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The Relationship Between Executive Functions and Prospective Memory in Survivors of Acquired Brain Injury

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THE RELATIONSHIP BETWEEN EXECUTIVE FUNCTIONS AND PROSPECTIVE MEMORY IN SURVIVORS OF ACQUIRED BRAIN INJURY

BY

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The Relationship Between Executive Functions and Prospective Memory

In Survivors of Acquired Brain Injury

BY

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Abstract

This study investigated the relationship between executive functions and prospective memory in a group of fifteen acquired brain injury (ABI) survivors. Differences in executive function and prospective memory were compared between an independent group of survivors that required no daily assistance and a dependent group that required a full time aid or lived in a facility. Overall, nine independent and six dependent survivors were tested on a series of executive function tests including the Executive Function Performance Test (EFPT), the Stroop Color Word Interference Test and the Trail Making Test. The EFPT showed significant differences between groups on speed of making a telephone call, accuracy on the medication management task and overall accuracy on the four tests. The groups showed significant differences on speed and accuracy of the Stroop test as well as speed on the Trail Making Test. On tests of prospective memory, the independent and dependent groups did not perform differently on the Memory for Intentions Screening Test (MIST); however, significant differences were identified on the return of a Prospective Memory Diary. Correlations were found between executive function and prospective memory measures. Prospective memory from the MIST predicted executive function ability on the time of EFPT task two. Results of this study suggest that survivors who are unable to live independently experience more executive function deficits that impact daily functioning. However, due to the difficulty with recruitment, the number of individuals would have to be expanded to further understand the relationship between executive function and prospective memory between the groups.

I. Introduction

Brain injuries impact over two million Americans each year and leave many survivors with long-term cognitive impairments that consequently impact daily functioning (About Brain Injury, 2012). These functional deficits, termed executive functions are of particular importance to clinicians in determining post injury independence levels. Therefore, the relationship between executive function and cognition will be investigated further within this study.

a. Definitions of Acquired and Traumatic Brain Injury

Acquired brain injury (ABI) occurs after birth and is not hereditary, congenital or degenerative. ABIs can include stroke, encephalitis, tumors, hypoxic brain injury and external or traumatic brain injuries (About Brain Injury, 2012). Traumatic brain injury (TBI) is a type of ABI and is caused by an external blow or force to the head and can be further broken down to mild, moderate and severe injury (Roebuck-Spencer & Cernich, 2014). The many types of brain injury lead to diverse post injury outcomes impacting different aspects of daily functioning and cognition.

b. Brain Injury Locations Predict Post Injury Outcome

The location of brain injury is also a crucial factor in determining post injury outcome with regard to physical, sensory and cognitive abilities. Survivors who sustain injury to the basal ganglia and cerebellum are more likely to experience motor control deficits. Basal ganglia damage causes difficulty initiating and controlling movements; therefore, survivors can experience muscle spasms; tremors; uncontrollable, repeated movements; or even difficulty moving at all (Jasmin, 2012). Cerebellar damage causes coordination and balance difficulties, leaving many survivors at risk for falling and injuring the brain further. As a result of the unpredictability of movement, many survivors have to rely on canes or walkers to regain some mobility and physical support. These physical deficits make it difficult for survivors to initiate and execute daily physical tasks such as dressing, toileting or even walking in a home or rehabilitation facility (Newby, Coetzer, Daisley, & Wheatherhead, 2013). Therefore, these physical deficits prevent many survivors from completing daily tasks, leaving them completely dependent on family and friends.

Other physical and sensory changes can result from damage to the temporal lobe. The temporal lobe is largely responsible for audition. As a result, damage to this area often causes hearing loss or tinnitus, which many survivors describe as one of the most frustrating side effects associated with ABI (Impact of Acquired Brain Injury on the Individual, 2014). Patients with tinnitus often complain about constant buzzing or ringing which serves as an immense distraction that hinders active participation in conversations with family, friends or even medical professionals. Temporal lobe damage can also impact sense of smell and taste (Newby et al., 2014).

Impact to the occipital nerve, which travels through the frontal lobe, can cause complete loss of vision, double vision, field cuts or sector losses. Survivors often have to develop compensatory techniques to regain some visual capability (Newby et al., 2014). Vision difficulties are also responsible for causing the lack of independence that many survivors experience; this hinders individuals from leaving their homes alone, driving a vehicle or even participating in physical activities (Jansari et al., 2014). Headaches, another common post injury outcome can be caused by pressure, inflammation or decreased blood pressure. Some survivors have debilitating headaches that can last hours to days, leaving them bedridden until the headaches pass. Sensitivity to light, dizziness, and sleep disturbances are common post injury side effects that negatively impact the daily lives of survivors (Impact of Acquired Brain Injury on the Individual, 2014).

However, in many ways the frontal lobe is the most vulnerable site of a brain injury when considering its location under bony protuberances. This area has been shown to be the most susceptible to injury following traumatic brain injury (Levin et al., 1987). Since this area is most impacted following traumatic brain injury, this commonality can be shared with ABI as well. Damage to the frontal lobe alone impacts physical, cognitive, social and behavioral abilities that alter the manner in which individuals execute daily tasks. These functions, called executive functions collectively, include some of the most important for daily life, such as self-monitoring, integrating activity, impulse and inhibitory control, as well as planning and decision-making (Hunt, Turner, Polatajko, Bottari, & Dawsom, 2013).

c. Definition of Executive Function

Executive function by definition is a non-automatic control process that allows individuals to carry out basic cognitive functions that have goal-directed outputs (Ward, 2009; Hunt et al., 2013). Executive function abilities are necessary for everyday tasks and can include making a meal for dinner, attending an appointment or mailing a package.

In order to understand executive function on a basic level, Sohlberg, Mateer and Stuss (1992) used a tiered system to illustrate the journey from input of information to output of function. Sensory perception serves as the first automatic process that provides the second layer, executive function with information input. Intact executive functions allow individuals to process sensory information using cognitive flexibility, planning and goal creation to initiate a behavioral output. Self-reflection, the remaining layer, comes as a result of a successful executive function output (Sohlberg, Mateer, & Stuss, 1992).

Ward (2009) suggests that there are five steps of executive function in order to obtain what Sohlberg, Mateer and Stuss (1992) consider a successful output. Tasks first need to be planned out effectively and decisions need to be made in order to initiate goal-direct outputs. When difficulties arise along the way, individuals need to be able to trouble shoot effectively in order to continue to achieve the end result. Additionally, it is important to have the capability to process new or novel information; in order to do this, individuals need to inhibit habitual responses and adapt to new rules along the way. Lastly, Ward (2009) suggests that executive functions can sometimes be difficult to complete successfully. This is especially true for survivors of brain injury because the most common area of damage, the frontal lobe, is equipped with the executive capability to overcome difficulties. Again, damage to this area can singlehandedly impact each step of executive function, which Ward (2009) suggests is crucial in the successful execution of an executive function task.

d. Executive Function Deficits Following ABI

Individuals with ABI who have frontal lobe injury have been shown to experience a lack of initiation of executive tasks, which decreases the likelihood that goal-directed tasks will be completed successfully (Baum et al., 2008). Further research has shown that attention, concentration, memory, processing, planning and problem solving decline as a result of brain injury, which decreases success of Ward’s (2009) five steps of executive function. Survivors often become overwhelmed with each of these components thereby making it difficult to complete basic, everyday tasks. Consequently, this forces survivors to rely on family members or friends to accomplish everyday abilities (Jansari et al., 2014).

Learning and information processing have been shown to be slower in tasks that involve problem solving or cognitive flexibility; survivors take more time to complete such tasks and struggle to do so. This cognitive rigidity, or inability to remove previous habitual rules, prevents many survivors from being able to properly encode and execute desired executive functions (Newby et al., 2013). Therefore, Sohlbergh, Mateer and Stuss' (1992) multitier organization can be considered an effective means of describing the connections needed to successfully complete executive functions. When the steps of executive function are not completed, neither is the successful output.

Other cortical connections have been associated with executive function in addition to those localized to the frontal lobe. Caeyenberghs et al. (2012) used structural magnetic resonance imagery (MRI) to determine the areas of the brain that are necessary for executive function tasks in individuals with TBI. The tasks of executive function included the Local Global Task, a dimensional target selection task, and the Trail Making Test. The study determined that TBI survivors had decreased global connections projecting from the frontal lobe and fewer white matter projections in the brain when completing these executive tasks. In addition to showing global deficits, this research further confirmed the impact of frontal lobe damage on the outcome of executive function tasks. This finding further highlights the overarching nature of executive functions and the impact of ABI on the brain. While Caeyenberghs et al. (2012) used structural MRI to determine the localized region and global connections associated with executive function, other researchers have attempted to use standardized clinical and behavioral measures to determine executive function changes after ABI.

e. Measures of Executive Function

Since executive functions by nature involve daily actions, it is often difficult to observe such functions in a lab setting. Often survivors and their families have to make clinicians aware of additional executive function deficits that impact independence that are not recognized on standardized clinical measures. As a result of this testing gap, researchers have developed behavioral measures, which involve daily tasks that can be executed and measured in a lab space (Jansari et al, 2014; Baum et al, 2008). Behavioral measures of executive function are used to help medical professionals obtain a better understanding of the interaction between physical and cognitive abilities in a realistic setting.

Jansari et al. (2014) provides a review of three widely used clinical executive function measures, which include the Trail Making Test, Wisconsin Card Sorting Test (WCST) and Controlled Oral Word Association Test (COWAT). The WCST attempts to identify cognitive flexibility and the Trail Making Test is used to determine attention and speed through the goal-directed lens of executive function. The COWAT identifies verbal fluency and also follows a time restraint that individuals with ABI often struggle with. Researchers around the world have recognized that many survivors will perform more slowly on these standardized clinical tests than they would have prior to the injury (Jansari et al., 2014; Chan, Shum, Toulopoulou, & Chen, 2008).

Despite the difference in performance when comparing healthy participants to survivors of ABI, these measures are not sensitive enough to generalize or to identify the complete scope of executive function deficits. Chan, Shum, Toulopoulou and Chen (2008) suggest that these standardized clinical measures are not straightforward in their approach and that improving then is not an effective means of rectifying the everyday deficits that family and friends are making physicians aware of. Research also suggests that these measures only indicate 18-20% variance of everyday executive function ability (Jansari et al., 2014). Since executive functions involve the interaction between each of these test aims, researchers sought to develop a new way to investigate executive function in its entirety.

As previously mentioned, researchers have been developing behavioral measures to assess executive function in the lab while modeling a realistic setting. The Naturalistic Actions Test (Schwartz, Segal, Veramonti, Ferraro & Buxbaum, 2002), is a behavioral measure used to assess everyday tasks that include making breakfast and lunch and wrapping a gift. Despite the natural environment and tasks resembling basic actions, Raskin & Benedetto (2014) determined that the test was not sensitive in identifying deficits of executive function in individuals with mild TBI. The Multiple Errands Test (MET) (Knight, Alderman & Burgess, 2002) resembles a shop-like setting that requires individuals to follow a list to place specific items in their cart (Burgess et al., 2011). Survivors of ABI have been shown to make more executive function errors on the MET and tasks have been shown to be highly predictive of daily executive function difficulties in this same population (Knight, Alderman & Burgess, 2002). These behavioral measures more accurately present real life situations that can help predict survivor executive function outcomes.

The Executive Function Performance Test (EFPT) (Baum et al., 2008), used during this study, was developed to help occupational therapists determine the level of support that ABI patients need during rehabilitation. The EFPT measures the cognitive steps associated with executive functions, which include task initiation, planning, organization, judgment of safety, and task completion. The ecological validity of this measure was established based on the everyday environment used, lack of artificial structure, and the reflection of everyday actions that require a level of multitasking (Baum et al., 2008).

Everyday tasks assessed in the EFPT include making oatmeal, medication management, making a telephone call and pretending to pay bills. Baum et al. (2008) identified significant differences when comparing a group of mild and moderate stroke survivors to a control population of healthy participants. Stroke survivors took longer to complete each of the desired tasks and required additional cues to assist with task completion. The EFPT investigated both time and accuracy based results, which allowed occupational therapists to directly observe realistic executive function performance.

More importantly, Baum et al. (2008) compared the EFPT's realistic setting to standardized clinical measures of executive function including Animal Naming, Trial Making Test, Wechsler Memory Scale and the Logical Memory Total Recall Test. While these measures were useful in identifying time based execution of executive function, they did not involve completion of realistic executive function tasks (Baum et al., 2008). As a result, they did not allow occupational therapists to accurately observe real life executive function performance. Therefore the EFPT was shown to be a more realistic and sensitive measure in identifying the complexity of executive functions.

f. Definition of Prospective Memory

Research has recently shown that executive function completion is closely connected with memory retention in survivors of ABI (Jansari et al., 2014). Since executive functions are cognitive in origin, memory, another crucial cognitive feature, greatly impacts the execution of daily tasks. Surely, if individuals forget what they are instructed to do they are committing both a memory and executive function failure.

When there is a delay before a task is executed, this type of memory is termed prospective memory and is considered the memory of a future act or intention. The delay occurs between initiation and completion of the task (Brandimonte, Einstein & McDaniel, 1996). Prospective memory involves self-initiation to facilitate encoding and activating the memory for execution. There are four steps to ensure that a future memory is encoded and retrieved effectively. First, an intention needs to be formed and encoded using organization and planning skills. Retention of the intention represents the second factor, which occurs over an extended time period accounting for the delay. The most influential step involves self-initiated retrieval, where event or time based subsections of prospective memory become relevant. Following independent initiation, the final step of prospective memory involves execution of the task itself (Carey et al., 2006).

Prospective memory can be further broken down into subsections, which include time and event based memory. Event-based prospective memory involves remembering to perform an intended action in response to a specific event or cue. If an individual were to remember to turn off the stove in response to a timer they would be completing an event-based prospective memory task. Time-based prospective memory involves remembering to execute an action at a specific time; remembering to take a medication at a specific time is an important time-based task (Wesslein, Rummel & Boywitt, 2014; Shum, Valentine, Cutmore, 1999).

Additionally, prospective memory encompasses decision-making, planning skills and inhibitory mechanisms (Groot, Wilson, Evans & Watson, 2002). The overlaps with the steps of executive function demonstrate how essential prospective memory is for daily functioning. Prospective memory tasks involved in daily life include remembering to pay monthly bills or remembering to take medication at a specific time, both are tasks that the EFPT uses to assess executive function in a behavioral setting.

The overlap between prospective memory and executive function is also present with regard to brain structures; prospective memory, like executive function, is initiated in the frontal lobe. Individuals with frontal lesions have shown prospective memory deficits from this lack of connectivity (Shallice & Burgess, 1991). Prospective memory is dependent on prefrontal-striatal circuits, which have a role in global networks necessary for intact executive functions (Carey et al., 2006).

g. Measures of Prospective Memory

The Memory for Intentions Screening Test (Raskin, Buckheit, & Sherrod, 2010) is a 30-minute standardized clinical measure of prospective memory (time and event based) that has been shown to serve as a predictor of executive functions in vulnerable populations (Carey et al., 2006; Raskin & Benedetto, 2014). The level of sensitivity within populations of ABI survivors, though, has been difficult to generalize based on the independent and varying post injury consequences (Raskin & Benedetto, 2014). Therefore, further research is necessary to understand the implications of prospective memory deficits in individuals with executive function impairments.

h. Relationship Between Prospective Memory and Executive Function

The closest connection between prospective memory and executive functions was observed in a virtual reality study, which considered prospective memory to be a key component involved in executive function execution (Jansari et al., 2014). Additionally, Jansari et al. (2014) discussed the possibility that future research connecting prospective memory impairments to executive function failure could provide occupational therapists with a way of redirecting survivors of ABI to obtain cognitive support for memory to help executive function recovery.

Further confirmation of the relationship between executive function and prospective memory in everyday life can help predict more specific changes in independence following brain injury. Since prospective memory helps individuals process and remember tasks of executive function, a failure in memory often causes an executive function failure. If a survivor of ABI forgets to turn off a stove with boiling hot water, the consequences become life threatening and often cause survivors to lose independence. Karlovits and McColl (1999) used a qualitative approach to determine consequences following brain injury and survivors noted loss of independence being one of the most stressful. Therefore, survivors are aware of these deficits and often address these concerns with medical professionals to obtain the help they need. As a result of the high stakes, this research is of critical importance with regard to survivor safety and independence.

i. This Study

The proposed study sought to identify the relationship between executive function and prospective memory in survivors of ABI with two different independence levels. A group of independent survivors of ABI, who required no daily assistance, were compared to a dependent group that required full time aids or reside in assisted living facilities. The MIST was utilized as the assessment of prospective memory while a combination of behavioral and standardized clinical executive function measures were used to determine time and accuracy on executive function tasks. The sensitivity of prospective memory measures in predicting executive function was investigated to one day determine if clinical rehabilitation methods can be established to help increase survivor independence.

i. Hypotheses

1. Dependent survivors were expected to perform more poorly and take more time on both behavioral and standardized clinical measures of executive function than a group of independent ABI survivors.
2. Dependent survivors of ABI were expected to perform more poorly on prospective memory measures than an independent group of survivors.

3. Prospective memory ability, determined by the MIST, was expected to predict executive function ability.

II. Methods

a. Participants

Participants were recruited using emails and flyers, which were distributed to an existing database of ABI participants. Additionally, medical professionals throughout the state of Connecticut posted the study flyer in their waiting rooms to inform potential participants in other regions of the state. A total of 66 participants were contacted, 34 were unreachable after three phone calls and/or emails and 17 individuals responded one or more times and scheduled testing sessions but did not show up or reschedule testing.

A total of 15 ABI survivors between the ages of 29 and 66 (M= 50.3 ± 12.5) were tested (See Table 1 for demographics). Independent survivors, who did not require the help of an aide, represented the independent group consisting of nine individuals (Age M=53.8 ± 11.0; Education M=17 ± 3.5 years). The remaining six dependent survivors required at home help, aides or Independent Living Skills Training (ILST) (Age M= 45 ± 14.6; Education M=15.5 ± 3.6 years). There were no significant differences associated with age and years of education between groups.

Exclusion criteria included current substance or alcohol abuse, severe auditory or visual impairments, neurological or psychiatric illnesses, and severe anxiety and depression determined by the Beck Depression and Anxiety Inventories (Beck & Steer, 1990; Beck & Steer, 1990). Individuals were asked to answer 21 questions, which were based on a scale from zero to three; an answer of three indicated more severe anxiety or depression for the given question. The scores were added and total Beck Anxiety Inventory and Beck Depression Inventory each out of 63 were determined. Individuals with scores between 30 and 63 were considered to be severely anxious or depressed and were therefore ineligible (Beck, Ward, Mendelson, Mock & Erbaugh, 1961).

Participants read and signed an IRB approved informed consent form. Confidentiality and compensation were addressed; individuals were compensated with a ten-dollar Barnes and Noble Gift Card. To ensure confidentiality, participants were given an ID number that was used on each questionnaire, test and mailed response form. A demographic form was used to collect information including sex, race, learning and psychological diagnoses as well as cause of head injuries (Table 1).

Table 1: Group demographics and acquired brain injury case information

Variable	Independent (n= 9)	Dependent (n=6)
Sex of Subject		
Male	3	2
Female	6	4
Race/ Ethnicity		
Caucasian	8	6
Hispanic	1	-
Cause of Brain Injury		
Trauma from Fall	2	1
Boxing Injury	1	-
Tumor	2	2
Motor Vehicle Accident	-	1
Brain Stem Contusion	-	1
Korsakoff's	-	1
Electrocution	1	-
Stroke	1	-
Unknown	2	-
Loss of Consciousness		
Seconds	1	-
2 Minutes	1	-
30 Minutes	1	-
20 Days	1	1
2 Months	-	1
3 Months	-	1
None	4	1
Time Unknown	1	2

b. Measures

i. Executive Function Assessments

The Executive Function Performance Test (EFPT) (Baum et al., 2008) was the behavioral measure of executive function used to determine the speed and accuracy of completing basic, everyday tasks. Participants were asked to make oatmeal, complete a medication management task, make a phone call and pay bills. Each task was timed and the EFPT Trinity College Scoring Sheet was used to determine accuracy of each task. Accuracy or task completion was based on the order that verbal instructions were given and completed; these instructions were provided before each task began. Therefore, intact memory was necessary for successful completion of each task.

Individuals were provided a hot pot, water, measuring cups, oatmeal, spoons, salt, a bowl and timer for task one. They were told to read the oatmeal instructions (provided in an enlarged version) and make one serving of oatmeal by following the stovetop instructions. After participants were asked if they had any questions, they were told to begin the task and accuracy and time were recorded. Participants were then asked to sit at the telephone desk for task two and were provided a pencil, paper, magnifying glass and phone book and were asked to locate the phone number of a local grocer and make a telephone call to ask if they deliver groceries. Task three involved medication management; participants were provided with one pill bottle filled with sugar free candy, one pill bottle with the participant's name, crackers, and water. Participants were told to find these items in the provided box, locate the pill bottle with their name and read the prescription's instructions, which involved taking two pills with food and water. They were told to take the correct number of pills and food and water out of the box and place them on the table. Task four was a bill paying task where two fake bills, a checkbook, balance sheet, pen and calculator were provided and individuals were asked to pay the bills and balance their checkbook after both checks were filled out.

Time and accuracy for each task and total time and accuracy were recorded. Accuracy was based on the completion of determined steps that were necessary to successfully make oatmeal, make a telephone call, manage medication and pay bills. On the oatmeal task, accuracy involved the completion of nine tasks including initiation and organization, followed by measurement of correct amount of water and oats and boiling successfully. The telephone call and medication management tasks involved six steps which included identifying the correct phone number or medication and carrying out the intended task completely. The bill-paying task involved five steps including locating bills, writing and balancing checkbooks. Individuals who completed each step received one point while incomplete or unordered steps received zero points; the total EFPT test time was out of 26 points.

The Trail Making (Delis & Kaplan, 2001) and Stroop Color Word Interference Tests (Trenerry, Crosson, DeBoe & Leber, 1989) were used as standardized measures of executive function. The Trail Making Test was used to assess visual attention and cognitive flexibility. Individuals were asked to perform a numbered connect-the-dot type task. In the second trial, the subjects alternated numbers and letters as they completed the task. Time was recorded for both conditions. The Stroop test is a timed task that requires participants to inhibit an automatic response (reading words) and instead, to read the ink color of the word. Individuals were first asked to read a list of 112 words as quickly as they could in the Color Interference section. Then they were asked to say the color of the 112 words provided on the Color Word Interference section. Again time and accuracy, measured by correct readings were recorded. These standardized clinical measures were used to determine cognitive flexibility in a time based setting.

ii. Prospective Memory Assessments

Prospective memory was assessed in two forms, using the Memory for Intentions Screening Test (MIST) (Raskin, Buckheit, & Sherrod, 2010) and a Prospective Memory Diary (Raskin & Mateer, 2000). The MIST requires participants to complete a series of time (two and fifteen minute), and event based tasks. An example of a time-based task is, “In two minutes, tell me a time of day that I can call you tomorrow.” An example of an event-based task is, “When I hand you a red pen, please write the date on your paper.” Half of the tasks require verbal response and half require an action. During the delay waiting period, participants completed an ongoing task, in this case a word search puzzle. Participants who completed the task at the correct time received two points, completion at the wrong time or with the wrong task were given one point, and lack of task completion garnered zero points. There were a total of eight tasks given during the 24 minutes test session.

At the end of eight prospective memory trials, individuals were asked retrospective multiple choice questions to determine if they could recognize the items they were previously asked of them. Lastly, participants were asked to complete a 24-hour delayed prospective memory follow up where they were to call the lab and state how many hours they slept the previous night. This final task received two points for time and task completion while one and zero points were earned when the task was either completed incorrectly, at the wrong time or not completed at all.

The Prospective Memory Diary was used to assess prospective memory in a more naturalistic setting. Individuals were asked to identify ten tasks that they needed to do in the seven days following the testing session. Each participant received the first task, "Mail memory diary in seven days;" the remaining nine tasks were created at the discretion of the participant. Individuals were then asked to rate the completion of each task in the diary and write if they used a memory aid to remember to complete the task during the following week. The scoring system ranged from zero to two; successful completion of the task (two points earned) was based on the correct mail date of the completed diary using the prepaid envelope. Individuals who received one point mailed the envelope later than seven days, or mailed on time but did not complete the memory reflections and zero points indicated that a Prospective Memory Diary was not returned.

iii. Community Integration Questionnaire

The level of independence by each of the two groups was assessed using the Community Integration Questionnaire (CIQ) (Dijkers, 2000). Individuals were asked about their daily involvement in the community, including involvement via friendships, meetings with family or interaction with other brain injured individuals. Additionally, participants reported involvement in household chores, volunteer work, and school or job settings. Maximum community integration was out of 29 points; individuals with minimal independence and integration received lower scores.

c. Analyses

IMB SPSS Statistics 22 was used to organize and analyze all data. Again, all participant data corresponded to a given ID number rather than a participant name to ensure confidentiality throughout the data process.

Statistical analyses comparing prospective memory accuracy to executive function time and accuracy between the independent and dependent groups were executed using both independent two-tailed t-tests and Mann-Whitney tests. Correlations were also used to determine if executive function and prospective memory relationships significantly related. Lastly, regression analyses were used to determine if prospective memory performance predicts executive function ability.

d. Procedure

Testing occurred in one session and lasted between two and three hours. Individuals were either tested at Trinity College in Life Science Center Room 102 or were tested in their home depending on mobility level and access to transportation. Once participants were comfortable in the testing space, the informed consent form was provided for the participant to read and was discussed verbally before the individual signed the form. Individuals were then asked to fill out the CIQ before being given the instructions for the MIST, which took 24 minutes to complete. After the retrospective recognition test and delayed prospective memory components of the MIST were completed, individuals were asked if they would like to take a break. The BAI and Trail Making Tests Conditions 1 and 4 were completed next followed by the BDI and Stroop tests. Individuals were then provided time to reflect on ten different tasks that they needed to complete in the next week; as each task was provided, the research assistant wrote them in the Prospective Memory Diary. After ten tasks were written in the diary, the research assistant informed participants that the diary would need to be filled out and returned in one week in the provided prepaid envelope.

In order to give the researcher time to set up for the executive function tasks, participants were next asked to complete a Background Information Sheet. After a series of executive function questions were asked, participants were asked to complete four executive tasks. The tasks were completed in the following order beginning with a simple cooking task followed by the telephone, medication management, and bill paying tasks. Participants were then given their $10 Barnes and Noble gift card and the testing session was complete.

III. Results

a. Executive Function Accuracy and Time

i. Executive Function Performance Test

Two-tailed t-tests revealed that EFPT total accuracy differed significantly between the groups (t (13) = 3.40, $p < 0.01$; Figure 1); however total time among the groups was not significantly different. Accuracy of task three, which involved medication management, indicated that dependent survivors performed more slowly than independent survivors (t (13) = 4.67, $p < 0.001$; Figure 2). It was determined that time was significantly different on the second EFPT task which asked individuals to call a local grocer and determine if they delivered groceries (t (13) = -2.99, $p < 0.01$; Figure 3).

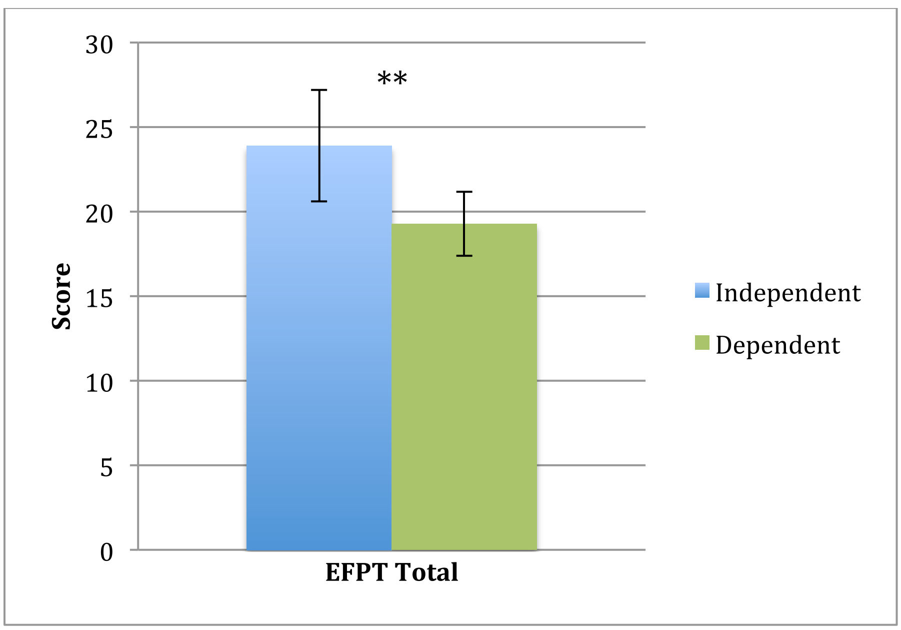

Figure 1: Total accuracy on EFPT tests showed a significant difference between groups ($p <$ 0.01).

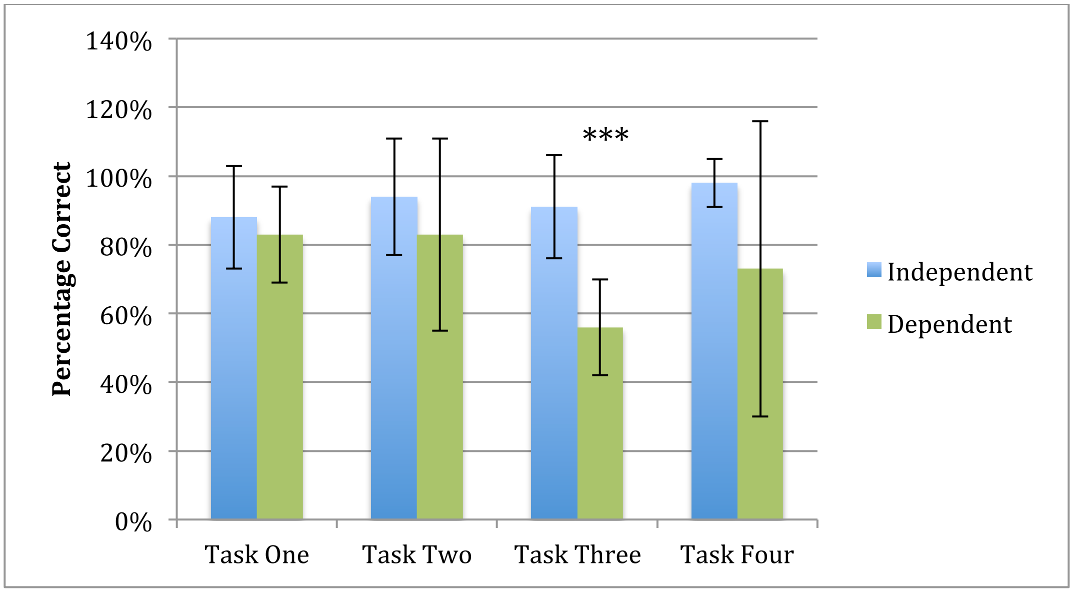

Figure 2: Accuracy of EFPT tasks differed significantly only on task three (p <0.001).

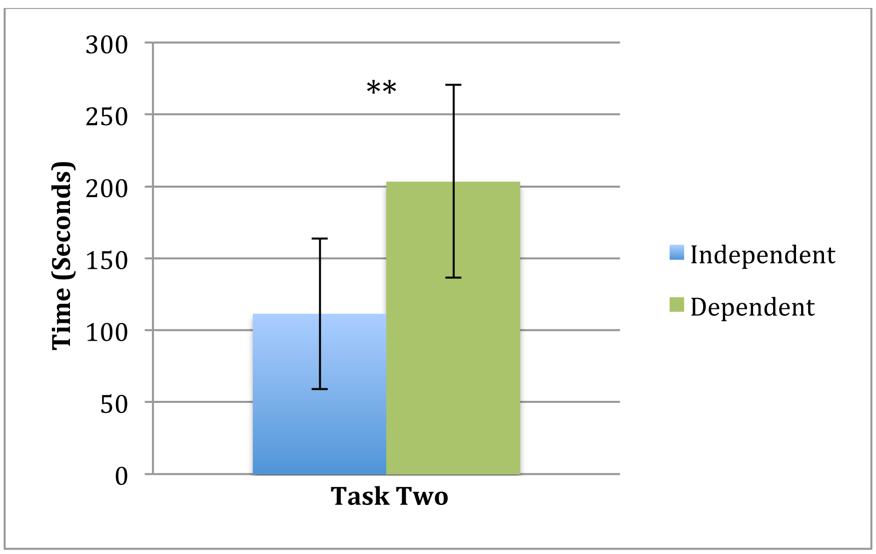

Figure 3: Speed of task two differed significantly between groups ($p < 0.01$).

ii. Stroop Color Word Interference Test

Two-tailed t-tests determined that survivors differed significantly on timing (t (12) = -2.18, $p < 0.05$) and accuracy (t (12) = 3.35, $p < 0.01$) of the Stroop Color Interference test; however no significant differences were revealed on the Stroop Color Word Interference Test between either time or accuracy (Figures 4 and 5).

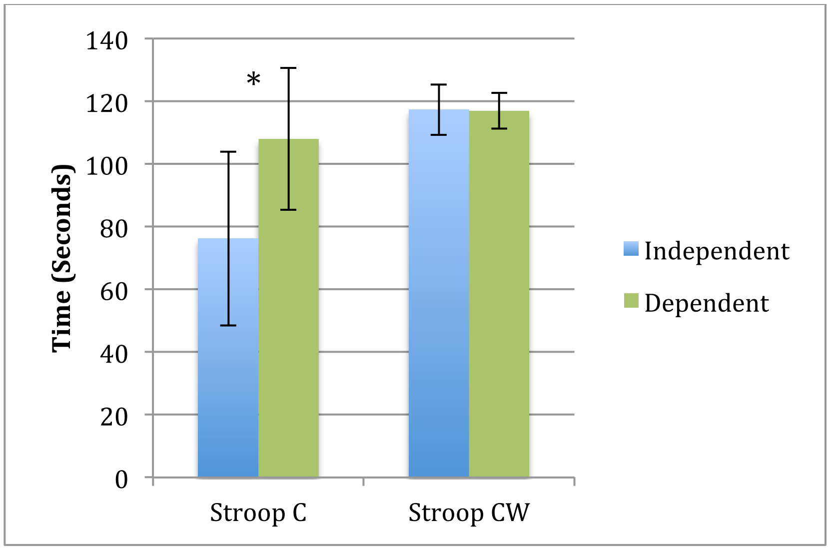

Figure 4: Time of Stroop Color Interference differed significantly between groups ($p < 0.05$).

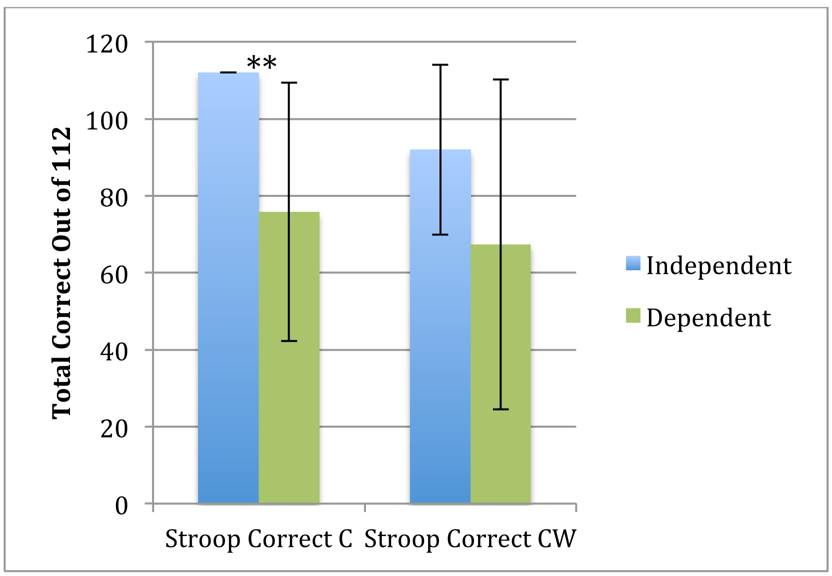

Figure 5: Accuracy on Stroop Color Interference differed significantly between groups ($p < 0.01$).

iii. Trail Making Tests

Two-tailed t-tests indicated that the dependent group had significantly slower performance time on condition one (t (13)= -2.21, $p < 0.05$); however no significant differences were determined on time of condition four (Figure 6).

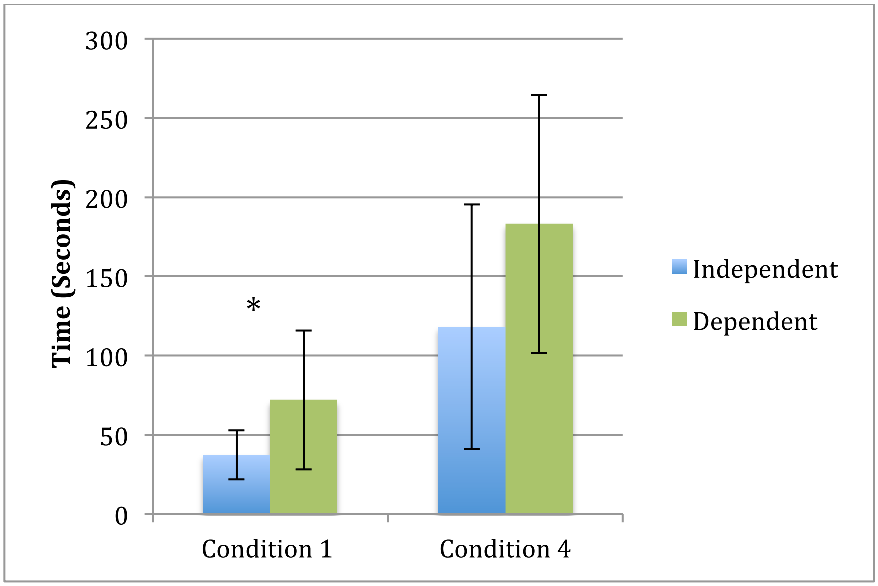

Figure 6: Speed on condition one differed significantly between groups ($p < 0.05$).

b . Prospective Memory Accuracy

i. Memory for Intentions Screening Test

Two-tailed t-tests did not reveal any significant differences between groups on any component of the MIST including subsections, retrospective recognition test (RRT) and delayed prospective memory tasks (Figures 7-10)

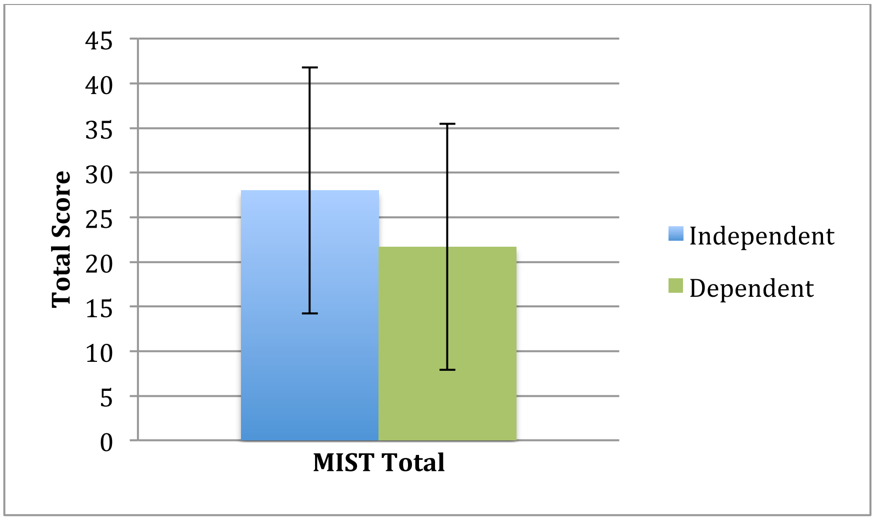

Figure 7: Total accuracy on the MIST did not differ significantly between the groups.

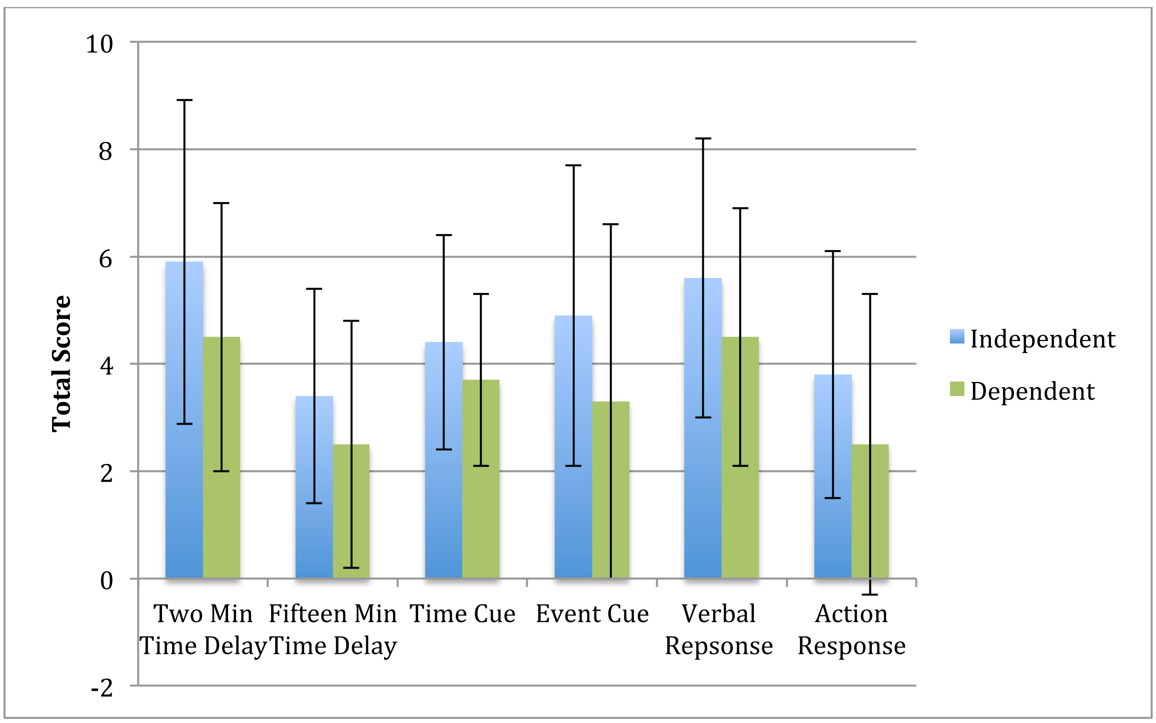

Figure 8: Accuracy on MIST subscales did not differ significantly between groups.

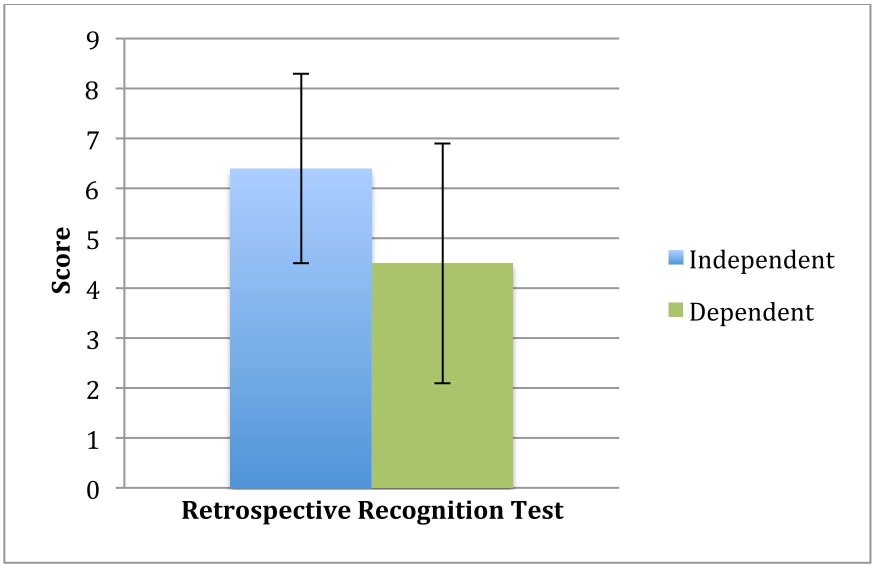

Figure 9: Accuracy of retrospective recognition did not differ significantly between groups.

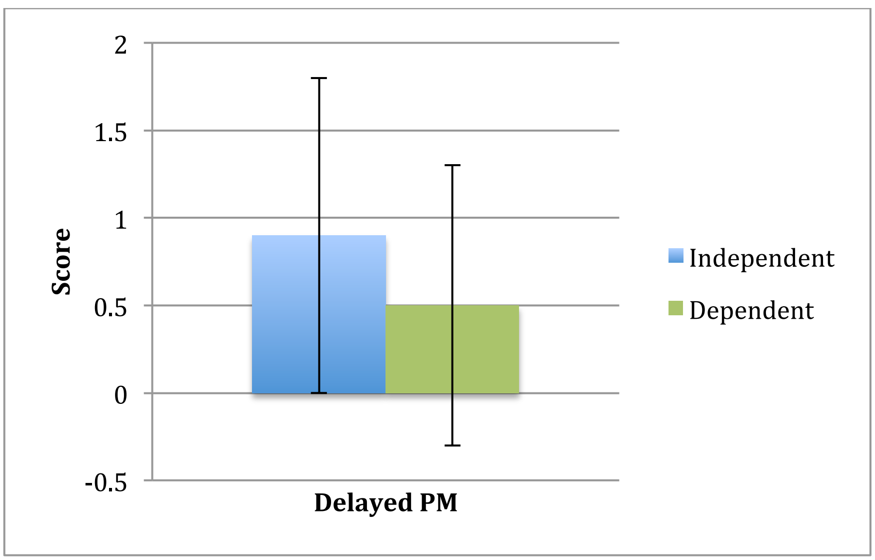

Figure 10: Accuracy of delayed prospective memory task did not differ significantly between groups.

ii. Prospective Memory Diary

Two-tailed t-tests revealed that individuals in the dependent group differed significantly on the return of the Prospective Memory Diary than independent survivors (t (13) = 2.70, $p <$ 0.05; Figure 11).

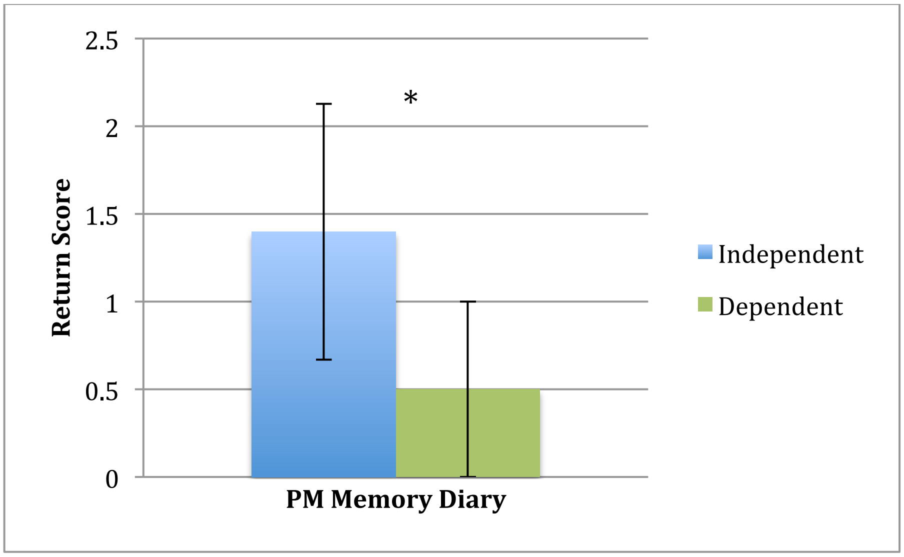

Figure 11: Returning of the Prospective Memory Diary differed significantly between groups ($p < 0.05$).

c. *Correlation Between Executive Function and Prospective Memory*

Correlations were revealed for both groups between many executive function and prospective memory tests. The secondary executive function measures including the Trail Making Condition 4, Stroop Color time and accuracy as well as Stroop Color Word accuracy correlated significantly to prospective memory measures including the MIST and Prospective Memory Diary (Tables 2-4). MIST total and MIST subsections were revealed correlations between the EFPT task 2 time, or the time it took to call a local grocer.

Table 2: Trail Making Condition 4 and prospective memory measures correlated significantly between groups.

		Trail Making Condition 4
Fifteen Minute Time Delay	Pearson Correlation	-0.637
	Significance (2-tailed)	0.011*
	N	15
Time Cue	Pearson Correlation	-0.522
	Significance (2-tailed)	0.05*
	N	15
Event Cue	Pearson Correlation	-0.576
	Significance (2-tailed)	0.02*
	N	15
Verbal Response	Pearson Correlation	-0.537
	Significance (2-tailed)	0.04*
	N	15
MIST Total	Pearson Correlation	-0.611
	Significance (2-tailed)	0.02*
	N	15
RRT	Pearson Correlation	-0.749
	Significance (2-tailed)	0.001***
	N	15

Table 3: Stroop Color and Color Word accuracy correlated significantly with RRT and Prospective Memory Diary.

		Stroop Color Accuracy	**Stroop Color Word Accuracy**
RRT	Pearson Correlation	0.567	0.854
	Significance (2-tailed)	0.03*	0.00***
	N	14	14
PM Diary	Pearson Correlation	0.559	-
	Significance (2-tailed)	0.04*	-
	N	14	-

Table 4: Stroop Color Time correlated significantly with MIST subsections.

		Stroop Color Time
Fifteen Minute Time Delay	Pearson Correlation	-0.645
	Significance (2-tailed)	0.013*
	N	14
Action Response	Pearson Correlation	-0.592
	Significance (2-tailed)	0.03*
	N	14

d. Prospective Memory Prediction of Executive Function Ability

Linear Regression Analysis was used to determine if prospective memory ability, determined by the MIST, predicted executive function results on the EFPT. It was determined that the MIST predicted performance on only EFPT Task 2 time (F (1,12) = 5.263, $p < 0.05$).

e. Remaining Questionnaires and Measures

Descriptive statistics of the Community Integration Questionnaire suggest that independent survivors are more involved (M=19.1 ± 5.3) than dependent survivors (M=13.4 ± 6.2). However two-tailed t-tests do no show a significant difference between groups. The Beck Anxiety Inventory average for independent survivors was 11.6 ± 9.5, while that of dependent survivors was 19.2 ± 15.5. The Beck Depression inventory did not indicate depression for either the independent (M=12.4 ± 5.0) and dependent (M=12.0 ± 9.2) groups.

IV. Discussion

This study aimed to determine the relationship between executive functions and prospective memory for independent and dependent survivors of ABI. Previous studies have attempted to investigate this relationship but this is the first that compares the independence of survivors with regard to these essential cognitive abilities.

Overall, it was determined that dependent survivors had more timing and accuracy deficits than independent survivors on specific tasks of executive function. Surprisingly, prospective memory did not differ between groups on the MIST; however, significant differences were identified on the return of the Prospective Memory Diary. Additionally, it was determined that the MIST served as a predictor of the length of time it would take for participants to complete EFPT Task 2, which involved making a telephone call to a local grocer. Due to recruitment difficulties, these findings do not indicate that prospective memory deficits predict all executive function deficits. Despite this limitation, the research does show that independent and dependent survivors have different executive function and prospective memory abilities, which could be informative for occupational therapists, physicians and clinicians to determine post injury rehabilitation measures and placements.

a. Executive Function Performance

Measures of executive function were examined for both completion time and accuracy. It was determined that dependent survivors took longer to complete the Stroop Color Interference Test as well as Trail Making Test Condition 1; Stroop Color Interference accuracy was also significantly different between groups. These findings correspond with similar studies of standardized clinical measures of executive function (Sigurdardottir et al., 2014). The Stroop and Trail Making Tests are considered cognitively demanding measures that identify performance on one aspect of executive function. Performance on the Stroop, for example, provides some indication of an individual's ability to overcome habitual responses and adapt to new rules for executive function completion (Sigurdardottir et al., 2014). It was observed, however, that performance on the Stroop Color Interference was often slower in the dependent group because of the survivors' ability to read; many experienced more debilitating injuries, which impacted elementary cognitive abilities such as reading speed.

The Trail Making Test is also an assessment of overcoming habituation by examining switch-costs; this measure also highlights an individual's processing speed, visual scanning ability and attentional capability (Sigurdardottir et al., 2014; Baum et al., 2008). Studies on attention and ABI show that self-reported executive function abilities predict attentional deficits. This suggests that attention plays a large role in the success of an executive function task when considering setting, planning and execution of desired goals (Schiehser et al., 2011).

Individual steps of executive function, determined by standardized clinical measures, do not allow researchers to examine the successful completion of daily tasks. Chan et al., (2008) compared these two types of executive function measures and proposed that standardized clinical measures informed clinicians of only impairments of executive function while behavioral measures could predict disability, participation and handicaps related to executive function. The standardized clinical measures are merely scratching the surface of post injury expectations with regard to executive function ability. This is the reason why researchers like Baum et al. (2008) and Jansari et al. (2014) developed measures to help clinicians further identify behavioral deficits. These behavioral observations are individualized and significantly more revealing of post injury outcomes.

The main behavioral measure of executive function was the EFPT; accuracy on all four EFPT tests was consistent with Baum et al. (2008), which showed that moderate stroke survivors performed more poorly than a group of mild stroke survivors who performed more poorly than healthy controls. Independent and dependent groups can also be divided in a similar way, as individuals with more severe brain injuries and consequently more severe post injury outcomes are often dependent on others to help with everyday functions. Dependency can cause self-doubt, which would make participants in this group more hesitant with unfamiliar tasks of executive function. Accuracy of the medication management task, for example, was significantly different between groups. While dependent survivors reported that they knew the location their medication, they often reported that their ILST or a family member dispensed medication. Whereas independent survivors reported that they knew the location and how to dispense their own medications. This familiarity could have contributed to the increased speed of independent survivors during the medication management task. These results are consistent with research suggesting that unfamiliar complex executive function tasks in dependent survivors require a significant level of attention and planning to complete successfully (Hunt et al., 2013). These findings are helpful for clinicians to gauge individual medication management and can help indicate the level of daily assistance needed. More generally, Jansari et al. (2014) suggests that behavioral measures of executive function are more informative because they involve realistic environments that can allow researchers and clinicians to observe these differences first hand.

b. Prospective Memory Performance and Correlations with Executive Function

Surprisingly there were no significant differences between groups on any measure of the MIST. Other studies have shown that survivors of ABI have prospective memory difficulties while healthy individuals do not (Raskin & Benedetto, 2014; Raskin, Buckheit, Waxman, 2012;

Shum, Valentine, Cutmore, 1999). Had there been a healthy group, it would be expected that both independent and dependent survivors would perform more poorly on prospective memory measures than healthy individuals. The non-significant findings could suggest, though, that the MIST is challenging even for independent survivors. Additionally, the individualized nature of brain injury and small yield number could be responsible for this difference as some participants in the dependent group actually performed better on the MIST than those in the independent group.

Significant differences were found between groups on the Prospective Memory Diary. The Prospective Memory Diary encompasses each of the components of prospective memory as well as executive function. Time-based memory is determined by the return date, event-based is a result of seeing the measure and completing the ten tasks and lastly the action, or executive function is required for completion and successful return of the test. Overall, the combination of both cognitive tasks suggests that many tasks of executive function require prospective memory for successful completion. Findings by Jansari et al. (2014) reveal that executive functioning tasks that require prospective memory show significant differences among groups of brain injury survivors and healthy individuals. This significance was consistent across all types of prospective memory including time and event based prospective memories (Jansari et al., 2014). An additional study by Hunter (2015) also determined that event-based prospective memory was more closely related to executive function performance. It is apparent that these cognitive abilities are interconnected and that success of executive function requires intact prospective memory.

Further connections between prospective memory and executive function were examined in this research. Results of this study also revealed that the MIST and Prospective Memory Diary were correlated with measures of executive function, which again highlights the connection between the two cognitive abilities and their impact on survivors of brain injury. Both factors are necessary for the completion of daily activities and this study demonstrates that the connection is an important one.

c. Prospective Memory Predictions on Executive Function Ability

The overarching goal of this study was to determine if prospective memory performance could predict executive function performance. It was determined that the MIST served as a sensitive predictor of the performance time of the EFPT telephone call task (Task 2). Surprisingly, the MIST did not predict executive function abilities on any of the other EFPT tasks, which suggests that additional research needs to be done to evaluate predictions in a larger sample size.

Studies investigating the predictions between prospective memory and executive function are few and far between. A recent study investigating the relationship between prospective memory and executive function revealed that executive function performance actually predicted prospective memory ability in older populations (Hunter, 2015). However, this is the first study to determine the reverse prediction, examining prospective memory predictions of executive function in populations of brain injury survivors.

The findings of this study suggest that prospective memory serves as a predictor of executive function time in independent and dependent survivors of ABI. It was determined that dependent survivors took longer on tasks of executive function and had more difficulties with accuracy. This is consistent with research suggesting that executive function tasks take more attention (i.e. time) to complete correctly in survivors of brain injury (Hunt et al., 2013). More importantly, results revealed that standardized clinical measures of executive function do not resemble real life executive functions but are an effective means in predicting what Ward (2009) described as executive steps. Overall, there is evidence of a connection between prospective memory and executive function that should be examined further and one day might be an effective tool for clinicians to use in practice to help with post injury rehabilitation for survivors of ABI.

d. Limitations

While significant differences between groups were identified on certain tasks of prospective memory and executive function, many studies have shown parallel differences on all measures and subsections of both prospective memory and executive function respectively (Raskin, Buckheit, Waxman, 2012; Baum et al., 2008). It was determined that the small sample size, due to immense recruitment difficulties, contributed to the lack of significance across the board. Out of the 66 individuals contacted for participation, only 15 were scheduled and successfully attended the testing session.

One of the limitations of working with individuals with brain injury is that survivors experience prospective memories difficulties, which is the cognitive ability necessary to remember to attend appointments (Raskin & Mateer, 2000). Instances occurred with three participants in particular who scheduled upwards of three times and confirmed via telephone the day before but forgot to attend on the day of the session. These are the types of prospective memory failures that are important to capture in a clinical setting and might be an effective means of identifying independence and compensatory techniques for survivors.

The immense variation of brain injury and post injury outcomes also presents a limitation to the consistency of the data between groups. Prospective memory performance on the MIST, for example, was higher in some individuals in the dependent group than those in the independent group. There was tremendous variability even within each group as seen by the large standard deviations. Age, which has been shown to impact prospective memory scores variably, could be a result of this difference despite the lack of significant difference between groups (Zollig, Mattli, Sutter, Aurelio & Martin, 2012).

Additionally, severity of injury can result in extreme variations in post injury outcome that differ for each survivor. In some cases, survivors with mild injury recover more slowly than those with severe TBI, thus making the recovery process highly individualized. Survivors commonly experience four types of post injury symptoms yet each subsection varies according to each patient. Physical or sensory difficulties, cognitive thinking difficulties, emotional or behavioral changes, and social and family consequences are all impacted following ABI. In a study examining post injury symptom variation in TBI survivors with severe brain injury; it was determined that 33% of survivors had no post injury cognitive impairments while other research has shown that survivors of mild TBI can experience cognitive impairments (Sigurdardottir et al., 2014; Raskin & Mateer, 2000). These studies highlight the diversity in post injury outcomes that physicians and therapists often struggle to identify on standardized clinical measures. As a result, these findings make it difficult for studies to group individuals together when post injury outcomes vary so immensely for each individual. Even though grouping by independence and dependence takes some of these physical, cognitive impairments into account, it is still difficult to generalize survivors of brain injury. As a result, it is important to find measures that are successful at examining different cognitive outcomes for groups so they can be applied on an individualized basis to tailor post injury treatments for each survivor.

e. *Future Directions*

Given the lack of significant findings on the main prospective memory and executive function measures, this study will be continued to obtain a larger sample size. Previous research suggests that effects of this size in this population can be identified in a total sample size of 50 or more individuals (Raskin & Benedetto, 2014). Therefore, an extended period of time and outreach to new ABI organizations, support groups and individual survivors will be necessary to expand of the proposed study.

Once research on a larger scale has been accomplished, measures of executive function and prospective memory could be given at different intervals after brain injury to determine if prospective memory at a certain period of time following injury could predict overall executive function outcome. Additionally, these measures could be used in studies of cognitive rehabilitation where survivors learn prospective memory compensatory techniques and receive rehabilitation to see if behavioral executive function accuracy and time improve.

f. *Conclusions*

The goal of this study was to investigate the relationship between executive function and prospective memory in independent and dependent survivors of ABI. This research suggests that prospective memory is an important component for executive function abilities on both behavioral and standardized clinical tasks. Additionally, prospective memory performance can predict executive function speed on behavioral measures resembling daily activities. These findings are useful for clinicians and indicate that assessments of prospective memory might be effective tools to predict executive function ability for post injury independence. Future research is necessary to understand the full scope of this study and will be continued to obtain such results.

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