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The effects of mild and severe traumatic brain injury on speed of information processing as measured by the computerized tests of information processing (CTIP)☆

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Abstract

In spite of the fact that reaction time (RT) measures are sensitive to the effects of traumatic brain injury (TBI), few RT procedures have been developed for use in standard clinical evaluations. The computerized test of information processing (CTIP) [Tombaugh, T. N., & Rees, L. (2000). *Manual for the computerized tests of information processing* (*CTIP*). Ottawa, Ont.: Carleton University] was designed to measure the degree to which TBI decreases the speed at which information is processed. The CTIP consists of three computerized programs that progressively increase the amount of information that is processed. Results of the current study demonstrated that RT increased as the difficulty of the CTIP tests increased (known as the complexity effect), and as severity of injury increased (from mild to severe TBI). The current study also demonstrated the importance of selecting a non-biased measure of variability. Overall, findings suggest that the CTIP is an easy to administer and sensitive measure of information processing speed.

Keywords: Computerized tests of information processing; CTIP; TBI

The potential value of using reaction time (RT) tests in neuropsychological evaluations was recognized as early as 1971 when Bruhn and Parsons (1971) stated "the simple RT test has merit as a diagnostic tool equivalent to that found in more sophisticated and complex psychological tests" (p. 614). More recent evidence from a variety of sources supports this contention and indicates that simple and choice reaction times provide a quick, yet easy and valid clinical tool for assessing cognitive status and should be incorporated into the neuropsychological assessment battery for traumatic

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brain injury (TBI) (Braun, Daigneault, & Champagne, 1989; Elsass & Hartelius, 1985; Ferraro, 1996). Moreover, Bleiberg, Halpern, Reeves, and Daniel (1998) concluded that RT procedures reveal cognitive impairment even when normal performance is shown on traditional neuropsychological measures. Further support for using RT tests clinically is the fact that relatively high test–retest reliability coefficients and split half coefficients are reported for RT tests (Godefroy, Lhullier, & Rousseaux, 1994; Hetherington, Stuss, & Finlayson, 1996; Stuss, Pogue, Buckle, & Bondar, 1994; Stuss et al., 1989).

However, not all reaction time measures are equivalent or sensitive. Simple RT tests, which reflect the speed at which a stimulus is detected, are less sensitive to the cognitive sequelae of TBI than are choice or discrimination paradigms where responding is contingent on the information contained in two or more stimuli (Collins & Long, 1996; Hugenholtz, Stuss, Stethem, & Richard, 1988; Stuss et al., 1989). This differential sensitivity is referred to as the complexity effect. Since simple reaction time is commonly regarded as a "pure" measure of speed of information processing, it can be used as a covariate in choice RT analyses to control for decreased speed of processing in basic cognitive processes. Several studies have adopted this procedure and reported that the previously observed RT difference between Control and TBI patients disappeared (Brouwer, Ponds, van Wolffelaar, & van Zomeren, 1989; Felmingham, Baguley, & Green, 2004; Spikman, van Zomeren, & Deelman, 1996; Veltman, Brouwer, van Zomeren, & van Wolffelaar, 1996). This has led to the suggestion that TBI produces a generalized slowing of information processing that has a major impact on various other attentional and cognitive processes such as encoding, verbal comprehension, and adaptive responding to novel situations (Felmingham et al., 2004; Ferraro, 1996).

The clinical utility of RT measures rests not only with the initial assessment for level of impairment, but also with tracking recovery. RTs have revealed that recovery of function occurs in cross sectional and longitudinal research, over short (3–6 months) and extended time periods (5 years versus 10 years), and with both mild and severe TBIs (Felmingham et al., 2004; Hetherington et al., 1996; Hugenholtz et al., 1988; MacFlynn, Montgomery, Fenton, & Rutherford, 1984; Spikman, Timmerman, van Zomeren, & Deelman, 1999; van Zomeren & Deelman, 1978; Zwaagstra, Schmidt, & Vanier, 1996). The lack of practice effects with most RT tests make them ideal measures for serial examinations.

In spite of the above, reaction time procedures have seldom been used in standard clinical evaluations (Erlanger, Kunter, Barth, & Barnes, 1999). The failure to incorporate RT measures into clinical neuropsychological assessments stems from several sources. One reason is that surprisingly few experiments have directly compared the relative sensitivity of RT and standardized neuropsychological measures to detect cognitive deficits. The few comparative studies that are available suggest that RT measures are more sensitive to the long term effects of head injury than are most traditional neuropsychological tests (Bleiberg et al., 1998; Collins & Long, 1996; Maddocks & Saling, 1996).

A second reason why RT measures are not commonly used in clinical assessments is the lack of adequately normed RT tests. This is attributed, at least in part, to the fact that until recently computer technology was not sufficiently advanced so that RT programs could be developed with sufficient temporal resolution (1 ms). Additionally, the computer programs that were available experimentally could not be readily adapted to the ordinary clinical environment. Recent advances in computer operating systems now makes it relatively easy to achieve a 1 ms resolution and most programs are compatible with existing operating systems. As a result of these advances, a panel of sports neuropsychologists have recommended the development and validation of computerized tests (Lovell & Collins, 1998).

In view of the above, Tombaugh and Rees (2000) developed the computerized test of information processing (CTIP) to provide a clinical tool for evaluating the degree to which various neurological insults, primarily traumatic brain injury, affect the speed at which information is processed. In order to do this, a series of computerized programs were developed that progressively increase the amount of information processed. The most basic test, Simple RT, is often viewed as a pure speed of information processing measure and can serve as a baseline for other tests. Choice procedures were also included. The type of choice paradigm was deemed to be critical and two types of procedures were employed. The first paradigm involved concrete or literal processing where two choice stimuli remained the same over all trials. The second procedure involved conceptual/semantic processing where the items varied between trials and the choice decision required a semantic or lexical search. The selection of this paradigm was based on the semantic search paradigm used in cognitive psychology (Chang, 1986; Loftus, 1973) and guided by neuropsychological research showing that a TBI decreases semantic processing (Haut, Petros, Frank, & Lamberty, 1990; Hinton-Bayre, Geffen, & McFarland, 1997; Levin & Goldstein, 1986; Timmerman & Brouwer, 1999; Wilson et al., 1999).