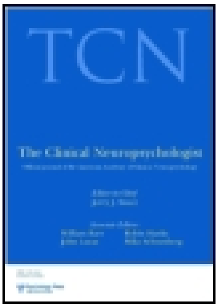

The Clinical Neuropsychologist
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/ntcn20

Neuropsychological Assessment of Distractibility in Mild Traumatic Brain Injury and Depression

Ralf Schnabel [a] & Rob Kydd [a]

[a] Department of Psychological Medicine, University of Auckland, New Zealand

Available online: 14 Jun 2012

The Clinical Neuropsychologist, 2012, 1–21, iFirst
http://www.psypress.com/tcn
ISSN: 1385-4046 print/1744-4144 online
http://dx.doi.org/10.1080/13854046.2012.693541

Neuropsychological Assessment of Distractibility in Mild Traumatic Brain Injury and Depression

Ralf Schnabel and Rob Kydd
Department of Psychological Medicine, University of Auckland, New Zealand

Traditional neuropsychological assessments are conducted exclusively in a quiet, distraction-free environment; clients' abilities to operate under busy and distracting conditions remain untested. Environmental distractions, however, are typical for a multitude of real-life situations and present a challenge to clients with frontal-temporal brain injury. In an effort to improve ecological validity, an extension of the traditional neuropsychological assessment was developed, comprising a standardized distraction condition. This allowed cognitive functions to be tested both in the traditional setting and with exposure to a specified audio-visual distraction. The present study ($n = 240$) investigated how clients with mild Traumatic Brain Injury (mTBI) ($n = 80$), Major Depression (MDE) ($n = 80$), and a healthy control sample ($n = 80$) performed on sub-tests of the Wechsler Adult Intelligence Scale-IV and the Wechsler Memory Scale-IV both in the standard and the distraction conditions. Test effort was controlled. Significant deterioration of performance in the distraction setting was observed among clients with mTBI. In contrast the performance of a healthy control sample remained unchanged. Significant improvement of performance in the distraction setting was documented for clients with MDE. Contrary to their improved performance, depressed clients experienced the distraction setting as more distressing than the control and mTBI group.

Keywords: Environmental distraction; Neuropsychological assessment; Ecological validity; Traumatic brain injury; Major depressive episode.

INTRODUCTION

A large number of cognitive studies in the past decades investigating mild Traumatic Brain Injury (mTBI) have failed to document significant cognitive incapacity on formal testing (Binder, Rohling, & Larrabee, 1997; Frencham, Fox, & Maybery, 2005; Rohling et al., 2011). These findings contrast the subjective appraisal of a sub-group of clients with mTBI who complain about a persistent constellation of cognitive, somatic, and emotional symptoms, typically described as "post-concussion syndrome" (PCS). The most commonly reported symptoms are physical and mental fatigue, headache, dizziness, decreased concentration, memory problems, irritability, sensitivity to noise and light, problems with decision making, depression, and anxiety (Rees & Bellon, 2007; Ryan & Warden, 2003). However, the construct of a PCS, neurologically related to mTBI, was challenged by the considerable overlap between the cognitive, physical, and emotional symptoms of PCS and the cluster of symptoms experienced by clients with chronic pain,

Address correspondence to: Ralf Schnabel, Department of Psychological Medicine, University of Auckland, Private Bag 92019, Auckland, New Zealand. E-mail: rsch087@aucklanduni.ac.nz
Accepted for publication: May 3, 2012. First published online: June 14, 2012.

depression, and stress disorders (Iverson & McCracken, 1997; Iverson & Lange, 2003). High endorsement rates of "PCS" symptoms were documented even for healthy participants with no history of brain injury (Chan, 2001; Garden & Sullivan, 2010; Gunstad & Suhr, 2004; Iverson, 2006; Wang, Chan, & Deng, 2006; Wong, Regennitter, & Barrios, 1994). The authors concluded that there are non-neurological mechanisms in the experience and expression of PCS following brain trauma, and called for caution in the clinical interpretation of results from symptom inventories of PCS. This has further been endorsed by concerns about the validity of cognitive impairment following mTBI. Studies investigating the role of motivational factors for sub-optimum test performance in mTBI populations have acknowledged the context of litigation and secondary gain, and highlighted the need to control for poor test effort, malingering, and factitious disorders (Bush et al., 2005; Green, Rohling, Lees-Haley, & Lyle, 2001; Sollman & Berry, 2011).

In recognizing the lack of evidence for significant cognitive impairment even for motivated mTBI sufferers, the following methodological question arises: Is there no cognitive impairment after mTBI or has the established approach to testing and assessment failed to identify cognitive changes secondary to mTBI? For instance, newer brain-imaging techniques suggest that at least a subset of these patients may have diffuse axonal injury, not evident on standard CT or MRI scans (Bigler & Bazarian, 2010). In other words, how sure can we be that test results obtained with traditional tools in the laboratory-type environment of a standard assessment are sufficiently representative of the clients' actual capacity; would an unimpaired performance on a concentration or memory test obtained in a quiet, distraction-free evaluation room be a valid predictor for unimpaired capacity of a client returning to a busy family or a workplace with multiple stimulation and complex attention demands? The question concerned is one of ecological validity, focusing on "transferability" of neuropsychological test results into other, potentially much more challenging, environments (Sbordone, 1996). The term *veridicality* ("truthfulness") has come to be used for describing the degree to which the performance on neuropsychological tests predicts real-life performance (Franzen & Wilhelm, 1996), and a substantial body of research has emerged analyzing the relationship between test achievements and actual functional capacity. The overall findings suggest that a "modest" or "moderate" relationship exists between performance on neurocognitive testing and everyday functioning, depending on the specific neuropsychological tests utilized (Kibby, Schmitter-Edgecombe, & Long, 1998), the specific real-life capacity investigated (Marcotte, Scott, Kamat, & Heaton, 2010), the type of injury/incapacity (Chaytor & Schmitter-Edgecombe, 2003; Silverberg, Hanks, & McKay, 2007; Wood & Liossi, 2006), and the brain function analyzed (Chaytor & Schmitter-Edgecombe, 2003).

Given concerns that abstract, clerical tests may insufficiently relate to challenges typical of real-life, efforts were made towards developing test material with greater intuitive resemblance to tasks of daily life. Such tests present a model-task with formal or conceptual characteristics which are closely related to a key task in everyday life. The assumption here is that ecological validity would increase, based on the close relationship between the test-task and the real-world activity (Spooner & Pachana, 2006). The degree to which a test resembles or approximates a real-life situation has been described as the *verisimilitude* ("truth-likeness") of a test

(Franzen, 2000). Examples for tests with improved verisimilitude are the Hamburger Turning Test (Shugars, 2007), the Test of Everyday Attention (Bate, Mathias, & Crawford, 2001; Robertson, Ward, Ridgeway, & Nimmo-Smith, 1996), and the Zoo Map Test (Wilson, Alderman, Burgess, Emslie, & Evans, 2003), which include a number of ''ecologically plausible'' tasks, such as searching through telephone directories, operating a faux barbecue, and planning a strategic route on the map of a zoo. Even such practical tests, however, are conducted in a testing environment with minimized distractions and fall short of representing more than a small section of the cognitive challenges in real-life (Chaytor & Schmitter-Edgecombe, 2003; Long & Collins, 1997; Long & Kibby, 1995).

Previous research has highlighted that one of the most prominent features of acquired brain damage, specifically with frontal lobe impact, is clients' inability to manage distractions imposed by complex, busy environments. Damage to the frontal lobes of the brain was demonstrated to correlate with deficits in working memory and inhibitory control in children and adolescents (Hartnedy & Mozzoni, 2000; Levin et al., 1993, 2002, 2004, 2008; Levin & Hanten, 2005). Similar association between frontal lobe brain damage and subsequent problems with attention control/distractibility have been documented among adults (Brewer, 1998; Brewer, Metzger, & Therrien, 2002; Couillet et al., 2010; Knight, Titov, & Crawford, 2006; Krawczyk et al., 2008; Lutz, 1999; Trudel, Tryon, & Purdum, 1998).

Given the substantial body of evidence recognizing distractibility and inability for blocking out environmental distraction as a key feature of acquired brain injury, it is striking that the formal evaluation of clients' capacity for managing environmental distractions has not been part of the clinical neuropsychological assessment. In order to obtain a more realistic picture of a client's cognitive capacities in a real-life situation, it would seem desirable that at least some cognitive functions be tested not only in the quiet, concentrated setting of the standard assessment, but additionally with (controlled) exposure to environmental distraction. The expectation that clients with frontal lobe injuries perform significantly worse with environmental distraction, compared to their achievements in the noise-reduced, standard testing-condition, is investigated in the current study.

Problems with environmental distractibility are reported not only by clients with brain injuries of various causation and severity, but occur frequently in the context of mental health disorders, including depression (American Psychiatric Association, 2000, p. 356). Neuropsychological assessments are increasingly utilized for comprehensively assessing the cognitive impact of a client's depression, for monitoring the progress of cognitive recovery (Elinson, Houck, Marcus, & Pincus, 2004), and for differential diagnosis between organic changes to the brain and depression (Attix & Welsh-Bohmer, 2005; Sweet, Newman, & Bell, 1992). Meta-analyses of depression-related cognitive impairment highlighted episodic memory and attention (Zakzanis, Leach, & Kaplan, 1999) and frontal lobe functions, encompassing executive functions and concentration/attention which, in turn, influence performance in other areas, such as memory (McClintock, Husain, Greer, & Cullum, 2010). Functional magnetic resonance imaging (fMRI) studies have suggested that these performance problems by clients with MDE are underpinned by altered neuronal functioning in the frontal lobe of the brain (Harvey et al., 2005; Hugdahl et al., 2007).

Consistent with tradition, neuro-cognitive assessments for clients with MDE are conducted solely in a quiet setting with minimized environmental distractions. In recognition that the engagement of frontal lobe functions, such as concentration and working memory, were found to be sub-optimum in low stimulation settings (McClintock et al., 2010), the current study examines the possibility for such decreased frontal lobe activation to be temporarily improved by exposure to a powerful environmental distraction during testing, resulting in enhanced performance. The expected effect is already well known in clinical settings. Depression-related rumination interferes with performance on academic tasks (Berman, 2010; Lyubomirsky, Kasri, & Zehm, 2003; Watkins & Brown, 2002). In contrast, task focus and test performance improve when depressed clients get temporarily distracted from thinking about their symptoms and problems (Donaldson & Lam, 2004). Therefore we expect the distraction condition to serve as an incentive for the depressed client to focus on the test task with positive effects on performance.

In analogy to everyday situations, a distraction condition as part of an extended neuropsychological assessment needs to comprise a primary attention task (focus task), preferably with known performance parameters under standard conditions, and a replicable audio-visual stimulation to create interference. Such a formalized distracting condition would be presented as a brief addition to the usual assessment procedure of not more than a few minutes and allow a direct comparison between performances under distraction and under standard conditions.

In summary, the current study had two main objectives. First, to develop a short, replicable, additional test condition that includes standardized auditory/visual distraction-stimuli; second, to examine the effect of this test condition on performance among mTBI and MDE patients and healthy controls.

METHOD

Testing of cognitive performance in a normative distraction condition

Development of an effective distraction condition. For this study we defined environmental distraction settings using two parameters: (1) a demanding primary attention task (focus task) in which the client is fully engaged and tries to remain fully engaged, and (2) a simultaneous, competitive environmental stimulation (distraction) which interferes with processing the primary attention task. The distraction has to be powerful enough to interfere with usual task processing in a measurable way without causing distress to the client. The stimulus has to bear close resemblance to distracting conditions commonly experienced in real-life situations to promote ecological validity (verisimilitude). For reasons of practicality, the distraction condition has to be easily reproducible by other clinicians in various clinical set-ups and short enough to ensure that the overall neuropsychological evaluation does not extend beyond more than 5 minutes in total.

In a pilot study different stimuli and physical set ups were trialed, including different auditory and visual distractions, different volumes, and different sitting arrangements. Clients rated how the specific test setting matched the experience of a busy environment in their daily lives, and the impact of different set-ups on test performances was analyzed. It quickly became apparent that the condition rated as most ''typical'' and ''natural'' for daily life distractions involved auditory distraction by a visible speaker. Most of our initial clients confirmed that the interference imposed was greatest when test material and distraction material were similar. Clients who listened to a set of short stories, such as the ''Logical Memory'' (LM) stories of the Wechsler Memory Scale [WMS-IV] (Wechsler, 2009), found it most distracting when other prose was read out simultaneously in the background. Correspondingly, while working on number tests such as ''Digit Span Forward'' (DSF), ''Digit Span Total'' (DST), or ''Letter/Number-Sequencing'' (LNS) of the Wechsler Adult Intelligence Scale (WAIS-IV) (Wechsler, 2008), maximum distraction was imposed by presenting numbers in the background.

Formal characteristics of the distraction condition. In taking into consideration the clients' feedback and the impact of different arrangements on test scores, defining parameters for an effective distraction setting were available. The format adhered to in this study is described below.

The seating of client and examiner, as well as other context variables of the test setting such as temperature, light, and sitting arrangement remained identical in the standard condition and the distraction condition. The distraction was provided by playing two specific computerized audio-visual recordings showing a woman reading a news item (''file 1'') and random numbers (''file 2''). The files were played on a laptop computer with a screen sized 365 mm × 205 mm (ø 16.5 inch) with an external speaker providing a sound level of 55 Db (±10 Db) for each file. The distraction story selected was rated as moderately interesting by both men and women without gender bias. The story line featured a non-violent robbery of diamonds narrated in easily understandable English. Readability parameters were broadly comparable to the WMS-IV LM stories, comprising a Flesch Reading Ease score of 50 and Flesch-Kincaid Grade score of 8.5. The laptop was positioned like a third person in an equilateral triangle, with a distance of approximately 1 meter (39 inches) from both client and examiner. After playing ''file 1'' (story file) for 8 seconds the examiner provided a short lead-in talk, comprising the following sentences (verbatim): ''So, you now hear and see our distraction. I will keep talking over her voice for a while so you get used to this background noise. You do not have to look at the screen. You can look at me or somewhere else in the room if you like. When I start reading my story you only listen to my story. Try to ignore this background noise; just listen to me. OK, here is my first story.'' The recoding was stopped immediately after the examiner finished reading the first story of the WMS-IV LM sub-test. Thereafter the client was asked to report as many items he or she remembered from the story, in accordance with the WMS-IV test manual. After noting the client's responses, the examiner resumed playing ''file 1'' in the background while reading out the second LM story. Once the reading was completed the examiner discontinued playing ''file 1'' and noted the client's recall of the second story. Using a similar format, the WAIS IV sub-tests Digit Span Forward (DSF), Digit Span Total (DSF), and Letter-Number-Sequencing (LNS) were presented. Here, however, ''file 2'' was played in the background comprising uninterrupted sequences of random numbers. The distraction procedure was additional to testing under standard conditions. The specified sub-tests of the WMS-IV and WAIS-IV were presented twice, under quiet conditions and with controlled environmental distraction. The order of presentation, standard setting followed by distraction setting, and distraction setting followed by standard setting, was counterbalanced.

Controlling practice effect when retesting logical memory. Testing of clients both in the standard condition and the distraction condition essentially constitutes a test/retest setting which can bear the risk of incurring learning effects. This risk is relatively low in the number and number/letter repetition/ordering tests (DSF, DST, LNS), as clients are unlikely to learn and recall multi-digit random numbers after singular exposure. In contrast, the stimulus stories of the LM are easily remembered and require the use of alternative stories (Schnabel, 2012). An alternative set of stimulus stories with high structural and empirical compatibility with the WMS standard stories was recently published by Schnabel (2012) based on a large clinical sample ($N = 240$) of clients with mTBI, MDE, and a Control Group. The current study utilizes the LM standard stories and the alternative stories in the two test conditions to minimize practice effects.

Participants

A total of 240 clients were recruited for the present study, comprising 80 clients with mTBI and 80 clients with a current diagnosis of MDE who were referred to a community-based Psychological Assessment and Rehabilitation Centre in Auckland, and a sample of 80 healthy volunteers (control group) recruited informally.

Clients were included in the mTBI sample when referred with this diagnosis made by a multi-disciplinary team, based on standard diagnostic parameters (Carroll et al., 2004; Ruff et al., 2009). The criteria comprise traumatic disruption of brain function, as manifested by at least one of the following: any loss of consciousness, any loss of memory for events immediately before or after the accident, any alteration in mental state at the time of the accident, and focal neurologic deficit(s) that may or may not be transient. The diagnostic parameters further include that the injury-related loss of consciousness does not exceed 30 minutes; an initial Glasgow Coma Scale score of 13–15 needs to be obtained after 30 minutes, and post-traumatic amnesia of less than 24 hours needs to be documented. For 74 clients of the mTBI sample comprehensive medical records were available, which noted GCS scores between 10 and 15 upon arrival in hospital[1] (mean 14.2, *SD* 1.3); all clients suffered LOC, with estimations ranging from 3 to 30 minutes (mean 9 minutes, *SD* 6 minutes). Length of PTA was formally documented only for 62 clients, and was less than 24 hours in all cases. A total of 59 clients received a CT brain scan, 27 for whom changes were identified on imaging which were treated conservatively. None of the mTBI clients had a pre-existing history of epilepsy, although eight clients suffered epileptic

[1]In nine cases GCS scores below 13 were documented upon admission which improved in A&E upon medical stabilization within 30 minutes.

seizures either at the scene of the injury (six clients) or within 1 month following the injury (two clients). A total of 31 clients had previous concussions or minor mTBI, but none of these injuries had resulted in significant or prolonged symptoms. For all clients, post-injury headaches, dizziness, fatigue, and concentration problems were recorded on file; these symptoms were confirmed as ongoing concerns at the time of the assessment. All mTBI clients were between 54 to 129 days (mean 88 days, *SD* 21 days) post-injury at the time of assessment. None of the mTBI clients had a formal psychiatric history or a history of acquired brain injury, including previous significant TBI, cerebral vascular accident, tumor, neurotoxic exposure, HIV, dementia, or other diagnosed cerebral conditions. The assessment was undertaken in the context of rehabilitation planning and not as part of a medico-legal dispute. All mTBI clients had an established claim with the national Accident Compensation Corporation and about one third had additional claims with private insurance companies and cover decisions that were pending. The Test of Memory Malingering [TOMM] (Tombaugh, 2003) and additional clinical and psychometric measures for appraising test effort was presented to all participants; 11 mTBI clients failed the TOMM cut-off criterion (fewer than 45 recognitions on Trial 2) by a wide margin (means 34,39, and 31, respectively for sub-tests) and were therefore not included in the sample. Recruiting continued until a target sample size of $n = 80$ was reached. The mean TOMM scores for the mTBI sample were 49.6, 50, and 50, respectively. Within the scope of mTBI definition, the sample recruited would rank in the middle to upper end of severity, with at least one third of the sample presenting with formal complications (prolonged LOC, low initial GCS, seizures, abnormalities on CT imaging). It is also important to highlight that the study sample was selected from the minority of clients with mTBI in the community, who presented to hospital-based emergency services and who continued to experience neuro-cognitive changes for longer than a few weeks post injury.

Clients with MDE were included in the study upon referral under such diagnosis according to DSM-IV TR criteria (American Psychiatric Association, 2000), assessed by the client's general practitioner (general medical officer) and confirmed separately by a psychiatrist. For 52.5% of clients selected for the study this was their first formally diagnosed depressive episode; for the remaining 47.5% the current episode was a relapse of symptoms in the context of a major depressive disorder. The sample did not include clients in the depressive cycle of a diagnosed bipolar disorder. About 13% of clients had a previous anxiety disorder diagnosis. None of the clients had a history of psychosis or a diagnosed personality disorder. Participating MDE clients had no history of acquired brain injury, including brain trauma, or other diagnosed cerebral conditions. All MDE clients had an established claim with an insurance company, covering loss of income due to medical incapacity (“income protection insurance”), and the assessment was conducted solely for the purpose of rehabilitation planning.

Inclusion criteria for the control group were absence of current or past mental health disorders (of any type), and absence of current or past acquired brain injury, other than trivial concussions. All members of the control group and of the MDE group met the TOMM criteria for sufficient test effort. Participants from either group had not been previously exposed to comprehensive neuro-cognitive testing.

Design and procedure

Three sub-tests of the WAIS-IV (DSF, DST, and LNS) and one sub-test of the WMS-IV (LM) were chosen for presentation with and without distraction. The common link of the selected sub-tests is a working memory component which was expected to be affected by distraction. DSF and DST are overlapping measures; DSF is a fully integrated sub-task (singularity) of the DST, a comprehensive compound test, which additionally includes Digit Span Backwards and Ascending Digit Span. While not independent measures, DSF, DST, and LNS represent increasing levels of complexity, ranging from simple, to mixed simple and complex, to very complex. The current research project presented the above measures, with and without distraction, to clients with mTBI, with MDE and a control sample. Each client was tested twice, in the distraction condition and in the standard condition. The order in which the conditions were presented was counterbalanced, whereby the first client took part first in the distraction setting followed by the standard setting, and the second client was first presented with standard testing, followed by distraction testing. Within the four sub-tests the order was not varied; LM was always followed by DSF, DST, and LNS. Alternative test stimuli and standard test stimuli for LM were presented in a randomized counterbalanced order, using a random-generation website (Haahr, 2002).

No significant amount of time elapsed between standard testing and distraction testing. Both raw scores and scaled scores were calculated. The conversion of raw scores into scaled scores was undertaken based on the client's age at the time of the assessment and the WMS-IV/WAIS-IV conversion tables. Subjective levels of distress imposed by the standard and distraction condition were obtained immediately after each condition was completed, using a 10 point Visual Analogue Scale (VAS). Scores on the Beck Depression Inventory 2nd edition (BDI-II) (Beck, Steer, & Brown, 1996) were obtained for all clients prior to commencing testing.

Statistical methods

Biases in the distribution of gender, age, ethnicity and education in the sample were explored using chi square analysis. A mixed-model ANOVA was used to explore the within-participants (standard vs distraction condition) and between-participants relationships (MDE, mTBI, Controls), separately for each test (LM, DSF, DST, LNS). Both raw and scaled scores were analyzed. Independent sample T-tests were used to analyze the impact of education, age, and gender on change of performance in the experimental condition for all sub-tests. Independent sample T-tests were also employed to investigate whether the order of testing conditions (standard setting followed by distraction setting, or distraction setting followed by standard setting) had an impact on the scores obtained. T-tests were also used to explore differences in the story presentation (first standard stories followed by alternative stories, or first alternative stories followed by standard stories). Furthermore it was investigated whether practice effects had occurred by comparing the means of performance in the first presentation with the means of the second presentation. Pearson correlations explored the relationship between

BDI-II scores and the change in test performance under the distraction condition. All analyses were performed using PASW/SPSS version 18 (IBM Corporation, New York, USA).

RESULTS

Consistent with the higher prevalence of depression among women (American Psychiatric Association, 2000), 60% of the MDE sample was female. Equally consistent with the epidemiological distribution of mTBI (Rickels, von Wild, & Wenzlaff, 2010; Tagliaferri, Compagnone, Korsic, Servadei, & Kraus, 2006) is the higher proportion of male clients in the mTBI group (61%). The control group was selected to have equal gender balance. Maori/Pacific-Islanders were over-represented in the mTBI sample (25%), consistent with the elevated incidence-rate of mTBI in these ethnic groups in New Zealand (New Zealand Guidelines Group, 2006). The control group is consistent with the ethnic distribution of the New Zealand population (Statistics New Zealand, 2010) (see Table 1).

Baseline testing of the different study groups in the controlled condition revealed overall similar achievements in most tests for all three groups, apart from LNS where MDE clients held an advantage over mTBI clients. The distraction condition impacted markedly on achievements of both mTBI and MDE clients

Table 1. Participants' sociodemographic characteristics by study group

	Study group		
Characteristics	MDE ($n = 80$)	mTBI ($n = 80$)	Controls ($n = 80$)
Age (mean ± *SD*)	44.7 ± 9.3*	38.6 ± 12.2	41.5 ± 13.9
Age (min/max)	23–60	18–64	16–69
Gender (*n*, %)			
Female	48 (60.0)**	31 (38.8)	40 (50.0)
Male	32 (40.0)	49 (61.3)**	40 (50.0)
Years of education (*n*, %)			
≤8	0 (0)	2 (2.5)	4 (5.0)
9 to 11	6 (7.5)	11 (13.8)	19 (23.8)
12	26 (32.5)	30 (37.5)	31 (38.8)
13 to 15	27 (33.8)	29 (36.3)	18 (22.5)
≥16	21 (26.3)	8 (10.0)	8 (10.0)
min/max	10–27	8–24	8–22
Ethnicity (*n*, %)			
Caucasian	69 (86.3)	51 (63.8)	56 (70.0)
Maori/Pacific	6 (7.5)	20 (25)***	10 (12.5)
Asian	5 (6.3)	2 (2.5)	8 (10.0)
Other	0 (0)	7 (8.8)	6 (7.5)

MDE = Major depressive episode.
mTBI = Mild traumatic brain injury.
*$p < .05$; MDE group older than mTBI group.
**$p < .05$; Female over-represented in MDE group, male over-represented in mTBI group.
***$p < .05$; Maori/Pacific over-represented in mTBI group.

Table 2. Test scores derived from standard and distraction setting by study group

Tests by study group	Standard condition *n*	Standard Mean	Standard *SD*	*p** MDE	*p** mTBI	*p** Control	Distraction condition *n*	Distraction Mean	Distraction *SD*	*p*** MDE	*p*** mTBI	*p*** Control	****p*
MDE (Raw Scores)													
Logical Memory	80	26.60	5.57	–	<.01	.40	80	29.63	5.15	–	<.001	<.001	<.001
Digit Span Forward	80	10.45	1.61	–	.33	.72	80	11.85	1.42	–	<.001	<.001	<.001
Digit Span Total	80	28.44	3.54	–	<.01	.17	80	30.93	2.95	–	<.001	<.001	<.001
Letter-Number-Sequ.	80	21.03	2.54	–	<.01	<.01	64	19.94	3.19	–	<.001	.04	<.001
MDE (Scaled Scores)													
Logical Memory	80	10.59	2.02	–	<.01	.34	80	12.00	1.80	–	<.001	<.001	<.001
Digit Span Forward	80	9.88	1.74	–	.74	.34	80	11.53	1.63	–	<.001	<.001	<.001
Digit Span Total	80	10.34	1.68	–	<.01	.31	80	11.59	1.49	–	<.001	<.001	<.001
Letter-Number-Sequ.	79	10.94	1.92	–	<.01	<.01	64	10.23	1.92	–	<.001	.06	<.001
mTBI (Raw Scores)													
Logical Memory	80	23.06	5.10	<.01	–	<.01	80	16.70	5.41	<.001	–	<.001	<.001
Digit Span Forward	80	10.18	1.97	.33	–	.23	80	7.71	2.14	<.001	–	<.001	<.001
Digit Span Total	80	25.71	4.51	<.01	–	.02	80	19.58	5.13	<.001	–	<.001	<.001
Letter-Number-Sequ.	37	17.27	3.76	<.01	–	<.01	37	12.65	4.15	<.001	–	<.001	<.001
mTBI (Scaled Scores)													
Logical Memory	80	9.18	2.24	<.01	–	.06	80	6.08	2.48	<.001	–	<.001	<.001
Digit Span Forward	80	9.78	2.09	.74	–	.24	80	6.96	2.43	<.001	–	<.001	<.001
Digit Span Total	80	9.09	1.92	<.01	–	.01	80	5.98	2.25	<.001	–	<.001	<.001
Letter-Number-Sequ.	37	8.24	2.20	<.01	–	<.01	37	5.46	2.38	<.001	–	<.001	<.001
Control (Raw Scores)													
Logical Memory	80	27.36	5.92	.40	<.01	–	80	25.96	6.25	<.001	<.001	–	.01
Digit Span Forward	80	10.55	1.93	.72	.23	–	80	10.45	2.05	<.001	<.001	–	.35
Digit Span Total	80	27.48	5.19	.17	.02	–	80	26.91	5.48	<.001	<.001	–	.02
Letter-Number-Sequ.	76	19.94	2.98	<.01	<.01	–	35	18.46	3.48	.04	<.001	–	<.01
Control (Scaled Scores)													
Logical Memory	80	10.24	2.54	.34	.06	–	80	10.21	2.49	<.001	<.001	–	.83
Digit Span Forward	80	10.19	2.36	.34	.24	–	80	10.01	2.55	<.001	<.001	–	.23
Digit Span Total	80	9.99	2.55	.31	.01	–	80	9.70	2.69	<.001	<.001	–	.01
Letter-Number-Sequ.	76	10.31	2.69	<.01	<.01	–	35	9.37	2.61	.06	<.001	–	<.01

MDE = Major depressive episode.
mTBI = Mild traumatic brain injury.
*p Difference between study groups in standard condition.
**p Difference between study groups in distraction condition.
***p Intra-participant difference between standard condition and distraction condition.

whereby, on a within-participants comparison, a significant deterioration of performance was noted with mTBI and a significant improvement was documented with MDE. For control participants no significant change of test performance was noted in the distraction condition. The described changes were demonstrated equally for raw scores and for scaled scores (see Table 2).

Significant differences between study groups were documented in the distraction setting, with MDE clients performing best, followed by Control and mTBI groups (Figure 1). A mixed-model ANOVA showed significant differences ($p < .001$) and medium to large effect sizes (eta^2 values between 0.07 and 0.49) on

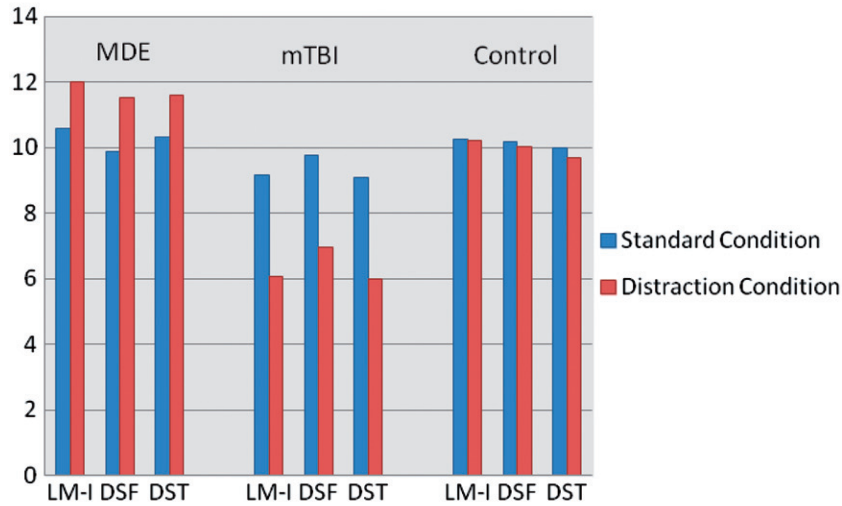

Figure 1. Change of performance in Standard vs. Distraction conditions ($n = 240$). MDE = major depressive disorder; mTBI = mild traumatic brain injury; LM-1 = logical memory test; DSF = digit span forwards; DST = digit span total.

within-participants comparison of performances in the two testing conditions. In comparing performances of different study groups (between-participants comparison), significant differences ($p < .001$) and large effect sizes (eta^2 values between 0.23 and 0.38) were obtained. Each comparison of the performances of the study groups found that the cognitive tests differ in usefulness and differential power. LM and DST produced the largest changes of performances in the distraction setting (raw score: eta^2 = 0.12 and 0.17; mean differences = 3.03 ± 3.83 and 2.49 ± 2.83, respectively). The within-participants performance on DSF still varied significantly with distraction, albeit to a lesser degree (eta^2 = 0.07; mean differences = 1.40 ± 1.20) (see Table 3). The highly demanding LNS test did not provide useful measurements: a substantial number of clients (20% MDE, 54% mTBI, 56% Control) abandoned working on the LNS test in distraction setting, as they felt overwhelmed. The significant drop-out rate for LNS makes this sub-test not a viable option for distraction testing. LNS scores were subsequently excluded from further analysis.

Consistent with expectations, BDI-II scores differed significantly between the three study groups, with MDE clients scoring in the "moderately-severe" range (mean 27.25 ± 5.99), mTBI[2] clients in the "mild" range (mean 16.61 ± 6.92), and control participants in the minimal range (mean 3.48 ± 3.25). In the MDE group clients with higher BDI-II scores were found to achieve greater improvement in the distraction condition ($r = .32$ for LM, $r = .44$ for DSF). No significant correlation

[2]It is important to note the overlap between PCS symptoms and the BDI-II questions, including ambiguous items such as "concentration difficulties", "problems with decision-making", "low energy", "fatigue", "irritability" etc. MTBI clients inevitably score in the "mild symptom range" on the BDI-II when they endorse common PCS symptoms.

Table 3. Mixed-model ANOVA analysis of within-participant and between-participant differences on test performance

	Within-participant differences (Standard vs. Distraction condition)					Between-participant differences (MDE, mTBI, vs. controls)				
Tests	Mean square	*df*	*F*	*p*	Eta^2	Mean square	*df*	*F*	*p*	Eta^2
LM I Raw Scores	299.25	1	32.17	<.001	0.120	3089.102	2	58.262	<.001	0.330
Digit Forward Raw Scores	18.019	1	17.492	<.001	0.069	205.652	2	34.484	<.001	0.225
Digit Total Raw Scores	236.602	1	48.150	<.001	0.169	2037.775	2	55.493	<.001	0.319
LNS Raw Scores	373.575	1	106.485	<.001	0.445	740.963	2	40.151	<.001	0.376
LM I Scaled Scores	39.102	1	28.756	<.001	0.108	569.652	2	63.144	<.001	0.348
Digit Forward Scaled Scores	23.852	1	17.834	<.001	0.070	234.452	2	29.280	<.001	0.198
Digit Total Scaled Scores	61.633	1	49.907	<.001	0.174	489.940	2	61.675	<.001	0.342
LNS Scaled Scores	148.653	1	129.578	<.001	0.493	348.186	2	39.529	<.001	0.373

MDE = Major depressive episode.
mTBI = Mild traumatic brain injury.
LNS = Letter-Number-Sequencing Test.

Table 4. Pearson correlation between BDI-II score and changes in performance (within participants) by study group (raw scores)

Tests by study group (raw scores)	*n*	Within-participants changes between Standard and Distraction condition (mean/*SD*)	BDI-II Scores	Pearson correlation coefficients
MDE			27.25** ± 5.99	
Logical Memory	80	3.03* ± 3.83		.32**
Digit Span Forward	80	1.40* ± 1.20		.44**
Digit Span Total	80	2.49* ± 2.83		.13
mTBI			16.61** ± 6.92	
Logical Memory	80	−6.36* ± 4.91		−.13
Digit Span Forward	80	−2.46* ± 1.96		−.08
Digit Span Total	80	−6.14* ± 4.15		−.05
Controls			3.48** ± 3.25	
Logical Memory	80	−1.40 ± 4.13		−.14
Digit Span Forward	80	−.10 ± .95		−.05
Digit Span Total	80	−.56 ± 2.05		−.07

*$p < .001$ within-participant difference between conditions.
**$p < .01$ correlation between change of performance and BDI-II scores.
MDE = Major depressive episode.
mTBI = Mild traumatic brain injury.
BDI-II = Beck Depression Inventory 2nd version.

between BDI-II scores and change in performance was documented for the mTBI and Control group (see Table 4). Subjective Levels of Stress (VAS) under the distraction condition were explored for different sub-groups. In contrast to their actual performance, MDE clients considered the distraction setting significantly more distressing than the mTBI clients. No significant gender differences were noted

Table 5. Differences in stress levels under Distraction condition for different groups

	Groups					
Stress levels (VAS)	MDE $n = 80$	mTBI $n = 80$	Female $n = 128$	Male $n = 132$	Complete LNS $n = 142$	Incomplete LNS $n = 108$
mean ± *SD*	6.58 ± 1.56	5.23 ± 1.64	5.36 ± 1.74	5.45 ± 2.05	5.82 ± 1.83	4.86 ± 1.87
Mean difference	1.35*		.09		.96*	

*$p < .001$ (2-tailed).
MDE = Major depressive episode.
mTBI = Mild traumatic brain injury.
LNS = Letter-Number-Sequencing Test.
VAS = Visual Analogue Scale.

in the appraisal of stress in all clinical groups. In comparing the stress levels of clients who abandoned the LNS tasks under the distraction condition with clients who completed this task, greater stress was reported by those clients who had continued exposure (see Table 5).

With regard to the order of test conditions (standard setting followed by distraction setting, or distraction setting followed by standard setting), no significant differences were found. Equally no significant differences were found between means of performance in the first presentation with the means of the second presentation of test stimuli of either sub-test, suggesting that no significant practice effects had occurred (Table 6).

No significant gender bias was demonstrated with regard to performance of most sub-tests under distraction (DSF and DST $p > .15$; LM $p = .05$ and .02). In addition the effect of distraction did not differ between older clients (43 years or older) and younger clients (<43 years old) ($p > .16$). Highly educated clients (more than 12 years of education) were equally affected by the distraction setting as less educated clients (12 or less years of education) ($p > .27$). This was demonstrated for all measures (LM, DSD, DST), both for raw scores and scaled scores (Table 7).

DISCUSSION

Although environmental distractibility is a well-known, often debilitating, feature of acquired brain injury the standard neuropsychological assessment investigates cognitive performance solely in a distraction-free environment. Traditionally clients' abilities to manage environmental distractions have remained untested. The current study presents a short, standardized, and easily replicable distraction procedure which allows the examiner to study a client's test performance with exposure to environmental distraction. The performances under the distraction condition and under the traditional, quiet condition can directly be compared. For a sample of mTBI clients, with injuries at the higher end of the mild category, significant decline was demonstrated in the distraction condition for working memory, including simple concentration (WAIS-IV DSF) and mixed simple/complex concentration (WAIS-IV DST) (overlapping with DSF), and for

Table 6. Differences in order of condition and order of stories

	First WMS stories, then Schnabel stories								First Schnabel stories, then WMS stories									
	Recall in Standard condition				Recall in Distraction condition				Recall in Standard condition				Recall in Distraction condition					
LM (Raw Scores)	*n*	*Mean*	*SD*	*p**	*n*	*Mean*	*SD*	*p**	*n*	*Mean*	*SD*	*p**	*n*	*Mean*	*SD*	*p**	*p***	*p****
First Standard then Distraction condition	60	25.23	6.07	.84	60	23.97	6.99	.78	60	25.80	5.30	.72	60	24.27	8.82	.91	.60	.84
First Distraction then Standard condition	60	25.47	6.53		60	23.56	9.13		60	26.17	5.54		60	24.44	7.23		.55	.58

**p* Difference between order of condition.
***p* Difference between order of stories in Standard condition.
****p* Difference between order of stories in Distraction condition.

Table 7. Change of performance (Standard vs. Distraction condition) by Education, Gender, and Age

	Years of education					Gender					Age					Order of test setting				
	≤12 years ($n = 129$)		>12 years ($n = 111$)			Male ($n = 121$)		Female ($n = 119$)			<43 years ($n = 115$)		≥43 years ($n = 125$)			Standard setting first ($n = 120$)		Distraction setting first ($n = 120$)		
Tests	*Mean*	*SD*	*Mean*	*SD*	*p*	*Mean*	*SD*	*Mean*	*SD*	*p*	*Mean*	*SD*	*Mean*	*SD*	*p*	*Mean*	*SD*	*Mean*	*SD*	*p*
Changes in LM (Raw Scores)	1.96	4.87	1.14	6.65	.27	2.31	6.35	.83	5.01	.05	2.07	5.2	1.13	6.25	.20	1.36	5.70	1.80	5.84	.55
Changes in DSF (Raw Scores)	.38	1.83	.40	2.47	.95	.59	2.39	.18	1.85	.15	.61	1.9	.18	2.30	.13	.24	2.03	.53	2.24	.29
Changes in DST (Raw Scores)	1.57	4.35	1.22	5.19	.57	1.57	4.97	1.24	4.53	.59	1.85	4.1	.99	5.24	.16	1.23	4.80	1.58	4.71	.56
Changes in LM (Scaled Scores)	.60	2.14	.54	2.87	.86	.96	2.73	.18	2.19	.02	.38	2.34	.38	2.63	.21	.46	2.35	.68	2.65	.49
Changes in DSF (Scaled Scores)	.49	2.36	.40	2.57	.77	.66	2.60	.23	2.28	.17	.65	2.41	.26	2.49	.21	.31	2.33	.58	2.58	.39
Changes in DST (Scaled Scores)	.80	2.17	.62	2.64	.57	.82	2.55	.61	2.23	.51	.89	2.11	.56	2.62	.29	.63	2.45	.81	2.34	.55

LM = Logical Memory I
DSF = Digit Span Forward.
DST = Digit Span Total.

logical memory (WMS-IV LM). No gender, education, or age biases were demonstrated. Motivational factors, including malingering, were excluded by employing clinical and psychometric procedures to establish the validity of the data obtained.

In contrast, participants from the control group did not present with significant changes of their test performance in the distraction condition. In full command of their regular cognitive capacities, healthy clients were able to "block out" the distracting stimuli without experiencing distress or decline in performance. It appears the specifics of the distraction setting and the WAIS-IV/WMS-IV sub-tests LM, DSF, and DST have struck the right balance to be sufficiently challenging for impacting on the performance in mTBI clients, but to be manageable enough for healthy clients to achieve essentially unchanged results. Such balance was not attained in the sub-test LNS which turned out to be unachievable in the distraction setting for both healthy and brain-injured clients, producing an unacceptable drop-out rate.

Significantly, depressed clients were shown to improve in the distraction condition on three measures: LM, DSF, and DST. An investigation of stress levels experienced by MDE clients in the distraction setting demonstrated significantly higher stress levels compared to the other groups. Although the additional challenge of environmental distraction caused rising stress levels in all study groups, the increase of distress was greatest for the MDE group. Qualitatively, clients with depression described the distraction condition as "unbearable" and "terrible", and often became tearful, despite their substantial improvement in test achievements. It appears that the distraction condition provided a "boost" and temporary lifted performance close to pre-morbid capacities, albeit at great costs for the client in terms of personal exertion and frustration. Of course these findings do not suggest that MDE clients would be able to sustain their improved cognitive performance for longer periods of time under such challenging distracting circumstances. Given the degree of distress and frustration with this setting and the high efforts required, it is likely that MDE clients would "burn out" after a relatively short time and return to the levels of cognitive functioning documented in standard testing conditions. MTBI clients, in contrast, reported only moderately increased emotional distress. On qualitative appraisal, clients with mTBI described "dizziness", "headaches", and "feeling puzzled" rather than emotional distress by the distraction, confirming that the decline in cognitive performance is not affect-related, according to clinical indicators.

The specific procedure of distraction-testing developed for this study appears to differentiate between clients with MDE, mTBI, and healthy controls, based on the changes in performances under distraction. This may be of clinical relevance for differential diagnosis between these groups, as well as for appraising the state of recovery of a client with either of the clinical diagnoses. Based on the data obtained, it would be indicative of substantial remission of the cognitive effects of either MDE or mTBI when the distraction condition no longer imposes significant changes of performance (in either direction) compared to the standard condition. Such unchanged performance would be characteristic for healthy control participants and suggest recovery. On the other hand, significant change of performance in the distraction condition would suggest that further rehabilitation needs to occur before a client can successfully or sustainably return to an occupational role with complex attention demands.

The distraction procedure also controlled for practice effects, based on alternative test stimuli which can be used for retesting LM in the distraction condition. Although learning of test material (stimulus learning) is the most obvious pitfall, practice effects can occur as a result of decreasing test anxiety, having greater familiarity with the test settings, procedural learning, and improvement in test-taking strategy (Goldberg et al., 2010). This was investigated and no practice effects were found.

The distraction procedure was validated as a short and practical addition to the standard neuropsychological assessment, adding less than 5 minutes to the testing time. The procedure is standardized, comprising objective parameters of setting and distraction stimuli which can be replicated easily in different clinical and research settings.

Further validation is needed to confirm the effectiveness of the distraction setting with additional diagnostic groups, such as severe TBI, dementia, HIV, toxicity, and other medical conditions with cerebral impact. As these groups often present with changes to frontal lobe functioning, significant enough to be evident on standard testing, an even greater incapacity to perform in the distraction condition is expected, compared to the mTBI sample of our study. Vice versa, mTBI clients who suffered relatively trivial injury with subsequent fast and uncomplicated recovery (representing the majority of mTBI) are expected to pass the distraction setting without significant changes, as no significant frontal lobe damage has occurred. Further investigations into different types of background distractions and variable time spans are also needed to determine parameters for improving or declining performance in different clinical groups.

Limitations of this study include the use of a solely New Zealand test population which may reduce the generalizability of results. It should also be considered that scaled scores were calculated based on the WMS-IV and WAIS-IV normative samples (Wechsler, 2008, 2009). There are insufficient data to assert that raw scores obtained in the distraction condition will universally correspond to the score distribution provided by the WMS-IV/WAIS-IV normative sample for the standard condition. Furthermore, the MDE sample did not include clients younger than 23 years or older than 60 years; the mTBI sample only had clients aged between 18 and 64, suggesting that additional validation efforts be undertaken for younger and older age groups.

Consistent with the epidemiological gender distribution of mTBI and MDE men were over-represented in the mTBI and under-represented in the MDE sample. As women performed slightly better than men on LM in the distraction condition, the possibility cannot be ruled out that gender differences drive some of the observed findings. Accordingly, future research may take an interest in gender specific responses to environmental distraction.

Future research might consider the involvement of fMRI imaging in studies on distraction, given the promising data presented in recent years about the recruitment of additional brain resources with exposure to auditory distraction (Campbell, 2005; Gisselgård, Petersson, Baddeley, & Ingvar, 2003; Gisselgård, Petersson, & Ingvar, 2004). For future research endeavors a validated environmental distraction procedure is herewith available, comprising objective parameters of test setting and distraction stimuli which can be replicated easily in different clinical and research settings with minimum impact on total assessment time.

REFERENCES

American Psychiatric Association (2000). *Diagnostic and Statistical Manual of Mental Disorders, 4th edition, text revision [DSM-IV-TR]*. Washington, DC: American Psychiatric Association..

Attix, D. K., & Welsh-Bohmer, K. A. (2005). *Geriatric neuropsychology: Assessment and intervention*. New York: Guilford Press.

Bate, A. J., Mathias, J. L., & Crawford, J. R. (2001). Performance on the Test of Everyday Attention and standard tests of attention following severe traumatic brain injury. *The Clinical Neuropsychologist*, *15*(3), 405–422.

Beck, T. A., Steer, R. A., & Brown, G. K. (1996). *Beck Depression Inventory – Second edition (BDI-II)*. San Antonio, TX: The Psychological Corporation.

Berman, M. G. (2010). Memory, interference, and depression. PhD, University of Michigan, Michigan..

Bigler, E. D., & Bazarian, J. J. (2010). Diffusion tensor imaging: A biomarker for mild traumatic brain injury? *Neurology*, *74*(8), 626–627.

Binder, L. M., Rohling, M. L., & Larrabee, G. J. (1997). Part I: Meta-analytic review of neuropsychological studies. *Journal of Clinical and Experimental Neuropsychology*, *19*(3), 421–431.

Brewer, T. L. (1998). Attentional impairment in minor brain injury. Dissertation Abstracts International: Section B. *The Sciences and Engineering*, *59*(2-B), 0599.

Brewer, T. L., Metzger, B., & Therrien, B. (2002). Trajectories of cognitive recovery following a minor brain injury. *Research in Nursing & Health*, *25*(4), 269–281.

Bush, S. S., Ruff, R. M., Tröster, A. I., Barth, J. T., Koffler, S. P., Pliskin, N. H., et al. (2005). Symptom validity assessment: Practice issues and medical necessity NAN policy & planning committee. *Archives of Clinical Neuropsychology*, *20*(4), 419–426.

Campbell, T. (2005). The cognitive neuroscience of auditory distraction. *Trends in Cognitive Sciences*, *9*(1), 3–5.

Carroll, L. J., Cassidy, J. D., Holm, L., Kraus, J., Coronado, V. G., & WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury (2004). Methodological issues and research recommendations for mild traumatic brain injury: The WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. *Journal of Rehabilitation Medicine*, *43*, 113–125.

Chan, R. C. K. (2001). Base rate of post-concussion symptoms among normal people and its neuropsychological correlates. *Clinical Rehabilitation*, *15*, 266–273.

Chaytor, N., & Schmitter-Edgecombe, M. (2003). The ecological validity of neuropsychological tests: A review of the literature on everyday cognitive skills. *Neuropsychology Review*, *13*(4), 181–197.

Couillet, J. S. S., Lebornec, G., Asloun, S., Joseph, P. A., Mazaux, J. M., & Azouvi, P. (2010). Rehabilitation of divided attention after severe traumatic brain injury: A randomised trial. *Neuropsychological Rehabilitation*, *20*(3), 321–339.

Donaldson, C., & Lam, D. (2004). Rumination, mood and social problem-solving in major depression. *Psychological Medicine*, *34*, 1309–1318.

Elinson, L., Houck, P., Marcus, S. C., & Pincus, H. A. (2004). Depression and the ability to work. *Psychiatric Services*, *55*, 29–34.

Franzen, M. D. (2000). *Reliability and validity in neuropsychological assessment*. New York: Springer.

Franzen, M. D., & Wilhelm, K. L. (Eds.). (1996). *Conceptual foundations of ecological validity in neuropsychological assessment*. Delray Beach, FL: GR Press/St. Lucie Press.

Frencham, K. A., Fox, A. M., & Maybery, M. T. (2005). Neuropsychological studies of mild traumatic brain injury: A meta-analytic review of research since 1995. *Journal of Clinical and Experimental Neuropsychology*, *27*(3), 334–351.

Garden, N., & Sullivan, K. A. (2010). An examination of the base rates of post-concussion symptoms: The influence of demographics and depression. *Applied Neuropsychology*, *17*(1), 1–7.

Gisselgård, J., Petersson, K. M., Baddeley, A., & Ingvar, M. (2003). The irrelevant speech effect: A PET study. *Neuropsychologica*, *41*, 1899–1911.

Gisselgård, J., Petersson, K. M., & Ingvar, M. (2004). The irrelevant speech effect and working memory load. *Neuroimage*, *22*, 1107–1116.

Goldberg, T. E., Keefe, R. S., Goldman, R. S., Robinson, D. G., & Harvey, P. D. (2010). Circumstances under which practice does not make perfect: A review of practice effect literature in schizophrenia and its relevance to clinical treatment studies. *Neuropsychopharmacology*, *35*, 1053–1062.

Green, P., Rohling, M., Lees-Haley, P. R., & Lyle, M. A. (2001). Effort has a greater effect on test scores than severe brain injury in compensation claimants. *Brain Injury*, *15*(12), 1045–1060.

Gunstad, J., & Suhr, J. A. (2004). Cognitive factors in post-concussion syndrome symptom report. *Archives of Clinical Neuropsychology*, *19*, 391–405.

Haahr, M. (2002). *www.random.org True Random Number Service*. Dublin: School of Computer Science and Statistics at Trinity College.

Hartnedy, S., & Mozzoni, M. P. (2000). Managing environmental stimulation during meal time: Eating problems in children with traumatic brain injury. *Behavioral Interventions*, *15*(3), 261–268.

Harvey, P. O., Fossati, P., Pochon, J. B., Levy, R., LeBastard, G., Lehéricy, S., et al. (2005). Cognitive control and brain resources in major depression: An fMRI study using the n-back task. *NeuroImage*, *26*, 860–869.

Hugdahl, K., Specht, K., Biringer, E., Weis, S., Elliott, R., Hammar, A., et al. (2007). Increased parietal and frontal activation after remission from recurrent major depression: A repeated fMRI study. *Cognitive Therapy and Research*, *31*(2), 147–160.

Iverson, G., & McCracken, L. (1997). 'Post-concussive' symptoms in persons with chronic pain. *Brain Injury*, *11*, 783–790.

Iverson, G. L. (2006). Misdiagnosis of the persistent post-concussion syndrome in patients with depression. *Archives of Clinical Neuropsychology*, *21*, 303–310.

Iverson, G. L., & Lange, R. T. (2003). Examination of "postconcussion-like" symptoms in a healthy sample. *Applied Neuropsychology*, *10*(3), 137–144.

Kibby, M. Y., Schmitter-Edgecombe, M., & Long, C. J. (1998). Ecological validity of neuropsychological tests: Focus on the California Verbal Learning Test and the Wisconsin Card Sorting Test. *Archives of Clinical Neuropsychology*, *13*(6), 523–534.

Knight, R. G., Titov, N., & Crawford, M. (2006). The effects of distraction on prospective remembering following traumatic brain injury assessed in a simulated naturalistic environment. *Journal of the International Neuropsychological Society*, *12*(1), 8–16.

Krawczyk, D. C., Morrison, R. G., Viskontas, I., Holyoak, K. J., Chow, T. W., Mendez, M. F., et al. (2008). Distraction during relational reasoning: The role of prefrontal cortex in interference control. *Neuropsychologia*, *46*, 2020–2032.

Levin, H. S., Culhane, K. A., Mendelsohn, D., Lilly, M. A., Bruce, D., Fletcher, J. M., et al. (1993). Cognition in relation to magnetic resonance imaging in head-injured children and adolescents. *Archives of Neurology*, *50*, 897–905.

Levin, H. S., & Hanten, G. (2005). Executive functions after traumatic brain injury in children. *Pediatric Neurology*, *33*, 79–93.

Levin, H. S., Hanten, G., Chang, C. C., Zhang, L., Schachar, R., Ewing-Cobbs, L., et al. (2002). Working memory after traumatic brain injury in children. *Annals of Neurology*, *52*, 82–88.

Levin, H. S., Hanten, G., Roberson, G., Li, X., Ewing-Cobbs, L., Dennis, M., et al. (2008). Prediction of cognitive sequelae based on abnormal computed tomography findings in children following mild traumatic brain injury. *Journal of Neurosurgery: Pediatrics*, *1*, 461–470.

Levin, H. S., Hanten, G., Zhang, L., Swank, P. R., L, E.-C., Dennis, M., et al. (2004). Changes in working memory after traumatic brain injury in children. *Neuropsychology*, *18*, 240–247.

Long, C. J., & Collins, L. F. (Eds.). (1997). *Ecological validity and forensic neuropsychological assessment*. New York: Plenum.

Long, C. J., & Kibby, M. Y. (1995). Ecological validity of neuropsychological tests: A look at neuropsychology's past and the impact that ecological issues may have on its future. *Advances in Medical Psychotherapy*, *8*, 59–78.

Lutz, R. L. (1999). Assessment of attention in adults following traumatic brain injury. *Vocational Evaluation & Work Adjustment Journal*, *32*(1), 47–53.

Lyubomirsky, S., Kasri, F., & Zehm, K. (2003). Dysphoric rumination impairs concentration on academic tasks. *Cognitive Therapy and Research*, *27*(3), 309–330.

Marcotte, T. D., Scott, J. C., Kamat, R., & Heaton, R. K. (2010). *Neuropsychology and the prediction of everyday functioning*. New York: Guilford Press.

McClintock, S. M., Husain, M. M., Greer, T. L., & Cullum, C. M. (2010). Association between depression severity and neurocognitive function in major depressive disorder: A review and synthesis. *Neuropsychology*, *24*(1), 9–34.

New Zealand Guidelines Group. (Ed.). (2006). *Traumatic brain injury: Diagnosis, acute management and rehabilitation*. Wellington, NZ: Accident Compensation Corporation..

Rees, R. J., & Bellon, M. L. (2007). Post concussion syndrome ebb and flow: Longitudinal effects and management. *NeuroRehabilitation*, *22*(3), 229–242.

Rickels, E., von Wild, K., & Wenzlaff, P. (2010). Head injury in Germany: A population-based prospective study on epidemiology, causes, treatment and outcome of all degrees of head-injury severity in two distinct areas. *Brain Injury*, *24*(12), 1491–1504.

Robertson, I. H., Ward, T., Ridgeway, V., & Nimmo-Smith, I. (1996). The structure of normal human attention: The Test of Everyday Attention. *Journal of the International Neuropsychological Society*, *2*(6), 525–534.

Rohling, M. L., Binder, L. M., Demakis, G. J., Larrabee, G. J., Ploetz, D. M., & Langhinrichsen-Rohling, J. (2011). A meta-analysis of neuropsychological outcome after mild traumatic brain injury: Re-analyses and reconsiderations of Binder et al. (1997), Frencham et al. (2005), and Pertab et al. (2009). *The Clinical Neuropsychologist*, *25*(4), 608–723.

Ruff, R. M., Iverson, G. L., Barth, J. T., Bush, S. S., Broshek, D. K., Policy, N. A. N., et al. (2009). Recommendations for diagnosing a mild traumatic brain injury: A National Academy of Neuropsychology education paper. *Archives of Clinical Neuropsychology*, *24*(1), 3–10.

Ryan, L. M., & Warden, D. L. (2003). Post concussion syndrome. *International Review of Psychiatry*, *15*(4), 310–316.

Sbordone, R. J. (1996). *Ecological validity: Some critical issues for the neuropsychologist*. Delray Beach, FL: GR Press/St. Lucie Press.

Schnabel, R. (2012). Overcoming the challenge of re-assessing logical memory. *The Clinical Neuropsychologist*, *26*, 102–115.

Shugars, S. L. (2007). *A functional assessment of executive functioning: the Hamburger Turning Task*. Masters: University of Pittsburgh.

Silverberg, N. D., Hanks, R. A., & McKay, C. (2007). Cognitive estimation in traumatic brain injury. *Journal of the International Neuropsychological Society*, *13*(5), 898–902.

Sollman, M. J., & Berry, D. T. R. (2011). Detection of inadequate effort on neuropsychological testing: A meta-snalytic update and extension. *Archives of Clinical Neuropsychology*, *26*(8), 774–789.

Spooner, D. M., & Pachana, N. A. (2006). Ecological validity in neuropsychological assessment: A case for greater consideration in research with neurologically intact populations. *Archives of Clinical Neuropsychology*, *21*(4), 327–337.

Statistics New Zealand. (2010). *The Social Report*. Wellington: New Zealand Ministry of Social Development..

Sweet, J. J., Newman, P., & Bell, B. (1992). Significance of depression in clinical neuropsychological assessment. *Clinical Psychology Review*, *12*(1), 21–45.

Tagliaferri, F., Compagnone, C., Korsic, M., Servadei, F., & Kraus, J. (2006). A systematic review of brain injury epidemiology in Europe. *Acta Neurochirurgica*, *148*(3), 255–268.

Tombaugh, T. N. (2003). The Test of Memory Malingering (TOMM) in forensic psychology. *Journal of Forensic Neuropsychology*, *2*(3&4), 69–96.

Trudel, T. M., Tryon, W. W., & Purdum, C. M. (1998). Awareness of disability and long-term outcome after traumatic brain injury. *Rehabilitation Psychology*, *43*(4), 267–281.

Wang, Y., Chan, R. C. K., & Deng, Y. (2006). Examination of post-concussion-like symptoms in healthy university students: Relationships to subjective and objective neuropsychological function performance. *Archives of Clinical Neuropsychology*, *21*, 339–347.

Watkins, E., & Brown, R. G. (2002). Rumination and executive function in depression: an experimental study. *Journal of Neurology, Neurosurgery, and Psychiatry*, *72*, 400–402.

Wechsler, D. (2008). *Wechsler Adult Intelligence Scale – Fourth edition – Technical and interpretive manual*. San Antonio, TX: Pearson.

Wechsler, D. (2009). *Wechsler Memory Scale – Fourth edition – Technical and interpretive manual* (4th ed.). San Antonio, TX: Pearson.

Wilson, B. A., Alderman, N., Burgess, P. W., Emslie, H., & Evans, J. J. (2003). Behavioural Assessment of the Dysexecutive Syndrome (BADS). *Journal of Occupational Psychology, Employment and Disability*, *5*(2), 33–37.

Wong, J. L., Regennitter, R. P., & Barrios, F. (1994). Base rate and simulated symptoms of mild head injury among normals. *Archives of Clinical Neuropsychology*, *9*(5), 411–425.

Wood, R. L., & Liossi, C. (2006). The ecological validity of executive tests in a severely brain injured sample. *Archives of Clinical Neuropsychology*, *21*(5), 429–437.

Zakzanis, K. K., Leach, L., & Kaplan, E. (1999). *Neuropsychological differential diagnosis*. the Netherlands: Krips, BV Meppel.