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TRINITY COLLEGE

INDIVIDUALIZED COGNITIVE REHABILITATION
FOR ADULTS WITH ACQUIRED BRAIN INJURY

BY

Emily M. Aiken

A THESIS SUBMITTED TO
THE FACULTY OF THE NEUROSCIENCE PROGRAM
IN CANDIDACY FOR THE BACCALAUREATE DEGREE
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Individualized Cognitive Rehabilitation
For Adults with Acquired Brain Injury

BY

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ABSTRACT

Acquired Brain Injury (ABI) can result from internal factors (e.g. tumor) or external causes (e.g. trauma). Three case studies of Korsakoff's syndrome, meningioma, and traumatic brain injury (TBI), will be presented to illustrate the variety of cognitive deficits across different individuals with ABI. This study uses cognitive rehabilitation therapies to target individual cognitive symptoms. Results and discussion place emphasis on the use of prospective memory (PM) training for treating Korsakoff's syndrome. The Memory for Intentions Screening Test (MIST) served as the assessment for PM analysis pre and post rehabilitation. The data from this study will be used as a model for a larger study analyzing the effectiveness of different cognitive rehabilitative therapies: PM training, attention process training (APT) and executive function training, in treating ABI that are individualized based on cognitive symptoms.

INTRODUCTION

a. Acquired Brain Injury

Acquired brain injury (ABI) is the term used to encompass all injuries to the brain that occur after birth which are not caused by biological or genetic factors (Brain Injury Association of America, 2014). Traumatic brain injuries (TBI), cerebral vascular accidents (CVA) and oxygen depletion are all considered to be ABI (Taub, Bartuccio & Manio, 2012).

Concussions are the most commonly known type of TBI; however TBI describes any injury to the brain that is caused by external force (Brain Injury Association of America, 2014). The Centers for Disease Control and Prevention (CDC) reports falls, blunt force trauma, assaults and motor vehicle incidents to be the leading causes of TBI (CDC, 2014). The development of the Children's Health Act of 2000 demanded that the CDC report and publish incidence and prevalence of TBI in America each year, across all age groups (CDC, 2007). On average 1.4 million people in America suffer from TBI per year; approximately 17% requiring hospitalization, 6% experiencing long term disability leading to inability to work, and 4% of cases report to be fatal (CDC, 2007; CDC, 2010).

Both CVA, such as stroke, due to blood depletion in a specific brain region, and oxygen depletion leading to hypoxia, are internally caused ABI (Brain Injury Association of America, 2014). Each year 15 million individuals around the globe suffer from a stroke. With an approximately 33% fatality rate and 33% incidence of permanent disability, stroke is a chronic form of ABI with numerous causes and risk factors (World Health Organization as cited in The Internet Stroke Center, n.d.). The severity of ABI correlates to the daily difficulties and cognitive deficits each individual experiences; however, the most common difficulties involve attention, memory and executive functioning (Mateer & Raskin, 1999).

b. Attention

i. Definition & Identification of Domains

Attention as a cognitive process is responsible for the enhancement and inhibition of stimulus information, so that more in-depth processing can occur for desired information at a given time (Smith & Kosslyn, 2007). Divided into subsets: selective, sustained and divided; intact attention capabilities are required for successful daily functioning.

Selective attention facilitates the interactions between perception and corresponding action, thus mediating concentration on specific stimuli within the environment (Houghton & Tipper, 1994; McKay, Halperin, Schwartz & Sharma, 1994). Selective attention is involved when one must focus on one stimulus and ignore others in the environment. Though basic definitions may suggest they similarities at the behavioral level, selective and sustained attention vary in neural substrates. Selective attention is responsible for controlling which sensory input is attended to, whereas sustained attention refers to continued cognitive arousal or vigilance over a period of time (McKay et al., 1994). Thus, in practice, hearing your name aloud in a large noisy space requires selective attention, and the ability to carry on conversation or stay tuned to a lecture over a period of time, calls upon sustained attention. Both attention subsets may occur consciously or subconsciously. More complex in nature, divided attention requires the ability to simultaneously perform two or more tasks, both of which require one's attention (University of the Witwatersrand, 2014), such as driving while listening to the radio. Alternating attention also involves two tasks but requires one to alternate between the tasks, such as cooking a meal while periodically monitoring your child's homework.

Cognitive Rehabilitation in ABI

ii. Neural Correlates

The neural correlates of attention differ based on source of stimuli, such as visual versus auditory inputs. Environmental inputs follow their corresponding processing pathways until ultimately reaching the temporal lobe, where information inhibition and enhancement occur (Desimone, 2007). Attentiveness to certain stimuli is postulated to result from neuronal firing synchrony, mediated by frontal and parietal regions, rather than as a result of degree of neural activity within a given brain region (Desimone, 2007).

Numerous hypotheses have been made pertaining to the exact neural mechanism behind attention. Some researchers have proposed a series of independent attentional pathways, whereas others propose an interconnected circuitry responsible for attention. A meta-analysis of various attentional network mechanisms, suggests a triad of networks termed alerting, orienting and executive attention; that in combination form the overall attentional network (Raz & Buhle, 2006). By the most elementary explanation, alerting and orienting attention may be used synonymously with sustained and selective attention, whereas executive attention encompasses divided attention but also, in a more general sense, refers to more complex attentional tasks. Consolidation of findings from various neuroimaging studies have identified right dorsolateral prefrontal cortex, right anterior cingulate cortex, right inferior parietal region and left hemispheric temporal area activity in examining alternating attention; pulvinar, superior colliculus, superior parietal and temporal lobe, and tempoparietal junction involvement in orienting attention; and both dorsal and rostral anterior cingulate cortex activity in executive attention (Raz & Buhle, 2006). As illustrated here, the neural correlates for the various attentional domains are spread throughout frontal, parietal and temporal lobes; all regions which are susceptible to damage resulting from ABI.

Cognitive Rehabilitation in ABI

iii. Relationship between Attention & ABI

Individuals with ABI often suffer from deficits of attention that in turn elicit difficulties in daily functioning. Attentional deficits resulting from ABI may alter a person's ability to learn new information or keep track of tasks, thus causing the individual to become easily frustrated and often embarrassed (Robertson, Manly, Andrade, Baddeley & Yiend, 1997). In a study comparing reaction time tasks between healthy and ABI persons, results for individuals across varying ABI severities indicated deficits in divided attention, speed of information processing and an inability to remain focused on the tasks provided (Stuss et al., 1989). Additionally, similar deficits in speed of processing and selective attention have been identified in ABI damage that is localized to medial thalamic lesions (Kraft et al., 2014). Attention dysfunction after ABI is variable, as there are so many domains of attention, however improvement of attention deficits is critical for future improvement of the more complex cognitive deficit of ABI. This information overload has also been reported to cause dizziness, fatigue and headaches, all side effects that alter an individual's ability to successfully function in everyday life (Talbot Group Brain Injury Services, n.d.). Treatment for attention deficits resulting from ABI will be further discussed in the methods section (*c.ii.*) of this paper.

c. Executive Function

i. Definition

Executive functions consist of a wide range of cognitive processes thus making a universal definition difficult. These inter-connected complex cognitive processes encompass working memory, planning, organization, thought plasticity, and situational adaptability, which holistically elicit goal-mediated behaviors (D'Esposito & Gazzaley, 2005; Elliot, 2003). A more formal definition provided in *Late, Lost and Unprepared* (2008) states, "executive functions are

Cognitive Rehabilitation in ABI

a set of processes that all have to do with managing oneself and one's resources in order to achieve a goal. It is an umbrella term for the neurologically-based skills involving mental control and self-regulation" (Cooper-Kahn & Dietzel, as cited on LD OnLine, 2014). Proper executive function capabilities enable the completion of automatic cognitive processes controlled via planning, monitoring, activating, switching, and inhibiting functions, and depend on intact working memory and information modulation capabilities (Cicerone, Levin, Malec, Stuss & Whyte, 2006).

ii. Neural Correlates

Appropriately, the terms executive function and frontal lobe function are often synonymously used (Elliot, 2003). Historically the frontal lobes have been identified as the primary area of activation with regards to executive functions, however additional brain regions have been identified via observation and analysis of neurological disorders and disruptions presenting with executive function deficits (D'Esposito & Gazzaley, 2005; Elliot, 2003; Perna, Loughan & Talka, 2012). As addressed by Elliot, various clinical findings have implicated the prefrontal cortex, striatum and basal ganglia in disruptions within subsets of executive function (2003).

iii. Relationship between Executive Function & ABI

As previously mentioned, ABI survivors suffer from executive function deficits that can pose extreme hindrance in everyday life if left untreated. Perna, Loughan and Talka (2012), provided numerous examples of these daily difficulties faced by individuals with ABI; inability to initiate basic tasks such as trips to the grocery store, balancing a checkbook or to adjust to novel social situations, to name a few.

Cognitive rehabilitation in the form of goal management training (GMT) has proven to be an effective intervention for treating executive function disturbances resulting from ABI. Patients

Cognitive Rehabilitation in ABI

are taught how to approach tasks that are applicable to daily functioning utilizing the seven divisions of GMT: 1) defining goals and acknowledging slip-ups or mistakes, 2) learning to stop automatic habits thus controlling responses, 3) checking working memory to increase present mindedness, 4) slating goals to stay on track, 5) making decisions and identifying goal completion, 6) splitting tasks into smaller tasks to avoid becoming overwhelmed, and 7) stopping and checking progress to avoid errors (Levin et al., 2011).

d. Prospective Memory

i. Define

Prospective Memory (PM) describes the capability of remembering to do an intended action at a specific time or in response to a specific cue in the future (McCauley, McDaniel, Pedroza, Chapman & Levin, 2009). The ability to carry out intended task in the future is vital for the completion of daily tasks such as remembering to take one's medications (Raskin & Sohlberg, 2009). There are two types of PM: event and time based; which are required for proper daily functioning. Remembering to take medications at the proper time each day serves as an example of time-based PM, whereas remembering to mail a letter when seeing a mailbox, pertains to event-based PM. Ellis (1996) discusses the complexity of PM processing in comparison to retrospective memory processes by suggesting that PM processing consists of five distinct steps: (1) the formation of an intended action, (2) retention of the intention, (3) remembering what was intended, (4) completing the intended action, and (5) determining if the produced outcome was correct. Further analysis of Ellis' (1996) proposed steps of PM processing show that the success of each step is dependent on various intact cognitive capabilities; step 1 dependent on proper attention functionality, steps 2 and 3 rely on intact memory processes, and steps 4 and 5 require intact executive function capabilities.

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ii. Neural Correlates

In the broadest sense, frontal lobe activation plays a role in the PM mechanism (McDaniel & Einstein, 2007). However, numerous findings suggest that various brain areas are impacted and play a role in PM processes. The bilateral frontal poles, right lateral prefrontal cortex, inferior parietal lobe, and precuneus of the superior parietal lobe have shown activation in response to maintaining an intention (Burgess, Quayte & Frith, 2001) whereas increased thalamic activity and decreased right lateral prefrontal activation have been observed in response to intention realization (Burgess, Quayte & Frith, 2001).

iii. Relationship between PM & ABI

Deficits of PM associated with ABI threaten an individual's ability to live and function independently. Patients with diagnosed brain injuries perform significantly worse on PM assessments in comparison to healthy participants, specifically on assessments focused on the ability to recall an intended action (Groot, Wilson, Evans & Watson, 2002; Raskin, Buckheit & Waxman, 2012). More importantly, self-reports indicate PM deficits as an individual's primary cognitive complaint post ABI (Tay et al., 2008), and all the memory impairments experienced by patients with ABI, deficits of PM appear to be the most detrimental to daily functioning (Shum, Fleming & Neulinger, 2002). There are various suggested approaches for improving PM in patients with ABI. Though compensatory methods such as journaling have proven to aid ABI patients, cognitive rehabilitation in the form of restorative intervention appears to be the best approach to actually treating and improving PM deficits (Raskin & Sohlberg, 2009).

e. Validity of Study

This study had two main foci pertaining to cognitive rehabilitation in ABI. The various difficulties and degrees of cognitive deficits that present in ABI are different for each person. A

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compilation of neuropsychological assessments from three case presentations of individuals with ABI whom have not previously received cognitive rehabilitation will be presented as evidence for individualized cognitive rehabilitation rather than uniform treatment across all ABI diagnoses. Additionally, specific methodologies pertaining to Attention Process Training (APT) and PM training in the form of rote repetition will be discussed in two of the three presented cases. Therapies for addressing and improving PM deficits are still quite new and underdeveloped. Mateer & Raskin (1999) discuss various studies that suggest problems with memory may not be independent from the other cognitive deficits faced by ABI patients. The effectiveness of individualized cognitive rehabilitations, specifically PM training, for improving PM difficulties and other cognitive difficulties, will be illuminated by analyzing rehabilitation progress and pre and post rehabilitation assessments for one ABI case study.

METHODS

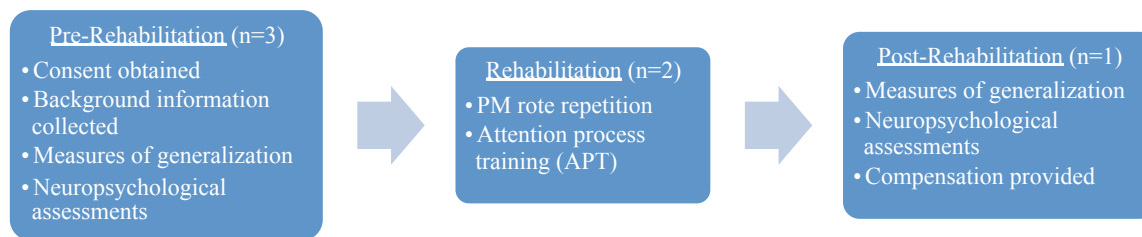


Diagram 1. Overall study design. Depicting the ongoing nature of recruitment and enrollment with special attention on number of participants that completed each phase of the study.

a. Recruitment

Participants were recruited from a database of ABI individuals who had expressed interest in receiving cognitive rehabilitation, individuals who previously participated in a study within the cognitive neuropsychology laboratory at Trinity College and from patient referrals received by Dr. Raskin (n=3). Additionally, advertisements were posted around the community and distributed to coordinators of brain injury support groups and local neurologists and neuropsychologists. Recruitment was ongoing with participants beginning rehabilitation immediately after completing pre-rehabilitation testing (n=2). In once case (n=1), the participant was recruited late in the study, thus a rehabilitation program could not be designed and administered prior to data analysis. In order to be deemed eligible for this study, participants had to:

1. be between the ages of 18 and 40 years old that had been diagnosed with an ABI, excluding mild TBI resulting from concussion, at least 1 year prior to participation
2. express the ability to speak, read, and accurately understand English
3. provide consent for participation and allowed access to medical records including but not limited to brain imaging

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4. commit to attending 10 scheduled appointments (45-60 minutes) for cognitive rehabilitation in addition to undergoing pre and post-rehabilitation testing;

Individuals were deemed ineligible to participate if they had:

1. been diagnosed with other neuropsychological or psychiatric disorders including but not limited to schizophrenia, manic depression, bipolar disorder, dementia, severe learning disabilities, seizure disorders, etc. which were independent of their ABI—unless they were receiving proper medication management and deemed stable by a monitoring physician and/or psychologist.
2. previously participated in cognitive rehabilitation therapy for their ABI
3. significant visual or auditory deficits which would interfere with proper participation

b. Assessment Tools

i. Measures of Generalization

In order to evaluate prospective memory functioning, and the difficulties faced by each individual as a result of their ABI, a collection of questionnaires was utilized. To determine a baseline of self-reported functionality, the following questionnaires were administered at the start of cognitive rehabilitation: The Prospective Memory Questionnaire (PMQ, Hannon, Adams, Harrington, Fries-Dias & Gibson, 1995), The Everyday Memory Questionnaire (EMQ, Sunderland, Harris & Baddeley, 1983), and the Community Integration Questionnaire (CIQ, Willer, Rosenthal, Kreutzer, Gordon & Rempel, 1993). In the case that a participant was unable to accurately account for their behaviors relative to these inquiries (n=1), their health care proxy or person(s) whom they lived with on a daily basis, were asked to complete these same questionnaires as supplementary accounts.

ii. Neuropsychological Assessments

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Administered in the pre-rehabilitation phase to all participants, the battery included measures that tested various cognitive functions in order to determine which areas of cognition were most impaired for each participant. The Controlled Oral Word Association Test (COWAT, Benton, Hamsher & Sivan, 1976) and Stroop Color-Word Test (Trenerry, Crosson, DeBoe & Leber, 1989) were used to assess executive function, attention was assessed via the Brief Test of Attention (BTA, Schretlen, 1996) and the revised Hopkins Verbal Learning Test (HVLT-R, Benedict, Schretien & Groninger, 1998), Logical Memory and Visual Reproductions sections from the Wechsler Memory Scale-IV (WMS-IV, Wechsler, 2009) and the Rivermead Behavioral Memory Test (RBMT, Wilson, Cockburn & Beddeley, 1985) were analyzed with regards to memory capability.

iii. Memory for Intentions Screening Test

The Memory for Intentions Screening Test (MIST, Raskin, 2004) served as an assessment of prospective memory. The MIST is comprised of both time (e.g., “In 12 minutes, tell me it is time to take a break”) and event (e.g., “When I hand you a postcard, self-address it”) based cues over a period of 30 minutes. Participant responses to event and time based cues are both verbal and action based. The cues used in the MIST are purposefully related to the natural response one should have to a given cue. There are both short and long term prospective memory tasks embedded into the MIST. To analyze delayed prospective memory, participants were told to contact the test administrator in 24 hours and report the number of hours they slept the night before. The MIST also looked at retrospective memory recognition by asking participants a series of multiple choice questions at the end of testing, regarding the tasks they had just been directed to complete. Errors or task omissions were coded as: prospective memory failure, task substitution, loss of content, loss of time or random error. Both retrospective recognition and

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prospective memory measures were scored taking into consideration participant age and level of education. This ensured that the determined percentile for each participant was solely comparing each participant's cognitive capabilities with what would be normally expected of them. The MIST was administered to each participant prior to participation, which served as a baseline, and at the completion of cognitive rehabilitation.

c. Cognitive rehabilitation

Two of the three study participants were assigned to cognitive rehabilitation in the form of rote repetition PM training or Attention Process Training (APT) based on their performance on the pre-rehabilitation neuropsychological assessments (Table 3). Each treatment was tailored to the individual needs of each participant, and adjustments pertaining to difficulty and progress were made accordingly. Cognitive rehabilitation was administered in time increments ranging from 45 to 60 minutes, with the time participants needed for breaks being excluded. Compensation in the form of gift cards was provided only to participant 1 at post rehabilitation testing as an incentive for participants to return for all necessary sessions. Each cognitive rehabilitative therapy has been proven to a viable means of cognitive rehabilitation and the specifics of each will be further discussed in the presentation of each participant.

i. Rote Repetition PM Training

Restorative intervention therapies such as Rote Repetition, require participants to accurately complete tasks repetitively until they are able to show proficiency, and then are asked to complete the same tasks after a longer time period (Raskin & Sohlberg, 2009). Consistent repetition of such interventions is said to be the important factor with regards to a patient PM improvement, based on the assumption that repetitive activation can lead to changes in cortical organization (Mateer & Raskin, 1999).

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ii. Attention Process Tracking (APT)

Attention process training (APT) is a cognitive rehabilitative program that focuses on the training and improvement of various attentional domains that may be impacted by ABI (Sohlberg, McLaughlin, Pavese, Heidrich & Posner, 2000). Persons with ABI may suffer from varying degrees of attentional difficulties and APT provides for an intervention that can be tailored to the deficits expressed by a give individual. The APT has a series of structured hierarchical exercises targeted to each component of attention (sustained, selective, divided, alternating). The use of APT in ABI populations have been shown to improve performance on neuropsychological assessments of attention as well as self-reported participant questionnaires focused on daily attention improvement (Palmese & Raskin, 2000; Sohlberg et al., 2000). Improvement has been observed on neuropsychological assessments corresponding to the specific attentional domain(s) targeted with APT (Sturm, Willmes, Orgass & Hartje, 1997).

d. Data Collection & Analyses

Upon individual study matriculation, participants were assigned codes in order to depersonalize data. Medical records, neuropsychological assessments, measures of generalization and weekly progress notes were keep in coded folders pertaining to each participant. Signed consent forms with participant names, served as the singular personal identifier in this study. Participant codes were included on signed consent forms, which were kept in a folder separate from individual data. Paper files were stored in a closed cabinet within a secure, code-protected room.

Normative data from neuropsychological assessments was used to convert pre-rehabilitation scores into percentiles. A reliable change index (RCI, Jacobson & Truax, 1991) was used to

analyze pre- and post-rehabilitation neuropsychological assessments in Participant 1 in order to determine the effectiveness of rote repetition PM training.

PARTICIPANTS & INDIVIDUALIZED PROTOCOLS

The pre-rehabilitation neuropsychological assessment data (Table 1) was used to create participant profiles, which in turn highlighted the degree of impairment each participant (n=3) performed at across each of the cognitive domains (attention, memory, executive functions). The raw scores from each assessment were converted into percentiles using the normative data provided for each measure.

Table 1. Pre-rehabilitation Neuropsychological Assessment Profiles. Degree of impairment (green: below average, blue: borderline impairment, red: impaired) derived from psychometric conversion table. (a) Participant 1 impairment primarily in memory functions (b) Participant 2 all scores showed impairment (c) Participant 3 showed low level of impairments in basic cognitive skills but some difficult in more complex skills (i.e. recognition discrimination index).

	Participant 1 _a	Participant 2 _b	Participant 3 _c
Memory for Intentions Screening Test			
Time Cue	<1	<1	48
Event Cue	<1	<1	16
RRT	25	<1	77
PMT	<1	<1	28
Wechsler Memory Scale-IV			
Logical Memory			
Immediate Recall	3	2	82
Delayed Recall	1	2	87
Visual Reproductions			
Immediate Recall	3	3	90
Delayed Recall	3	6	71
Discrimination	32	<1	14
Hopkins Verbal Learning Test			
Immediate Recall	<1	<1	6
Delayed Recall	<1	<1	47
Recognition Discrimination Index	<1	<1	2
RBMT Screening Score	<1	<1	87
Brief Test of Attention (Numbers)	50	<1	85
Stroop Color-Word	78	<1	39

a. Participant 1*i. Case Presentation*

Patient 1 is a 50-year-old Caucasian female who was diagnosed with Korsakoff's syndrome in 2011. Her primary language is English but she also speaks French in the presence of her family, who are French Canadian. She is unable to drive and is dependent on her parents. The patient's mother, whom she reported as her best friend, accompanied her to all appointments. Her sister accompanied her to her first appointment and provided documentation of incompetence, indicating that her parents and sister make her medical decisions.

This patient was diagnosed with Korsakoff's encephalopathy in 2011 after second hospital admission that year, as a result of alcoholism that began in her 20s. It is worth noting that the patient's paternal relatives have a long-standing history of alcoholism. She is being medicated for Korsakoff's with 100 mg of Thiamine daily. Prior to diagnosis of Korsakoff's the patient suffered from a vitamin B12 deficiency. Since diagnosis, she and her family reported that she has remained abstinent. She has severe cognitive deficits as result of the Korsakoff's, specifically pertaining to her in ability to create new memories or learn new information. Additionally, her family remarked that over time it appears as though she is beginning to lose old memories. Patient was unaware of the extent of her disability and did not acknowledge the cognitive deficits associated with it. Psychological ramifications of disease were being monitored and treated by a psychiatrist, thus she was deemed eligible to participate.

Patient 1 graduated from high school and thereafter she received a certificate in banking from Williams College, and prior to her disability she worked full time as a vice president at a bank. In 2012 she was placed on disability, however at her appointments she continuously reiterated

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that she has a strong desire to go back to her job and does not understand why she cannot return to. Patient 1 has never been married and does not have children. She currently lives with her parents, upon whom she is dependent. She reported that she enjoys puzzles, specifically word searches.

During initial encounter, patient was unaware of the extent of her deficits and denied any depressive or suicidal ideologies. Self-reports indicated that she did not feel as though her ABI impacted her daily functioning, however, family accounts indicated that patient was unable to complete tasks without constant reminders, she was unable to form new memories and that she forgets discussion content during conversations that last more than a few moments. Her mother said that she becomes frazzled and irritated when separated from parents, however that Patient 1 will forget their absence in a few moments if her attention is redirected. Family expressed that they wanted “anything to improve her memory”, stating that her deficits have not improved since 2011, if anything her ability to retain old memories had worsened.

ii. *Protocol.*

Consent for participation was obtained from Participant 1 as well as from her mother, along with background medical and social histories. She completed pre-rehabilitation testing in 2 sessions over a period of 2 weeks. She was uncomfortable in the absence of her mother and repetitively asked “Why am I here?” and “Where is my mom?” and breaks were needed during assessments based on her commenting “I don’t want to do this any more” and “I want to be with my mom”. During memory recall measures, she confabulated responses. Pre-rehabilitation neuropsychological assessment scores (Table 1) indicated her impairments primarily in memory functions, thus why she was assigned rote repetition PM training for cognitive rehabilitation. Participant 1 completed 455 minutes of PM training, with the average session lasting 45.5

Cognitive Rehabilitation in ABI

minutes. After 4 sessions, there was a period of 8 weeks where patient 1 did not receive rehabilitation. This was due to the patient canceling two appointments and the college holiday recess. Examples of tasks similar to those administered in PM training were provided for the participant's mother so that she could simulate rehabilitation in the home environment. After completing 10 sessions of PM training, Participant 1 completed post-rehabilitation assessment and received compensation. Additionally, she has since continued attending appointments to receive PM training.

iii. Rote Repetition PM Training

Participant began PM training with 1 minute waiting intervals between task administration and proper task execution time. As an initial ongoing task, word search puzzles were selected, as participant 1 had previously mentioned that she enjoyed them. After simultaneously executing 5 PM tasks accurately, the waiting interval was increased by 1 minute (Figure 1). Accurate task completion was dependent on Participant 1 completing the correct task at the correct time. This same pattern of interval increase after 5 successful task completions was followed throughout the duration of rehabilitation. After successful completion of the 5 minute waiting time, crossword puzzle difficulty was increased. Puzzle difficulty was derived by the puzzle provider's categorizations: Easy, Medium & Difficult. An additional increase in distractor difficulty was applied after success at 10 minutes.

PM Task	Time	Performed at correct time?	Performed correct action?
"Open the drawer"	1 min	✓	✓
"Hand me the tape recorder"	1 min	✓	✓
"Tell me it is time to take a break"	1 min	✓	✓
"Turn the computer screen off"	1 min	✓	✓
"Push your chair back"	1 min	✓	✓

↓

PM Task	Time	Performed at correct time?	Performed correct action?
"Open the drawer"	2 min		
"Hand me the tape recorder"	2 min		
"Tell me it is time to take a break"	2 min		
"Turn the computer screen off"	2 min		
"Push your chair back"	2 min		

PM Task	Time	Performed at correct time?	Performed correct action?
"Open the drawer"	1 min	✓	✓
"Hand me the tape recorder"	1 min	✓	✓
"Tell me it is time to take a break"	1 min	✓	✓
"Turn the computer screen off"	1 min	x	x
"Push your chair back"	1 min	x	✓

↓

PM Task	Time	Performed at correct time?	Performed correct action?
"Open the drawer"	2 min		
"Hand me the tape recorder"	2 min		
"Tell me it is time to take a break"	2 min		
"Turn the computer screen off"	2 min		
"Push your chair back"	2 min		

Cognitive Rehabilitation in ABI

Figure 1. Rote Repetition PM Training Mechanism. Examples of PM tasks provided to Participant 1. (a) Denotes the increasing delay time between task administration and proper execution time dependent on 5 successful completions. (b) Example of trails with unsuccessful task completion resulting in no delay time change.

iv. Results

Over the course of 10 rehabilitation sessions, the time delay between PM task administration and accurate time of execution by Participant 1 increased from 2 minutes to 11 minutes (Figure 2). Moreover, this change generalized to the neuropsychological assessment. Reliable change index (RCI) found significant change between pre- and post-rehabilitation MIST variables ($p < 0.01$, $p < 0.05$), WMS-IV visual reproductions copy and recognition variables ($p < 0.05$) and Stroop Color-Word ($p < 0.01$) (Table 2).

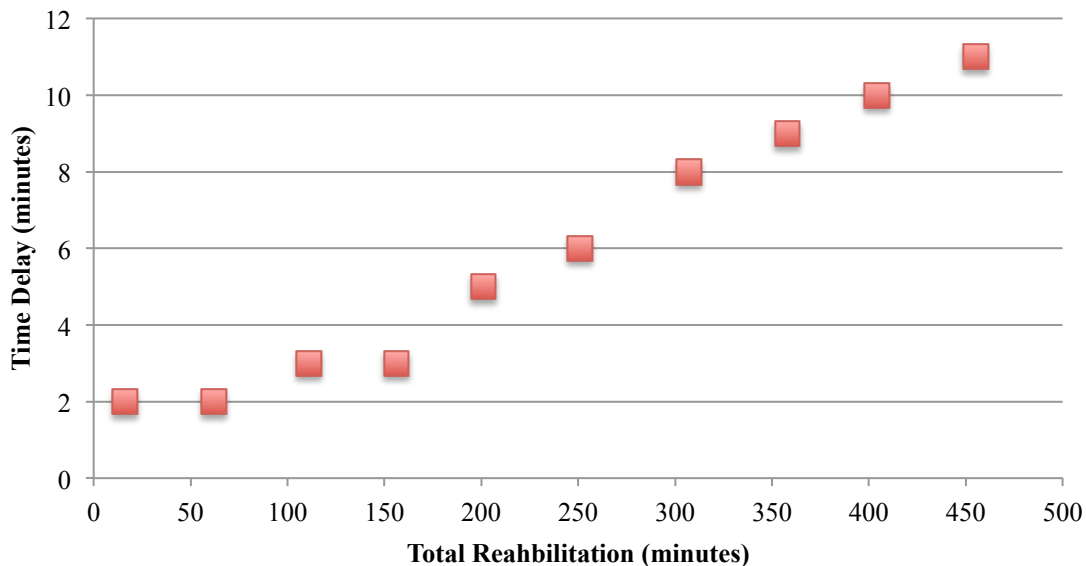


Figure 2. Participant 1 PM Training Progress Showing Relationship Between Time Delay & Overall Rehabilitation Time

Table 2. Participant 1 Effect of PM Training on Neuropsychological Assessments (*p < 0.05, **p < 0.01)

	Pre	Post	RCI
MIST			
2 minute	4	7	2.77**
15 minute	0	2	1.55*
Time Cue	2	3	NS
Event Cue	2	6	2.45**
Verbal	4	5	NS
Action	0	4	2.89**
RRT	7	7	NS
PMT	12	27	2.90**
WMS-IV			
Logical Memory			
Immediate Recall	4	5	NS
Delayed Recall	3	4	NS
Visual Reproductions			
Immediate Recall	5	4	NS
Delayed Recall	5	4	NS
Recognition	3	6	1.27*
Discrimination Index			
Copy	10	14	1.20*
HVLT			
Total Recall	18	21	NS
Delayed Recall	1	0	NS
Recognition			
Discrimination Index	6	-1	NS
BTA (Numbers)	8	2	NS
RBMT Screening Score	2	4	NS
Stroop Color-Word	111	112	2.50**
COWA Test	36	42	NS

b. Participant 2*i. Case Presentation.*

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Patient 2 is a 42-year-old Puerto Rican female diagnosed with a TBI in January 2014. She is bilingual in English and Spanish. Initial meeting indicated that patient was severely depressed and thus unable to participate in the study. However after continuing psychotherapy and proper medication management she was deemed stable and re-referred for study participation by Dr. Raskin.

Patient sustained her most recent TBI after jumping from second story floor of house in a suicide attempt. Neuroimaging indicated a mild left temporal subarachnoid hemorrhage. In addition to the TBI incurred, the patient suffered from bilateral rib fractures and multiple spinal fractures. As result of these injuries, she now uses to cane to walk. Following hospitalization for her injuries, she was discharged to an inpatient psychiatric facility where she resided for a total of 18 days. Patient 2 received speech and physical therapy following her injury. Her speech was comprehensible but rather slurred and her responses were delayed and slightly disjointed.

Patient received her high school diploma and completed some college courses in Puerto Rico. She has two children and was previously married; however she is now single. Patient 2 worked in a medical office prior to her injury but is currently unemployed.

She has a history of depression, suicidal ideation and posttraumatic stress disorder, which previous practitioners attributed to multiple years of childhood abuse. This remark from a previous consultation is significant based on there not being previous medical records indicating head trauma, and cognitive damage may have occurred as a result of her previous abuse. Thus, her performance on neuropsychological assessments following her ABI may have been due to the combination of unaccounted for damage and her most recent injury. Her father accompanied her to all appointments, as she is unable to drive. During her second encounter Patient 2 indicated that she suffered from numerous deficits in memory, several times a day. She

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expressed difficulty with remembering names, topics of conversations, and on measures of generalizations she indicated that forgetting how to execute the steps required for the completion of daily tasks. Additionally, she stated that she has difficulty finding the correct words to use in order to properly articulate her thoughts, and that she struggles paying attention to conversations in the presence of auditory competition. Patient 2 indicated that she is able to physically execute proper self-care and household tasks, however she has a personal care assistant that helps to ensure she remembers to do everything.

ii. Protocol.

After consent was obtained from Participant 2 during her second referral, her social and medical histories were collected along with responses to measures of generalization. All pre-rehabilitation scores showed some degree of impairment (Table 1). Given that attention is required for all cognitive functions, APT was selected as her treatment to first treat her attention deficits. Over the course of her treatment Participant 2 completed 5 sessions of APT training, however she unexpectedly stopped attending her reoccurring weekly appointment. Numerous attempts to re-contact Participant 2 were made, however there was no response. Thus Participant 2 did not complete rehabilitation or post-rehabilitation testing.

iii. Attention Process Training.

A computerized version of APT training (APT-III, Sohlberg & Mateer, 2010) was used to create a 55-minute rehabilitation program for Participant 2. This APT program consisted of tasks within 3 domains of attention: alternating attention, executive control: suppression, and sustained attention. An example task in the sustained attention domain would be “Listening for 1 Noise”. For this activity, Participant 1 would hear the following directions from the on screen therapist: “Listen carefully to the series of sounds. You are to press the button every time you

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hear the high tone like this---get ready, begin”. Along with these directions Participant 1 was provided an example of the tone she should listen for. Once the task began, she was required to use the computer mouse to click a response button on the screen each time she heard the target noise. This high tone was mixed in with other sounds, and it was her job to differentiate between sounds. The pacing or time between sounds could be decreased from slow to fast in order to increase task difficulty. The program for Participant 2 began at the lowest level, with the slowest rate of stimulus delivery and least amount of sensory competition. Additionally, the on screen therapist was selected to be female. Participant 2 completed 2 tasks of sustained attention over 5 rehabilitation sessions (Figure 4), whereas the remainder of her APT training occurred over 3 sessions (Figure 3). The degree of difficulty was not altered for the tasks which Participant 2 only completed over 3 sessions, however the difficulty was increased (noted in red) for the 2 sustained attention tasks which were administered 5 times (Figure 4). After completing each activity, Participant 2 was able to report her level effort and motivation during that task by using a simple rating scale on screen. Computer generated results were provided for individual task performance on a specific day as well as for overall progress across sessions for a specific.

iv. APT Results

An upward trend in task response accuracy was observed over 3 rehabilitation sessions (Figures 3 & 4). The difficulty of tasks that were administered over 5 sessions was increased after 3 sessions, leading to a decline in task response accuracy (Figure 4).

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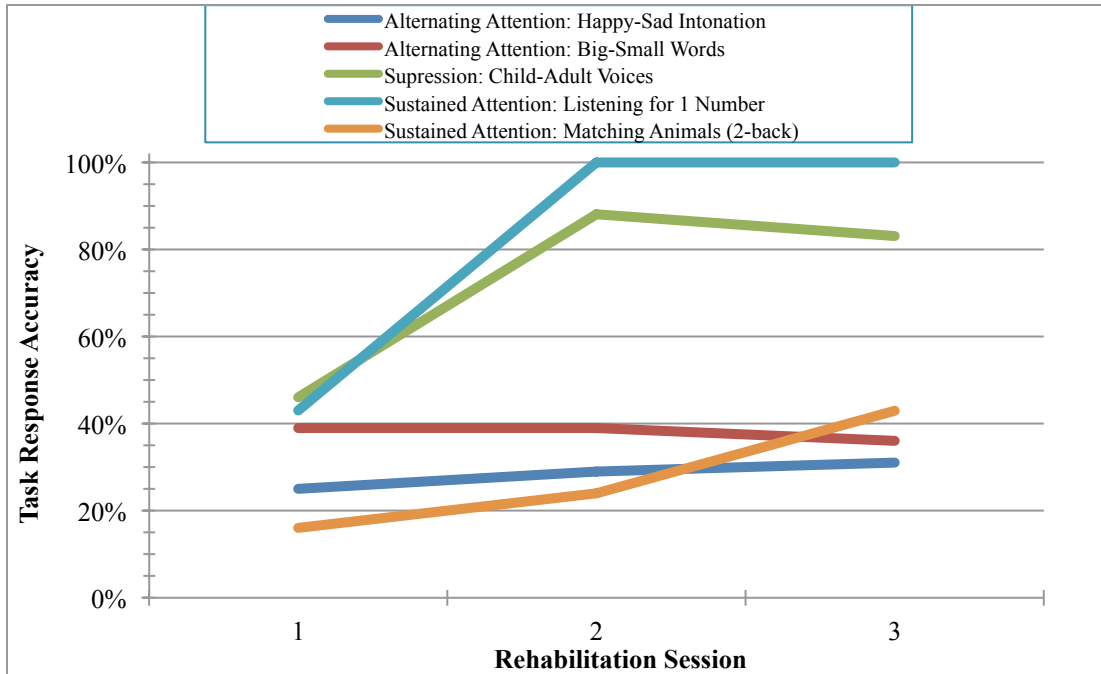


Figure 3. Participant 2 APT Response Accuracy Progression for Alternating Attention, Suppression & Sustained Attention Tasks.

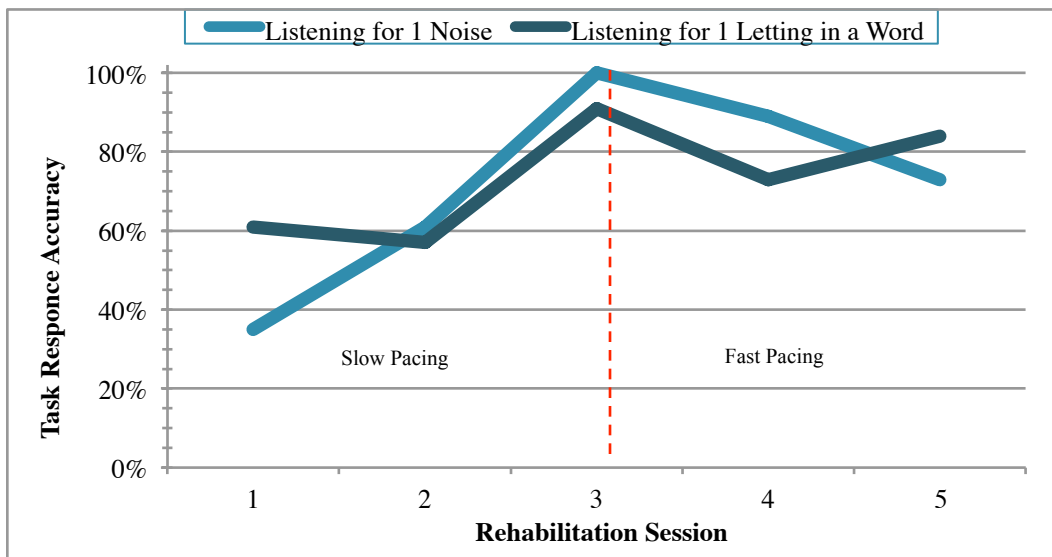


Figure 4. Participant 2 APT Response Accuracy Progression for Sustained Attention Tasks.

c. Participant 3

i. Case Presentation.

Patient 3 is a 37-year-old Caucasian English-speaking female. She functions independently, and presented with cognitive complaints of her own intuitions. Patient expressed that since having a craniotomy in January 2014, she has experienced sensory processing issues, occasional migraines, decreased patience, difficulty with finding the correct words to use, and deficits of attention and focus maintenance.

Patient 3 had a craniotomy for the resection of a meningioma in January 2014. The discovery of her meningioma was due to self-referral to a neurologist after she noticed sensory motor difficulties. She reported having changes in her personality, emotion and mood, as well as mental activity, since undergoing surgery. Additionally, she reported having problems with sleep. She has experienced mild seizure activity since the craniotomy, which is being monitored and preventatively treated with Topamax and Lamotrigine by a neurologist. Patient 3 takes Vyvanse for difficulties with attention and is currently seeing a counselor to tend to her emotional changes since the injury. She was deemed eligible to participate because other diagnoses are being properly managed and they are cofactors of her ABI. With regards to family history, mental health diagnoses (depression, Bipolar disorder, psychosis and suicidality) in her maternal relatives, her father had seizures, and her uncle also had a meningioma.

Patient earned her Bachelors of Science and Masters in Education from the University of Connecticut. She previously held a full time teaching position for a total of 10 years, however is currently unable to work full time due her problems with mental activity that have presented since her injury. Patient indicated that quitting her job has decreased the family income, which has lead to financial difficulty. Currently, she works part time as a substitute teacher and does

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the bookkeeping for her husband's business. She has been married for 14 years and lives at home with her husband and two children, both of whom have development problems that require her attention. Patient reported that she runs for physical activity and enjoys reading and sewing.

During initial encounter, patient indicated that her problems with mental activity include trouble focusing, inability to multitask and make decisions, and difficulty having a conversation in the presence of background noise. She reported that since her craniotomy, she has experienced problems with speaking, understanding, and spelling, which were not previously problematic. With regards to her memory, patient reported having difficulty remembering names, words, appointments, how to do things and memories from her childhood. She stated that other people have noticed changes in her personality and emotional status since surgery. Since her surgery she is easily distracted, less patient and more irritable, which she said has an impact on intra-family relationships. Patient 3 reported being more moody, attesting this to being easily frustrated with her mental difficulties. She is physically and mentally capable of driving, however she mentioned feeling as though her reaction time is slower than before and that she is constantly double checking her surrounding while operating a motor vehicle.

ii. Protocol.

Patient 3 provided consent and underwent pre-rehabilitation testing over a period of 2 days during a 3-week timeframe. As mentioned, at the time she was working part time as a substitute teacher, which can provide a rather unpredictable schedule, and has two children for whom she cares. She was unable to hold her second appointment due to occupational demand, hence her pre-rehabilitation testing was spread over a longer period of time. Additionally, she was referred for assessment during the tail end of this project and after completion of pre-rehabilitation testing there was not adequate time to design and commence cognitive rehabilitation. Her pre-

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rehabilitation neuropsychological assessment scores showed a low level of impairment on measures of basic cognitive skills (attention and memory), and difficulty on assessments that required complex skills such as memory discrimination (Table 1c). Thus, when Patient 3 does begin therapy, executive function rehabilitation in the form of Goal Management Training is recommended. The patient was asked to provide the researcher with a day and time that she will be available every week, and was told that she would be re-contacted for rehabilitation during the summer months when she will not be facing unexpected vocational conflicts.

DISCUSSION

a. Interpretation of Results

Results showing cognitive rehabilitation to improve ABI impairments were only obtained for Participant 1, as she was the only participant that completed pre- and post-rehabilitation assessments. Successful completion of PM tasks at increased delay times was positively correlated to amount of cognitive rehabilitation administered and increased degree of distractor difficulty after 5 and 10 minutes, did not impact this positive trajectory (Figure 2). This along with post-rehabilitation scores for six MIST variables ($p < 0.01$, $p < 0.05$) showing significant change from initial scores (Table 2), further validates the use of rote repetition PM training as a restorative rehabilitation which has shown to be the best approach for treating PM deficits (Raskin & Sohlberg, 1996; Raskin & Sohlberg, 2009). Additionally, this validates the effectiveness of selecting individualized cognitive rehabilitation based on neuropsychological assessment profiles, for providing cognitive improvement to specific impairments.

Additionally, significant change for WMS-IV visual reproductions copy and recognition discrimination index ($p < 0.05$) and Stroop Color-Word ($p < 0.01$) in pre- and post-rehabilitation testing values (Table 2) may indicate that rote repetition PM training may be useful for treating other cognitive impairments such as generalized memory and executive function respectively. However, because Participant 1 did not show significant improvement on the other measures of executive function (COWAT) and generalized memory (HVLTR, RBMT & additional WMS-IV variables), additional research would need to be conducted to verify this conclusion.

Due to the small number of rehabilitation sessions attended by Participant 2, definitive conclusions could not be made about the effectiveness of APT in improving her cognitive impairments. Task response accuracy showed an upward trend over the course of 3 rehabilitation

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session prior to difficulty increase (Figures 3 & 4), which may be an indication of improved attention, however this conclusion cannot be made. Additionally, the increased difficulty after session specific sustained attention tasks resulted in a downward trend (Figure 4). More sessions at this increased level of difficulty would be required in order to comment on progression trends at a higher difficulty.

b. Study Limitations

The primary limitations of this study pertained to recruitment and time commitment. The three participants were all referred to Dr. Raskin for further assessment pertaining to cognitive rehabilitation, thus illustrating that this method of recruitment was most successful. However, the problem here was that the referrals came at different times thus requiring that recruitment be ongoing. This was a limiting factor for analysis of the individual impacts of different forms of cognitive rehabilitation (APT and PM Training) in ABI. In order to conduct cross condition analysis, rehabilitation time, duration or rehabilitation and administration of both pre and post-testing would be required.

Similarly, the time commitment required of study participants was a limiting factor. As outlined by the exclusionary measures, participants were required to attend 10 sessions of rehabilitation, with each session lasting approximately 45-60 minutes. Individuals requested additional information after receiving recruitment fliers, however after receiving follow-up information, many individuals declined participation indicating that they did not have the time for such a commitment. Additionally, this time commitment presented as a problem with the study participants. The initial study design did not take into consideration a participant's rehabilitation schedule being interrupted by the examiner's school recess nor had conditions been set pertaining to patient cancelations due to illness, family or work.

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Specifically with regards to patient 2, a study limitation was missing two weeks of appointments without providing notification. Attempts were made to contact her after each missed session, however she was not reachable by telephone, thus the reason for her discontinuance was unknown.

c. Future Directions

In order to avoid appointment cancelations and long term dependence on participants attending rehabilitation procedural changes are recommended. It is suggested that once a potential participant is identified that they immediately undergo pre-rehabilitation testing within a 2 day period, followed by massed practice administration of assigned cognitive rehabilitation treatment. The recommended massed practice administration should require that each participant complete 10 sessions, ranging from 45-60 minutes, over a period of 2 weeks. Additionally, potential participants should be asked prior to pre-testing to schedule appointments within the 2-week time frame, in addition to scheduling 2 days for post rehabilitation. With regards to recruitment, it is recommended that fliers be hand delivered to head injury support groups and practitioners outside the Hartford area, expanding to other clinical populations such as Baystate Medical Center and the Carson Center for Human, as well as reaching out to the local Veteran's Associations and Easter Seals offices.

In addition to the mentioned procedural modifications, it would be beneficial to expand the pre- and post-rehabilitation measures to include EEG to have an electrophysiological measure for observing cognitive improvement after rehabilitation. As a continuation from a fellow student's theses (Pedro, 2015), the EPRs deemed significant for PM processing (N300, LPC, and frontal slow wave) would be observed during pre and post-rehabilitation. As the paradigm used by Pedro (2015) pertains to PM and the identification of ERPs pertaining to the

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different subsets of PM, improvement on the task is observed for participants that receive APT or executive function GMT therapies would indicate that the subsets of PM processing are in fact due to deficits of attention and executive function.

The future application of this study is expected to commence during the summer months where university recess should not cause a hindrance. Findings from this pilot study validated the use of neuropsychological assessment measures for creating participant profiles to be used in designing cognitive rehabilitation tailored to each individual, and further substantiated previous studies that used rote repetition PM training for treating PM deficits. In addition to the mentioned modifications, the future study plans to do a cross condition analysis of executive function training in addition to APT and PM tracking, to determine the effectiveness of each therapy in treating PM deficits in ABI.

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