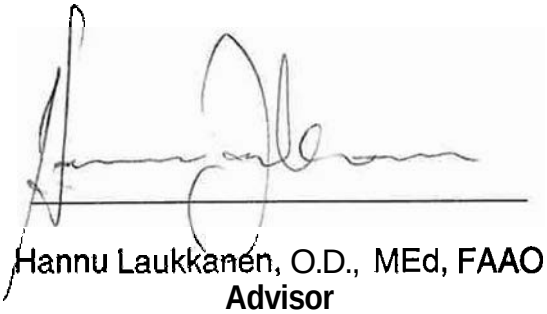

Hannu Laukkanen, O.D., MEd, FAAO
Advisor

Biographies

Emily McCart, B.S.

Emily was born and raised in Fort Collins, Colorado where she attended high school at Rocky Mountain High School. Emily was always interested in both people and science, which led her to major in psychology at Colorado State University. It wasn't until her last semester of school, while taking a Psychology of Sensation and Perception class, that Emily decided she wanted to go to optometry school. So, after graduation she continued to attend Colorado State to fulfill the pre-requisites for optometry school. Emily enrolled in the optometry program at Pacific University in the fall of 2002. After graduation, Emily will return to Colorado with her husband to begin her career as an optometrist. She would like to thank Gaggan, Dr. Laukkanen and Dr. Baxstrom for their help on this project, as well as her husband, friends and family for their constant support.

Gaggan Basra, B.Sc.

Gaggan was born in Vancouver, British Columbia and moved to Surrey, BC shortly after. She attended Queen Elizabeth Senior Secondary where her interest in becoming an Optometrist began. She attended the University of British Columbia and graduated in 2001 with a degree in Biology and a minor in Psychology. Gaggan then spent a year working as a lab technician in a local Gastroenterology lab. During this year she also spent time preparing for her big move to the United States to begin the Optometry program at Pacific University. After graduation, Gaggan will be beginning her journey as an OD in Canada. Gaggan would like to give a heartfelt thank you to Emily, Dr. Laukkanen and Dr. Baxstrom for their help and support on this project. She would also like to thank family and friends for their unconditional support.

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We would like to acknowledge all those that made this project possible. We thank Dr. Laukkanen for providing us with support, guidance and invaluable feedback throughout this project. Thanks for the reassurance that things would work out during those questionable times. We would like to acknowledge Dr. Baxstrom for taking time out of his busy schedule to help us out in this project. We appreciate you sharing your expertise in this interesting field of Unilateral Spatial Inattention. We would like to say thank you to Dr. Goodwin for her technical assistance with Photoshop. Without her expertise the process of putting together the vertical version of the TVPS would have lasted much longer. Also, thanks to Pacific University College of Optometry for allowing use of their computer lab. Finally, we would like to thank all our family and friends who have supported us in putting together this project.

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PREFACE

"Discussion of Unilateral Spatial Inattention and a Proposed New Screening Method for its Detection" was initially titled 'Introduction of a New Screening Method to Uncover Unilateral Spatial Inattention with Brain Injury Patients'. The title was changed because the study was unable to begin testing of patients in time for thesis submission, due to slow processing at the hospital Institutional Review Board level. We therefore wrote a review paper on the research currently available on Unilateral Spatial Inattention. The main purpose is to educate Optometric practitioners about Unilateral Spatial Inattention, although we believe it can be useful for a broader audience as well. We review the basics of Unilateral Spatial Inattention including its definition, prevalence, manifestations, diagnosis, testing methods, treatment, and prognosis. We believe we have provided a simple, yet thorough review of Unilateral Spatial Inattention. We have also included in this paper our initial thesis design where we propose a new screening method to uncover Unilateral Spatial Inattention.

Abstract

Unilateral spatial inattention, also known as neglect, is a condition associated with brain injury that results in the patient being unaware of one hemifield, usually contralateral to the side of the lesion. It is commonly the result of traumatic or acquired brain injury (stroke) and it can be quite variable in its presentation and severity. Unilateral spatial inattention typically requires an extensive battery of tests to confirm its presence or absence, and thus is often not identified by individuals working with these patients. This lack of recognition often leaves unilateral spatial inattention patients underserved with their visual needs.

In this paper we review some of the common definitions, causes, rates of occurrence and different manifestations of unilateral spatial inattention. We further review some of the classifications of unilateral spatial inattention as well as the more common tests used to detect and diagnose it. An area of much debate, treatment of unilateral spatial inattention, is also examined along with the clinical prognosis for unilateral spatial inattention patients.

In this discussion we propose a new testing method to aid in the detection of unilateral spatial inattention. Brain injury patients commonly present with visual perceptual deficits for which The Test of Visual Perceptual Skills non-motor is commonly administered. This test is frequently used by rehabilitation specialists and optometrists to help identify these deficits. We postulate that patients with unilateral spatial inattention will show more mistakes on those test plates where the correct answer choice falls into the neglected hemi-field. Therefore, it may be possible to uncover and

diagnose unilateral spatial inattention solely by analyzing a patient's pattern of errors on the Test of Visual Perceptual Skills. If it were easier to detect unilateral spatial inattention, it would likely lead to better rehabilitative care of unilateral spatial inattention patients.

DISCUSSION OF UNILATERAL SPATIAL INATTENTION AND A PROPOSED NEW SCREENING METHOD FOR ITS DETECTION

Definition of USI

Unilateral Spatial Inattention (USI); otherwise known as neglect, visual USI, or unilateral neglect; is a condition associated with brain injury—either acquired or traumatic. It is a phenomenon where an entire hemifield (generally the left) is ignored. USI is defined as a condition where the "patient fails to report, respond or orient to novel or meaningful stimuli presented to the side opposite of the brain lesion."[1] The patient acts as if a hemianopia were present, however the patient is unaware of the defect.

Figure 1. Visual representation of USI; the lighter shaded area represents the affected portion of the patient's body (including the left half of the face not shown in the picture) and space.

Causes of USI

USI may be present after various types of unilateral brain damage in various locations. It can be seen after traumatic brain injury (TBI) or acquired brain injury (ABI). The most common cause of TBI is motor vehicle accidents; other causes include assault, accidents in the home or workplace, and sports injuries.[2] ABI is caused by cerebrovascular accidents (CVA) such as stroke. USI is seen more commonly after stroke, particularly when the middle cerebral artery is involved.[3,4] USI can be seen after left brain damage (LBD), but is more frequently seen, more severe and longer lasting after right brain damage (RBD).[3,5]

Unilateral spatial inattention can occur following a lesion to any of the following areas: posterior parietal cortex, frontal lobe, cingulate gyrus, thalamus and striatum. [6] These areas are located throughout the brain, but they are all important components in attention. USI is most frequently seen after insult to the right inferior parietal lobe, also identified as the posterior parietal lobe. This area of the brain seems to play a large role in representation of personal space or body image, and external space. [3] More specifically, research suggests that the posterior parietal area is responsible for spatial localization, directing attention for voluntary and tactile tasks and visual awareness. [7] It is believed that the area receives and integrates incoming sensory input and produces a spatial representation of the world relative to the self. [7] The posterior parietal lobe integrates converging information from visual, auditory and vestibular areas. The posterior parietal lobe has extensive interconnections with the premotor cortex, the frontal eye fields, the superior colliculus and the paralimbic areas (the strongest being the cingulate gyrus). [6]

Researchers tend to associate deficits with a lesion in just one area, but Mesulam [8, 9, 10] believes this to be a mistake. He claims there are no distinct boundaries between different types of USI due to the tightly interwoven attentional network. Mesulam [8, 9, 10] claims that a certain behavior is not a product of one specific area of the brain, but is instead due to the many interconnections found within that area of the brain and the connections between it and other parts of the brain.

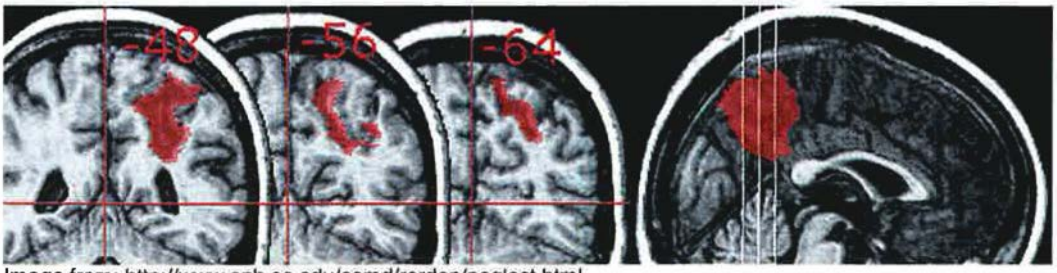


Image from: http://www.sph.sc.edu/comd/rorden/neglect.html

Figure 2. MRI scan of a patient with USI. The red region shows the area of the brain that has been damaged.

Rate of Occurrence of USI

Estimates of the occurrence of unilateral spatial inattention vary greatly in the literature. Stone et al. [11] reported that over 80% of patients demonstrate USI following a right cerebrovascular accident, whereas Denes et al. [12] reported only a 17% rate of occurrence of USI following a right CVA.

There is agreement in the literature, however, that USI is more likely to occur following lesions to the right hemisphere (causing left spatial inattention) vs. the left hemisphere (causing right spatial inattention). Allegri [13] found that 31% to 46% of right hemisphere stroke patients exhibited USI, vs. only 2% to 12% of left hemisphere stroke patients. Left USI is more severe than right USI as measured in neuropsychological testing. [12] Also, larger lesions increase the severity of the USI. [6] USI appears to occur more frequently following stroke than following TBI, [3] however we were unable to find exact numbers comparing the incidence of USI in stroke patients vs. in TBI patients. Much more literature exists about USI following stroke than USI following TBI.

One reason for the discrepancies in rate of occurrence found in the literature could be the method of testing used to determine if USI was present or not. Hier et al.[14] (studying the same group of patients) found a rate of 46% from behavioral observations

of USI and 88% from a paper and pencil Figure Copying Test. Another study [15] found a difference in occurrence of USI on 2 different paper and pencil tests, from 49% on a letter cancellation task to 30% on Albert's Test, a line cancellation test.

Another reason for the wide range of occurrence reported could relate to selection criteria used in different studies and exclusion of patients who could not complete certain tasks required for some studies. One other thing to keep in mind when comparing incidence data is the wide range in sample size used in different studies; many studies only recruited very small samples. For example, one study that Bowen et al. [5] looked at found a rate of occurrence of USI to be 100% in RBD patients, however only 9 RBD patients were looked at in the study.

Implications for Daily Living/ Different Manifestations of USI

Unilateral spatial inattention can be very debilitating for patients. There are many different manifestations of the condition and possibly even different forms of USI. There is a wide range in severity seen in USI patients. In one severe case, the patient would lie in bed with eyes and head rotated toward the side ipsilateral to the lesion, unable to look to the contralateral side of space even when spoken to from that side. [3] Many varying manifestations are often seen in day to day living. For example, the patient may be unable to pick up food from the side of the plate contralateral to the lesion, or unable to brush their hair, apply makeup, or shave their face on the side contralateral to the lesion. Even as USI begins to resolve it can still be a very disabling condition. If patients go out on a busy street, for example, many possible dangers exist if they are unaware of objects, people, or worse, traffic on their left side.

It is believed that patients with USI experience a shift in their perception of "straight ahead" or egocentric localization. These patients' subjective perception of straight ahead does not correspond to their objective midline. This creates a "spatial mismatch between their subjective and objective visual spaces." [7] Karnath [7] provided the first scientific demonstration of this phenomenon. He found that the midline shift can be 15 degrees or more. Patients with large midline shifts tend to report that they feel "unsteady," "out of synch with the world," and "not grounded." [7] Symptoms associated with midline shift syndrome include –the floor may appear tilted, -person leans away from the affected side, -the walls and/or floor may appear to move and shift.

Another phenomenon seen with many mild USI patients (or possibly a sub-type of USI, or a step in the recovery process from USI) is extinction. Extinction is a condition where patients are capable of distinguishing contralesional stimuli presented alone, but are unable to detect the stimuli when competing stimuli are also present in the patient's ipsilesional, intact field. [16] This behavior is referred to as extinction because the competing ipsilesional stimulus appears to extinguish the contralesional stimulus. [16] Extinction often becomes apparent when double stimulus presentation confrontational fields are done with the patient.

Patients with USI can vary in the degree of awareness of their defect. Suchoff [7] proposes that a continuum exists ranging from no neglect (basic hemianopia with total awareness of the field cut) to complete neglect (USI with complete unawareness of the field cut). Patients can fall anywhere along this continuum.

Categories of *USI*

Swan [6] claims that there are 3 different categories of unilateral spatial inattention: memory and representational deficits, action-intentional disorders (motor neglect), and inattention (sensory neglect).

Memory and representational deficits describes a condition where USI extends to visual memory and imagery of that space in patients' minds. Bisiach et al [17, 18] described the condition in studies done with RBD patients. Two patients with lesions in the right temporo-parietal region, and consequently left USI, were asked to describe, from memory, a familiar square in Milan containing a cathedral, palaces and shops. The patients were asked to imagine themselves lined up in front of the cathedral. The patients both accurately described the right side of the square but left out many things on the left side of the square. They were then asked to imagine themselves facing the other direction (away from the cathedral). This time they were able to accurately describe what was previously on their left (now their right) and omitted landmarks on the other side of the square that they had recalled perfectly when oriented the other direction. [17, 18] This study suggests that memories of extra-personal space are stored in relation to one's own self in that space. Swan [6] states that this study shows that USI is not limited to motor and sensory deficits and extends to behavioral aspects of brain function.

Motor neglect is not a deficiency of the motor pathway; instead it refers to an inability or failure to move in space contralateral to the damaged hemisphere. [6] Motor neglect can manifest with respect to any part of an individual's body. Swan references a study by Watson et al. [19] in which five monkeys were trained to open a door to their right

after left leg stimulation and open a door to their left following right leg stimulation. The monkeys were then surgically given unilateral lesions in the frontal arcuate gyrus or the intralaminar nucleus of the thalamus and the mesencephalic reticular formation. Lesions were placed in either the right or left hemisphere of the monkeys' brains. Following surgery the monkeys demonstrated USI. None of the monkeys were afflicted with limb weakness. The monkeys were then retested on the door-opening task and showed mistakes when the stimulus was presented to the ipsilesional limb (failure to open the door on the side contralateral to the brain lesion). However, when the stimulus was applied to the contralesional limb, no mistakes were made (they correctly opened the door on the side ipsilateral to the brain lesion). This showed that the monkeys were able to make motor responses following a sensory stimulus, but with decreased responses in contralateral space (with the ipsilesional limb) as shown by the number of incorrect responses or failure to respond.

Sensory neglect is a decreased awareness or lack of awareness of sensory stimulation in contralesional space. [6] This decreased sensory awareness occurs in spite of intact primary sensory cortical areas and sensory pathways. [6] This pertains to the observation that following right hemisphere lesions, patients with USI fail to attend to left hemispace (the field beginning at the body's midline and extending laterally to the left). Swan [6] states that over time these observations have led to the following theory: "in an individual with no known neurological pathology or impairments, the right hemisphere of the brain attends to both the right and left hemispace while the left hemisphere attends primarily to the right hemispace. Following a right hemisphere lesion, attention is directed primarily to the right hemispace, resulting in a neglect of the left hemispace. **A**

lesion of the left hemisphere does not usually result in USN [unilateral spatial neglect] because the intact right hemisphere can direct attention to both hemispaces."

Stein [20] proposed a different system for categorizing USI. He believes there are two general categories. The first involves somatic dysfunctions. This includes impaired tactile perception and denial of the existence to the contralesional side of the body. These are dysfunctions in personal space. The second category involves dysfunctions of visual motor control, visual localization and impaired visual representation of the outside world. These are dysfunctions in extra-personal space. He further subdivides this category into dysfunctions in peri-personal space. [20]

Suchoff and Ciuffreda [3] believe that initially the most obvious manifestations of USI occur in personal space and then proceed to dysfunctions in peri-personal space. They state that generally it is not possible to evaluate dysfunctions in extra-personal space at this stage. Suchoff and Ciuffreda [3] give examples of dysfunctions seen in each of the above categories. Personal space USI behaviors include: anosognosia—failure to recognize a motor dysfunction, asomatognosia—failure to recognize body parts as one's own, instability of the body in space, and akinesia—failure to move a body part. Peri-personal space behaviors include: failure to groom one side of the body, failure to read one side of a book, failure to copy one side of pictures, unawareness of objects on one side of a table and failure to place one arm in a shirt sleeve. Extra-personal space behaviors include: an unawareness or inattention to one side of the external world, frequent objects, people or traffic on one side of them.

How USI is Currently Diagnosed

There are a wide range of tests used by professionals to help detect USI. The most popular are "pen and paper" tests, which include line bisection, cancellation, copying and drawing tasks. [21] One of the more popular test batteries that employs several of these tasks is The Behavioral Inattention Test (BIT). It consists of six pencil-and-paper tests (line crossing, letter and star cancellation, figure and shape copying, line bisection and representational drawing), and nine 'behavioral' tests. [22] Here we will discuss some of the more commonly used tests for the detection of USI. When looking at the accuracy of tests, factors such as test sensitivity and specificity should be kept in mind. A test with high sensitivity and high specificity is favorable in that it will have low false negatives and low false-positives, respectively. Most of the studies done on USI detection tests focus primarily on sensitivity (accuracy).

The Line Bisection Test is a common USI assessment tool that is part of the BIT battery. It requires the patient to determine the mid-point of a horizontal line. The line is presented to the patient on a piece of paper placed in front of them and centered with respect to the patient's midline. [23] The test is typically scored by measuring the deviation of the bisection relative to the true center of the line. A deviation toward the ipsilateral side of the lesion is usually indicative of USI. [23] For example, a patient with a right parietal lobe lesion would bisect the line more toward the right of the center. The measure of the deviation can greatly vary with the extent of USI in each patient. One of the problems associated with the line bisection test is that there are many different versions of it and the different versions are not standardized. [24] Some also feel that other

factors may influence the results of this test, such as hemianopia. One study found that the line bisection test missed 40% of USI patients. [25] The test-retest reliability however was found to be 0.97, using intra-class correlation coefficient (ICC), indicating good reliability for USI subjects. [26] The ICC is a measure of the similarity of observations within groups relative to that among groups. [27]

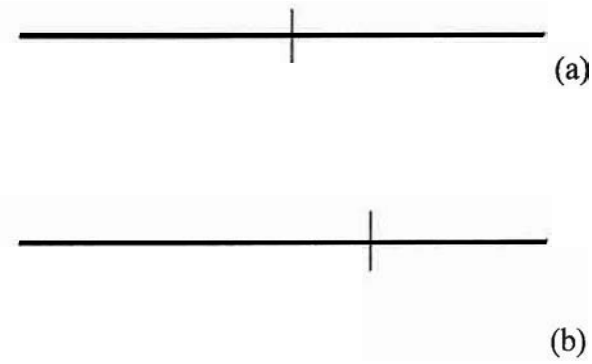


Figure 3. Line Bisection Test (a) subject performance without USI, (b) subject performance with USI (right brain lesion)

Cancellation tests involve the skill of visual search and some may involve figure-ground also. They require the patient to search a page for targets and to cross each one out. [23] Patients with USI have a tendency to miss cancellation of targets contralateral to the side of the brain lesion. Cancellation tests are considered to be one of the most sensitive pen and paper tests available. [28] Sensitivity is increased when the cancellation tests have a high density of targets as well as distracter items. [29]

There are a variety of different cancellation tests, some of which include the Line Crossing test, Bells test and the Star Cancellation test. [23] The star cancellation test has been shown to be the most sensitive [21] and is also part of the BIT battery. The test, as presented to patients, is a page with 56 small stars, 52 large stars, 13 letters, and 10 short words on it. Again, the goal of this test is to have the patient cross out all of the small stars. [21] This test design has the potential for being a high sensitivity test because of the presence of distracter items as well as the high density of targets. Bailey et al. [26] found the test repeatability, through intra-class correlation analysis, to have a coefficient of 0.89, indicating good repeatability. Another study found that the star cancellation test had a diagnostic sensitivity of 80% and a diagnostic specificity of 91%. [30]

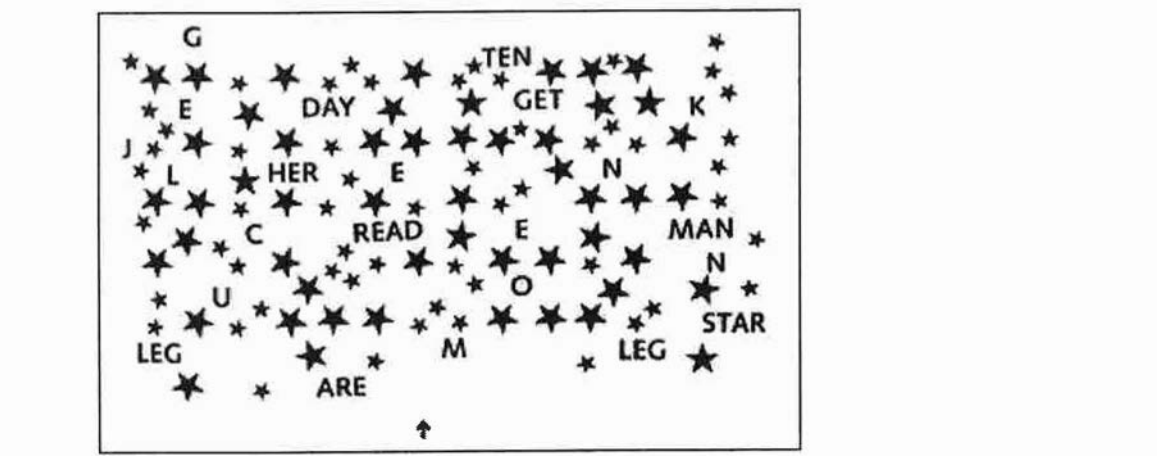


Figure 4. Star Cancellation Test
Image from: http://www.undergrad.ahs.uwaterloo.ca/~aktse/assessment.html

The Line Crossing Test, also part of the BIT battery, can be confused with the line bisection test, but it is a different assessment tool. The line crossing test that is part of the BIT is composed of uniform black lines placed randomly on a page in various orientations.[21] The subject is asked to cross out every black line on the page. It is

believed that a patient with USI will make more omissions on the side contralateral to the side of the lesion. One study found a sensitivity of 23% for the line crossing test. [21]

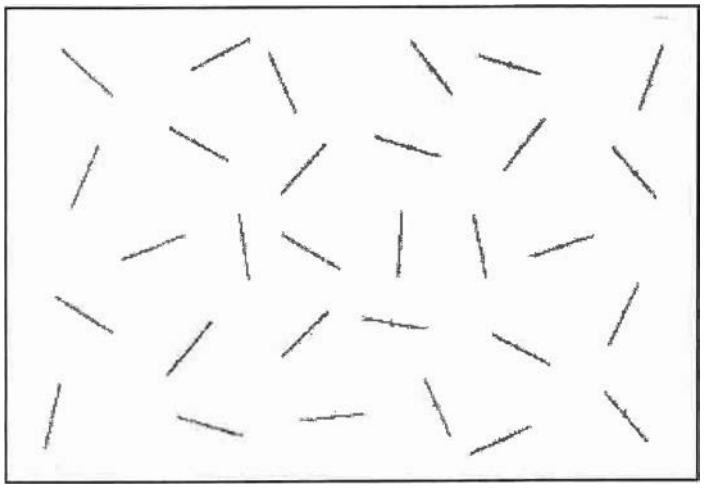


Figure 5. Line Crossing Test
Image from: http://www.undergrad.ahs.uwaterloo.ca/~aktse/assessment.html

The Indented Paragraph test is another commonly used test and is also part of the BIT battery. The paragraph is indented a different number of spaces on each line and the patient reads the paragraph aloud. The examiner has a copy of the paragraphs and follows along as the subject reads. The examiner notes any omissions and additions and how long it takes to complete the task. In one study the sensitivity of this test was found to be 77%. [21]

The Baking Tray Test is another test used to detect USI. For this test the subject is asked to place buns, which are actually wooden cubes, on a baking tray, which is also a wooden board. The subject is supposed to place the buns as evenly and symmetrically as he can. Subjects with USI generally are found to skew the distribution of the buns in an ipsilesional direction. Bailey et al. [26] found the test-retest reliability to be an ICC of 0.87 for patients with USI (good reliability).

Another test that is part of the BIT battery is the Clock test, which is used as a test for representational inattention. [22] There are different versions of the test, but all have the common theme of drawing from memory. A pre-drawn circle may be presented to the subject. The subject is then required to draw in the clock face from memory. The hands of the clock are rarely required to be drawn. In patients with USI the numbers on the clock are usually skewed towards one side of the circle (ipsilateral to the brain lesion).

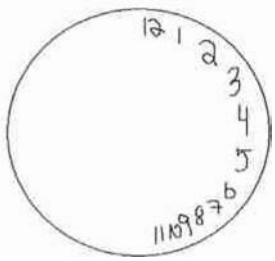


Figure 6. Clock Test: Performance of a USI patient (right sided lesion)

Many studies have been done to assess the effectiveness of different tests in the detection of USI. The studies primarily have relied upon stroke patients because there is a higher USI prevalence with this population than with traumatic brain injury patients. Consequently, the majority of studies have been limited to elderly patients, because this population has a higher occurrence of strokes. [26]

Marsh and Kersel's [21] investigation compared four different tests. The tests are all part of the BIT battery; Star Cancellation, Line Bisection, Indented Paragraph and the Line Crossing test. They found that the star cancellation test was the most sensitive test of the four. They determined this by examining the performance of those patients who demonstrated USI on any of the four tests. They found that the line bisection and the line

crossing were the least sensitive with 31% and 23% detection rates respectively. The indented paragraph test had a sensitivity of 77% and the star cancellation test was found to have a sensitivity of 100%. Interestingly, they found a significant correlation between the star cancellation test and the results of a daily living assessment.

A study done by Stone et al. [31] tested for USI using a "modified" neglect test battery with elderly patients. Their test battery included the following tests: 1. Pointing to objects located about the ward, 2. Food on a plate, 3. Reading a menu, 4. Reading a newspaper article, 5. Line cancellation, 6. Star cancellation, 7. Coin selection and 8. Figure copying from the left. Criteria used to determine USI were based on a comparison to age-matched controls. If more omissions were found with any one test than those by age-matched controls then USI was considered to be present. The researchers also used some other sensitive indicators of the testing battery to assess for USI. These included major or minor omissions on left figure copying, Crowding (patient draws more toward one side of page) and a Right Hand Start on the reading tests. Although these indicators cannot be scored on an ordinal scale, the researchers found that these variables were not present in the control sample. Therefore, they believe that these factors are clinical indicators of USI. [31]

Stone et al. [31] tested right hemisphere stroke and left hemisphere stroke patients three days post stroke. They found that 72% of the right hemisphere stroke patients and 62% of the left hemisphere stroke patients demonstrated USI on at least one test. It was found that the Newspaper reading, Star cancellation, Pointing to objects, Food on a plate and Line cancellation were more sensitive to USI in patients with right hemispheric stroke.

The validity of this test battery was confirmed by two occupational therapists (blind to the results of the test battery) by comparison to a specific checklist of USI behaviors. Some examples of the questions on the checklist were "Did the patient fail to dress, wash or groom their contralateral side?" and "Did the patient fail to orientate to environmental stimuli on the side opposite the cerebral lesion?". The results of the validity testing showed that 16 out of 17 patients identified with USI based upon the test battery also manifested USI behaviors on the occupational therapist checklist. [31] This test battery also showed that it was sensitive to changes in USI over time. Of all the tests in this battery, the Star Cancellation test was found to be the most sensitive. [31]

A study done by Bailey et al. [22] examined the results of a battery of tests to determine appropriate cut-off scores to use with a sample of elderly stroke patients. The battery they used "included validated tests for visuo-spatial neglect within extra-personal or reaching space, directional hypokinesia (inability or slowness to move the non-affected hand across into contralesional space), representational neglect, and personal neglect." [22] Test sensitivity and ease of use were also considered in this study. The Star Cancellation Test, Line Bisection, Copy-a-Daisy, The Baking Tray Task, Draw-a-Clock, Exploratory Motor Task and Personal Neglect Test were all part of the test battery. The first four tests were used as a measure of USI, the fifth test an assessment of directional hypokinesia and the sixth evaluated personal neglect. The scores of all the tests combined for the stroke patients were compared to the cut-off scores determined by an age-control group of healthy elderly subjects to assess whether or not USI was present. The score of each test in the battery was then assessed for the USI patients and the sensitivity of the individual tests was determined. Bailey et al. [22] found that the star cancellation test and the line

bisection were the most sensitive in detecting USI. They both had a sensitivity of 76.4%. This group also believes that "Clock drawing is not recommended for the assessment of representational neglect, and daisy copying is insufficiently sensitive as a test for visuo-spatial neglect."[22]

Azouvi et al.[28] also examined a battery of tests to assess the sensitivity of the tests in detecting USI. The battery of tests included paper and pencil tests of extra-personal USI as well as a behavioral assessment of USI and anosognosia. The paper and pencil tests included The Bells test, Figure copying, Clock drawing, Line bisection, Overlapping figures test, Reading and Writing. The behavioral assessment was done using the Catherine Bergego Scale (CBS), a test that assesses the presence and severity of USI. The CBS uses a checklist to assess USI in a number of daily activities and the subject is given a score for each activity. The values are then summed up to determine if there is USI and if so, how severe.[23] In this study they found the Bells tests and the reading test were the most sensitive paper and pencil tests. Instead of the typical omissions measured on cancellation tests, these investigators also examined on which side the patient started the test. They found that in 50.5% of the patients they started the test on the right sided columns. They also looked at the number of right and left side omissions on the Bells tests, which was also one of the more sensitive measures, just below that of the reading test, which was scored on the total number of omissions. Azouvi et al.[28] also found that sensitivity of the behavioral assessment was higher than any single test in the paper pencil battery and the sensitivity was comparable to that of the test battery as a whole. Although others have suggested that the clock test[22] is not very sensitive, and therefore not a valuable part of the testing battery, Azouvi et al.[28] believe

otherwise. They found that the clock drawing, figure copying, and the total number of omissions and starting point on the Bells test were able to significantly predict behavioral USI. This is significant in that this shorter testing battery may be a more practical clinical tool for the assessment of USI. [28]

Some studies have examined how a time limit on completion of a test affects the outcome of the test. Most tests administered to USI patients do not specify a time limit in which the test must be completed. This may result in misjudgment of the severity of the USI. Schendeal and Robertson [16] give an example of where there is unlimited exposure time to a test, the line cancellation test. They point out that many patients may initially show inattention to contralesional items, but as they continue to search or re-check their work they may find the missed items. This presents a problem when comparing scores for two different patients. One patient may have mild USI and obtain the same score as a patient with a higher degree of USI. These scores do not represent how the patients arrived at their end performance; the patient with a higher degree of USI may have just taken longer to complete the task. Schendeal and Robertson [16] believe that reaction time measures are advantageous, both clinically and experimentally.

Undoubtedly there are many different tests in use for the detection of USI and studies show varying results for which test(s) is/are the best for this purpose. The Line Bisection test is a commonly used tool for detection of USI, but we believe that different factors such as hemianopia can influence the accuracy of this test. Another commonly used test is the Clock Test which is a drawing task. This test is used to identify representational inattention and may be influenced by other factors, such as subjectivity in scoring. We therefore do not believe it is a good detection tool for USI.

From the studies discussed previously, it is apparent that having a greater number of tests in the testing battery increases its sensitivity for detection of USI. [28] However, many times the practitioner is limited in time and/or resources, making it difficult to use a testing battery consisting of a number of different tests. Not only that but, patient fatigue and attention level should also be considered with time consuming tests. [22] We believe that in such cases the use of the Star Cancellation test is very valuable. Literature has shown that on its own it is one of the more sensitive tests for the detection of USI. [31, 21,22] To make the testing more sensitive, observation of which side the patient begins the test is also helpful. This type of observation is simple and does not lengthen the testing time but provides useful information. We believe that this combination allows for the detection of USI but does not differentiate between the different types of USI. However, detection alone is important because many USI patients are undiagnosed and therefore do not receive the appropriate care they need. Therefore, for practitioners who do not specialize in USI patients a simple detection tool such as the Star Cancellation test can be very useful. It allows them to recognize the condition and provide the USI patient with the appropriate care and referrals. For a more complete diagnosis of presence and severity of USI, we believe that a more thorough testing battery such as the BIT should be used. We also believe that a behavioral assessment, such as the Catherine Bergego Scale, is very valuable in making the diagnosis of USI.

Differential Diagnosis: Field Cuts vs. USI

USI can easily be mistaken for a hemianopia (although they can occur together), but the damaged brain structures in the two conditions are quite different. Hemianopia is

a sensory loss in which the damaged neural elements are in the postchiasmal visual pathway including the primary visual cortex. USI, on the other hand, is a perceptual deficit in which there is no problem with the neural components necessary for sight. Instead, the visual pathways necessary to attend to or perceive the sensory input are not intact—a lesion is present in the parietal cortex. [32]

One way for clinicians to differentiate USI from a hemianopia is with line bisection tasks. Patients with USI typically transect the line off to the side contralateral to their field defect, whereas patients with hemianopia typically do the opposite and transect the line off in the direction of their scotoma. [32] Another way to differentiate USI from a hemianopia is the difference in scan paths. Patients with USI have more abnormal scan paths and fewer glances into their blind field compared to patients with hemianopia. [32]

Visual acuity testing is another good way to differentiate hemianopia vs. USI. [3] The hemianopic patient will initially omit letters on one side of the chart, but once this omission is pointed out to them they will then turn their head to scan into the missing field, so that all letters are then called out. USI patients, in contrast, will also omit letters, but even when the omission is pointed out they will continue to omit the letters. [3]

Another important, yet simple, differential can be observing the patient walk down a hallway. [3] Patients without hemianopia or USI will generally walk straight down the hallway without favoring one side or the other. Patients with hemianopia (right lesion) will tend to swerve off toward the left part of the hallway and will generally show a head turn toward that side or will scan into that field showing an awareness of the defect. However, USI patients (right lesion) will tend to swerve off to the right side of

the hallway and generally will not show a head turn or scan into the missing field, showing their unawareness of the missing field.

Another simple way to differentiate hemianopia from USI is simply asking the patient if it appears that "one side of the world is missing," if he or she "frequently bumps into things on one side." Patients with purely hemianopia will generally answer yes to these questions, whereas patients with USI will answer no, demonstrating denial typical of the condition.[3] Other useful questions to ask the patients and their significant other/family/caregiver are does he/she tend to leave food on one half of the plate, does she put makeup on only one side of her face or does he shave only one side of his face. Patients with USI will deny most of these behaviors, but their caretaker will disagree.[3]

It is important to point out that hemianopia and unilateral spatial inattention may not be distinct, mutually exclusive diagnoses. Depending on the site of the lesion, either hemianopia or USI may be present or both hemianopia and USI together to varying degrees. Suchoff and Ciuffreda[3] propose 4 different diagnostic categories. Category 1: Hemianopia without neglect—hemianopia indicated by confrontation and perimetric testing, and patient is aware of the field loss and does not demonstrate USI behaviors. Category 2: Hemianopia with USI—hemianopia indicated by confrontation and perimetric testing, however patient is unaware of the field loss and demonstrates USI behaviors. Category 3: Incomplete hemianopia with USI—hemianopia is not indicated on confrontation testing, but extinction is present with a double stimulus presentation. A relative decrease in sensitivity is shown in the left field in perimetric testing. The patient is unaware of the field loss and shows USI behaviors, but inconsistently. Category 4: USI without hemianopia—hemianopia is not indicated with single stimulus

confrontations or perimetric testing. A double stimulus presentation shows extinction, and the patient is unaware of any field loss and shows USI behaviors. [3]

Treatments for USI

There is some controversy in the literature regarding the best treatment for patients with USI. Some researchers even argue that rehabilitation for USI patients is unnecessary due to the high rate of spontaneous recovery. [16] There are two different approaches to treatment: behavioral methods (or a rehabilitation approach), and what seems to be a more recent approach, optical methods (or a compensation approach). Behavioral methods involve training attention in the neglected left hemispace and scanning training. This type of training tends to be more successful in patients with at least some awareness of their field defect. Patients with severe USI tend to not respond well to this type of training since they are being asked to look into a part of space that is nonexistent to them. [3]

With behavioral methods, the patient is encouraged to become aware of and look into the affected field. Some techniques used mimic paper and pencil tests. Patients are asked to circle or cross out certain words on a newspaper page, in an attempt to makes them more aware of the unattended area. [3] Another technique involves reading with red tape on the left side of the page to draw attention to the neglected side. [3]

Computer based programs, which are sometimes used for diagnosis of USI, can also be helpful for treatment; 2 common programs are Reaction Time Measure of Visual Field (REACT) and The Single and Double Simultaneous Stimulation Test (SDSST). In REACT the patient presses a button each time they perceive a single stimulus at random locations on the screen. The stimuli are presented in a butterfly-shaped pattern of 16

trials. The rate of stimulus presentation increases in increments of 0.01 sec. This allows the examiner to compare the reaction time in one field vs. the other and compare reaction speeds in one trial to another (gauge improvement). [3] In SDSST, minus (-) and equal signs (=) act as stimuli. Either single or double presentations of these stimuli are randomly presented in 45 trials at extreme sides of the screen. Responses are recorded and evaluated for awareness and accuracy. [3]

Several researchers have found a reduction in USI following manipulation of sensory information transmitted to the brain carrying information about the position of the head in space. [6] Some studies looked at vestibular stimulation through caloric irrigation and found a temporary remission of USI. [6] Other studies looked at galvanic stimulation of the vestibular nerves and also found a temporary reduction in USI which seemed to last for about a day. [6] Karnath et al. [33] found a temporary reduction in USI by vibrating the left posterior neck muscles and also thru lengthening the left posterior neck muscles by rotating the trunk 15 degrees to the left. This temporary reduction was presumed to be due to changed proprioceptive input from the neck muscles. [33]

One example of a specific training technique [34] or sequence could begin by asking the patient to look straight ahead at a target on a table (e.g. a coin). The optometrist1 occupational therapist1 trainer could then ring a bell in the unperceived field and ask the patient to find the bell. Next the patient would be asked to find the bell using only their eyes (teaching scanning). The patient would then be asked to touch the bell using both hands. The patient would next be asked to look back at the coin, and then to look at the coin and touch the bell location from memory using only one finger (the bell would not be ringing for this stage of training). The patient would be asked to look and see where

they touched. This sequence would be repeated with the bell in different locations. Training would then progress to 2 simultaneous stimuli in the unperceived field (e.g. a bell and a cube). The patient would be asked what they see and then asked to touch the bell and then the cube. The trainer would then ask the patient different questions about the 2 objects, like "which one is larger?", "which one is closer?", etc. This procedure could then be repeated and expanded upon by modifying targets and stimuli.

Optical methods for treating USI work to eliminate or diminish the visual field defects experienced by patients with USI by modifying the visual input. The most common method is the use of yoked prisms. One variety is partial (or half-field) yoked prisms—either Fresnel prisms or prism ground into half of each lens. The base of each prism is placed in the direction of the field loss. This requires less of an eye movement to view targets in the compromised area. The problem, however, is that patients need to actively look into each prism in order for there to be any benefit, thus making them not particularly effective for USI patients since they are unaware of their field loss. [3] Full field ground in yoked prisms seem to be more effective because these do not require the patient to actively look into the prism for there to be a benefit. [3] The effect with these prisms is that of the entire field being shifted over in the direction of the apex of each prism. This helps the patient to become more aware of people and objects present in their compromised field. The only problem with these prisms is that in shifting the entire field over, part of the patient's peripheral intact field is lost. [3] However, this method of treatment seems to be quite successful. Rossi et al. [35] used base left yoked prisms on right brain damaged USI patients. After four weeks of wearing the prisms, these patients

showed improvement on visual perception tests when compared with patients in the control group.

Mirrors have also been used as a therapeutic device to draw attention to the impaired field. [3] Mirrors are either mounted or clipped to the nasal side of the spectacle lens on the same side as the field defect (i.e. on left lens for a left field defect). The mirror is tilted to reflect the missing field. However, as with the partial yoked prisms discussed above, these require the patient to actively look into the mirror in order to see the missing field. Other problems include the reversed image of the field now seen by the patient and the cosmetic issues of wearing a mirror. [3] Ramachandran et al. [36] placed a mirror in the right plane of patients with left USI. Patients were then asked to reach for an object in the left field that was visible in the mirror, some patients were able to locate the object, while other patients attempted to reach for the mirror image of the object. Ramachandran et al named this behavior "mirror agnosia." [36]

Several researchers have looked at using an eye patch with USI patients. Research has shown that in a person with an intact nervous system, retinal input is strongest to the contralateral superior colliculus. [6] Visual stimuli transmitted to the right superior colliculus produces leftward saccades, and visual stimuli transmitted to the left superior colliculus generates rightward saccades. [6] When the right eye of left USI patients is covered with a patch, the visual stimuli to the left eye most likely follows the stronger pathway to the right superior colliculus and results in a leftward saccade, thereby shifting the patient's attention over to the compromised left field. [37] It is therefore theorized that the eye patch affects perception and attention by shifting the patient's attention to the left. [37] Beis et al. [37] looked at different kinds of patching methods on

RBD stroke patients with left USI, using photo-oculography, overall score on the FIM (Functional Independence Measure), and a letter cancellation test as measurements. Patients were divided into a control group, a group with a monocular patch over the right eye, and a group with a binocular patch covering the right hemifield. The patches were worn for 12 hours a day for 3 months. Results of the study showed significant improvement in the patients with right half-eye patches vs. the control group. However, no significant differences were found between the right monocular patch group and the control group. [37]

One study [38] suggested that administration of carbidopa L-dopa (Sinemet) to USI patients reduces USI as measured by improved scores on the Behavioral Inattention test (BIT). This study used a small sample size (4 USI patients), so further research will be needed to determine if this is indeed an effective treatment.

Clinical Prognosis with Diagnosis of USI

Another area of disagreement in the literature is the recovery period for patients with USI. Cassidy et al. [39] found the rate of recovery to be the greatest in the first month post stroke. Dombovy and Aggarwal [4] stated that gross neglect resolves to a large extent by 8 to 12 weeks, but subtle defects can persist which impede daily living. It has been suggested that major recovery from USI occurs within the first 6 months, but the effects can remain for years. One study even reported features of USI 12 years after the stroke. [3]

Bowen et al. [5] looked at 4 different studies of USI patients and compared the rate of recovery reported in those studies. They found that only 1 out of the 4 studies reported a decrease in the rate of incidence of stroke patients with contralateral USI over a 6

month period, from 13% to 3%. [40] They found that a reduction in frequency of USI following stroke was more likely with LBD vs. RBD. [5]

Cassidy et al. [39] found that a high initial score on the line cancellation test was associated with recovery from USI, whereas poor scores on the line cancellation test (a test with no distracting stimuli) suggested a more severe form of USI and was a poorer prognostic indicator.

There is agreement in the literature that the presence of USI is a very negative prognostic indicator on recovery fiom stroke or TBI. [3, 4, 6, 39] Patients with USI have been found to have longer lengths of stay in rehabilitation facilities and require more assistance when discharged from facilities than patients without USI. [6]

Current Direction of Research on USI

One area of current research deals with the "cross-over phenomenon" that seems to occur with some USI patients. [41, 42] It has been found that patients with left USI who demonstrate this phenomenon tend to bisect long horizontal lines to the right of the true center, however, when asked to bisect a shorter line, the same patients mark the midpoint to the left of the true center—towards their neglected field. Researchers are trying to determine the cause of this cross-over phenomenon. Doricchi et al. [41] looked at line bisection of 20, 100 and 200mm horizontal lines in unilateral brain damaged patients divided into 4 categories: USI with hemianopia, USI without hemianopia, hemianopia without USI, without USI or hemianopia. Cross-over was found on 20mm lines only in USI patients with hemianopia. [41] In a second study Doricchi et al. [41] compared RBD patients: patients with USI and inferior quadrantanopia and patients with inferior

quadrantanopia but no USI. They found that when 20 mm lines crossed the blind quadrant, USI patients showed the cross-over effect, however, when 20 mm lines crossed the seeing quadrants the cross-over phenomenon was not seen. [41] Researchers concluded that "cross-over seems to depend on the small spatial effects produced by reflexive contralesional gaze shifts allowing eccentric fixations with the seeing hemifield." [41] Wang et al. [42] found that if the cross-over effect occurred in right space, it was strongly supported that the patient had moderate to severe USI. [42]

Another area of current research is with impaired spatial working memory (SWM) as a possible component of USI. [43, 44] Researchers have suggested that a deficit in keeping track of spatial locations may contribute to the severity of USI in some RBD stroke patients. Malhotra et al. [43] looked at right hemisphere stoke patients' (10 with USI and 10 without) performance on a computerized vertical version of the Corsi task in which patients were shown vertical spatial sequences on a screen and then asked to respond verbally (yes or no) if a single location had been in the previous sequence. Patients with USI demonstrated significantly poorer performances on the task vs. control groups. Poor performance on the task, which measures SWM capacity, correlated with left USI on cancellation tasks. [43]

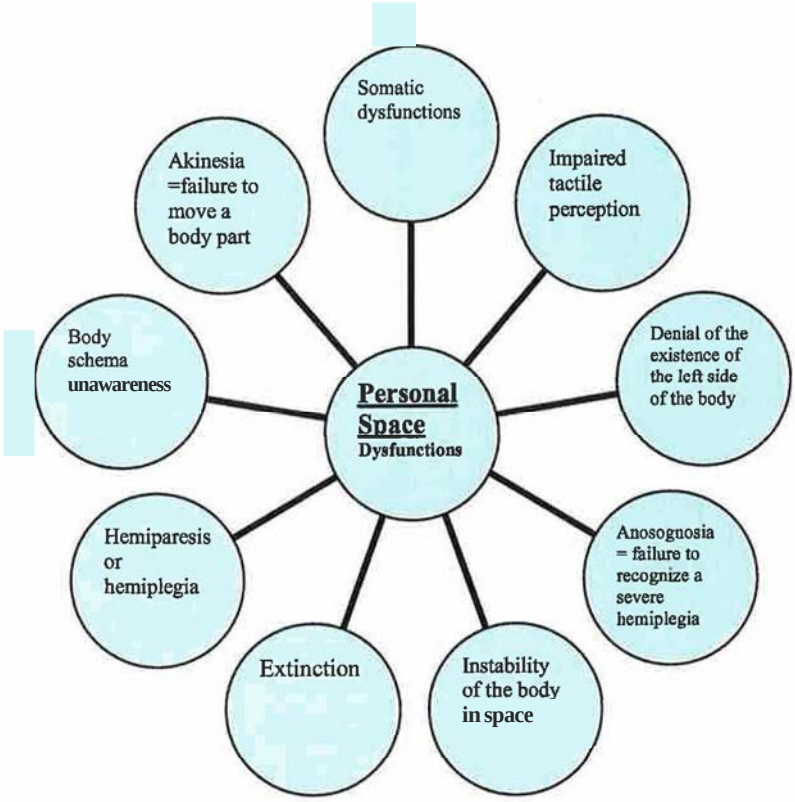
One other area of current research deals with prism adaptation. [3, 45, 46] Maravita et al. [45] looked at four patients with USI who wore 20 degrees right-shifting prisms for 10 minutes. All patients showed an improvement in contralesional tactile perception. When Suchoff and Ciuffreda [3] compared the reactions of USI patients vs. hemianopic patients without USI to yoked prisms they found that USI patients reported they "feel more grounded" or "the world is now moving with me", vs. hemianopic patients who tend to

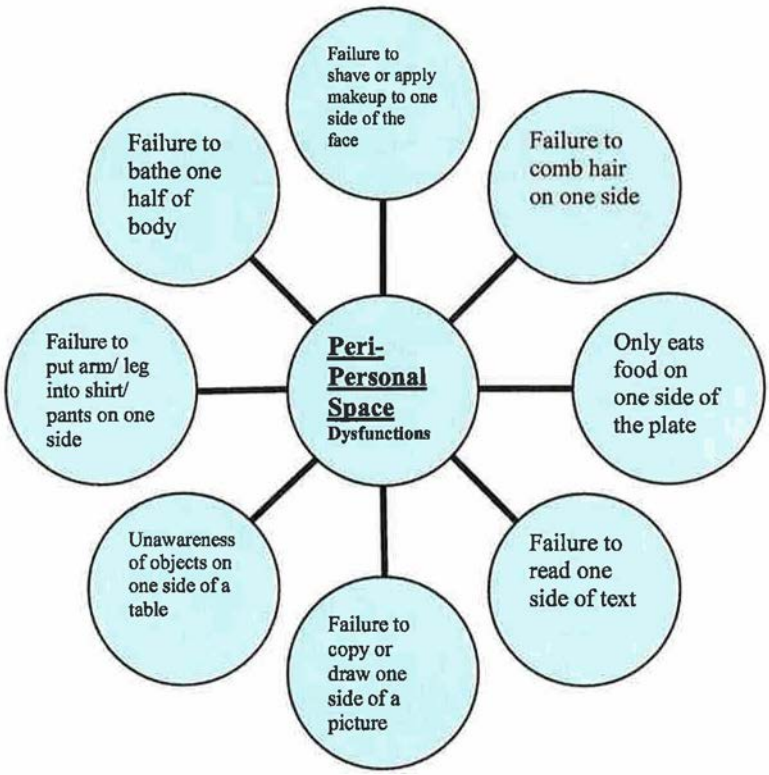
report the opposite.[3] They feel this could be explained by the mid-line shift that many USI patients experience—the yoked prisms on the USI patients with mid-line shift straightened out the mismatch between their perception of "straight ahead" and objective "straight ahead."[3]

Summary

Unilateral Spatial Inattention is a condition in which the patient ignores one hemifield, yet is unaware of the defect. It may be present after various types of unilateral brain damage in various locations (either traumatic or acquired).

USI has many different manifestations and categories. It can have very negative implications for daily living—affecting personal, peri-personal and extra-personal spaces. One helpful model for understanding USI is that of Suchoff and Ciuffreda; we have created a graphical representation of their model.


Somatic dysfunctions
Impaired tactile perception
Denial of the existence of the left side of the body
Anosognosia = failure to recognize a severe hemiplegia
Instability of the body in space
Extinction
Hemiparesis or hemiplegia
Body schema unawareness
Akinesia =failure to move a body part
Personal Space
Dysfunctions


Failure to shave or apply makeup to one side of the face
Failure to comb hair on one side
Only eats food on one side of the plate
Failure to read one side of text
Failure to copy or draw one side of a picture
Unawareness of objects on one side of a table
Failure to put arm/ leg into shirt/ pants on one side
Failure to bathe one half of body
Peri-Personal Space
Dysfunctions

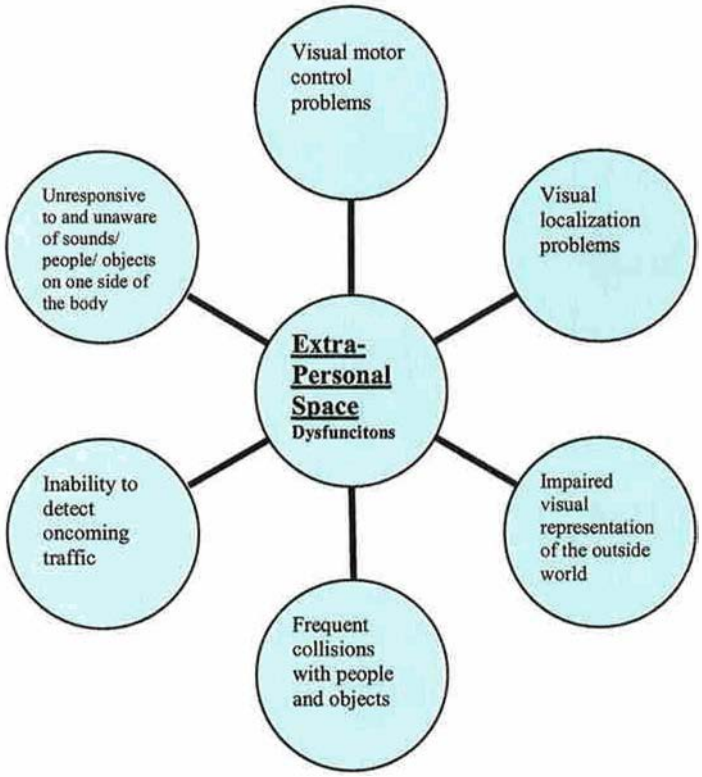


Figure 7. Categories of USI

There are a wide range of tests used by professionals to help detect USI. The most popular are "pen and paper" tests, which include line bisection, cancellation, copying and drawing tasks. To aid in understanding the different types sf USI tests, we have created a graph that illustrates the different categories,

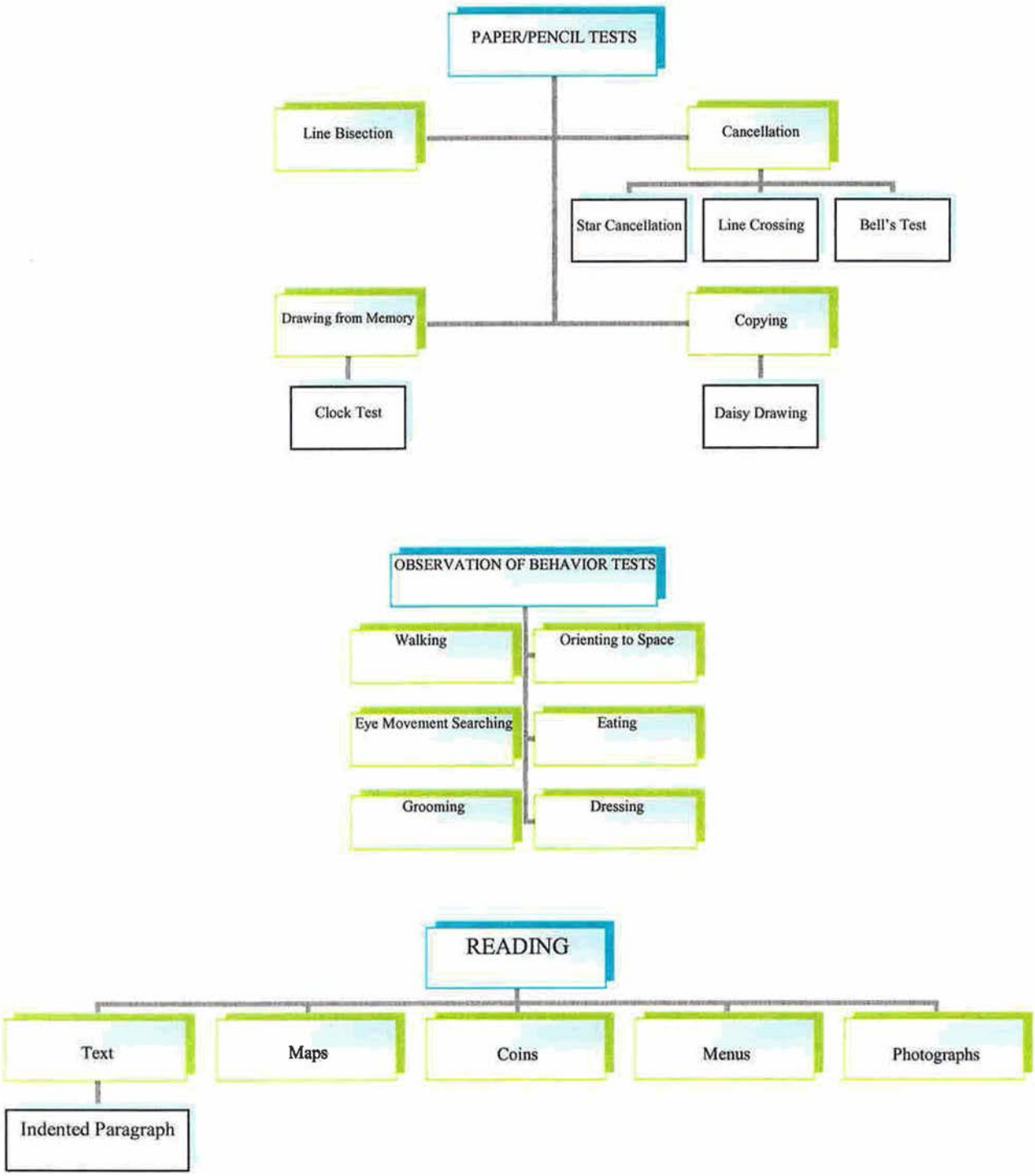


*Figure 8. **Different** diagnostic tools used in the assessment of **USI.***

We believe that, for screening purposes, the Star Cancellation test (including observation of which side the patient begins the test) is the best tool. For a more complete diagnosis of presence and severity of USI, we believe that a more thorough testing battery such as the BIT should be used.

USI can easily be mistaken for a hemianopia (although they can occur together). There are several different methods optometrists can use to differentiate the two—ranging from visual acuity testing to line bisection tasks. We have created a table which may help clarify this differentiation process for the clinician.

	Hemianopia indicated by perirnetric testing	**Hemianopia indicated by single stimulus confrontation testing**	**Patient is aware of defect**	**Patient demonstrates USI behaviors**	**Extinction present with double stimulus presentation confrontation testing**	**Performance on the Line Bisection Test**
Category 1: Hemianopia without USI	Yes	Yes	Yes	No	No	Contralesional displacement of bisection
Category 2: Hemianopia with USI	Yes	Yes	No	Yes	No	*Depends on side of hemianopia and USI
Category 3: Incomplete hemianopia with USI	Relative decrease in sensitivity shown in left field	No	No	Inconsistently	Yes--left field	*Depends on side of hemianopia and USI -inconsistent results expected
Category 4: USI without hemianopia	No	No	No	Yes	Yes--left field	Ipsilateral displacement of bisection

Table 1. Differentiating between USI and Hemianopia; responses of patient with right sided brain lesion. Note where effected field has been identified it would be opposite in patient with left sided brain lesion. *Expected results based upon author's understanding

Several different treatment methods exist for USI. The two main types of treatment are optical methods and behavioral methods. We have created a diagram to help organize treatment.

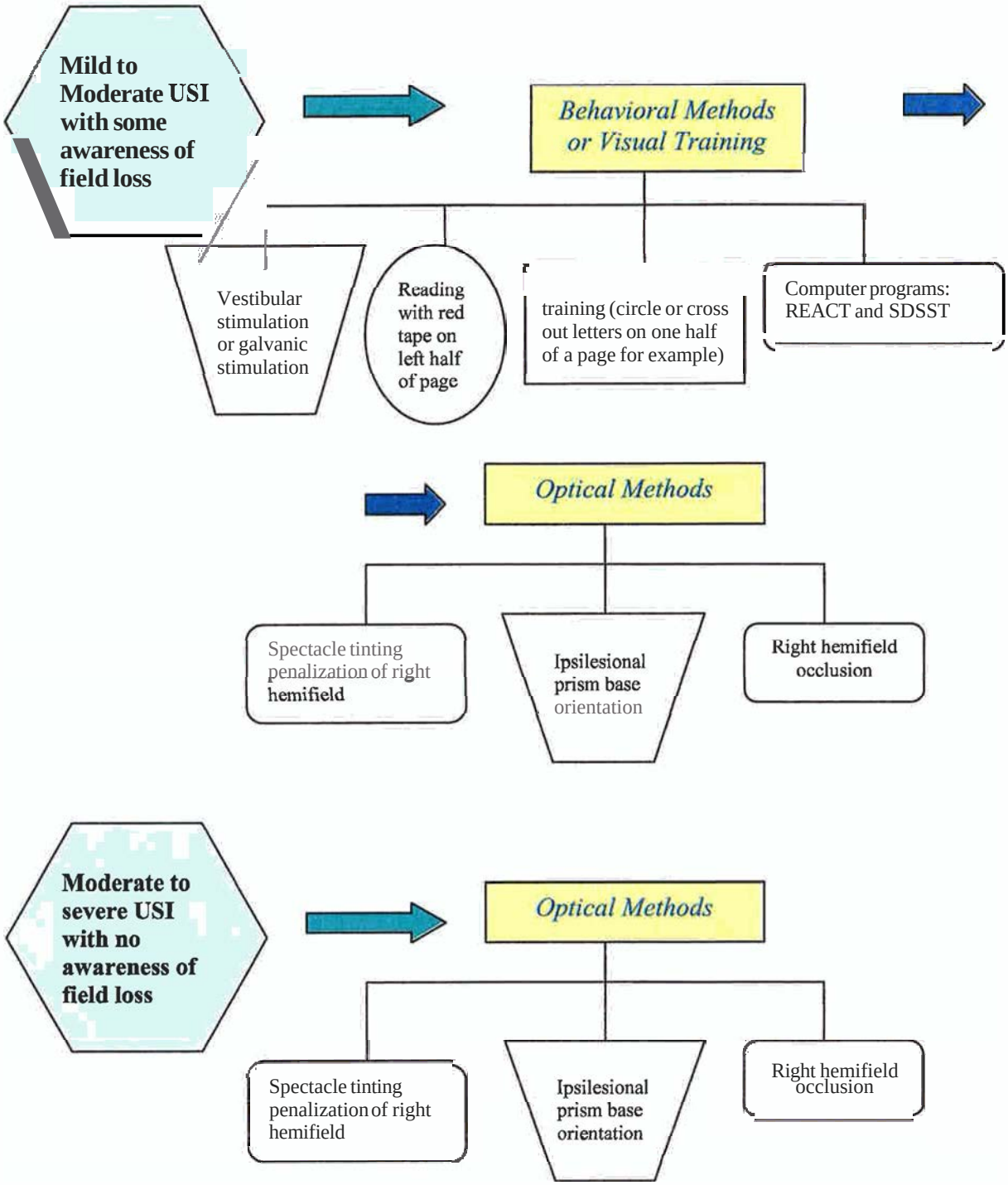


Figure 9. Treatment Methods for USI (assuming right brain damaged patient).

The clinical prognosis for patients with USI is an area of controversy; however researchers do agree that the presence of USI is a negative prognostic indicator for recovery from brain injury. There is still a great deal we do not understand about USI; much research in the area is currently being conducted to improve our understanding and help us better diagnose and treat patients with the condition.

THESIS DESIGN

One of the main goals of this study was to determine whether a commonly used visual perceptual test can be utilized as a screening tool to help identify USI. Brain injury patients commonly present with visual perceptual deficits for which The Test of Visual Perceptual Skills non-motor (TVPS) is commonly administered. This test is frequently used by rehabilitation specialists and optometrists to help identify these deficits. The TVPS is composed of seven subtests with each having 16 test plates. Each plate has four or five figures (depending on the subtest) displayed horizontally as answer choices, with only one being correct. Literature has shown that patients with USI are less likely to visually search in areas that are contralateral to the side of the brain injury. [3] We hypothesized that USI patients would be more likely to make mistakes on those test plates where the correct answer choice falls into the neglected hemi-field. Therefore, it may be possible to uncover and diagnose USI solely by analyzing a patient's pattern of errors on the TVPS. In other words, if the TVPS is already being administered to brain injury patients, then the results of these tests can be further analyzed to test for USI. This would be significant because many times USI patients are undiagnosed and their needs

underserved. We hope this tool will increase the detection of USI and therefore allow health care professionals to provide these patients with the appropriate care.

Subjects

The intended subjects for this study were traumatic brain injury (TBI) and acquired brain injury (ABI) patients primarily from a private optometric practice, with additional patients possibly available from a local health sciences university, and two neurorehabilitation centers. The number of subjects in the study would have depended on the number of available TBI and ABI patients in these clinics who would have agreed to participate, and fulfilled requisite inclusion criteria for participation. Ideally we would have liked to have seen at least 30 brain injury patients with equal distribution of TBI and ABI patients.

The exclusion criteria for participants would have included: Near visual acuity of 20150 or worse OU, central visual field defect (central 10 degrees), eye movement limitation (within 15 degrees of primary gaze), or manifest strabismus or diplopia at near (40-50cm).

Testing

The testing for the exclusion criteria would have included best corrected near visual acuity testing using a Snellen near point card held at 40 centimeters. The visual field defect would have been assessed using a screening threshold Frequency Double Technology (FDT) field test, excluding any patients with any significant field loss equivalent to $p<5\%$ in the central 10 degrees. This testing would not have required the

subject to maintain attention for a long period of time. The subjects' eye movements would have been tested using traditional version and duction testing looking for limitations in movement or diplopia. The patients would have undergone a cover test at 40 centimeters as well as a stereopsis test at near to determine the presence of strabismus. Patient testing would have been administered by Dr. Curtis Baxstrom, and hospital based rehabilitation specialists at those Seattle area hospitals where Dr. Baxstrom has privileges. All test administrators would be given a testing and study protocol orientation.

As mentioned before, this study was to be focused on whether or not the TVPS can test for USI. In order to test this idea, we developed a vertical version of the TVPS to eliminate the variable of patient understanding. We wanted to make sure that if we saw any mistakes on the TVPS horizontal they were not due to the patients' lack of understanding of the test. The appropriate statistical analysis would have been done to measure the correlation between the two versions. We scanned each page of the TVPS into Photoshop 5.0. We then made the proper adjustments to the page followed by cutting and pasting the shapes into a vertical orientation. We printed out each page of the vertical modified TVPS onto to an 8.5" x 14" sheet of card stock. This was done for TVPS revised and the test pages were then bound together.

We would have used the Star Cancellation test, a subtest of the Behavioral Inattention Test, to assess subjects for USI. The Star Cancellation test has been shown to be one of the most sensitive tests for detecting USI [47], although a battery of tests has been shown to be even more sensitive.[28] Due to time constraints in patient testing and to prevent patient fatigue we would have used this single test to test for USI. To increase

the sensitivity of the Star Cancellation test we would have looked at two different variables on this test. Observing the side the patient starts the test (right versus left), and the number of omissions on the left side versus the right have both been shown to increase the sensitivity of the test. [28] Patients would have been divided into two groups, brain injury with USI and brain injury without USI, based on the results of the Star Cancellation test.

We would also have had experienced health care providers give a subjective behavioral assessment of whether USI was present or not. These results would have been used in the data analysis to see the correlation between the behavioral assessments and the TVPS results.

Two versions of the TVPS would have been used—one version with answer choices presented horizontally and one version with answers presented vertically. The test would have consisted of alternate presentations of horizontal answer choices and vertical answer choices. We would have randomized which test page was presented first—horizontal or vertical. Half of the patients would have been presented with a page with horizontal answer choices first and half would have been presented with a page of vertical answer choices first. To insure that each test was presented on the patients' midline, we would have used a head rest to steady and maintain the ideal position through each test.

The TVPS has seven sub-tests which include Visual Discrimination, Visual Memory, Visual Spatial-Relationships, Visual Form-Constancy, Visual Sequential-Memory, Visual Figure-Ground and Visual Closure. Each sub-test has sixteen pages, the first four of the sub-tests have 5 different answer choices for each question and the last

three have 4 different answer choices. The answer choices begin on the left side of the page with number 1 and end with number 5 on the right side of the page. The frequency of position for each correct answer choice in a subtest can be seen in table 2.

	Position of Correct Answer on Test Plate				
	1	2	3	4	5
Visual Discrimination	25%	12.5%	12.5%	18.75%	31.25%
Visual Memory	31.25%	18.75%	12.5%	18.75%	18.75%
Visual Spatial-Relationships	12.5%	25%	18.75%	25%	18.75%
Visual Form-Constancy	12.5%	18.75%	18.75%	31.25%	18.75%
Visual Sequential-Memory	25%	25%	25%	25%	
Visual Figure-Ground	25%	18.75%	25%	31.25%	
Visual Closure	25%	18.75%	31.25%	25%	

Table 2. Frequency of Correct Answer Position in Each Subtest (16 pages each) of the TVPS

All patients would have also gone through a midline shift test because USI patients can experience a shift in their perception of "straight ahead" as discussed previously. For this test the patient would have stood two meters from a wall, wearing red green glasses, and projected a laser beam onto a grid on the wall where they believed midline to be. The point at which patients subjectively identified as straight ahead would have been measured and compared to objective straight ahead in both USI and non-USI groups. The deviation from the true midline would have been measured and analyzed to detect a shift in the patients' perception of midline.

Analysis

After test administration was completed, results would have been statistically analyzed without previous knowledge as to whether or not each patient had USI (we would have been blind to which group the patient belonged to—brain injury with USI or brain injury without USI—until after analysis had been completed). The hypothesis was that there would have been a significant difference between the test results of the TVPS horizontal and the TVPS vertical for patients with USI. We would have looked to see if USI patients made more mistakes on questions that had the correct answer choice on the contralateral side to the brain lesion. These results would then be correlated with performance on the vertical version of the test to account for the variable of general difficulty for the patient. The difficulty could simply arise from lack of understanding of the test. We would have accounted for a learning effect by alternating presentations from horizontal to vertical and vice versa as previously mentioned. We would have assessed the sensitivity of the TVPS to detect USI by correlating the results with those on the Star Cancellation test, as well as with behavioral assessments made by health care providers. We would have also analyzed how many of the patients showed a midline shift and how this correlated with our TVPS results.

Challenges

The main problem encountered in this study was not having access to any subjects in time for completion of this study. The study is a complicated one involving the coordination of many individuals to get it started. There were many different committees that needed to approve the study before any subjects could be tested. There was the

Pacific University IRB and the board from a Seattle area hospital. Although work on this study began in the summer of 2004, there was not sufficient time to deal with all the political aspects surrounding the study. We were unaware at the start of the project that so many obstacles in approval of this study would arise. The surprising thing is that the study did not require any major invasion of subjects. It simply required administering tests, often times part of their regular test battery, in a more controlled environment for study purposes. One thing to learn from this is to never underestimate the time it may take for hospital committees to approve projects. The key thing to remediate any of this would be to allow more time for a project of this nature. It is also important when collaborating with many different people to keep the lines of communication open. Never assume that something is being done, always take the time to check it is being done. Although it is hard to say whether anything could have sped up the process, we believe persistence and communication are always helpful.

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