Test of Variables of Attention®

Evaluating Attention Deficits in Brain Injury with the T.O.V.A.

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Abstract

Traumatic brain injury is a potential consequence of accidents involving trauma to the head with nearly 1.7 million new cases reported each year. Attention deficits are common sequelae of traumatic brain injury. Whether these deficits are due to primary brain damage or secondary factors such as sleep disturbance, assessment of sustained attention is a vital component of treatment planning and rehabilitation monitoring. The Test of Variables of Attention (T.O.V.A.) is an objective test designed to validly and reliably assess attention deficits and provide advantageous information about vigilance, impulsivity, response variability, and reaction time in a paradigm that tests limits and supersedes compensatory mechanisms. It has been used to monitor treatment effects in a wide variety of conditions and can help identify exaggerated deficits. With the T.O.V.A., clinicians can confidently assess the attentional foundation that is often undermined in traumatic brain injury.

1 Attention

Attention is a basic component upon which all neural processes rely. As such, it is the most fragile cognitive function and attention deficits will undermine the efficiency of more obvious cognitive processes (Miller & Cummings, 2007). The multi-component nature of attention necessitates evaluation of basic, divided, shifting, and sustained attention (Mirsky et al., 1991). Although clinicians may find it expedient to measure basic, divided, and shifting attention through short tasks such as Digit Span or the Trail Making Test, no evaluation of traumatic brain injury is complete without taking the time to assess sustained attention as well.

Attention broadly affects our ability to function and often subjective complaints of memory deficits or other cognitive problems can be attributed to objective attentional impairment. Difficulty with sustained attention leads to problems encoding novel information, accessing stored memories without external cues, and appreciating all relevant information in stressful environments such as driving. It can also lead to slowed response times and problems with multitasking. For children, this may mean difficulty learning in the classroom, keeping up with task demands, or completing assignments on time. For adults, this

may result in missing instructions, forgetting tasks or meetings, and misplacing materials necessary for the job. Attention deficits are associated with poor peer relationships due to difficulty with social exchanges (Barkley, 2002).

2 Traumatic Brain Injury

Traumatic Brain Injury (TBI) has rapidly gained interest in the research and clinical community due to its widespread prevalence in sports and military combat. According to the CDC, approximately 1.7 million people sustain a TBI each year. Of these, about 275,000 are hospitalized and 1.3 million are treated and released from an Emergency Department without further follow-up (Figure 1) (Faul et al., 2010). It is estimated that 5.3 million Americans have persisting cognitive dysfunction secondary to TBI (Stierwalt & Murray, 2002). Because of the potential life-long difficulties associated with moderate to severe TBI, careful cognitive assessment is critical for rehabilitation efforts.

Certainly moderate to severe TBI can result in visible evidence of focal damage to attention structures, but it may also result in diffuse axonal injury. This results in widespread damage to neural networks (Smith & Meaney, 2000), even when the TBI seems mild (e.g., concussion). Symptoms of a TBI are typically most severe at the time of injury before the brain begins a process of recovery. The recovery course depends on the type and severity of injury, and can be monitored with tests of cognition. Whereas one may typically recover from uncomplicated mild TBI within a week, recovering from moderate to severe TBI may take as much as two years (McCrea, 2008), necessitating serial evaluations to monitor progress and modify treatment approaches.

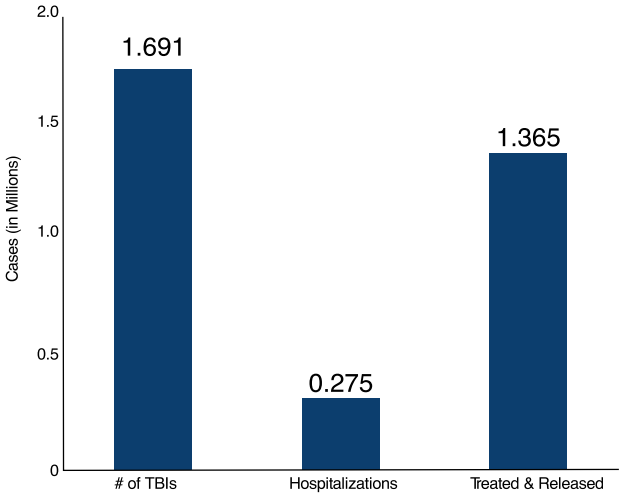

Figure 1: Annual TBI Statistics (Faul et al., 2010)

3 Attention Deficits Following Traumatic Brain Injury

Attention can be compromised by nearly any disruption to normal brain functioning, including acquired traumatic brain injury (Reitan & Klove, 1959). Recent studies have shown that various aspects of attention are affected following TBI, including the ability to initially attend to and encode information (Dejong & Donders, 2010), maintain focus (Thaler et al., 2010), shift attention (Catroppa & Anderson, 2005), and sustain attention (Smilek et al., 2010). Nevertheless, Ginstfeldt & Emanuelson, 2010 found that sustained attention was most vulnerable to TBI, whereas basic attention was least affected. Additionally, Bloomfield et al., 2010 demonstrated that sustained attention measures were sensitive to sleep disturbance following TBI, while other measures of attention were not. Over the course of three months, divided attention has been shown to improve, while sustained attention remained impaired, demonstrating the specific need to assess this important cognitive skill (Kwok et al., 2008). Additionally, studies have linked diffuse axonal injury in frontal and subcortical structures to sustained attention deficits, making this a critical area of assessment (Bonne et al., 2003).

Given the need to sustain attention throughout lengthy tasks, classes, and workdays, and its significant vulnerability to TBI and secondary sequelae, the assessment of sustained attention clearly deserves prominent attention in any clinician's evaluation and treatment of brain-injured individuals. The only caveat is the need for objective assessment given that subjective complaints often have minimal relationship to actual abilities in cases of TBI (Draper & Ponsford, 2009; Lannoo et al., 1998) (Table 1).

Basic Attention	-0.11
Sustained Attention	-0.07
Working Memory	-0.2
Long Term Memory	-0.33

Table 1: Correlations Between Subjective Symptoms and Objective Test Data (Draper & Ponsford, 2009)

4 Test of Variables of Attention

Fortunately, the T.O.V.A. (Test of Variables of Attention) (Greenberg, 2011) provides clinicians with a suitable objective assessment of sustained attention in children as young as four, as well as adults of all ages, in a non-language-based format. Impulse control and consistency of responses in both the visual and auditory domains can also be assessed. Furthermore, reaction times are recorded, which have been found to be the most sensitive single indicator of a brain injury (Collie et al., 2003; Makdissi et al., 2001). In studies of TBI, the T.O.V.A. was sensitive to abnormal attention performance in blast-exposed veterans even when a lifetime history of ADHD was controlled (Trudeau et al., 1998).

The T.O.V.A. Visual and Auditory tests are each 21.6 minutes in length to fully assess the persistence of attentional control in a real-world paradigm that approximates the length of a typical lesson or meeting. The extended length also helps to supersede any com-

pensatory mechanisms that may have been learned and would mask underlying attention deficits. The T.O.V.A. uses specialized hardware and software to precisely, accurately and reliably record responses and reaction times, unlike other continuous performance tests on the market which may include error variance as high as 20% (Leark et al., 2011). The graphical user interface is modern, sophisticated, and user-friendly.

The T.O.V.A. includes two conditions: a low-target-frequency condition that is more sensitive to inattention and a high-target-frequency that is more sensitive to problems with impulse control. Each of these conditions is divided into halves to assist the clinician in detecting difficulty shifting rapidly to a new condition or fatigue over the course of the condition. Across the entirety of the test, basic reaction times are recorded, as is the consistency of those reaction times within the test administration. This provides additional essential information to clinicians for identifying variability in responses, indicative of losing focus when attentional resources are overwhelmed.

Clinicians will appreciate the abundance of data available from the T.O.V.A. The four main factors (attention, impulsivity, reaction time, and reaction time variability) are summarized in text and graph format across the four quarters of the test, in the high- and low-target-frequency conditions only, and for the overall measure. Both raw data and normative comparisons are available. Areas of borderline and abnormal performance are clearly marked. For more advanced users, a multitude of additional information is available. This includes anticipatory responses, post-commission errors, multiple responses (particularly indicative of neurologic dysfunction), and d' (the rate of performance deterioration over time). Graphs of errors are included with visibly identified areas of normal performance. Graphs and tables of individual responses are provided and color-coded with errors in red to make them readily identifiable at a glance.

5 Monitoring TBI with the T.O.V.A.

One of the major benefits of the T.O.V.A. in the assessment of attention deficits following TBI is its ability to be used repeatedly over time to assess recovery and treatment effects with good test-retest reliability and no appreciable practice effects. The Visual T.O.V.A. test has been shown to be sensitive to treatment effects in as little as 90 minutes (Leark et al., 2004), and test-retest coefficients are high (Table 2).

Performance Variable	**After 90 minutes**	**After 1 week**
Response Time Variability	0.87	0.87
Response Time	0.84	0.79
Commission Errors	0.78	0.74
Omission Errors	0.70	0.86

Table 2: Test-retest reliability in the T.O.V.A. after 90 minutes and 1 week (Leark et al., 2004)

The T.O.V.A. has strong empirical support in its use as a measure of change following treatment in a variety of conditions, including ADHD, intellectual abilities, Asperger's Syn-

drome, personality disorders, and medication effects. The use of the T.O.V.A. in monitoring rehabilitation progress following TBI provides clinicians and patients with an objective measure of their progress, which can inform treatment changes as well as decisions regarding return to work or school, especially when these might conflict with subjective impressions of the patient.

6 Detecting Symptom Exaggeration with the T.O.V.A.

For better or worse, many individuals with TBI are involved in litigation or are seeking some type of benefit or accommodation. There is a propensity for some individuals to feign symptoms or put forth suboptimal effort that invalidates the results. The T.O.V.A. provides a Symptom Exaggeration Index within the test that takes no additional time or special procedures (Hughes et al., 2008). This can help to detect individuals who are providing insufficient effort to return valid results or who are fabricating symptoms altogether, leading clinicians to make informed decisions regarding the need for further assessment, treatment, or accommodations without being mislead by erroneous data. The Symptom Exaggeration Index has been independently validated to detect individuals attempting to feign attention deficits associated with ADHD (Leark et al., 1999). This was later extended to include individuals attempting to feign attention deficits in the context of mild TBI (Henry, 2005).

7 Conclusion

Sustained attention is highly vulnerable to TBI, and a deficit in this cognitive area has a significant impact on all aspects of daily functioning, from completing tasks in a timely manner to maintaining quality relationships. A deficit in sustained attention is difficult to self-identify and is often overlooked in traditional office visits. The T.O.V.A. provides a valid and reliable objective measure of sustained attention that can be used for the detection of attention deficits following TBI, as well as to monitor recovery and treatment progress.

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