Visual Perception in Traumatic Brain Injury: Effects of Severity and Effort

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Visual Perception in Traumatic Brain Injury: Effects of Severity and Effort

A Thesis

Submitted to the Graduate Faculty of the
University of New Orleans
In partial fulfillment of the
requirement for the degree of

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in
The Department of Psychology

by
Luis Aguerrevere
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Abstract

Previous studies have found that poor effort can significantly impact psychometric performance by Traumatic Brain Injury (TBI) patients. So far, this impact has been relatively well studied in attention and memory. However, this is not the case for visual perception functions. Thus, the goal of this study was to determine to what extent TBI severity affect visual perception after controlling for effort. Results showed that mild TBI good effort group did not differ from a demographically matched control group. In contrast, a mild TBI poor effort group, a moderate-severe TBI group and a right hemisphere cerebro-vascular (CVA) group performed worse than the mild TBI good effort group and the control group. The results suggest a dose response relationship between injury severity and visual perception performance. After controlling for effort, results indicated that moderate-severe TBI, but not mild TBI, has long lasting effects on visual perception. Clinical implications are discussed.

Keywords: Traumatic Brain Injury, Visual Perception, Perceptual Organizational Index, Block Design, Picture Completion, Matrix Reasoning, Rey Osterrieth Complex Figure, Benton Facial Recognition Test, Effort, Malingering, Neuropsychological assessment.
Introduction

In the United States, Traumatic Brain Injury (TBI) is one of the leading causes of death and long lasting disability among people. According to the National Institute of Health (NIH; 1999), about 5 million Americans have experienced TBI. Injuries to the brain occur to 100 per 100,000 people each year due to car accidents, falls, sports hits, and others causes, of these about 52,000 die. Financially, the direct and the indirect cost of TBI are measured in the tens of billions of dollars. This estimate includes $4.5 billions in direct expenditures for hospital care, extended care, and other medical care and services; as well as $20.6 billions in injury-related work loss and disability (Thurman, Alverson, Dunn, Guerrero, & Sniezek, 1999). As a result, health care professionals, researchers, and policy makers have increasingly focused on understanding the course, pathology and outcome following TBI.

TBI is commonly defined as an induced head-injury (for review see, Nolan, 2005), a characterization that contrasts with other brain damage pathologies that are caused by organic elements such as dementia or stroke (Lezak, Howieson, & Loring, 2004). TBI beyond causing significant tissue damage, it disrupts the internal circuits and external neuronal connections that are involved in cognitive functions and those crucially involved in sensori-motor functions (Wieloch & Nikolich, 2006). Today, it is well accepted that there are multiple factors, such as injury severity, time since injury, as well as psychosocial and interpersonal characteristics of the TBI patient that influence performance in neuropsychological testing (Dikmen, Machamer, Miller, Doctor, & Temkin, 2001; Binder & Rohling, 1996). In term of psychosocial factors, it has been
demonstrated that lack of effort performing these tests accounts for more variance than severity of brain damage (Green, Rohling, Lees-Haley, & Allen, III, 2001). So far, the impact of poor effort in attention, memory, and executive functions psychometric test performance by TBI patients have been relatively well studied. However, this is not the case for visual perceptual testing (Reid & Jutai, 1997; McKenna, Cooke, Fleming, Jefferson, & Ogden, 2006). Therefore, the purpose of this study is to evaluate the impact of severity and poor effort in visual perceptual test performance by brain injured patients.

**Classification of TBI Severity**

TBI refers to generally any damage caused to the brain (Lezak et al., 2004). Therefore, the range of TBI severity is very broad: at one extreme of the continuum, there are some patients that suffer bumps so mild that leave no behavioral traces; and on the other, there are patients that suffer prolonged coma, stay in a vegetative state or death (Levin, Benton, Muizelaar, & Eisenberg, 1996). As a result, classification of initial severity and estimation of risks of complications is important when determining what level of care and treatment the individual may require, as well as possible physical, behavioral, and cognitive disabilities that the individual will present in the near or long-term future (Lipper-Gruner, Wedekind, & Klug, 2002; Millis et al., 2001; Novack, Alderson, Bush, Meythaler, & Canupp, 2000; Novack, Bush, Meythaler, & Canupp, 2001; Steadman-Pare, Colantonio, Ratcliff, Chase, & Vernich, 2001).

Brain injuries are often differentiated in two ways, penetrating, if the dura is perforated, and closed, if the dura is intact (Lezak et al., 2004). Neurologically, there
are many ways that TBI can cause cell damage: diffuse brain injuries, or axonal injury (DAI), are the result from inertial forces that generate rotational twisting and waves of contraction and expansion in the brain (Alexander, 1995; Gaetz, 2004; Gennarelli, 1994); direct blunt traumas can result in hemorrhages and cerebral contusions at the point of impact, and on the opposite side of the head (Gennarely, 1994); penetrating injuries can cause primary damage directly to natural tissue or vascular structures, which can lead to hematoma, ischemia, or edema (Gaetz, 2004); and blast traumas, which is the results of a combination of blunt and penetrating forces (Nolan, 2005).

Patients that suffer a TBI are classified according to clinical severity, mechanism of injury and morphologic changes (van Baalen et al., 2003), which are evaluated by length of coma, post traumatic amnesia, alteration of consciousness, focal neurophysiological signs, and abnormalities revealed during neuroimaging (Binder, Rohling, & Larrabee, 1997; Alexander, 1995). The Glasgow Coma Scale (GCS) is a widely accepted standardized method for evaluating level of consciousness in patients with acute neurological disorders (Teasdale & Jennett, 1974; Whyte, Cifu, Dikmen, & Temkin, 2001). The GCS is composed by three response scores (eye opening, motor score, verbal score), which, for the purpose of research and classification, may be summated to a total score (3-15). Coma is defined as GCS score < 8 and inability to open the eyes; TBI patients with GCS <9 are classified as severe; moderate TBI is defined as a GCS of 9-12; and mild TBI is defined as GCS of 13-15 (see Table 1; Hall, 1997; World Health Organization, 1980).
Table 1

Glasgow Coma Scale Score and Associated Traumatic Brain Injury Levels

<table>
<thead>
<tr>
<th>Score</th>
<th>Level</th>
</tr>
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<tbody>
<tr>
<td>3 to 8</td>
<td>Severe</td>
</tr>
<tr>
<td>9 to 12</td>
<td>Moderate</td>
</tr>
<tr>
<td>13 to 15</td>
<td>Mild</td>
</tr>
</tbody>
</table>

The length of posttraumatic amnesia (PTA) is sometimes used as a substitute measure of injury severity (Bigler, 1990). In 1993, the American Congress of Rehabilitation Medicine (ACRM) established a set of diagnostic criteria based on the length of PTA. A commonly employed scale for PTA is: amnesia lasting less than 24 hours corresponds to mild TBI, 1 to 7 days corresponds to moderate, and longer lasting amnesia corresponds to severe injuries (see Table 2).

Some other techniques have also been proven successful for evaluating severity of injury by highlighting neurological abnormalities. For example, patients who have longer and deeper comas, behavioral and neuropsychological deficits show cerebral abnormalities seen by using the Magnetic Reasoning Imaging (MRI), and the Computerized Tomography (CT) scans (Green, Rohling, Iverson, & Gervais, 2003; Greiffenstein, Baker, Gola, Donders, & Miller, 2002). MRIs are quite sensitive to traumatic damage, even if the injury is not severe, especially non-hemorrhagic diffuse axonal injuries (Huisman, 2003; Huisman, Sorensen, Hergan, Gonzalez, & Schaefer, 2003). CT scans, on the other hand, are usually done in the early stages after the
traumatic event since it detects practically all surgically significant lesions (i.e. visualizes blood and bone fractures; Hankings, Taber, Yeakly, & Hayman, 1996).

In summary, while criteria changes from study to study, GCS, PTA, MRI and CT are used by researchers and clinicians to differentiate across the different severities in TBI patients. For comparative and illustrative purposes, this study will divide TBI patients into mild if they show a GCS of 13 to 15, a PTA < 24 hours and no MRI or CT abnormalities (see tables 1 and 2). Patients will be classified as moderate-severe if they showed a GCS < 13, PTA > 24 hours or MRI or CT abnormalities In some instances, individuals that would normally be classified as mild TBI but have neuroimaging/neuroradiological evidence (i.e., MRI abnormality) are classified as ‘mild-complicated.’ For the purposes of this study, those individuals where excluded from the analysis.

Table 2

American Congress Rehabilitation Medicine Mild Traumatic Brain Injury Criteria

<table>
<thead>
<tr>
<th>Inclusion Criteria- one or more must be manifested:</th>
<th>Exclusion Criteria- one or more must be manifested:</th>
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<tr>
<td>-Any period of loss of consciousness for up to 30 minutes</td>
<td>-Loss of consciousness exceeding 30 minutes</td>
</tr>
<tr>
<td>-Any loss of memory for events immediately before and after the accident for as much as 24 hours</td>
<td>-Posttraumatic amnesia (PTA) persisting longer than 24 hours</td>
</tr>
<tr>
<td>-Any alteration of mental state at the time of accident (dazed, disoriented or focal confused)</td>
<td>-After 30 minutes, the GCS falling below 13</td>
</tr>
</tbody>
</table>
Among the impairments that can be found in individuals with TBI are changes in emotional stability, personality, and independence for activities of daily living (Thurman et al., 1999). Nevertheless, some of the most common and damaging are those impairments that affect cognition, since these deficits in turn, mediate the most distal outcome of TBI, such as driving, returning to work, and other aspects of social role engagement (Sherer et al., 2002; Hammond et al., 2004). In all TBI severity groups the most acute cognitive impairments are found in the early stages after the injury (Salmond, Menon, Chatfield, Pickard, & Sahakian, 2006; Salmond & Sahakian, 2005; Webbe & Barth, 2003). However, successful recovery closely depends on the nature and the amount of brain damage caused by the injury (Dikmen, Ross, Machamer, & Temkin, 1995; Millis et al., 2001; Rohling, Meyers, & Millis, 2003). In general terms the more severe the injury is, the longer and the poorer the outcome will be.

Moderate to Severe TBI

About 20% of all TBI patients are believed to suffer from moderate to severe TBI (Kraus & McArthur, 1998). Moderate-severe TBI patients present a social and a financial problem, including rehabilitation needs, since it takes them a long time to return to baseline functioning (Machamer, Temkin, Fraser, Doctor, & Dikmen, 2005; Machamer, Temkin, & Dikmen, 2002). While not universal, attentional and memory impairments are the most common cognitive symptoms (Lardelli et al., 2003). However, depending on the site and the severity of the injury, these patients often suffer from
many cognitive disturbances in areas such as executive function, language, and visual perception (Rapoport, McCauley, & Levin, 2002; Hellawell, Taylor, & Pentland, 1999; Dikmen, Machamer, Temkin, & Powell, 2003; Sherer, Hart, & Nick, 2003; Formisano et al., 2004). In terms of progression of the symptoms, the most severe cognitive impairments are found in the early stages after the injury (Salmond et al., 2006; Salmond et al., 2005; Webbe et al., 2003) which could persists for two or more years after injury (Millis et al., 2001; Wilson, Pettigrew, & Teasdale, 2000; Hellawell et al., 1999). Therefore, moderate-severe TBI patients show moderate to severe disabilities that persist for long period after the injury.

**Mild TBI**

The majority of TBI patients seen in hospitals and neuropsychological clinics are classified as mild (Bazarian et al., 2005). Patients with visible intracranial abnormalities who have all other injury severity characteristics in the mild range have been categorized as mild complicated TBI (Borgaro, Prigatano, Kwasnica, & Rexer, 2003). However, the vast majority of mild TBI's are not characterized by macroscopic brain damage (Alexander, 1995). The most common cognitive deficiencies after an uncomplicated mild TBI are in attention and memory areas (for review see Iverson, 2005). However, deficiencies in executive dysfunction, language and visual perception are still elevated. Deficiencies in all cognitive areas often persist for 7 to 10 days after the accident (Dikmen, Machamer, & Temkin, 2001). However, by 1 month, the number of deficiencies in these cognitive areas will have dropped (Landre, Poppe, Davis, Schmaus, & Hobbs, 2006). In the month 3, neurological recovery is substantial, at least
by the commonly used neuropsychological measures (Lundin, de Boussard, Edman, & Borg, 2006). Even when some patients still have cognitive deficiencies, usually the number has fallen below 20% of the original group (Carroll et al., 2004; Ryan & Warden, 2003). These results have leaded many researchers to conclude that mild TBI cognitive dysfunctions, in most cases, should resolve within 3 months (Binder et al., 1997; Belanger, Curtiss, Demery, Lebowitz, & Vanderploeg, 2005)

*Long lasting Cognitive Deficiencies after a Mild TBI*

The research field has shown contrasting results regarding how significant is the number of mild TBI patients that show symptom maintenance above the 3 months period. For example, Binder et al., (1997) conducted a meta-analytic review of neuropsychological studies that looked at mild TBI’s cognitive sequelae using the GCS criteria, with a loss of consciousness (LOC) of 30 minutes or less, and normal MRI data. Studies were included if they met the following criteria: they were quasi-prospective studies or non-clinical studies (i.e. where mild TBI was seen as a secondary interest), and the patients were studied at least 3 months after the injury. Results from this meta-analysis showed a very small effect size between mild TBI injury and maintenance of neuropsychological dysfunction after 3 months. Contrastingly, a subsequent meta-analysis conducted by Zakzanis, Leach and Kaplan (1999) based on 12 studies, which included both clinical and non-clinical samples, found very different results as Binder et al. (1997). In this case, Zakzanis and colleagues reported that there is a strong effect of mild TBI and symptom maintenance. However, in this study, the authors did not indicate study selection criteria and time since injury. Therefore, it was not clear
whether the larger effects found in Zakzanis and colleagues study are due to the inclusion of individuals with acute symptoms or the inclusion of a clinical sample as defined by Binder et al., (1997).

A recent meta-analysis (Schretlen & Shapiro, 2003) attempted to clarify these contrasting results by separating the analysis in non-clinical samples and clinical samples, and including both mild TBI studies and moderate-severe studies. Based on 15 studies, the overall neuropsychological dysfunction effect size of mild TBI was substantially smaller than moderate-severe TBI. In addition, these findings suggest that it was the inclusion of clinical based studies that resulted in the larger effect sizes in the Zakzanis and colleagues (1999). Moreover, the study also found that in terms of symptom maintenance, mild TBI patients recover from cognitive dysfunctions rapidly during the first few weeks, and basically returns to normal within 1 to 3 months. Moderate-severe TBI patients, on the other hand, show some cognitive functioning improvement during the first few weeks, but in general, these functions remain impaired over 2 years post injury (Schertlen & Shapiro, 2003).

In 2004, the World Health Organization's Collaborating Center completed an extensive review of the mild TBI literature attempting to clarify the characteristics of those patients who suffer this type of injury. In this meta-analysis, 120 studies related to prognosis after mild TBI had sufficient scientific credit to be accepted. The inclusion criteria included both clinical and non-clinical studies that examined diagnosis, incidence, risk factors, prevention, prognosis, treatment and rehabilitation or economic cost of mild TBI. This large-scale, comprehensive review of the literature concluded that
as a rule, adults have a good outcome following uncomplicated mild TBI. In terms of symptom maintenance, the accepted studies provided consistent and methodologically sound evidence of cognitive deficits within the first few days after a mild TBI, including memory and attentional problems. Nevertheless, the stronger studies, using control groups and controlling for confounding factors, suggest that post-concussion symptoms after mild TBI are largely resolved within 3 months (Carrol et al., 2004). In general, this large and comprehensive study showed that mild TBI patients show symptom maintenance after the 3 months period only in studies where confounding factors have not been controlled.

Effects of Effort during Neuropsychological Testing

In the neuropsychological area, one way that individuals can maintain their symptoms is by faking or exaggerating their real capacities. Specifically, the individuals perform with insufficient effort neuropsychological examinations so he/she appears to have a dysfunction (Slick, 1999, Bianchini, Greve, 2004). For that reason, Neuropsychologists have developed techniques that help identify individuals whose performance in the testing session does not correspond with their level of injury (see Slick et al., 1999). The symptom validity testing (SVT) is a set of techniques based on forced-choice testing that reliably identifies examinees that perform psychological testing with incomplete or insufficient effort (for review, Bianchini, Mathias, & Greve, 2001). Specifically, SVT’s rule out the possibility that poor performance is due to real pathologies by demonstrating that a below chance score on an SVT requires an active avoidance of a correct response, and by showing that scores lower than well

A study conducted by Green, Rohling, Lees-Haley and Allen (2003), addressed the importance of distinguishing between individuals that show poor effort and those that show optimal effort on neuropsychological tests. First, the authors looked at the relationship between neuropsychological test scores and injury severity while controlling for poor effort. Then they looked at the same relationship in the context of poor effort. Poor effort was defined by an individual's score less than the established cut-off on the Word Memory Test (WMT; Green, Allen, & Astner, 1996; Green et al., 2003). Results from the study showed that when only those showing optimal effort were included, patients with severe brain injuries and neurological diseases scored significantly lower than the groups presumed to have no neurological impairment. However, these group differences were not seen when those showing poor effort were in the analysis (Green et al., 2001). These data indicate the importance of measuring and controlling for poor effort in individual neuropsychological evaluations, and it suggests that suboptimal effort is not controlled it has more effect on these evaluations than brain damage.

In a similar study, Binder, Kelly, Villanueva and Winslow (2003) examined if below cutoff scores on the Portland Digit Recognition Test (PDRT, Binder, 1991) are associated with low performance on several standardized neuropsychological tests.
that measure many aspects of cognitive abilities, including sensory function, motor function, attention, intelligence, abstract reasoning, and memory. In that study, groups were divided into mild TBI subjects that scored above published cutoff on the PDRT (good effort), mild TBI that score below cutoffs on the PDRT (poor effort), and moderate-severe TBI that showed good effort (moderate-severe). Results demonstrated that the mild TBI good effort individuals scored significantly higher than moderate-severe TBI in all neuropsychological tests. However, as expected, mild TBI patients who showed poor effort scored significantly worse in all neuropsychological tests than mild TBI good effort and moderate-severe patients (Binder et al., 2003). Two conclusions can be made from this study: first, when mild TBI patients show sufficient effort, there is a dose response effect between performance and severity; second, when mild TBI patients show poor effort, they perform lower than patients with more severe injuries that show good effort. Consequently, it is essential to reevaluate other standardized neuropsychological tests that show cognitive delay in the context of TBI, since the results may be due to lack of effort shown while performing these tests, and not to the direct effects of the brain injury.

Visual Perception

Visual perceptual skills combined with other elements, such as motor response, memory, attention, and visuospatial skills, underlie some of our non-verbal understanding of the world (Lezak et al. 2004). These includes our ability to visually match objects and figures, recognize faces, draw, design, and construct (Harvey & McCallum, 2003). The optimal performance of these visual perceptual skills requires an
integral process of sensory stimulations, which involves integration of visual stimulus into meaningful psychological data (i.e. recognition of target; Fuster, 2003). This integrative processing can be divided into two consecutive brain functioning stages. First, it includes the functions in charge of simplest sensory characteristics, such as color or shape. Second, it includes those functions that are in charge of the higher levels of cognitive skills such as reception and storage of visual data, visual recognition of shapes and forms, perception of spatial orientation and perspective, and copying and drawing geometric and representational designs and pictures (Benton, Silvan et al, 1994 (Ganis, Thompson, Mast, & Kosslyn, 2003a). Therefore, these skills require a high degree of integration and analysis of the situation, particularly when it involves non-concrete, unfamiliar and detailed visual information or conditions under which unique visual features are partially unclear (Martin et al, 2000).

In most cases, the right hemisphere is the structure in charge of our higher degree visual perceptual skills (for review see, Vallar, Papagno, Rusconi, & Bisiach, 1995; Viader, 1995). Therefore, individuals that suffer from conditions that affect the right hemisphere show a decrease in these complex visual processes (Heilman, Bowers, Valenstein, & Watson, 1986). In some cases these visual difficulties occur in the context of diffuse brain damage, whereas others are the result of focal insults (Ganis, et al, 2003). For example, information regarding the characteristics and the severity of the visual dysfunction may help the diagnosis of dementia, one of the best models of diffuse injury, while other neurologic disorders, such as cardiovascular accidents (CVA), may have direct damage to occipital and right temporal brain regions
resulting in specific visual perceptual disturbances (Huxlin & Merigan, 1998; Ganis, Thompson, Mast, & Kosslyn, 2003b).

TBI and Visual Perceptual Impairments

Some studies have suggested that visual perceptual impairments are present in the acute stages of TBI (Cocchini, Beschin, & Sala, 2002; Wilson, 2003), and in many cases these difficulties are maintained over a period of a year or longer (Kersel, Marsh, Havill, & Sleigh, 2001). Nevertheless, the type of dysfunctions is highly linked to the severity, the location, and the nature of the brain injury (McKenna et al., 2006; Wallesch, Curio, Galazky, Jost, & Synowitz, 2001). For example, diffuse TBI has been specifically associated with elements necessary for optimal performance in some visual perceptual tests, such as mental flexibility and processing speed (Mataro et al., 2001; Schmitter-Edgecombe & Beglinger, 2001); while focal TBI, particularly in the right hemisphere temporal lobe and the occipital lobe, have been found to cause general impairment in simple and complex visual processes (Akshoomoff, Feroleto, Doyle, & Stiles, 2002; Benton & Tranel, 1993).

In a recent study, McKenna et al, (2006) investigated the incidence of visual perceptual impairments in a sample of patients with severe TBI using the Occupational Therapy Adult Perceptual Screening Test (OT-APTS) by comparing the perceptual impairment incidence rates to a normative sample, and exploring the relationship between the presence of visual perceptual impairment and the severity of cognitive and functional impairment. Results indicated the most common impairments in the severe TBI sample were unilateral neglect (inability to attend to a stimulus located in one side
of the space), impairments of body scheme (difficulty identifying body parts), and constructional skills (difficulty assembling different parts into a two-three dimensional whole; McKenna et al, 2006). These results suggest that visual perceptual changes are evident in patients with severe TBI when compared to a healthy control group. In addition, the authors highlighted that the more typical visual perceptual dysfunction after TBI are unilateral neglect, body scheme, and constructional skills, since they occur more often than any other visual perceptual dysfunction (McKenna et al. 2006).

**Common Visual Perceptual Neuropsychological Tests**

Examinations that measure visual perceptual functions identify the critical components of each of the deficits that integrate these skills (Lanca, Jerskey, & O'Connor, 2003). Benton and Tranel (1993) define visual perceptual tests as those that focus on the analysis, synthesis, and identification of visual stimuli. Some of the most used neuropsychological tests that evaluate dysfunctions in these area are the Perceptual Organizational Index tests in the Wechsler Adult Intelligence Scale (POI)--block design, matrix reasoning, and picture completion (Wechsler, 1997)--, the Rey-Osterrieth Complex Figure (ROCF; Osterrieth, 1944), and the Benton Facial Recognition Test (BFRT; Levin, Hamsher, & Benton, 1975; Lanca et al., 2003). A recent survey of neuropsychological test use showed that the percentage of Neuropsychologist that use the WAIS-III is 25.1 %, the ROCF is 45.3 % and the BFRT is 4.45 % (Rabin, Barr, & Burton, 2005).
Perceptual Organizational Index

The POI which is part of the Performance section of Wechsler Adult Intelligence Test- 3 edition (WAIS-III; Wechsler, 1997) has been shown to reliable measure complex visual processes (Psychological Corporation, 1997). The POI is composed by three tests: Block design, a two-dimension constructional task, where assembling and construction skills are required (Wechsler, 1997); Matrix Reasoning, a task that presents a series of progressively difficult analogy problems, which measures pattern completion, classification, and serial reasoning functions (Wechler, 1997); and Picture Completion, a task that consists of identifying the important part missing on incomplete pictures of human features, familiar objects, or scenes, which measures visual organization, processing speed, and reasoning abilities; (Wechsler, 1997). In general, many studies have shown that the POI is sensitive to organic pathologies, especially those that affect the right hemisphere, such as cortical right hemisphere stroke and dementia (Miyairi et al., 2004; Sunderland & Dukoff, 1996; Ryan et al., 2005). In terms of TBI, moderate-severe forms of this injury show lower general POI scores than controls (Langeluddecke & Lucas, 2003; Ferri et al., 2004); however, separately, only Block Design and Picture Completion, but not Matrix Reasoning, seem to be sensitive to patients with moderate-severe TBI (Wilde, Boake, & Sherer, 2000; Donders, Tulsky, & Zhu, 2001; Correll, Brodginski, & Rokosz, 1993; Ryan et al., 2005). Therefore, this suggests that POI scores generally differentiate patients with moderate-severe problems from controls. However, reservation is suggested in the interpretation of the capacity of Matrix Reasoning to differentiate between these two groups.
Rey-Osterrieth Complex Figure

The ROCF measures visual information and visual memory functions, as well as constructional patterns (Knight & Kaplan, 2006). Optimal performance in the ROCF test requires intact organizational skills, visual scanning, attention and visual memory but not over-learned language or another verbal fluency ability (Ashton, Donders, & Hoffman, 2005). The test is composed by a figure made up of a complex pattern that the examinee has to demonstrate efficacy copying and recalling (Knight & Kaplan, 2006). The evaluation of visuospatial and constructional abilities in this task is principally measured in the copy section of the test (King, 1981). It has been demonstrated by several researches that those patients who sustain organic pathologies that affect the right brain hemisphere (i.e. CVA, dementia) show low scores replicating the complex figure (Max et al., 2004; Pillon, 1973; Knight et al., 2006). TBI patients, on the other hand, show significantly higher performance than right hemisphere CVA patients in the ROCF copy section (Cate & Richards, 2000); but show lower performance compared to healthy controls (King, 1981).

Benton Facial Recognition Test

The BFRT examines the patient’s ability to discriminate facial features by requiring a patient to match target faces with faces in which clothing and hair have been shaded out. This recognition of unfamiliar faces requires the use of visual perceptual abilities, which help differentiate between the particular features of the faces (Lanca et al., 2003; Warrington & James, 1967). Similar to the previous tests, the BFRT has also shown to be highly sensitive to right hemisphere CVA as well as focal injuries that affect
the right hemisphere temporal lobe (Benton, 1985; Borod, Bloom, Brickman, Nakhutina, & Curko, 2002). Studies suggest that TBI patients demonstrate some dysfunction on the BFRT (Levin & Benton, 1977). Levin et al. (1993) found that about 50% of patients with moderate-severe injuries showed defective performance in this task. In addition, the BFRT in combination with other neuropsychological tests have shown to predict 77% of the variance in source error for TBI subjects (Dywan, Segalowitz, Henderson, & Jacoby, 1993).

Persistence of Visual Perceptual Dysfunctions in Mild TBI Patients

And Effects of Effort

Dysfunctions in visual perceptual processes after a mild TBI follow a similar course over time as other neuropsychological dysfunctions, such as memory and attention deficits (Millis et al., 2001). Thus, some visual perceptual deficits are expected at early stages after the injury (Ponsford et al., 2000), but not to persist long post-injury (Dikmen et al., 1995; Ponsford et al., 2000). However, similar to other cognitive functions, some studies have shown mild TBI patients with dysfunctions in this area (Heaton, Grant, & Matthews, 1991; Levin et al., 1977; Raskin, Mateer, & Tweenten, 1998). Therefore, it is important to identify if poor effort affects the preservation of visual perceptual impairments in these patients.

Studies conducted by Fisher et al. (2000) and Donders et al. (2001) used the POI to compare mild TBI patients with moderate-severe TBI patients and controls in their visual perceptual abilities. To control for possible symptom exaggeration and lack
of effort during performance, Fisher et al. excluded participants from the study if they scored below published cut-off scores in the F-K index of the Minnesota Multiphasic Personality Inventory (MMPI-2; Butcher, Dahlstrom, Graham, Tellegen, & Kaemmer, 1989), the Rey 15 item procedure (Rey, 1964) respectively. On the contrary, Donders et al. excluded participants based on more reliable effort measurements such as Recognition Memory Test (RMT; Warrington, 1984) or the Test of Memory Malingering (TOMM; Tombaugh, 1996). Results from both studies indicated that mild TBI patients did not differ from controls in any of the POI tests, while moderate-severe TBI patients showed more impairment than the mild TBI patients. Therefore, these studies confirm that when levels of effort are controlled, mild TBI injuries is associated with persisting poor performance in the POI tests. Furthermore, they suggested that effort aside there is a dose-response effect between injury severity and visual perceptual performance.

*Purpose*

Visual perceptual deficits are commonly associated with sustained TBI. Thus, it is important to understand how the severity of the injury impacts performance in tests that measure these skills. Nevertheless, this has become complicated due to the fact that some TBI patients show poor effort during these examinations, affecting true positive indication of dysfunction. To date, Fisher et al. (2000) and Donders et al. (2001) have looked at this performance in patients affected by different TBI severity levels while controlling for effort. However, these studies are limited in the sense that they used only a specific set of visual perceptual tests, they used indicators of effort that have a high false negative rate and they did not examine the degree of impact of poor
effort on performance. Therefore, in order to better understand the nature of these visual perceptual impairments on TBI patients, the purpose of this study was to analyze the effects of injury severity and poor effort on a number of standardized tests that measure visual perceptual skills.

Hypotheses

1) The Effect of Traumatic Brain Injury Severity

When participants show sufficient effort, it was expected a dose response relationship between injury severity and scores on the visual perceptual tests. Therefore:

1a) Mild TBI good effort patient (see below) and controls would show little or no observable score differences on the visual perceptual test.

1b) Moderate-severe TBI patients and right hemisphere CVA patients would score lower than the mild TBI good effort patients and controls on the visual perceptual tests.

2) The Effect of Effort

When participants do not show sufficient effort, it was expected that the effect of effort would have more impact than the effect of injury severity. Therefore:

2a) Mild TBI poor effort patients (see below) would score lower than the controls and mild TBI good effort patients on visual perceptual tests.

2b) Mild TBI poor effort patients would score similar to the moderate-severe TBI patients and the right hemisphere CVA patients on the visual perceptual tests.
Methods

Participants

A total of 100 patients were included in this study. Archival data were obtained from 60 (N = 20 patients per group) traumatic brain injury (TBI) and 20 right hemisphere Cerebro-Vascular Accident (CVA) patients evaluated for neuropsychological evaluations at a suburban neuropsychology practice located in southern Louisiana. In addition, 20 demographically matched subjects were recruited from the community and awarded with financial compensation for their participation. In order to be included in the study, all participants had to have completed the subtest that comprise the Perceptual Organizational Index of the Wechsler Adult Intelligence Scale (POI WAIS-III; Wechsler 1997), The Rey-Osterrieth Complex Figure (ROCF; Osterrieth, 1944), the Benton Facial Recognition Test (BFRT; Levin, Hamsher, & Benton, 1975), and the Portland Digit Recognition Test (PDRT; Binder et al., 1991). Medical records and neuropsychological assessment results were extensively reviewed in order to determine group assignment of the individual.

The TBI patients have been referred by physicians, attorneys, and worker’s compensation companies. All TBI patients included in this study have been seen in the context of a worker’s compensation claim or personal injury suit and thus, have known external incentive (i.e., worker’s compensation claims, disability benefits). On the contrary, CVA patients were referred by Neurologists, Neurosurgeons and other general medical practitioners. Thus, none of the CVA patients were seen in the context of a worker’s compensation claim or personal injury suit.
**TBI Groups Assignments**

*Mild TBI Group:* Patients in this group were referred for a neuropsychological evaluation after suffering from an apparent traumatic brain injury (TBI). Mild TBI Patients were classified as having suffered a mild head injury if there was evidence that they have sustained a blunt trauma to the head, some evidence of alteration of consciousness and met the criteria set by the Mild Traumatic Brain Injury Committee of the Head Injury Interdisciplinary Special Interest Group of the American Congress of Rehabilitative Medicine (ACRM; 1993). These criteria include: 1) an initial Glasgow Coma Scale (GSC) of 13 to 15 after 30 minutes from the time of the injury/accident; 2) loss of consciousness (LOC) of approximately 30 minutes or less; 3) posttraumatic amnesia (PTA) not greater than 24 hours (see Tables 1 and 2). In addition, patients were separated according into two different groups to their level of effort.

*Mild TBI Good Effort Group:* Patients were included if they exhibited good effort on the Portland Digit Recognition Test defined by scores equal to or greater than 22 on the easy trials, 20 on the hard trials, or 44 on the total score (see below; Binder & Kelly, 1996).

*Mild TBI Poor Effort Group:* Patients were included in this group if they obtained score less that the established cut-offs, 22 on the easy trials, 20 on the hard trials, or 44 on the total score (see below; Binder & Kelly, 1996).

*Moderate to Severe TBI group:* Patients were included in this group on the bases of two main criteria. First, patients in this group have exhibited good effort on the PDRT
using the same cut-offs for effort described above (Binder & Kelly, 1996). In addition, patients were included in this group if they showed a GCS score of less than 13 and/or a PTA greater that 24 hours and/or LOC greater than 30 minutes.

Comparison Groups Assignments

*Right Hemisphere CVA group:* Patients in this group showed a verifiable cortical or subcortical right-hemisphere cerebro-vascular accident (CVA). However, CVA patients were excluded from this group if they show bilateral damage or they have known financial incentive. Due to the nature of these evaluations, no PDRT was administered and good effort was assumed.

*Control Group:* Non-head injured subjects were recruited from the community to match the demographic characteristics of the TBI groups. Subjects were screened and excluded if they had previous brain injury or were formally diagnosed with psychiatric problems. Controls who did not complete testing or who failed the PDRT were excluded from the study.

Variables and Measures

**Dependent Variables**

*The Rey-Osterrieth Complex Figure* (ROCF; Osterrieth, 1944) copy and recall test that investigates both perceptual organization and visual memory in brain impaired subjects. Three phases divide the testing procedure. For the purpose of this study only the copy section was used. In this section, the individual is asked to copy the complex figure onto a piece of paper. The figure was scored accordingly to the Meyer’s scoring system (Meyer & Meyer, 1995). *Interrater reliability:* two independent raters were
trained using the Meyer’s scoring system (the author and another graduate student). Twenty five protocols (5 per group) were selected from the whole population. Each rater was blind both to the scores generated by other rater and any identifying information associated with group participation. Inter-rater reliability coefficients (single measure interclass correlation) was .94. These results indicate excellent interrater reliability (Shrout & Fleis , 1979).

*Benton Facial Recognition Test* (BFRT; Levin, Hamsher, & Benton, 1975) provides a standardized procedure for assessing the capacity to identify and discriminate photographs of unfamiliar human faces. To complete this test, the individual has to match identical front views, front with side views, and front views taken under different lighting conditions. For the purpose of this study, the short form of this test was used. The short form includes 27 items that have been developed for use when the time available is limited (Levin et al, 1975). Then, the total score of correct responses was recorded and converted to a long form score.

*Block Design* (Wechsler, 1997): is a construction test where the subject is presented with red and white blocks: two, four, or nine, depending on the item. Each block has two white sides, two red sides, and two half-red half-white sides with the colors divided along a diagonal. The subject’s task is to use the blocks to construct replicas of the block construction made by the examiner on the early trials and from figures throughout. The scale scores were used accordingly to the WAIS-III administration manual (Wechsler, 1997).
Matrix Reasoning (Wechsler, 1997): presents a series of increasingly difficult visual pattern completion and analogy problems. The subject is asked to choose from a multiple choice array the item that best completes the pattern. This test has no time limit but frequently takes 20 minutes for completion. The scale scores were used accordingly with the WAIS-III administration manual (Wechsler, 1997).

Picture Completion (Wechsler, 1997): to give this test, the examiner shows the subjects incomplete pictures of human features, familiar objects, or scenes, arranged in order of difficulty with the instruction to tell what important part is missing. Twenty seconds are allowed for each response. The scale scores were used accordingly with the WAIS-III administration manual (Wechsler, 1997).

Perceptual Organizational Index (POI; Wechsler, 1997): is composed by the combination of Block Design, Picture Completion and Matrix reasoning. The index score is presented in intelligence type scale accordingly with the WAIS-III scoring manual (Wechsler, 1997).

Measure of Effort

Portland Digit Recognition Test (PDRT; Binder et al., 1991). The PDRT is a 72-item SVT employing recognition of a five-digit number string (Binder et al., 1991), which includes a counting distractor period between the stimulus presentation and recognition. The test “appears” to have increasing difficulty as the distractor periods grow from 5 seconds during the first 18 items to 15 seconds for the second quartile and 30 seconds for the final half of the 72 cards (Binder, 1991).
The PDRT has been shown by many researchers to detect individuals that purposely show poor effort, by using recommended cut-offs, based on zero percentile (Binder and Kelly, 1996). For the purpose of this study, the cut-offs used to detect poor effort (see above) occurred less than 2% of the time in the no incentive brain injured patients (Binder & Kelly, 1996). A shortened version of the PDRT was used to determine good effort in the control participants; if a participant scores at least 19/36 on the easy trial and then correctly answer 7 of the first 9 or 12 out of the first 18 hard trials, he/she was considered to be showing good effort (Binder, 1993b; Doane, Greve, & Bianchini, 2005).

Validation of Effort

To assess the effectiveness of effort classification, the scores of the patients in all TBI groups were examined using external indicators that are sensitive to feigned impairment. This ensured that the patients have been correctly classified into the appropriate group based on the PDRT performance. The first indicator is the Reliable Digit Spam (RDS; Greiffenstein, Baker, & Gola, 1994; Greiffenstein, Gola & Baker, 1995), an internal validity indicator derived from the digit span test, a component of several commonly used test batteries, as for example, the WAIS-III. RDS is based on the assumption that a person attempting to fake or exaggerate impairment will perform poorly on digit span because it looks like a test on which brain injured patients might experience difficulty (Meyers & Volbrecht, 1998), although digit span in actually fairly well preserved even among patients with brain dysfunction, including amnesia (Greiffenstein et al., 1994). For this study, scores below 7 were considered evidence of
poor effort, a cut-off associated with less than 5% false positive error rate in TBI (Heinly et al., 2005; Meyers & Volbrecht, 1998).

The second indicator, the *Fake Bad Scale* (Lees-Haley, English, & Glenn, 1991) is devised from the Minnesota Multiphasic Personality Inventory – Second Edition (Butcher et al., 1989). FBS was developed as a way to detect individuals attempting to appear honest and psychologically normal but there is an emphasis on somatic complains, which appear as if their injury is the primary reason for their problems. In the context of TBI research, FBS has also been proven to be powerful at detecting exaggeration of complaints associated with physical injury as opposed to psychopathology (Greiffenstein et al., 1994; Greiffenstein et al., 2002; Greiffenstein, Baker, Axelrod, Peck, & Gervais, 2004; Iverson, Henrichs, Barton, & Allen, 2002; Meyers, Millis, & Volkert, 2002; Ross, Millis, Krukowski, Putnam, & Adams, 2004). Scores above 27 on FBS will be considered indication of symptom exaggeration (Greve, Bianchini, Love, Brennan, & Heinly, 2006)
Results

Group Characteristics

Demographics

Demographic and injury related variables were evaluated to determine differences among the Control group, the TBI groups (mild good effort, mild poor effort, and moderate-severe) and the right hemisphere cerebro-vascular accident (CVA) group (see table 3). Analyses of variance (ANOVA) were used for age, education level, and the amount of time that has elapsed between the time of the injury and the evaluation. Chi-square analyses were performed for gender and race.

The five groups (Controls, three TBI and right hemisphere CVA) did not show significant differences in education ($F[4, 90] = .85, p = n/s$, partial $\eta^2 = .04$) and race ($\chi^2[df = 1] = 9.74, p = n/s$). Significant differences were seen in age ($F[4, 89] = 7.22, p < .001$, partial $\eta^2 = .24$), gender ($\chi^2[df = 1] = 10.01, p < .05$) and time post-injury ($F[3, 76] = 7.13, p < .001$, partial $\eta^2 = .2$). TBI groups did not differ from each other on any demographic variable. However, right hemisphere CVA showed less time since injury, higher age and a higher number of females than the other groups. Table 3 and 4 provide the detailed results and descriptive statistics of the demographic variables.
Table 3

Means and SD Related to the Demographic Characteristics of the Current Sample by Group

<table>
<thead>
<tr>
<th>Group</th>
<th>Controls Mild TBI</th>
<th>Mild TBI Mod-Sev</th>
<th>TBI</th>
<th>CVA</th>
<th>F</th>
<th>p &lt;</th>
<th>eta²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>good effort</td>
<td>poor effort</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>M 33.2 (10.6)</td>
<td>40.5 (9.4)</td>
<td>40.7 (8.6)</td>
<td>37.3 (15.1)</td>
<td>52.4 (13.6)</td>
<td>7.5</td>
<td>.001</td>
</tr>
<tr>
<td>Education (years)</td>
<td>M 12.7 (2.1)</td>
<td>12.4 (2.3)</td>
<td>12.4 (2.6)</td>
<td>12.2 (3.4)</td>
<td>14.0 (1.9)</td>
<td>1.2</td>
<td>n/s</td>
</tr>
<tr>
<td>Months Since Injury (months)</td>
<td>M -- (14.7)</td>
<td>28.5 (26.4)</td>
<td>52.1 (44.8)</td>
<td>16.08 (33.62)</td>
<td>3.94</td>
<td>.05</td>
<td></td>
</tr>
<tr>
<td>GCS Score</td>
<td>M -- (0)</td>
<td>15.0 (0)</td>
<td>14.6 (0.7)</td>
<td>7.9 (3.9)</td>
<td>--</td>
<td>49.9</td>
<td>.001</td>
</tr>
</tbody>
</table>

Note. R-H = Right Hemisphere; CVA = Cerebro-Vascular Accident; Mod-Sev = Moderate-to-severe; TBI = Traumatic Brain Injury; n/s = Not significant.

Table 4

Percentages related to the Gender and Race of the Current Sample by Group

<table>
<thead>
<tr>
<th>Group</th>
<th>Controls Mild TBI</th>
<th>Mild TBI Mod-Sev</th>
<th>TBI</th>
<th>CVA</th>
<th>X²</th>
<th>p &lt;</th>
<th>eta²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (% Female)</td>
<td>80 35 30</td>
<td>10.5 50 10.3</td>
<td></td>
<td></td>
<td>n/s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Race (% of Caucasian)</td>
<td>70 70 50</td>
<td>50.0 70 15.1</td>
<td></td>
<td></td>
<td>n/s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(% of African Am.)</td>
<td>25 15 5</td>
<td>10 20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(% of Hispanic)</td>
<td>5 0 10</td>
<td>10 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(% of N/I)</td>
<td>0 15 15</td>
<td>30 10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. R-H = Right Hemisphere; CVA = Cerebro-Vascular Accident; Mod-Sev = Moderate-to-severe; TBI = Traumatic Brain Injury; N/I = Not Indicated; n/s = Not significant.

Row Means with same letter represent homologous subgroups using Tukey’s corrections at p = .05
Validation of Effort

To assess the effectiveness of the effort classification method, an ANOVA was conducted on the TBI groups (mild TBI good effort, mild TBI poor effort, moderate-severe TBI) using the external methods Reliable Digit Span and the Fake Bad Scale. There were no group differences in RDS \([F(2, 1) = 1.69, n/s]\). Contrary, there were significant group differences in FBS \([F(2, 1) = 13.634, p < .001]\). The mild TBI poor effort and the mild TBI good effort had significantly higher mean scores than the moderate-severe TBI (Table 5).

Table 6 present a frequency table of those patients that failed the validity measures. The mild TBI poor effort group has about 2 times more individuals failing the validity measures than the mild TBI good effort group and 6 times more individuals failing the validity measures than the moderate-severe TBI group. However, despite these general results, this table also shows that the PDRT did not fully purify the groups. This is because some mild TBI good effort patients and some moderate-severe TBI patients failed the validation methods. As a result, these patients which were classified as good effort by the PDRT, show evidence of cognitive exaggeration and/or psychological exaggeration.
Table 5

Effort Validation Scores

<table>
<thead>
<tr>
<th></th>
<th>Mild TBI good effort</th>
<th>Mild TBI bad effort</th>
<th>Mod-Sev TBI</th>
<th>F</th>
<th>p&lt;</th>
<th>eta2</th>
</tr>
</thead>
<tbody>
<tr>
<td>RDS M</td>
<td>8.45</td>
<td>7.5</td>
<td>8.45</td>
<td>1.69</td>
<td>n/s</td>
<td>.05</td>
</tr>
<tr>
<td>(sd)</td>
<td>(1.93)</td>
<td>(2.21)</td>
<td>(1.43)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FBS M</td>
<td>25.4</td>
<td>28.8</td>
<td>18.7</td>
<td>13.64</td>
<td>.001</td>
<td>.32</td>
</tr>
<tr>
<td>(sd)</td>
<td>(5.12)</td>
<td>(6.0)</td>
<td>(7.3)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. R-H = Right Hemisphere; CVA = Cerebro-Vascular Accident; Mod-Sev = Moderate-to-severe; TBI = Traumatic Brain Injury; RDS = reliable Digit Span; FBS = Fake Bad Scale.

abcRow Means with same letter represent homologous subgroups using Tukey’s corrections at p = .05

Table 6

Frequency of Patients who Show Exaggeration in Validity Indicators

<table>
<thead>
<tr>
<th></th>
<th>Mild TBI good effort</th>
<th>Mild TBI bad effort</th>
<th>Mod-Sev TBI</th>
</tr>
</thead>
<tbody>
<tr>
<td>RDS</td>
<td>3 (15 %)</td>
<td>6 (30 %)</td>
<td>0</td>
</tr>
<tr>
<td>FBS</td>
<td>5 (25 %)</td>
<td>11 (55 %)</td>
<td>2 (10%)</td>
</tr>
</tbody>
</table>

Note. R-H = Right Hemisphere; CVA = Cerebro-Vascular Accident; Mod-Sev = Moderate-to-severe; TBI = Traumatic Brain Injury; RDS = reliable Digit Span; FBS = Fake Bad Scale.

Dependent Variables Analysis

A multivariate analysis of variance (MANOVA) was conducted to examine differences between the five groups (controls, mild TBI good effort, mild TBI poor effort, moderate-severe TBI, right hemisphere CVA) on the six dependent variables scores: Rey-Osterrieth Complex Figure (ROCF), Benton Facial recognition test (BFRT), Block Design, Picture Completion, Matrix Reasoning, and Perceptual Organizational Index.
(POI). Follow up ANOVAs were conducted to identify the specific variables where the groups differed on. Post-hoc comparisons were performed to examine how the groups differed.

First, preliminary assumption testing for the MANOVA was conducted to check for normality, and homogeneity. In terms of multivariate normality, the maximum Mahalanobis distance value obtained (20.49) was below the chi-squared critical value associated with 6 dependent variables ($\chi^2_{\text{critical value}} = 22.46$ at $p<.001$; Tabachnik & Fidell, 2001). There was a violation of homogeneity of covariance matrices ($p<.001$). However, because the sample sizes are equal robustness of significant test is expected; therefore, the outcome of Box’s M test was disregarded.

There was an overall significant difference between the five groups in all six dependent variables ($F_{[24,315]} = 2.83$, $p<.001$, Wilk’s = .51, partial $\eta^2$ = .16). Follow up analyses of variance (ANOVAs) showed significant differences between the groups in all six variables: ROCF ($F_{[4, 95]} = 3.59$, $p < .01$, partial $\eta^2$ = .13), BFRT ($F_{[4, 95]} = 6.63$, $p < .001$, partial $\eta^2$ = .23), block design ($F_{[4, 95]} = 3.74$, $p = .007$, partial $\eta^2$ = .14), picture completion ($F_{[4, 95]} = 8.51$, $p < .001$, partial $\eta^2$ = .26), matrix reasoning ($F_{[4, 95]} = 5.7$, $p < .001$, partial $\eta^2$ = .19), and the POI ($F_{[4, 95]} = 8.7$, $p < .001$, partial $\eta^2$ = .27).

Tuckey HSD significant difference post-hoc comparisons were conducted on the significant variables. For all variables the mild TBI good effort did not differ from controls. In contrast, the mild TBI poor effort always performed worse than the mild TBI
good effort except on block design. Moreover the mild TBI poor effort performed at the same level as the moderate-severe TBI and the right hemisphere CVA on all variables. The moderate-severe TBI and the right hemisphere CVA constantly performed worse than the mild TBI good effort although not always significant. Table 7 summarizes the results associated with the individual ANOVAs. A graphical representation of the mean z-scores calculated in the four treatment groups (mild TBI good effort, mild TBI bad effort, moderate-severe TBI and right hemisphere CVA) for each of the six variables based on the z-scores of the control group can be seen in Figure 1.

Table 7

<table>
<thead>
<tr>
<th>Group Analysis of Visual Perceptual Tests (standard scores)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controls</td>
</tr>
<tr>
<td>ROCF M</td>
</tr>
<tr>
<td>BFRT M</td>
</tr>
<tr>
<td>Block Design M</td>
</tr>
<tr>
<td>Matrix Reasoning M</td>
</tr>
<tr>
<td>Picture Completion M</td>
</tr>
<tr>
<td>POI M</td>
</tr>
</tbody>
</table>

Note. R-H = Right Hemisphere; CVA = Cerebro-Vascular Accident; Mod-Sev = Moderate-to-severe; TBI = Traumatic Brain Injury; ROCF = Rey Osterrieth Complex Figure; BFRT = Benton Facial Recognition Test; POI = Perceptual Organization Index; abc Row Means with same letter represent homologous subgroups using Tukey’s corrections at p = .05
Figure 1. Group Performance relative to control group on all the Visual Perceptual variables. Z-scores were created from the control group distribution. R-H = Right Hemisphere; CVA = Cerebro-Vascular Accident; Mod-Sev = moderate to severe; TBI = traumatic brain injury; ROCF = Rey Osterrieth Complex Figure; BFRT = Benton Facial Recognition Test; POI = Perceptual Organization Index

Effect Sizes Analysis

In order to determine if there are differences between the effect sizes of injury severity and effort, means and F scores were converted into Cohen d’s for the following injury severity levels: mild TBI good effort (mild TBI), moderate-severe TBI (moderate-severe TBI), and right hemisphere CVA (right hemisphere CVA) in relation to controls; and for the effort level mild TBI poor effort in relation to mild TBI good effort (effort).
Then, an ANOVA was performed to see if there were differences between these levels.

Effect sizes (Cohen’s $d$) for mild TBI ranged from -.04 to .05 ($mean = .01$, $sd = .30$), for moderate-severe TBI ranged from .12 to .71 ($mean = .32$, $sd = .22$), for right hemisphere CVA ranged from -17 to .70 ($mean = .32$, $sd = .19$), and for effort ranged from .77 to 1.22 ($mean = .96$, $sd = .20$; see figure 2). The ANOVA was significant. Results showed that the effect size for effort was significantly higher than all the other groups. In addition, the effect sizes for moderate-severe TBI and right hemisphere CVA were significantly higher than mild TBI good effort (see table 8). Thus, these results demonstrate that when effort is controlled there is not effect of mild TBI in visual perception. In addition, there is a clear dose-response curve between the effect sizes of TBI severity in visual perceptual functions. Moreover, the results show a greater effect for effort than all injury severities. A graphical representation of the mean effect sizes calculated in the four treatment groups (mild TBI good effort, mild TBI bad effort, moderate-severe TBI and right hemisphere CVA) for the overall visual perception effect can be seen in Figure 3.
Figure 2. Mean Effect sizes of Mild TBI, Mod-Sev TBI, R-H CVA, and Effort across all the examined variables.

R-H = Right Hemisphere; CVA = Cerebro-Vascular Accident; Mod-Sev = Moderate-to-severe; TBI = Traumatic Brain Injury; ROCF = Rey Osterrith Complex Figure; BFRT = Benton Facial Recognition Test; POI = Perceptual Organization Index.
Table 8

Minimum, Maximum, Mean, Standard Deviation of Visual Perceptual Effect Sizes by Group

<table>
<thead>
<tr>
<th></th>
<th>Mild TBI</th>
<th>Mod-Sev TBI</th>
<th>R-H CVA</th>
<th>Effort</th>
<th>F</th>
<th>p&lt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.01&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.32&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.32&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.96&lt;sup&gt;c&lt;/sup&gt;</td>
<td>29.73</td>
<td>.001</td>
</tr>
<tr>
<td>(SD)</td>
<td>(0.03)</td>
<td>(0.22)</td>
<td>(0.19)</td>
<td>(0.19)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min</td>
<td>-.04</td>
<td>.12</td>
<td>.17</td>
<td>.77</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max</td>
<td>.05</td>
<td>.71</td>
<td>.70</td>
<td>1.22</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. R-H = Right Hemisphere; CVA = Cerebro-Vascular Accident; Mod-Sev = Moderate-to-severe; TBI = Traumatic Brain Injury.

<sup>abc</sup> Row Means with same letter represent homologous subgroups using Tukey’s corrections at p = .05
Figure 3. Mean Effect sizes of Mild TBI, Mod-Sev TBI, R-H CVA, and Effort for overall Visual Perceptual Dysfunction.

R-H = Right Hemisphere; CVA = Cerebro-Vascular Accident; Mod-Sev = Moderate-to-severe; TBI = Traumatic Brain Injury; ROCF = Rey Osterrieth Complex Figure; BFRT = Benton Facial Recognition Test; POI = Perceptual Organization Index.

Individual case Analysis

Visual Perceptual Impairment

In order to understand possible implications of this study to the individual patient, it is important to evaluate the frequency of patients that show visual perceptual impairment. A score of 1.5 standard deviations (sd) or less below the control mean was
considered impaired for this study. Table 9 shows impaired score distribution across each visual perceptual test. Table 10 shows the distributions of the number of impaired test scores by group, as well as the cumulative frequency of impaired scores. What is outstanding about these two tables is that mild TBI poor effort and right hemisphere CVA groups always have a higher number of individuals impaired than the other groups.

In addition, an “overall” visual perceptual impairment was determined. The criteria to determine “impairment” was: scores below 1.5 standard deviations (sd) of the expected score (control group mean) in at least 2 out of the 5 independent tests. This is because the probability to obtain these scores is less than 5% (Ingraham & Aiken, 1996). These standards are conservative because the scores come from one domain (visual perception) and they are not truly uncorrelated. As can be seen in table 10, none of the mild TBI good effort patients showed visual perceptual impairment. Of the moderate-severe TBI group, 3 (15%) patients showed visual perceptual impairment. On the other hand, 9 (45%) of the mild TBI poor effort patients and 6 (30%) of the right-hemisphere CVA showed impairment. A Krustal Wallis was preformed to see if there were significant differences between the groups. Results were significant, $X^2 (df = 2) = 12.91, < .01$. The right hemisphere CVA and the mild TBI poor effort groups appeared more impaired than the mild TBI good effort group ($p < .001$). In addition, mild TBI poor effort group was more impaired than moderate-severe TBI group ($p < .05$). Thus, as
individuals or as a group, mild TBI poor effort patients and right hemisphere CVA patients are more visual perceptually impaired than the mild TBI patients.

Table 9

Frequency of Patients that Failed Test by Group

<table>
<thead>
<tr>
<th>Test</th>
<th>mild TBI good effort</th>
<th>mild TBI bad effort</th>
<th>mod-sev TBI</th>
<th>R-H CVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROCF</td>
<td>0</td>
<td>8 (40%)</td>
<td>4 (20%)</td>
<td>4(20%)</td>
</tr>
<tr>
<td>BFRT</td>
<td>0</td>
<td>2 (10%)</td>
<td>1(5%)</td>
<td>1(5%)</td>
</tr>
<tr>
<td>Block design</td>
<td>1 (5%)</td>
<td>3 (15%)</td>
<td>4(20%)</td>
<td>6(30%)</td>
</tr>
<tr>
<td>Picture com.</td>
<td>1 (5%)</td>
<td>9 (45%)</td>
<td>3(15%)</td>
<td>4(20%)</td>
</tr>
<tr>
<td>Matrix reasoning</td>
<td>1 (5%)</td>
<td>11 (55%)</td>
<td>6(30%)</td>
<td>6(30%)</td>
</tr>
<tr>
<td>POI</td>
<td>1 (5%)</td>
<td>7 (35%)</td>
<td>3(15%)</td>
<td>6(30%)</td>
</tr>
</tbody>
</table>

Note: R-H = Right Hemisphere; CVA = Cerebro-Vascular Accident; Mod-Sev = Moderate-to-severe; TBI = Traumatic Brain Injury; ROCF = Rey Osterrieth Complex Figure; BFRT = Benton Facial Recognition Test; POI = Perceptual Organization Index.
Table 10

Frequency and Cumulative Frequency of Patients that scores 1.5 SD below control mean

<table>
<thead>
<tr>
<th>mild TBI</th>
<th>mild TBI</th>
<th>Mod-Sev</th>
<th>R-H</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>good effort</td>
<td>bad effort</td>
<td>TBI</td>
</tr>
<tr>
<td>F</td>
<td>F (%)</td>
<td>Cum F</td>
<td>F</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>15%</td>
<td>15%</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>15%</td>
<td>30%</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>15%</td>
<td>15%</td>
</tr>
<tr>
<td>0</td>
<td>17</td>
<td>85%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Note. F = Frequency; Cum F = Cumulative Frequency; R-H = Right Hemisphere; CVA = Cerebro-Vascular Accident; Mod-Sev = Moderate-to-severe; TBI = Traumatic Brain Injury.

Malingering Diagnosis

In the previous section it was found that a strong association between effort and visual perceptual dysfunction. Thus, there is a high possibility that those patients who were impaired in visual perception qualify for a diagnosis of Malingering as a Neurocognitive Dysfunction (MND) as defined by Slick, (1999). Criteria were met if the patients had a below chance finding from the PDRT or the test of memory malingering (TOMM), or two indications of malingering from cognitive measures (including the PDRT), or indication of malingering on cognitive measures (including the PDRT) and self-report measures (see Appendix 1 for a list of MND indicators). Results showed that there is, in fact, a strong correlation between visual perceptual dysfunction and the diagnosis of malingering in the mild TBI patients $X^2 (df = 1 ) =19.9, p< .001; Cohen d’s =$
1.41. Table 11 presents the frequency of patients in the mild TBI and moderate-severe TBI groups classified as MND.

**Table 11**

*Frequency of Visual Perceptual Impaired Patients by Malingering Status*

<table>
<thead>
<tr>
<th></th>
<th>Not Malingering</th>
<th>Malingering</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild TBI good effort</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mild TBI bad effort</td>
<td>0</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Mod-Sev TBI</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
</tbody>
</table>

Note: *Mod-Sev = Moderate-to-severe; TBI = Traumatic Brain Injury.*

**Outlier Analysis**

In the previous sections it was concluded that most patients identified as visual perceptually impaired were considered to be classified as poor effort or to have a CVA on the right hemisphere. However, three patients (BC, CW, and MS) from the moderate-severe TBI group passed the PDRT and they were still classified as visual perceptually impaired. Therefore, these patients were selected to be extensively analyzed in order to show what factors affected their performance.

*Patient BC* (for scores see table 12) a 20 years old female with 12 years of education, was classified in this study as a moderate-severe. However, according to the medical records, as a result of the accident the patient also suffered an anoxic injury which could explain her performance. Patient BC stayed in a coma for 45 days. A CT scan revealed no focal injury. In this case medical and neuropsychology experts
concluded that even when patient BC suffered a concussion, the patient’s brain damage was not directly caused by the brain trauma but to the anoxic injury. This patient scored well above cutoffs on all effort testing. Therefore, the poor visual performance of patient BC can be attributed to the complications of the anoxic injury.

Table 12

Visual Perception Scores of Patient BC

<table>
<thead>
<tr>
<th></th>
<th>Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROCF</td>
<td>23.5</td>
</tr>
<tr>
<td>BFRT</td>
<td>34*</td>
</tr>
<tr>
<td>Block Design</td>
<td>5*</td>
</tr>
<tr>
<td>Matrix Reasoning</td>
<td>5*</td>
</tr>
<tr>
<td>Picture Completion</td>
<td>4*</td>
</tr>
<tr>
<td>POI</td>
<td>69</td>
</tr>
</tbody>
</table>

Note. ROCF = Rey Osterrieth Complex Figure; BFRT = Benton Facial Recognition Test; POI = Perceptual Organizational Index.
* Scores below the criteria of Impairment

Patient CW: (for scores see table 13) a 72 years old male with 14 years of education, had a severe TBI. It is outstanding that this patient had a 45 days lost of consciousness. A CT scan showed multiple small contusions in the right frontal and right posterior parietal areas. Athrophy was also noted throughout the fourth ventricle. In addition, patient CW had a pre-accident diagnosis of early Alzheimer’s disease and Alzheimer’s dementia which can be associated in different stages with all the visual perceptual scores. Despite the Alzheimer’s disease patient CW scored well above cutoffs on the effort validity indicators. In general, the head injury that patient CW suffered could have accelerated his dementia process.
Table 13

**Visual Perception Scores of Patient CW**

<table>
<thead>
<tr>
<th></th>
<th>Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROCF</td>
<td>18.5*</td>
</tr>
<tr>
<td>BFRT</td>
<td>41</td>
</tr>
<tr>
<td>Block Design</td>
<td>4*</td>
</tr>
<tr>
<td>Matrix Reasoning</td>
<td>5*</td>
</tr>
<tr>
<td>Picture Completion</td>
<td>5*</td>
</tr>
<tr>
<td>POI</td>
<td>69</td>
</tr>
</tbody>
</table>

*Scores below the criteria of Impairment

*Note. ROCF= Rey Osterrieth Complex Figure; BFRT = Benton Facial Recognition Test; POI = Perceptual Organizational Index.*

Patient MS: (for scores see table 14) a 29 years old male with 13 years of education, classified as moderate TBI. He was comatose for a period of 8 days. In addition, the patient had a previous history of meningitis as a child and had a shunt placed at two weeks of age. Moreover, the patient had seizures at the scene and in the emergency room. An EEG showed a few runs of intermittent theta activity over the frontal regions. Therefore, it is possible that these factors complicated his brain injury. His performance in the effort testing showed no attempt to appear more cognitively impaired than is the case. The patient responses on the MMPI-2 yielded an invalid profile, VRIN = 99, TRIN = 72, suggesting some possible confusion with his responses. In general, patient MS poor performance could be attributed to secondary factors that amplified the brain damage.
Table 14

Visual Perception Scores of Patient MS

<table>
<thead>
<tr>
<th>Test</th>
<th>Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROCF</td>
<td>16.5*</td>
</tr>
<tr>
<td>BFRT</td>
<td>39</td>
</tr>
<tr>
<td>Block Design</td>
<td>5*</td>
</tr>
<tr>
<td>Matrix Reasoning</td>
<td>4*</td>
</tr>
<tr>
<td>Picture Completion</td>
<td>4*</td>
</tr>
<tr>
<td>POI</td>
<td>67</td>
</tr>
</tbody>
</table>

*Scores below the criteria of Impairment.

Note. ROCF = Rey Osterrieth Complex Figure; BFRT = Benton Facial Recognition Test; POI = Perceptual Organizational Index.
Discussion

The present study examined the visual perceptual performance of traumatic brain injury (TBI) patients classified by their injury severity and their effort during the examination. The goal of the present study was to assess and measure the extent of any visual perceptual dysfunction among different injury severity groups and a poor effort group. Results yielded no observable differences between the mild TBI good effort patients and the matched controls. Moderate-severe TBI and the right-hemisphere CVA patients were more impaired than controls and mild TBI good effort patients. Mild TBI poor effort patients showed large impairments despite no observable brain damage.

Implication of the Findings

Effect of Mild TBI in Visual Perception Measurements

The current results are consistent with previously reported findings regarding the long lasting visual perception effects of mild TBI (Fisher, Ledbetter, Cohen, Marmor, & Tulsky, 2000; Donders & Axelrod, 2002). All visual perceptual tests demonstrated zero effect size distinguishing mild TBI good effort with the matched controls. This suggests that if effort is controlled, mild TBI does not have an effect on any visual perceptual measure. These findings are also consistent with the vast majority of previous investigations suggesting that such injuries are typically not associated with persistent symptomatology (Binder et al., 1997; Schretlen et al., 2003; Carroll et al., 2004). Hence, the mild TBI is self-limiting and its effect on visual perceptual performance is, after one year period, imperceptible.
Effect of Severity in Visual Perception Measurements

Previous meta-analytic investigations have suggested that moderate-severe TBI patients remain markedly impaired, in general cognitive tests, 1 year after the injury (Schretlen and Shapiro, 2003). The present findings support these investigations by suggesting a dose-response effect of severity and visual perception. Moderate-severe TBI caused a small to medium impairment effect on overall visual perceptual functioning (Cohen’s d = .32, see Cohen, 1988). Therefore, consistent with the findings of Fisher et al. (2000), these results suggest that the impact of moderate-severe TBI on visual perception measurements is long lasting.

Despite the overall visual perceptual results shown in this study and other studies, different tests have different sensitivities to moderate-severe TBI. The present findings showed that picture completion was the most sensitive to moderate-severe TBI. Specifically, picture completion demonstrated a large effect size (Cohen’s d = .7). In contrast, the ROCF, BFRT and matrix reasoning were the least impaired tests (Cohen’s d range .1 to .3). These findings have been found elsewhere (Ashton et al., 2005; Donders et al., 2001; Levin, 1993). This suggest that the fact that picture completion involve a time limit and the other three tests do not, may be an important reason why there is such a difference. Therefore, despite the similarities of all the visual perceptual tests, the time aspect of the test picture completion and seems to account for a good portion of the overall visual perception variance.

In addition, the nature, the location and the extent of the brain pathology determined test performance. The present findings show that not all patients with moderate to severe TBI demonstrated visual perception impairments, including in
picture completion. In fact, only 15% of the moderate-severe TBI patients (see above) were considered to be visual perceptual impaired (in contrast to 45% of the right-hemisphere CVA patients). This is because some tests designed to measure these cognitive functions are highly sensitive to brain damage in the right-hemisphere and less sensitive to damage in other areas (Ryan et al., 2005; Knight et al., 2006; Benton, 1985). In other words, if the brain injury does not directly affect the area involved in visual perceptual functions, the individual will show less decrement in his/her performance on these specific tests. For example, patient CG a 34 years old men, was found to have a GCS of 9. A Computerized Tomography (CT) scan of his head showed multiples areas of hemorrhaging and contusion status which necessitated a post left parietal craniotomy with a subtotal left frontal lobe resection. This indicates that the patient’s condition involves severe damage localized on the left side with a mild damage on the right side of the brain. Patient CG was aphasic; however, despite this substantial radiologic evidence of brain damage, patient CG did not fail any of the visual perceptual tests. In fact, this patient scored just below the control mean in most tests (see table 16 for test results). Thus, this example clearly suggests that brain damage causes impairment in visual perceptual tasks only if this damage affects the area involved in these functions.
Table 15

Visual Perception Scores of Patient CG

<table>
<thead>
<tr>
<th>Scores</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ROCF</td>
<td>28</td>
</tr>
<tr>
<td>BFRT</td>
<td>39</td>
</tr>
<tr>
<td>Block Design</td>
<td>10</td>
</tr>
<tr>
<td>Matrix Reasoning</td>
<td>11</td>
</tr>
<tr>
<td>Picture Completion</td>
<td>7</td>
</tr>
<tr>
<td>POI</td>
<td>95</td>
</tr>
</tbody>
</table>

Note. ROCF = Rey Osterrieth Complex Figure; BFRT = Benton Facial Recognition Test; POI = Perceptual Organizational Index.

In summary, the current findings propose a dose-response effect between injury severity and visual perception task performance. The impairment effect of moderate-severe TBI in the tasks that measure these skills ranged from small to large. However, it is suggested that an important portion of this effect size correspond to tests that have time constraints. In addition, it was found that the effects of moderate-severe TBI are highly dependent on the nature, the location and the extent of the brain damage. For these reasons, it is crucial that neuropsychologists extensively evaluate a moderate-severe TBI case before diagnosing him/her with visual perception dysfunction.

Effect of Effort on Visual Perception Measures

The work by Green and colleagues (2003) demonstrated that effort affects the dose-response relationship between injury severity and neuropsychological test scores. Moreover, Binder and colleagues (2003) showed that scores below cut-offs in the PDRT are associated with low scores in standardized neuropsychological tests. The present findings support the previous literature by showing large visual perception impairments in the mild TBI poor effort group, despite the fact of having no observable brain damage. Specifically, effort had an effect size on overall visual perceptual functioning 9.6 times
higher than mild TBI, and 3.2 times higher than moderate-severe TBI and right-hemisphere CVA. These results are very similar to those proposed by Iverson’s (2005) review study suggesting that poor effort/malingering has large impairment effect size in cognition (Cohen’s d = 1.1). As a result, the present study reinforces the importance of considering the impact of effort in the context of brain damage-psychometric tests in patients with mild TBI.

Poor effort mild TBI patients not only showed excessive measurable visual perceptual impairment, but they also showed different score patterns than those with brain damage. Malingering studies which have demonstrated that matrix reasoning type tests (Sensitivity = 83 %, false positive error = 5; McKinsey, Podd, Krehbiel, & Raven, 1999), and the copy section of the ROCF (Sensitivity = 50%, false positive error = 18.6; Lu, Boone, Cozolino, & Mitchell, 2003) are more sensitive to exaggeration than brain damage. The present study supports these studies by demonstrating that regardless of time constrain or task requirements, effort had a large impact on all visual perceptual tests. As a consequence, inconsistencies in the mild TBI poor effort patients' behavior are not supported by the parameters of their physical injury, but by their lack of motivation.

Finally, the present findings show that all mild TBI patients classified as visual perceptual impaired where also found to give measurable poor effort (n = 9). In addition, results showed a very strong correlation between those individuals leveled as visual perceptual impaired and those shown to be malingering (Cohen d = 1.41) This suggests that mild TBI causes persistent visual perceptual dysfunctions only when the effects of poor effort and very likely malingering are present. Thus, evidence of poor effort on
even one test raises questions about impaired scores particularly in the mild TBI population, in which persistent cognitive impairment is not expected. In this context, practitioners should always account for effort when determining cognitive outcome of mild TBI; not doing so may lead to erroneous conclusions about the “real” effects of brain damage.

**Limitations and Future Directions**

The limitations of this study need to be recognized. First, it is unlikely that all low performance in visual perceptual tests are limited to only brain dysfunction and malingering. Thus, it is important to recognize that aspects of personality, emotional and/or psychiatric disturbances can have an effect on poor in TBI patients (Emilien & Waltregny, 1996). In addition, it is also possible that pre-morbid intelligence level and drug abuse history can affect visual perceptual performance (Dikmen, Machamer, & Temkin, 1993). Therefore, even when this study has a high internal validity, when applying it to a single clinical patient, other aspects beyond brain damage and malingering should also be studied.

Second, using only the PDRT as effort measure may not fully correspond with good effort during cognitive examinations. Studies have shown that sensitivity to malingering by the PDRT is 71% in mild TBI and 56% in moderate-severe TBI at the 2% cutoffs (Bianchini, Mathias, Greve, Houston, & Crouch, 2001; Greve & Bianchini, 2006). Therefore, the rate of false negatives (i.e. poor effort patients classified as good effort) was expected to be 29% in the mild TBI good effort group. As a consequence, the
present study cannot fully guarantee that good effort in the PDRT is equivalent to good effort in the visual perceptual measurements.

Finally, these groups should be considered the worst case scenario and do not fully represent the TBI population at large. Specifically, these samples represent a population of patients who are seen for neuropsychological evaluation one year post-injury, and they are all involved in litigation or compensation cases. As a result, these patients represent a small sub-population of TBI patients who are particularly prone to persistent symptomatology.

Considering these limitations, further research might focus on the degree that other factors beside brain damage and malingering affect visual perceptual dysfunctions. Additionally, further research should focus on determining new statistical procedures to better classify poor effort individuals.

**Conclusion**

The results of this investigation suggest that visual perceptual impairments can be caused by moderate-severe TBI. However, this effect is highly correlated with the requirements of the task, and the extent of the brain damage. In terms of mild TBI, visual perceptual dysfunctions are not expected, unless evidence of poor effort and/or malingering are present. Therefore, evidence of poor effort on the PDRT increases doubts about impaired visual perception scores; particularly in this population in which persistent cognitive impairment are not expected. As a result, clinicians should extensively examine factors related to psychometric tests, brain damage characteristics -and very importantly poor effort/malingering before diagnosing visual perception dysfunction in TBI patients.
References


## Appendix

### Table A

*Indicators Used to Determine Status for Malingering Neurocognitive Dysfunction*

<table>
<thead>
<tr>
<th>Indicator/Test</th>
<th>Cut-off Below Chance</th>
<th>Reference for Cut-off</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>B2 Criterion</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portland Digit Recognition Test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Easy</td>
<td>&lt; 22</td>
<td>&lt; 12</td>
</tr>
<tr>
<td>Hard</td>
<td>&lt; 20</td>
<td>&lt; 12</td>
</tr>
<tr>
<td>Total</td>
<td>&lt; 44</td>
<td>&lt; 28</td>
</tr>
<tr>
<td>Test of Memory Malingering</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial 2</td>
<td>&lt; 45</td>
<td>&lt; 18</td>
</tr>
<tr>
<td>Retention</td>
<td>&lt; 45</td>
<td>&lt; 18</td>
</tr>
<tr>
<td>WAIS-III</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reliable Digit Span</td>
<td>&lt; 7</td>
<td></td>
</tr>
<tr>
<td><strong>C5 Criterion</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MMPI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>&gt; 80</td>
<td></td>
</tr>
<tr>
<td>Fb</td>
<td>&gt; 80</td>
<td></td>
</tr>
<tr>
<td>FBS</td>
<td>&gt; 27</td>
<td></td>
</tr>
<tr>
<td>Meyers Index</td>
<td>&gt; 5</td>
<td></td>
</tr>
</tbody>
</table>

*Note. WAIS-III = Wechsler Adult Intelligence Scale – Revised or Third edition; MMPI = Minnesota Multiphasic Personality Inventory – Revised; F = Infrequency-back; Fb = Infrequency back; FBS = Fake Bad Scale.*
**Vita**

Luis Aguerrevere was born in Barquisimeto, Venezuela and received a Bachelor of Science in Psychology from Tennessee Technological University in December 2004. Currently, he conducts research with Dr Kevin W. Greve and is a teaching assistant in the UNO Psychology Department. Recently, he has become interested in investigating the contributory factors for cognitive decline in traumatic brain injury patients. He plans to continue this line of research for his dissertation.