Ecological Validity of Traditional Neuropsychological Tests

Role of Memory and Executive Skills in Predicting Functional Ability in a Clinical Population

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Table of Contents

Abstract

While neuroimaging data are useful in assessing brain-injury outcomes, these data do not provide information regarding how a patient will function in their everyday environment (Bigler, 2001). Consequently, neuropsychological evaluations are often conducted in order to obtain information regarding the extent of cognitive impairment, which is often used to make predictions about functional capacity (Lezak, Howieson, & Loring, 2004). Neuropsychology may be an especially appropriate arena in the prediction of resuming everyday activities for those who have experienced a brain injury (e.g., closed head injury, cerebrovascular accident, cerebral abscess) or for those who have a neurodegenerative disorder (e.g., dementia). Past research that has examined the ecological validity of neuropsychological tests for predicting functional outcome has resulted in mixed findings. Therefore, the question to be addressed is whether ecological validity exists for traditional neuropsychological tests in the prediction of everyday skills. To address these research questions, data were collected and analyzed on 39 outpatients who were referred for a neuropsychological evaluation at Allegheny General Hospital. Specific areas that were examined included measures of executive functioning and memory. Functional ability was assessed using the Independent Living Scales (ILS), which assesses cognition as it affects daily functioning (i.e., instrumental activities of daily living [IADL]). Using multiple regression analyses, the role of tests of memory and executive functioning in predicting everyday skills suggests that traditional neuropsychological tests can demonstrate acceptable levels of ecological validity within the population investigated in the current study. Specifically, although the pattern of explained variance in IADL functioning increased with the inclusion of executive functioning measures, memory was still a significant predictor in the final model, suggesting that both domains provide a unique contribution in accounting for the variance in functional impairment.

Introduction

The Role of Neuropsychology

The potential sensitivity of neuropsychological tests in detecting abnormalities has led to a burgeoning reliance on neuropsychologists to make statements regarding the functional ability of individuals who have been diagnosed with dementia or who have sustained a brain injury, specifically, whether the patient is able to resume their prior roles and responsibilities. Neuropsychological tests are specifically designed to identify the functional consequences as a result of cerebral dysfunction. These tests were never intended to predict whether patients would be able to live independently, return to work, or function at their premorbid levels. Although current magnetic resonance (MR) neuroimaging provides excellent views of gross anatomy, anatomy provides only one aspect of functioning (Guilmette, 2005). Moreover, research has shown that some cases of traumatic brain injury (TBI) do not result in detectable abnormalities on traditional MR scans (Bigler, 2001).On the other hand, the absence of a neuroimaging abnormality does not necessarily equate to the absence of a functional abnormality. For instance, mild cases of TBI typically do not result in detectable abnormalities on traditional MR scans (Bigler, 2001); therefore, it should not be assumed that functional impairment will not be present. To complicate matters, individual brains are the unique result of genetic endowment and environmental interaction; therefore, brain-behavior relations will, largely, be unique for each individual (Bigler, 2001). As a result, an individual who is described as having a "mild TBI" can be misleading when making judgments regarding functional impairment. Given these issues, neuropsychological tests may be better indicators of cognitive functioning.

Research has also found that cognitive functioning can explain significantly more variance in models of forensic outcomes such as decision-making capacity (Royall et al., 2007). This suggests that higher-order functional abilities such as medical decision-making capacity can be predicted by cognitive variables (Okonkwo et al., 2008). Although there has been recent literature available that addresses the issue of the ecological validity of neuropsychological measures, the amount of research is relatively disproportionate to the amount of reliance on neuropsychologists to make predictions regarding a patient's functional capacity. For instance, it is unclear how much variance in functional ability can be explained by cognitive functioning (Royall et al., 2007).

Ecological Validity

With the increasing availability of sophisticated brain-imaging techniques, neuropsychologists are receiving referral questions that are more focused on predicting what a patient can do in the real-world setting and less on diagnosing and localizing brain impairment (Kibby et al., 1998). However, the same neuropsychological tests that were developed to address diagnostic questions are now being used to answer questions about everyday functioning, with very little empirical evidence to support this practice (Chaytor & Schmitter-Edgecombe, 2003). Moreover, research has shown that even our best contemporary functional neuroimaging tools are limited in their ability to assess neurobehavioral correlates (Lucas & Addeo, 2006). Consequently, the shift in neuropsychological assessment from identifying brain lesions to predicting functional ability (Lezak et al., 2004) has exacted an analogous shift from "traditional" validity issues to ecological validity issues (Franzen & Wilhelm, 1996). According

to Franzen and Wilhelm (1996), an ecologically valid assessment measure is one that has characteristics similar to a naturally occurring behavior and has value in predicting everyday functioning. More specifically, ecological validity may be conceptualized as the "functional and predictive relationship between the patient's performance on a set of neuropsychological tests and the patient's behavior in a variety of real-world settings" (Sbordone, 1996, p. 16).

There are two conceptual approaches to addressing the issue of the ecological validity of assessment measures. The first approach is verisimilitude, which is the degree to which the cognitive demands of a test theoretically emulate the cognitive demands in the everyday environment (Franzen & Wilhelm, 1996). Therefore, the focus of such tests is on how well the test captures essential everyday cognitive skills (Chaytor & Schmitter-Edgecombe, 2003). The second approach is veridicality, which refers to the degree to which traditional tests are empirically related to indicators of everyday functioning (Franzen & Wilhelm, 1996). This type of technique involves using statistical analyses to determine the relation between performance on traditional neuropsychological tests and measures of everyday functioning. Veridicality operates under the assumption that even though traditional tests were not designed with ecological validity in mind, they may be able to predict everyday functioning. Both approaches have been employed in past research to investigate the ecological validity of neuropsychological tests among individuals who have experienced a TBI (e.g., Cuberos-Urbano et al., 2013; Odhuba, van den Broek, & Johns, 2005).

Neuropsychological Assessment and TBI

Brain imaging techniques can sometimes lack specificity and, therefore, may not be useful in diagnosing certain neurological conditions (Marcotte, Scott, Kamat, & Heaton, 2010). Moreover, as mentioned above, some of our best functional neuroimaging tools are limited in their ability to assess neurobehavioral correlates. Even though lesion-localization relations do occur, an identified lesion in a scan does not necessarily indicate a specific focal brain-behavior relation. From a neuropsychological standpoint, TBI can result in a wide spectrum of functional deficits. However, most frontal-temporal injuries will present with changes in memory, executive functioning, and personality. Because it is possible that a patient's impairment can be significant without the presence of a neuroimaging abnormality, neuropsychological assessment has become increasingly valuable in this regard.

While traditional neuropsychological tests may not be direct indicators of everyday skills (Lezak et al., 2004), they demonstrate certain advantages. First, the most commonly used instruments are standardized with norms, allowing for group comparisons, which is not possible with qualitative assessments of abilities. Furthermore, they provide more direct measures of performance in certain cognitive domains than injury- or severity-related variables such as Glasgow Coma Scale, posttraumatic amnesia, or location of lesion. Lastly, neuropsychological tests are considered to be the standard for assessing impairment and oftentimes are useful in treatment planning.

Neuropsychological impairments refer to cognitive difficulties such as problems in attention, memory, processing speed, executive functions, language, and visuospatial skills. Neuropsychological skills are particularly sensitive to the effects of TBI, which may substantially impact an individual's day-to-day functioning as well as their quality of life. Therefore, this area of research has received substantial attention. Several studies have investigated the long-term effects of moderate to severe TBI on learning and memory. Vakil

(2005) found that individuals who have sustained a moderate to severe TBI have deficits in verbal and visual immediate memory, a decreased rate of learning across trials, and a faster rate of forgetting after a standard delay compared to a control group.

Research on outcome as it relates to injury severity has been observed on other measures of severity and has revealed comparable findings. However, variability in performance within each of the severity levels was observed. Specifically, those with less severe injuries were relatively homogenous in performance whereas those with more severe injuries were relatively heterogeneous (Dikmen et al., 2009). This suggests that even though there is a general "dose-response" relation between severity of injury and neuropsychological performance, there is significant variability within each of the severity levels, suggesting that other factors are involved to moderate the impact of severity on performance. There is little disagreement on the negative neuropsychological consequences of moderate or more severe TBIs; however, the sequelae of mild TBIs (mTBIs) have been much more controversial (Dikmen et al., 2009). Less agreement exists regarding the persistence of neuropsychological impairments in individuals with mTBIs and whether or not they can explain long-term disabilities (Dikmen et al., 2009). For instance, there has been substantial controversy as to whether the persistence of symptoms among patients with mTBI are due to psychological or neurological factors, litigation, premorbid psychosocial functioning, postinjury stressors, personality, or other factors not attributable to the mTBI (McCrea, 2008). Schretlen and Shapiro (2003) conducted a meta-analysis of cognitive recovery among mTBI patients and found that overall cognitive functioning returns to baseline by three months, with most improvement occurring in the first few weeks postinjury. Together, these data indicate that the initial deficits in cognitive functioning are relatively small and resolve rapidly following an mTBI.

TBI is considered to be a major public health problem based on prevalence, disability, utilization of health care resources, and economic cost (McCrea, 2008); therefore, further research is necessary in order to understand the functional effects and recovery trajectory following a TBI. TBI has also been identified as a possible risk factor for the occurrence or earlier onset of neurodegenerative disorders, namely, dementia.

<u>Neuropsychological Assessment and Dementia</u>

The reliance on neuropsychological testing has important implications for individuals with dementia for at least two reasons. First, related to the issues mentioned earlier with neuroimaging with TBI patients, some of the most reliable neuroimaging techniques have difficulty detecting the earlier stages of Alzheimer's disease (Marcotte et al., 2010). Second, many of the early structural and functional changes of Alzheimer's disease can emulate the same types of changes that occur in normal aging (Bondi et al., 2009). For example, research has revealed that normal aging is associated with mild brain atrophy on structural MRI (Jernigan et al., 2001), decreased brain volume (Scahill et al., 2003), and increased white matter abnormalities (Guttman et al., 1998).

Consequently, in order to improve discriminating Alzheimer's disease from normal aging, research over the past several years has attempted to identify specific neuropsychological deficits that occur in the earliest stages of Alzheimer's disease. Neuropsychological performance of Alzheimer's disease patients generally reveals a substantial decline in their ability to learn and retain novel verbal or nonverbal information (i.e., anterograde amnesia) as well as deficits in the ability to recall recent information (i.e., retrograde amnesia; Salmon & Squire, 2009).

Additionally, memory for concepts, semantic memory, implicit memory, and remotely acquired factual information may also be impaired in patients with Alzheimer's disease. This is commensurate with research that has found that measures assessing the ability to learn and retain new information can effectively differentiate between individuals at risk for Alzheimer's disease versus healthy older adults (Chang et al., 2010). Moreover, patients in the early stages of Alzheimer's disease are particularly impaired on measures of delayed recall and executive functions (Chen et al., 2001). This hypothesis is supported by studies that show Alzheimer's patients demonstrate an inability to access information after a delay even if retrieval demands are reduced by the use of recognition format or other cues (Delis et al., 1991).

Impairment in the ability to encode information has also been associated with poor performance on episodic memory tests among preclinical Alzheimer's patients (Backman, Jones, Berger, Laukka, & Small, 2005). In the early stages of Alzheimer's disease, the retrograde amnesia is temporally graded with memory impairment for recent events, leaving long-term (remote) memory largely intact (Muangpaisan, 2007). Moreover, the semantic memory that underlies general knowledge and language is often affected relatively early in the course of the disease (Salmon, Butters, & Chan, 1999). As the illness progresses, individuals with Alzheimer's disease begin to show deficits in the ability to recall more remote memories (Muangpaisan, 2007). Taken together, the neuropsychological research findings suggest that Alzheimer's disease usually results in a specific pattern of cognitive deficits in episodic memory, executive functions, and semantic knowledge. However, the extent to which these neuropsychological findings can be used to predict real-world behavior remains questionable. Consequently, research has attempted to address this issue.

Issues with Neuropsychological Assessment

Although neuropsychological tests may be sensitive in the detection of the functional consequences of a brain injury or neurodegenerative disorder, there are several issues with neuropsychological assessment. First, the testing environment is artificially designed to eliminate distractions that would normally interfere with optimal cognitive functioning. Neuropsychological assessment is based on the premise that if a patient has difficulty performing under putatively ideal testing conditions, it might be reasonable to predict that the individual would exhibit impairment in real-life situations, where distractions are not controlled for. However, poor neuropsychological test performance should not be equated with disability and average performance should not be equated with the absence of a disability without obtaining relevant information from other sources (Sbordone, 2001).

For many reasons, what a patient can do in the controlled testing environment is not necessarily what the individual can do in his or her everyday environment (Chaytor & Schmitter-Edgecombe, 2003). In other words, performance in the testing environment may not necessarily reflect daily behavior. For instance, the testing environment may provide enough structure that it prohibits problems in executive functioning from manifesting in an individual with deficits in executive skills (Lezak et al., 2004). To elucidate, if part of the conceptualization of executive functions is the ability to plan, and the nature of neuropsychological assessment is such that the patient is told what to do, deficits in the ability to plan may not be observed in the testing session.

Furthermore, neuropsychologists sometimes obtain data from patients over a short period of time in very specific circumstances and attempt to predict their behavior over a long period of

time across different situations, thereby introducing error into ecological validity. It should be recognized that scores on neuropsychological tests represent a snapshot of a person's performance under the circumstances from which a patient was tested.

Another problem for ecological validity research is the lack of agreement regarding the definition of certain constructs that neuropsychological instruments measure. For example, there is much disagreement on the definition of executive functioning, which has resulted in differences in the classification of some neuropsychological tests (Chaytor & Schmitter-Edgecombe, 2003). For example, an "executive functioning" test such as the Controlled Oral Word Association Test (COWAT) might reveal deficits in cognitive flexibility in one patient whereas the same test might reveal deficits in language in another. Moreover, most neuropsychological instruments measure a wide range of abilities beyond the targeted ability (Long, 1996). The issue is that patients use different processes and strategies during these tasks and sometimes these processes are not captured by the test scores. For example, a patient may generate a large number of words under the COWAT and the score might fall at intact levels despite the presence of significant perseveration or set loss errors.

Additionally, an individual's premorbid functioning can obfuscate the relation between test performance and everyday functioning (Long & Kibby, 1995; Williams, 1988). Specifically, an individual's level of premorbid functioning may influence the extent to which functional impairment is observed. For instance, an individual whose premorbid functioning was above-average may exhibit significant everyday functional impairment with a minor decrement in cognitive ability. However, an individual whose premorbid functioning was below-average may experience limited real-life functional changes with the same amount of cognitive decline.

Lastly, ecological validity may be confounded by the use of compensatory mechanisms (Long & Kibby, 1995). This usually manifests when individuals are prevented from relying on compensatory mechanisms during an assessment that they would typically depend on in their everyday life. Because neuropsychological assessment aims to identify cerebral dysfunction, the use of compensatory mechanisms can obscure the presence or absence of this dysfunction. Consequently, neuropsychological assessment may underestimate what an individual can do in their everyday life if they do not utilize compensatory mechanisms during assessment (Long, 1996). After all, there are few real-life situations in which individuals are required to learn a random list of 15 items or perform a mental calculation without the use of external aids. Given the pervasive use of electronic aids (i.e., reminder notes, lists, calculators, calendars) that facilitate various tasks associated with cognitive ability, it is likely that most people's everyday environmental demands are reduced or circumvented by these external aids. Arguably, it may not be ecologically valid to conclude that an individual who has difficulty with a list-learning task would be related to general memory failures in everyday life (Chaytor & Schmitter-Edgecombe, 2003). For all these reasons, the question of the ecological validity of neuropsychological testing has been an increasing area of research given its potential utility as well as its issues.

Past studies suggest that there are certain tests that demonstrate strong evidence for ecological validity and other tests that seem to have limited ecological validity (Lezak et al., 2004). Research has demonstrated that tests of executive functioning (Perna, Loughan, & Talka, 2012; Marshall et al., 2011; Tan, Hultsch, & Strauss, 2009) and memory (Royall et al., 2007; Tan, Hultsch, & Strauss, 2009) appear to best predict the ability to carry out complex activities.

Past Research

Research has shown that verbal memory is correlated with current everyday functioning and can predict future functioning (Gross, Rebok, Unverzagt, Willis, & Brandt, 2011). In this study, 2,802 community-dwelling adults over the age of 65 were given two separate list-learning tasks (Hopkins Verbal Learning Test [HVLT] and Auditory Verbal Learning Test) as well as measures of everyday functioning. These researchers operationalized functional ability as being comprised of three continuously distributed constructs: instrumental activities of daily living (IADL), problem-solving ability, and psychomotor speed. Results of this study revealed that all verbal memory measures were significant predictors of each functional outcome. Everyday problem-solving and everyday psychomotor speed was best predicted by HVLT at each follow-up interval (i.e., 1, 2, 3 and 5 years). However, everyday IADL functioning was poorly predicted by all verbal memory measures at each follow-up interval. These data suggest that verbal memory can predict different aspects of concurrent as well as future functional ability.

Although it has been demonstrated that cognitive variables can predict everyday functioning in community-dwelling adults, these findings may not generalize to more impaired older adults. Marshall and colleagues (2011) investigated the extent to which executive functioning relates to IADL functioning among older adults with mild cognitive impairment (MCI) and mild Alzheimer's disease. Data were collected from the Alzheimer's Disease Neuroimaging Initiative study (228 normal older controls, 387 patients with MCI, 178 patients with Alzheimer's disease). Results of the multiple regression analysis revealed that for all subjects, there was a significant ($P < .0001$) overall regression model, accounting for 60% of the variance of performance on a measure of IADL impairment. In a separate analysis of only MCI participants, a significant relation between executive functioning and IADL impairment emerged ($R^2 = .16$, $P < .0001$ for model). These findings reveal a significant relation between executive functioning and IADL impairment after controlling for diagnosis, global cognitive impairment, memory functioning, depression, and apathy. Furthermore, these results suggest that deficits in executive functioning affect functional ability in individuals with milder cognitive impairment.

Research suggests that performance on executive functioning measures is positively correlated with independent functioning among individuals who have experienced an acquired brain injury (Perna, Loughan, & Talka 2012). These researchers examined the impact of executive functioning proficiency on various aspects of independent living among 65 adults who experienced an acquired brain injury. The neuropsychological evaluation included the following instruments: Mayo-Portland Adaptability Inventory (MPAI-4), Wechsler Adult Intelligence Scale-Third Edition (WMS-III), Wisconsin Card Sorting Test (WCST), Trail Making Test (TMT) A and B, and the Ruff 2 & 7 Selective Attention Test. The MPAI-4 was used in the study as it includes items rating aspects of independence including residence, money management, transportation, and employment. The results showed significant differences in executive functioning scores across levels of proficiency in several independent living skills. Specifically, people who drove independently, managed money independently, and worked full-time generally had scores on executive functioning measures at a standard score of approximately 79 or greater (9th percentile). Measures of visual scanning, divided attention, working memory, and information processing speed all appeared to be significantly correlated with the ability to work, drive, manage finances, and live independently. Together, these data suggest that impairments in executive functioning, including mild deficits, can significantly interfere with a person's ability to perform daily activities.

Another study that investigated the relation between executive functions and IADL performance among fifty demented and non-demented adults found evidence of the predictive value of tests of executive functions (Bell-McGinty, Podell, Franzen, Baird, & Williams, 2002). The researchers administered the WCST, TMT Part B, COWAT, Mattis Dementia Rating Scale, and The Manual Postures Test to serve as predictor variables. In order to measure IADLs, they utilized The Independent Living Scales (ILS), which is considered to be an objective performance-based assessment of IADLs. The results revealed that the five tests of executive functions accounted for 54% of the variance in ILS performance. In separate analyses, the five tests of executive functions did not significantly predict ILS performance among demented patients; however, a significant prediction was found among non-demented patients. Of all the executive functioning tests employed, TMT Part B and WCST were found to be the best predictors of the ability to perform IADLs even after accounting for the effects of age, gender, and education. Taken together, these findings suggest that the cognitive demands of TMT Part B and WCST may be particularly sensitive to functional ability.

Past research has had some success in demonstrating the ecological validity of certain memory and executive functioning tests. However, there is still a paucity of available research that has substantially validated the ecological validity of neuropsychological tests in predicting functional impairment among a clinical population. In summary, given the problems with the best contemporary neuroimaging tools, the issues in assessing ecological validity from a neuropsychological context, and the mixed results of past literature, further research is needed.

Current Study

The current study expands on the findings from Bell-McGinty and colleagues (2002). As mentioned earlier, there are two conceptual approaches in addressing the issue of the ecological validity of assessment measures. The current study examined ecological validity through a combination of the verisimilitude and veridicality approach. However, it should be noted that, in the current study, the ILS is used as a proxy of everyday functioning.

Research has demonstrated that self- and informant-rated measures of functional status may not provide a valid picture of an individual's functioning (Royall et al., 2007). Furthermore, research has shown that individuals with MCI may exhibit subtle changes in functional ability that may only be captured by more objective measures of functional ability (Pereira, Yassuda, Oliveira, & Forlenza, 2008). The ILS has been described as an objective measure of IADLs; therefore, it may be a more accurate outcome measure than less objective measures of IADLs. Lastly, the ILS has not been widely studied in research with psychiatric populations.

Disability has been conceptualized as a hierarchically arranged sequence of self-care abilities that include activities of daily living (ADLs) and IADLs. However, there is mixed findings on whether IADLs require higher level cognitive skills (i.e., memory, planning) compared to basic ADLs (Royall et al., 2007). Rather, it appears that the relation between cognition and IADLs may be domain-specific. Therefore, the current study aims to determine the ecological validity of neuropsychological measures in predicting IADL performance by examining more than one cognitive domain (i.e., memory and executive functioning).

To reiterate, the structured environment of neuropsychological assessment may prohibit problems in executive functions to manifest during a testing session. For this reason, executive functions have been challenging to assess and have been an increasingly important area within ecological validity research. Memory is an important variable to study because of the fact that

any problems in memory can have a significant impact on functioning (Chaytor & Schmitter-Edgecombe, 2003). Moreover, memory complaints cross-cut many neurological disorders; therefore, establishing the ecological validity of memory tests can have significant clinical implications. Both executive functioning and memory have been most strongly correlated with return to work or return to productivity; however, inconsistencies have been found (Green et al., 2008). Therefore, the current study investigated the ecological validity of neuropsychological tests by examining the extent to which performance on tests of memory and executive functioning can predict IADL functioning. The ecological validity of neuropsychological tests was also examined by relating neuropsychological test scores within a specific cognitive domain to scores on a measure of everyday skills within the same cognitive domain. In other words, tests of memory were related to indices of everyday memory ability and tests of executive functioning were related to an index of everyday executive functioning.

Hypotheses

First, it is hypothesized that for each functional domain and factor comprising the ILS (i.e., Memory/Orientation, Managing Money, Managing Home and Transportation, Health and Safety, Social Adjustment, Problem-Solving factor, and Performance-Information factor), there will be moderate correlations with multiple neuropsychological measures, indicating that a variety of different cognitive abilities will be important in performing various everyday tasks. Second, it is hypothesized that the neuropsychological variables will add significantly to the prediction of overall ILS performance above and beyond the contribution made by demographic variables, namely, age, gender, and education. Third, insofar as IADLs reflect independent living, it is hypothesized that executive functioning will significantly predict impairment in IADLs and will account for a greater proportion of variance in ILS scores than tests of memory. Lastly, research has found that tests that measure a specific cognitive domain can predict everyday functioning in that particular domain. Therefore, it is also hypothesized that memory test performance will significantly predict performance on the Memory/Orientation scale and the Performance-Information Factor of the ILS; whereas executive functioning test performance will significantly predict performance on the Problem-Solving Factor of the ILS.

Methods

Participants

The sample consisted of outpatients who were referred to the Department of Psychiatry at Allegheny General Hospital (AGH) for a neuropsychological evaluation. Patients who experienced an acquired brain injury (i.e., TBI, cerebrovascular accident, encephalopathy, anoxia) or a brain injury for which the etiology was known were included in the study. Patients were also included if there were concerns regarding executive or memory functioning. Therefore, individuals who were evaluated to confirm or rule out dementia and individuals with intellectual disability were included. The data of patients who completed a baseline neuropsychological assessment were included in this study. After removal of cases for which a baseline neuropsychological evaluation was not completed, the final sample size consisted of 39 participants (20 females, 19 males). Nineteen participants were evaluated following an acquired brain injury, 17 had been evaluated to confirm or rule out the presence of dementia, and 3 were

evaluated for other reasons including the ability to care for themselves (e.g., intellectual disability). The mean age was 60.13 (range: 30 to 88). The mean years of education completed were 13.00 with a range of 8 to 20 years. Thirty-eight individuals were Caucasian and one individual was African American.

Another sample consisted of 120 outpatients (some included from the above-mentioned sample) who were referred to the Department of Psychiatry at AGH for a neuropsychological evaluation. These participants were selected based on the same inclusion/exclusion criteria described above. The purpose of this sample was to collect existing data in order to conduct a confirmatory factor analysis to assess the extent to which the cognitive measures loaded onto their respective cognitive domain. Data were only collected in which there was no missing data on the neuropsychological measures.

Measures

The current study used data in a clinical outpatient setting at AGH. Therefore, a "standard" neuropsychological battery was not employed, as tests were selected based on the referral question. Nevertheless, there are certain measures that are routinely used to test certain cognitive domains.

Delayed Verbal Memory

Studies have investigated memory in ecological validity research because of the fact that any difficulties in memory can have a significant effect on everyday functioning (Chaytor & Schmitter-Edgecombe, 2003). Moreover, memory complaints are observed in many neurological disorders. Therefore, establishing the ecological validity of memory tests can have significant clinical implications. Tasks specifically measuring delayed verbal memory were included.

The Wechsler Memory Scales 4th Edition (WMS-IV; Wechsler, 2009) is an omnibus measure of memory that is designed to assess memory related to verbal and nonverbal components. The WMS-IV was selected because of its high reliability and widespread use within the field of neuropsychology. Logical Memory (LM) is a subtest from the WMS-IV and it assesses memory for verbal information that is conceptually organized and semantically related. The examiner reads two paragraph-length stories, stopping after each story for an immediate free recall. After a 20 to 30 minute delay, the examinee is asked to recall as many elements of the story. The delayed recall score was used, which is based on the number of correct elements the examinee recalls. It may be argued that LM has greater ecological validity than random list-learning tasks since most verbal information in everyday life is organized in a meaningful way. Research has found that patients with probable dementia of the Alzheimer's type scored significantly lower than the matched control group on LM II ($d = 2.20$; Wechsler, 2009).

Verbal Paired Associates (VPA) is another subtest from the WMS-IV and it assesses memory for word pairs. In the first part of this task (VPA I), the examiner reads aloud 14 word pairs over four trials to the examinee. After each trial, the examinee is given the first word of each pair and is asked to recall the second word. Some word pairs are semantically related (e.g., "sky" and "cloud") while others are not (e.g., "zoo" and "girl"). After each item, the examiner provides feedback to the examinee as to whether they are correct or incorrect, providing the correct word if they are incorrect. After a 20 to 30 minute delay (VPA II), examinees are provided the first word of each pair and asked to recall the second word. The score for the

delayed recall was used and is calculated using the number of correctly recalled word pairs. Research has found a large effect size for VPA II among individuals with TBI ($d = 1.33$; Wechsler, 2009).

Executive Functioning

The fundamental issue that arises with tests of executive functions is that they are difficult to operationalize and there is no universal agreement as to what constitutes executive functions. Lezak (1982) defined executive functions in terms of four major functional categories of executive capacities: (1) formulating goals; (2) planning; (3) carrying out plans to reach goals; and (4) performing these activities effectively. These classes involve distinct sets of behavior and "all are necessary for appropriate, socially responsible, and effectively self-serving adult conduct" (pp. 281-285).

Trail Making Test Part B (TMT; Heaton, Grant, & Matthews, 1991) is a timed test that requires participants to connect numbers to corresponding letters in sequence (i.e., 1-A-2-B…12-L-13). This task assesses cognitive flexibility, conceptual tracking, set-shifting, sustained attention, visual search, psychomotor speed, and working memory. The TMT has been shown to be sensitive to attention, concentration, executive deficits, and processing speed. The score for completion time was used. Research has shown a relation between TBI injury severity and TMT performance, with slowed performance increasing with severity of damage (Lange, Iverson, Zakrzewski, Ethel-King, & Franzen, 2005).

The Stroop Test requires an individual to inhibit their natural inclination to respond in order to respond according to a set of defined rules. In the color/word (C/W) interference condition, the examinee is required to name the color that the word is printed in without reading the incongruent color word. Scores are computed based on the number correct within a 45-second time limit. This task taps into verbal inhibition, simultaneous processing, and cognitive flexibility. Studies have found that individuals with left hemisphere lesions have greater impairment on the interference condition (Lezak et al., 2004).

The Wisconsin Card Sorting Test (WCST; Heaton, 1981) is a widely used test devised to measure abstract reasoning, set-shifting, cognitive flexibility, deductive reasoning, concept formation, and perseveration. The test requires examinees to match cards to one of four symbols (i.e., triangle, star, cross, or circle) in red, green, yellow, or blue on a computer. Cards can be matched according to one of three principles: color, form, or number. After 10 consecutive correct placements made according to one principle, the program switches the principle. Participants must deduce the proper matching principle based on the computer program's feedback. A variant of this test involves the examiner administering the cards, which has shown to produce comparable results as the "standard" administration (Lezak et al., 2004). The number of perseverative errors (P-E) was used as a measure of executive functioning. Research supports the utility of this measure in detecting executive or frontal lobe dysfunction (Stuss et al., 2000).

Functional Ability

Functional impairment can be conceptualized as a hierarchically nested set of impairments as a result of fundamental deficits in physiological, cognitive, and behavioral systems (Royall et al., 2007). The Independent Living Scales (ILS; Loeb, 1996) assesses cognition as it affects IADLs. The test items target situations relevant to independent living and

measures an individual's ability to problem solve, demonstrate knowledge, and perform different tasks that would be required to live independently. The ILS is composed of five scales: Memory/Orientation, Managing Money, Managing Home and Transportation, Health and Safety, and Social Adjustment. Memory/Orientation measures general awareness of the environment as well as short-term memory. It contains items that include orientation to time and place, recall of a short shopping list, and recognition of a missing object. Managing Money assesses the ability to count money, perform monetary calculations, pay bills, budget, and protect financial assets. Managing Home and Transportation measures an individual's ability to use a telephone and public transportation as well as skills in home management. Health and Safety tests an individual's awareness of health problems, ability to evaluate health problems, deal with medical emergencies, and take safety precautions with potential hazards around the home. Social Adjustment measures an individual's level of affect, adjustment, and attitudes about interpersonal relationships.

The ILS also has two factor-analyzed subscales. The Performance-Information factor measures actual skills or knowledge used to carry out tasks (e.g., using a telephone book). The Problem-Solving factor assesses everyday judgment, practical problem solving, and abstract reasoning (e.g., "Tell me two ways you would know it's safe to cross a busy street."). The ILS Full Scale Score provides a measure of overall level of independent functioning.

Procedures

The data were retrospective in nature and were composed of neuropsychological evaluations conducted at AGH. The following variables were obtained from the patient's medical chart: demographic information (i.e., age, years of education, gender), past medical history, diagnosis, and neuropsychological test performance.

Statistical Analyses

To ensure that the results for test performance were comparable, all neuropsychological test scores were converted to a common metric (i.e., T scores) based on their respective published sources or well-established normative data (Strauss, Sherman, & Spreen, 2006). A dimension reduction technique based on the regression weights from the results of the confirmatory factor analysis was employed in order to form indices for the memory and executive functioning domains. The measures included in the "Memory Index" were performance on LM II and VPA II. An "Executive Functioning Index" score was also calculated, based on the same dimension reduction procedure, using the T scores for the time to complete TMT B, the color-word interference score on the Stroop Test, and perseverative errors on the WCST. To account for the fact that not all participants received all the neuropsychological tests used in the multiple regression analyses, some of the test scores were estimated based on the standardized score of at least one of the tests within an index. For example, if the Stroop Test was the only executive functioning test given, the Stroop score was used to estimate performance on the WCST and TMT B. For this reason, data were only collected on participants who completed at least one test within a cognitive index (i.e., memory, executive functioning).

A confirmatory factor analysis was conducted in order to assess the internal consistency of the measures comprising its corresponding cognitive domain. The confirmatory factor analysis was also performed in order to provide justification for using an average score for any participant

who had missing data within a domain. The program AMOS 18.0 was used to examine the extent to which the hypothesized relations among the variables adequately described the data. Maximum likelihood estimation was used to perform the confirmatory factor analysis. The hypothesized model was compared to the independence model in order to assess model fit. Given the lack of agreement regarding appropriate indices of fit and because χ^2 is influenced by sample size, several goodness-of-fit indices, residual error terms, and modification indices were examined in order to assess model fit. Specifically, the indices used were the χ^2 to *df* ratio index (i.e., relative chi-square), the root mean square error of approximation, (RMSEA), the goodness of fit index (GFI), the adjusted goodness of fit index (AGFI), the parsimony goodness of fit index (PGFI), the normed fit index (NFI), the relative fit index (RFI), the incremental fit index (IFI), the Tucker-Lewis index (TLI), and the comparative fit index (CFI).

SPSS version 19 was used to perform correlational and multiple regression analyses. The study aimed for an effect size of $f^2 = 0.35$, which is considered to be a large effect size. In order to reach a power estimate of 0.80, a total sample size of 34 was recommended (Soper, 2013).

Results

Confirmatory Factor Analysis

In order to evaluate violations on the assumption of normality, descriptive statistics for each indicator were obtained. There was evidence indicating the presence of univariate nonnormality. Specifically, TMT B and WCST were statistically significant for skewness and kurtosis (critical values exceeded ± 1.96). However, the TMT B and WCST absolute values for skewness and kurtosis were both less than 3, which is within acceptable levels. Further, an examination of the histograms and Q-Q plots revealed that the distributions were within acceptable limits. Therefore, none of the indicators was eliminated.

Results from the confirmatory factor analysis revealed that all indicators had significant factor loadings ($p < .001$). Figure 1 represents the path diagram of the hypothesized model with the value loadings as well as the R^2 explained by each of the indicators. The bivariate correlation between delayed verbal memory and executive functioning revealed a significant correlation ($r = .85$, $p < .001$).

The relative chi-square, an index that may be less sensitive to sample size, suggested good model fit. Results of the RMSEA indicated good model fit. The linear structural relations (LISREL) GFI and AGFI also suggested good fit. However, the LISREL PGFI suggested poor fit. However, the LISREL fit indices are controversial because it requires examining the difference between the actual and reproduced correlational matrix, which is based on the residual correlation matrix. Consequently, if the data deviate from normality, the results may provide a distorted picture. Therefore, a better set of fit statistics involves computing a null model. The independence model is a null model that tests the hypothesis that there are no significant relations between the variables. This model of "worse fit" is compared to the hypothesized model. Results suggest that the independence model was a poor fit for the data and should be rejected, χ^2 (10, $N = 120$) = 212.54, $p = .000$. Results revealed that the hypothesized model was a good fit for the data and should be retained, χ^2 (4, $N = 120$) = 2.46, $p = .652$. Table 1 presents a summary of the goodness-of-fit statistics for the hypothesized model as well as optimal cutoff values (Sivo, Fan, Witta, & Willse, 2006; Kline, 2010).

Table 1

Summary of goodness-of-fit indices

| | Goodness-of-Fit Indices | | | | | | | | |
Models	$\chi2/df$	RMSEA	GFI	AGFI	PGFI	NFI	RFI	IFI	TLI	CFI
Optimal value	< 3.0	$< .06$	$> .89$	$> .87$	$> .72$	$> .88$	$> .87$	$> .96$	$> .95$	$> .95$
Hypothesized model	.62	.00	.99	.97	.26	.99	.97	1.01	1.02	1.00

Figure 1

Five-indicator three-factor confirmatory factor analysis model
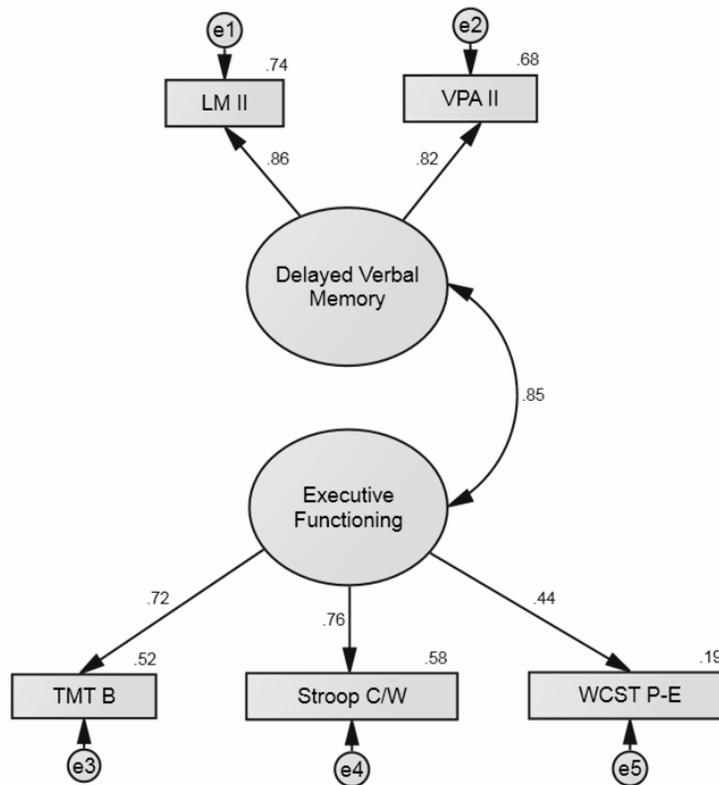
Values above the indicators (as indicated by boxes) represent the R^2 explained by the respective indicator; values next to the one-way arrows indicate the standardized regression weights; value next to the two-way arrow represents the bivariate correlation between the two factors (as indicated by ovals).

Correlational Analyses

Descriptive statistics for performance on the neuropsychological measures are presented in Table 2. Also, descriptive statistics for performance on the ILS based on Full Scale Scores in the low, moderate, and high functioning ranges are provided in Table 3 (values are presented in *T* scores to compare test performance). In order to test the first hypothesis that for each ILS

subscale/factor there would be moderate correlations with multiple neuropsychological measures, a series of correlational analyses were performed (Table 4). The correlation between the ILS Full Scale Score and the Memory Index was .65 ($p \leq .01$), suggesting a strong positive relation. The correlation between the ILS Full Scale Score and the Executive Functioning Index was .40 ($p \leq .05$), also suggesting a strong positive relation. The only demographic variable that was significantly correlated with the ILS Full Scale Score was years of education ($r = .47$, $p \leq .01$). In line with the first hypothesis, the Memory Index had large correlations with the Memory/Orientation scale ($r = .62$, $p \leq .01$) and the Performance-Information factor ($r = .50$, $p \leq .01$) as well as with the Money Management scale ($r = .57$, $p \leq .01$), the Health and Safety scale ($r = .57$, $p \leq .01$), and the Problem-Solving factor ($r = .62$, $p \leq .01$). In addition, the Executive Functioning Index had a moderately positive correlation with the Problem-Solving factor ($r = .33$, $p \leq .05$), as hypothesized. The Executive Functioning Index also had moderately positive correlations with the Money Management scale ($r = .39$, $p \leq .05$), the Health and Safety scale, ($r = .36$, $p \leq .05$), the Social Adjustment scale ($r = .35$, $p \leq .05$), and the Performance-Information factor ($r = .34$, $p \leq .05$).

Table 2

Descriptive statistics for performance on neuropsychological measures and ILS

		Logical Memory II[1]	Verbal Paired Assoc. II[1]	Trail Making Test B[2]	Stroop[3]	Wisconsin Card Sorting Test[4]	ILS Full Scale Score[5]
N	Valid	39	39	38	37	33	38
	Missing	0	0	1	2	6	1
Mean		7.38	8.69	140.71	33.70	23.09	234.18
Std. Deviation		3.18	4.07	87.61	9.73	13.33	40.88
Range		13	14	328	36	53	157
Minimum		1	1	47	14	6	139
Maximum		14	15	375	50	59	296

[1]Scaled score; [2]Total seconds; [3]Total responses (age-corrected); [4]Perseverative errors; [5]Total score.

Table 3

Descriptive statistics for ILS performance based on low, moderate, and high functioning ranges

	Low (55-84)*		Moderate (85-99)*		High (100-121)*	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Logical Memory II	31.56	6.82	39.80	10.21	48.60	7.03
Verbal Paired Associates II	31.78	7.97	44.33	11.46	55.40	10.28
Trail Making Test B	25.08	8.57	39.69	10.99	51.85	7.39
Stroop (Color-Word)	31.33	8.25	36.07	8.01	44.80	8.67
Wisconsin Card Sorting Test	36.31	17.61	43.33	15.40	45.33	8.16

All values are presented in *T* scores.

*Based on the ILS Full Scale Score.

Table 4

Correlations between the ILS scales/factors and neuropsychological variables

	Delayed Verbal "Memory Index"	"Executive Functioning Index"	Gender	Age	Education
Memory/Orientation	**.62****	0.12	-.07	**-.34***	**.37***
Money Management	**.57****	**.39***	-.17	-.07	**.36***
Home and Transportation	**.37***	0.15	-.03	-.27	.22
Health and Safety	**.57****	**.36***	-.23	-.14	**.40***
Social Adjustment	0.25	**.35***	-.23	.27	**.35***
Problem-Solving	**.62****	**.33***	-.27	-.19	**.41****
Performance-Information	**.50****	**.34***	-.07	-.20	.26
ILS Full Scale Score	**.65****	**.40***	-.21	-.12	**.47****

*Correlation is significant at the .05 level (2-tailed);
**Correlation is significant at the .01 level (2-tailed).

Multiple Regression Analyses

A hierarchical multiple regression analysis was conducted in order to assess the uniqueness of the predictors on the outcome variable after the previous variables were controlled for. The predictors were entered in blocks in the order specified based upon theoretical grounds. Prior to conducting the hierarchical multiple regression analysis, multicollinearity was assessed by examining each predictor's Tolerance and Variance Inflation Factor (VIF). Tolerance is the percentage of variance in the predictor variable that is not accounted for by the other predictor variable(s). Generally, tolerance values of .10 or less are indicative of problematic (multi)collinearity (Belsey, Kuh, & Welsch, 2004). In the current study, all tolerance values ranged from .78 to .99. VIF indicates the degree to which the standard errors are inflated due to the levels of (multi)collinearity. VIF values greater than 10 suggest poor beta estimates due to large beta standard errors (Belsey et al., 2004). All VIF values were between 1.00 and 1.28. Furthermore, all follow up regression analyses indicated that tolerance and VIF were within acceptable limits. Additionally, the Mahalanobis distance scores suggested no multivariate outliers. Finally, there was no evidence indicating the presence of univariate or multivariate nonnormality. Specifically, the skewness and kurtosis values for the Memory and Executive Functioning indices did not exceed the critical values.

A three-stage hierarchical regression analysis was conducted to address the second hypothesis that scores on tests of memory and executive functioning would predict impairment in IADLs and would account for a greater proportion of variance above and beyond the contribution made by demographic variables. The hierarchical regression analysis also addressed the third hypothesis that executive functioning scores would uniquely predict ILS performance above and beyond memory performance. For this analysis, the ILS Full Scale Score was the outcome variable and the demographic variables and the Memory and Executive Functioning Indices were the predictor variables. The demographic variables (i.e., age, gender, education) were entered first (Model 1) and accounted for 27% of the variance in the ILS Full Scale Score (p = .012). The Memory Index was entered next (Model 2) and produced an R^2 change of .25 (p

= .000) demonstrating that the Memory Index contributed significantly to the model, F (4, 34) = 8.86, $p \leq .000$. The Memory Index and years of education were the only significant predictors in this model. Introducing the Executive Functioning Index (Model 3) explained an additional 19% of the total variance accounted for in ILS performance and this R^2 change was significant (p = .000), indicating that the Executive Functioning Index contributed significantly to the model, F (5, 33) = 15.23, $p \leq .000$. In the final model, a total of 70% of the variance (adjusted R^2 = .65) was accounted for in the ILS Full Scale Score, with education, the Memory Index, and the Executive Functioning Index being significant predictors. Therefore, evidence was provided for the hypothesis that memory and executive functioning would provide unique contributions to the prediction of ILS performance even after controlling for demographic variables. Further, the hypothesis that executive functioning would account for a larger variance above and beyond the contribution made by memory was supported; however, the Memory Index continued to be a significant predictor in the final model. The results are presented in Table 5.

Table 5

Summary of hierarchical regression analysis for variables predicting ILS Full Scale Score

Variable	β	t	Sig.	R	R^2	Adj. R^2	ΔR^2	Sig. F Δ
Model 1				.52	.27	.20	.27	.012
Gender	-.19	-1.28	.210					
Age	-.06	-.38	.706					
Education	.47	3.22	.003					
Model 2				.71	.51	.45	.25	.000
Gender	-.13	-1.06	.295					
Age	-.00	-.02	.981					
Education	.29	2.24	.032					
Memory Index	.54	4.12	.000					
Model 3				.84	.70	.65	.19	.000
Gender	-.05	-.46	.648					
Age	-.19	-1.79	.083					
Education	.31	3.00	.005					
Memory Index	.51	4.95	.000					
Exec. Func. Index	.47	4.52	.000					

The hierarchical regression analysis revealed that the Memory Index and the Executive Functioning Index were significant predictors of the ILS Full Scale Score in the final model. Therefore, separate multiple regression analyses were performed by entering the demographic variables in the first step followed by the simultaneous entry of the various tests comprising the Index in order to examine the predictive power of the individual tests. For the Memory Index, the analysis was performed by entering the demographic variables in the first step followed by the simultaneous entry of scores on LM II and VPA II. The results revealed that education (β = .29, p = .025) and VPA II (β = .46, p = .045) were the only significant predictors of the ILS Full Scale Score. For the Executive Functioning Index, the demographic variables were entered in the

first step followed by the simultaneous entry of scores on TMT B, WCST, and Stroop. Results showed that education (β = .32, p = .008) and TMT B (β = .61, p = .001) were the only significant predictors of the ILS Full Scale Score.

To address the final hypothesis, a series of stepwise multiple regression analyses were conducted to examine the extent to which the neuropsychological variables predicted performance on the scales and factors comprising the ILS. Because education was the only significant predictor among the demographic variables in the previous analyses, education, the Memory Index, and the Executive Functioning Index were included as the predictors in this analysis. The results revealed that the Memory Index significantly predicted performance on the Memory/Orientation, Managing Money, Managing Home and Transportation, and Health and Safety scales as well as the Problem-Solving and Performance-Information factors. The Executive Functioning Index significantly predicted performance on the Managing Money, the Health and Safety, and the Social Adjustment scales as well as the Problem-Solving and Performance-Information factors. The results are presented in Table 6.

A separate hierarchical regression analysis was conducted for participants who experienced an acquired brain injury. Again, the only demographic variable used in the analysis was education. Analysis of the acquired brain-injured group revealed that at Model 1, education did not contribute significantly to the regression model, F (1, 17) = 3.12, p = .095 and accounted for 16% of the variance in ILS performance. Adding the Memory Index (Model 2) explained an additional 36% of variation in ILS performance and this change in R^2 was significant (p = .003), suggesting that the Memory Index contributed significantly to the overall model, F (2, 16) = 8.56, p < .003. Finally, the addition of the Executive Functioning Index (Model 3) explained an additional 28% of the variation in ILS performance and this change in R^2 was significant (p = .000), indicating that the Executive Functioning Index contributed significantly to the overall model, F (3, 15) = 19.88, p < .000. In the final model, the only significant predictors were the Memory Index (β = .56, p = .000) and the Executive Functioning Index (β = .54, p = .000). The number of participants diagnosed with mild cognitive impairment was small (n = 5) as was the number of individuals diagnosed with dementia (n = 5). Therefore, analyses were not conducted for these groups. The sample size for the acquired brain-injured group was not large enough for the desired effect size and power; therefore, these results are merely provided for exploratory considerations.

Table 6

Summary of multiple regression analyses for variables predicting ILS domains

Criterion	Predictor	β	p	R^2	Adjusted R^2	F	df	p
Memory/Orientation				.38	.36	22.63	1, 37	.000
	Memory Index	.62	.000					
Managing Money				.47	.44	15.98	2, 36	.000
	Memory Index	.57	.000					
	Exec. Func. Index	.39	.003					
Managing Home/Transportation				.14	.12	5.92	1, 37	.020
	Memory Index	.37	.020					
Health and Safety				.45	.42	14.75	2, 36	.000
	Memory Index	.56	.000					
	Exec. Func. Index	.36	.006					
Social Adjustment				.26	.22	6.28	2, 36	.005
	Exec. Func. Index	.37	.015					
	Education	.37	.015					
Problem-Solving				.49	.46	17.01	2, 36	.000
	Memory Index	.62	.000					
	Exec. Func. Index	.33	.010					
Performance-Information				.37	.33	10.33	2, 36	.000
	Memory Index	.50	.001					
	Exec. Func. Index	.34	.015					
Full Scale Score				.66	.63	22.50	3, 35	.000
	Memory Index	.55	.000					
	Exec. Func. Index	.41	.000					
	Education	.30	.008					

Discussion

The results of the current study provide support for the hypothesis that traditional tests of memory and executive functioning are significant predictors of IADL functioning in a clinical population. Together with age, gender, and education, performance on tests of memory and executive functioning accounted for 70% of the variance in IADL performance as measured by the ILS in this sample. After age, gender, and education were entered in the prediction model, the Memory Index accounted for an additional 25% of the variance in IADL functioning. Further, after age, gender, education, and the Memory Index were entered in the model, the Executive Functioning Index accounted for an additional 19% of the variance in IADL functioning. In the final model, the Memory Index was still a significant predictor, suggesting that the Memory Index and Executive Functioning Index provide unique contributions in accounting for the variance in IADL performance. This provides support for the pattern of the explained variance in IADL to increase with the inclusion of both memory and executive functioning measures.

From a neuropsychological perspective, independent living is closely associated with executive functions. The executive functions consist of capacities that enable a person to engage successfully in independent, purposive, self-serving behavior (Lezak et al., 2004). Even when other cognitive functions are intact, impairment in executive functioning can lead to an inability to care for oneself, work independently, or maintain social relationships. The results of this study revealed that the Executive Functioning Index was a uniquely significant predictor of the Social Adjustment Scale. It is believed that social behavior requires more complex cognitive abilities, as it often requires that the individual be organized enough to plan and maintain contact with others. Insofar as social skills and interpersonal interactions require higher order organization, synthesis, and planning, it has been hypothesized that executive functioning may be associated with social functioning (Plehn, Marcopulos, & McLain, 2004). Therefore, the results of the current study provide convergent evidence that social functioning is inextricably intertwined with executive skills.

Separate analyses revealed that among the executive functioning and memory tests, TMT B and VPA II, respectively, were significant predictors of IADL performance. Bell-McGinty and colleagues (2002) also found TMT B to be a significant predictor of ILS performance. TMT B measures various aspects of executive functioning such as cognitive flexibility, conceptual tracking, set-shifting, sustained attention, visual search, psychomotor speed, and working memory. However, the current study did not investigate which of these processes are important in predicting functional impairment. Future studies should employ signal detection theory in order to determine the underlying processes and strategies for decision-making that are specifically related to IADL functioning.

Surprisingly, the results of the present study revealed that LM II was not a significant predictor of IADL performance. It could be argued that LM is a test of semantic memory and, therefore, has greater ecological validity than random list-learning tasks since most verbal information in everyday life is organized in a meaningful way. Instead, episodic memory appeared to be a significant predictor in IADL functioning as measured by VPA II. One possible explanation for this finding may be that to the extent that IADLs reflect overlearned behaviors, for some individuals, carrying out IADLs may require having to remember some information on a particular occasion in order to activate the previously learned behavior. For example, the ability to write a check might require an individual to recall a specific aspect of how to write a check from an earlier experience. Another explanation may be that VPA II requires learning,

organization, retrieval strategy, and manipulation of items held in short-term memory, all processes involved with executive functions. Given that the executive functions are closely related to independent living, this may have mediated these results. Nevertheless, this study corroborates previous research that demonstrates that verbal memory (Gross et al., 2011) is related to concurrent functional ability. However, Gross and colleagues (2011) also found that verbal memory measures were poor predictors of future IADL performance. Therefore, future studies might investigate whether VPA II demonstrates future predictive power in IADL functioning.

The current study also examined the predictive value of neuropsychological variables on IADL performance in an acquired brain-injured group. In this group, the Memory Index and Executive Functioning Index were significant predictors of IADL functioning, which is consistent with the results of the primary analysis that found that both the Memory and Executive Functioning Indices were significant predictors even after controlling for demographic variables in a general clinical population. However, in the analysis with the acquired brain-injured group, education was no longer a significant predictor ($\beta = .12$, $p = .361$). Because the sample size for the acquired brain-injured group was small, these results should be interpreted with caution. Nevertheless, future studies with larger sample sizes might investigate the ecological validity of tests in certain groups and whether they may be generalizable to other groups. Research that has examined different populations has found differences between groups. For instance, Evans, Chua, McKenna, and Wilson (1997) investigated the relation between the Behavioural Assessment of the Dysexecutive Syndrome (BADS) and a measure of executive functioning among individuals diagnosed with schizophrenia, individuals who sustained a brain injury, and healthy controls. They found a significant relation between the BADS and informant ratings of executive skills in the brain-injured group, but a significant relation was not found in the schizophrenia group. For this reason, future studies should include analyses comparing two or more groups.

The current study improves on the methods employed in previous research with the addition of an empirical justification for inclusion of measures within a cognitive domain. Past research that has aggregated measures to form various cognitive indices has generally based their methodology solely on theoretical grounds. As a result, past studies have used a mean of the scores to produce an index, thereby giving equal weight to each test. By using a dimension reduction technique in the present study, a more parsimonious and theoretically relevant score to represent an index was used by weighing each test score based on their respective regression weight. Furthermore, the outcome measure used in the present study is an objective performance-based measure of IADLs.

However, one of the limitations of this study was the use of the ILS as a proxy for indicators of everyday functioning. Although the ILS is a more objective test than other instruments of IADLs, the ILS does not measure whether an individual actually carries out these tasks in their own environment. For instance, a patient may be able to demonstrate the ability to write a check to pay their bills when asked to do so; however, they may not actually carry out this behavior in a real-life situation for various reasons (e.g., deficits in memory, planning, organization; failure to appreciate consequences). Therefore, additional (qualitative) information is needed to ascertain the severity of one's functional impairment. Another limitation was the relatively small sample size for the confirmatory factor analysis. Although the confirmatory factor analysis provided justification for employing mean substitution for any case that had missing test scores within a domain, using an average may not be valid, especially in the case of

the Executive Functioning Index. Specifically, because the tests comprising the Executive Functioning Index tap into various aspects of executive skills, it may not have been valid to use the mean of other test scores of executive functioning to represent the score for a different executive functioning test. In addition, one of the limitations of multiple regression analyses is that standardized regression weights only provide information on the relative importance of the predictor variables. Therefore, a predictor variable's absolute contribution to functional outcomes cannot be fully described because the shared variance with multiple predictors cannot be separated. Therefore, the same predictor may fare differently in another model with different predictors. Finally, another limitation of the current study is that the sample was comprised of mostly Caucasian participants, which may not be generalizable to other groups.

　　　　Nevertheless, the findings from this current study may be useful in disability determination decisions. First, these results suggest that individuals with difficulty in memory and executive functioning can predict impairment in IADL functioning. Specifically, tests of memory appear to predict IADL performance in all domains with the exception of social adjustment. Further, tests of executive functioning seem to best predict the ability to manage money, awareness of health and safety issues, social adjustment, and problem-solving skills. Moreover, based on the Social Security Administration's (SSA) "Disability Evaluation Under Social Security," an individual must meet a medically determinable impairment that is expected to last at least 12 months, provide evidence for the disorder, and meet the severity requirements of functional limitations. These functional limitations include, but are not limited to, restriction of ADLs and difficulty in social functioning. Therefore, the SSA may be able to use information from executive functioning measures along with other germane medical evidence to determine whether an individual's social functioning is severe enough to satisfy the functional limitation criterion. Also, in the present study, the ILS demonstrated significant correlations with cognitive deficits. Therefore, the SSA might consider requesting similar measures of IADL functioning for certain cases in which information regarding an applicant's functional ability may be limited or cannot be obtained otherwise (e.g., lack of reliable informant reports). Further, these tests can be re-administered and, therefore, can be used for disability re-evaluation purposes.

　　　　Finally, the SSA may be able to use scores from neuropsychological tests as a screening tool to facilitate disability determination decisions. Specifically, the descriptive statistics for performance on neuropsychological tests among the levels of IADL functioning (Table 3) indicates that individuals who scored in the low level of functioning generally had memory and executive functioning T scores of less than 36 (8th percentile). Individuals whose IADL functioning was at moderate levels of functioning had T scores between 36 and 44 (8th to 30th percentile). Finally, those in the high level of IADL functioning had T scores on tests of memory and executive functioning generally greater than 45 (32nd percentile). Interestingly, Perna and colleagues (2012) found that individuals who were independent had scores of executive functioning measures that were greater than the 9th percentile. The results from the present study imply that individuals who are independent generally have memory scores also in the same range. This may suggest that those who are at moderate levels of IADL functioning may be able to drive independently, manage money independently, and work full-time. It should be noted that impairment on neuropsychological tests cannot solely determine disability; therefore, additional information is required to support the severity of functional limitations. Nevertheless, the results of the current study provide support for the validity of neuropsychological tests in predicting IADL performance and underscore the importance of obtaining quantitative and qualitative information on an individual's functioning when making judgments regarding disability.

Appendix A
Acronyms

ADL	Activities of Daily Living
AGFI	Adjusted goodness of fit index
AGH	Allegheny General Hospital
BADS	Behavioural Assessment of the Dysexecutive Syndrome
C/W	Color/Word (condition of the Stroop Test)
CFI	Comparative fit index
COWAT	Controlled Oral Word Association Test
GFI	Goodness of fit index
HVLT	Hopkins Verbal Learning Test
IADL	Instrumental Activities of Daily Living
IFI	Incremental fit index
ILS	Independent Living Scales
LM	Logical Memory
MPAI	Mayo-Portland Adaptability Inventory
MR	Magnetic resonance
mTBI	Mild traumatic brain injury
NFI	Normed fit index
P-E	Perseverative errors on the Wisconsin Card Sorting Test
PGFI	Parsimony goodness of fit index
RFI	Relative fit index
RMSEA	Root mean square error of approximation
SSA	Social Security Administration
TBI	Traumatic brain injury
TLI	Tucker-Lewis index
TMT	Trail Making Test
VPA	Verbal Paired Associates
WCST	Wisconsin Card Sorting Test
WMS	Wechsler Memory Scales

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