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Comparison Of Performance Between Elderly Individuals And Collegiate Athletes On The Immediate Post-Assessment And Cognitive Test

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COMPARISON OF PERFORMANCE BETWEEN SENIOR INDIVIDUALS AND
COLEGIATE ATHLETES ON THE IMMEDIATE POST-ASSESSMENT AND COGNITIVE
TEST

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Dean of the Graduate School

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Dedication

There are several individuals that I hold dear to my heart to which I am deeply thankful for.

All the time and effort put forth in this document would have not been possible if it had not been for Shane, Catherine, and Cindy—thank you for everything you've done.

My classmates and colleagues, you all know who you are.

Mother, thank you for being that one person that will always tell me I'm right, through the good times and the bad.

And Mango, you've seen it done. It's your turn now.

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TEST

by

KEVIN VAN DEN BOGAARD

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Abstract

Preventing falls in the elderly population requires a collaborative effort that includes medical treatment, rehabilitation, and environmental modification. Medical assessment of the elderly after a fall is designed to treat the potential conditions associated with the fall, such as broken limbs and trauma to the head resulting in a mild traumatic brain injury (mTBI). Currently, there is no standardized test or protocol accepted across health care facilities to track the cognitive-communicative recovery of elderly patients. A group of elderly individuals deemed healthy and capable of independent living were administered the baseline Immediate Post Assessment and Cognitive Test (ImPACT). This study will investigate the *hypothesis* of whether there is a statistically significant difference in performance on the ImPACT test between a group of senior individuals and a group of collegiate age healthy individuals.

Results show statistically significant differences between the senior population and the collegiate norms obtained from the UTEP Concussion Management Clinic. These statistical differences were found on all composite scores related to memory, processing speed, reaction time, and impulse control. Further analysis of the sub-tests that comprise the composite scores showed no statistically significant differences on sub-test scores that used stimuli that elicited semantic memory (SMTCV, CMTCC, 3LTSC, and WMTPC).

The results of this comparative study have shown a correlation with current literature on working memory in the senior population with neurocognitive tests similar to the ImPACT test. The results from this preliminary study may not hold true once a larger group of seniors of varying socioeconomic statuses is administered the ImPACT.

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Chapter 1: Introduction

Seniors are known to suffer from a variety of conditions that increase their likelihood of falling and sustaining a concussion. Mild traumatic brain injury and its relationship with falls and dementia will be discussed, as well as, Baddeley's Working Memory Model and several neurocognitive tests as they are pertinent to the understanding of the test used in this study. This preliminary study will investigate whether a computerized test of cognitive-communicative status that is readily available on the internet and has no normative data on the elderly population, can be used on a sample of seniors.

Senior citizen statistics

Senior citizens are the fastest growing population in the United States (U. S. Census Bureau, 2000). An influx of a population such as this one has not been seen in this country in many years. This makes it increasingly important to have standardized assessments and prevention measures for potential cognitive-communicative deficits for the senior population.

The U. S. Census Bureau (2000) projected the number of individuals age 65 and older will continue to grow each year. Trends predict this number will increase from 39 million to 69 million between 2010 and 2030. In 2010, the U.S. Census Bureau reported that this population increased at a faster rate than the total U.S. population between 2000 and 2010. The fastest growing age group within this population consists of individuals age 75 and older. This group will be doubling its current size by 2025 and increasing five-fold by 2050 (U. S. Census Bureau 2010).

It is important to note that the quality of healthcare varies from setting to setting (nursing home, hospital, and clinics) and from patient to patient and the standardized assessments used vary as well. In a recent life expectancy study, researchers found that seniors are living longer;

this will ultimately cost more to whoever is absorbing the costs (Lubitz, Cai, Kramarow, & Lentzner, 2003). Lubitz et al. (2003) also pointed out that “The expected cumulative health expenditures for healthier senior persons, despite their greater longevity, were similar to those for less healthy persons”. The price of a longer, healthier life will therefore cost about the same for seniors so long as preventive measures are taken. Ultimately, preventive measures adopted by a senior individual will lead to a longer life.

Traumatic brain injury (TBI) is one of the leading causes of death among all age groups, especially for seniors age 65 and older. The Center for Disease Control (CDC, 2008) reported that individuals age 65 and older are twice as likely to suffer a TBI and three times more likely, if older than age 75.

Falls are the leading cause of TBIs in the senior population, consisting of 65% of all individuals that sustain a TBI (Jager, Weiss, Coben, & Pepe, 1999). Tinetti (2003) found that individuals that have a history of a single fall are more likely to fall again; 1 in 10 of these falls result in hip or other types of fractures, subdural hematomas, tissue injuries, and head injuries which result in TBIs. Thompson, McCormick, & Kagan (2006) conducted a literature review on the functional outcome post-TBI in the elderly and found that those of advanced age are more likely to suffer a worse functional outcome after sustaining a TBI. Bhullar, Roberts, Brown, and Lipe (2006) conducted an age comparison study and found that seniors with a prior history of falls were found to have a worse functional outcome versus younger individuals who present an injury of the same magnitude. Furthermore, Luukinen, Viramo, Herala, Kervinen, Kesäniemi, Savola, Winqvist, Jokelainen, & Hillbom (2005) collected and analyzed data from several studies of both younger and older subjects. They found a clear relationship between neurocognitive functioning after TBI and functional outcome in the senior and younger adults.

Senior citizens may suffer from some of the following age related ailments: dementia, Parkinson's disease, stroke, depression, vision problems, and vertigo (Kannus, Sievanen, Palvanen, Jarvinen, & Parkkari, 2005); other chronic illnesses that may arise as the aging process takes place include but are not exclusive to arthritis, hypertension, coronary disease, diabetes, and cerebrovascular accidents (CVA). These illnesses may cause disturbances in executive functioning and gait which may lead to a higher risk of falling and decreased executive functioning (Kannus et al., 2005).

Decreased executive functioning may contribute to emotional liability. For example, Thompson et al. (2006) found that senior citizens are at a higher risk of clinical depression as a result of declined executive functioning and were found to have the highest suicide attempt rate out of all populations. Firearms were found to be the weapon of choice, resulting in a high prevalence of open head injuries. Head injuries have been known to inhibit executive functioning and cause the elderly to respond to life's problems more impulsively (Thompson et al., 2006).

Gait and balance are two critical sensori-motor components that are needed in individuals of all ages. They are interrelated and have a hybrid relationship in that one process is needed for the other to function in an individual that is capable of ambulation. Kannus et al. (2005) conducted a meta-analysis of fall prevention strategies that were implemented with senior citizens. Strength and balance training, along with dietary supplements, were found to reduce the risk of falling.

Even when fall prevention strategies are implemented, many senior citizens are dependent on equipment that enables them to perform their daily activities. For example, a

patient may simply forget to use their walker, then fall, and as a result, injure their body whether it is in the form of fractured/broken bones or a brain injury (Kaye, Kang, & LaPlante, 2000).

Current population estimates show that 6.1 million senior citizens use the aid of an assisted mobility device such as crutches, a walker, and a cane (Kaye, et al. 2000). The use of assisted mobility devices will only increase as the senior population grows. Additionally, seniors have a high prevalence of arthritis and osteoporosis, both of which involve the extremities and affect the function and ease of use of mobility devices (Tinetti, 2003). As can be expected, a senior citizen with any combination of these ailments is at a higher risk of falling.

Stroke victims may suffer from paresis or paralysis of vital muscle groups needed for ambulation, and they also run a high risk of being diagnosed with aphasia. Aphasia, as defined by Brookshire (2007) is “impaired comprehension and production of language, usually caused by damage in the language-competent brain hemisphere.” (page 37) Individuals that have sustained a TBI as the result of a fall are at a heightened risk of acquiring aphasia. Seniors with a TBI may not be capable of understanding or using language to communicate. This deficit may lead to misunderstandings, which further exacerbates the likelihood of a fall. Stroke victims are also at a risk of suffering from right hemisphere syndrome, which affects visuospatial perception. This may result in visual neglect which in turn may increase the likelihood of a fall.

Medication, both dosage and combination, is a known factor that contributes to falls. Medications, such as antidepressants, block the reabsorption of serotonin in the brain which in turn increases the user’s mood; some side effects include restlessness, drowsiness, and insomnia (Mayo Clinic, 2011). Clearly, these medications may also change the senior’s daily living in

ways that cannot be predicted. Antidepressants, in combination with other medications, may cause other symptoms such as dizziness which could disturb the individual's gait.

In a study by Hukkelhoven (2003), several age groups were given a CT scan post-concussion to determine whether age related differences manifested when a TBI is sustained. The senior group was found to have lesions in the brain that were more severe than that of middle aged groups. In a different study, again by Hukkelhoven (2008), the results of the senior citizens were compared with the data available for young children; both of these groups showed similar results on the CT scans in the severity of the lesions. Why the seniors and young children have similar results on CT scans post-mTBI is not well understood. The results from the previous studies highlight the need to continue research with this population so that high quality care may be provided to them.

Mild traumatic brain injury (mTBI)

Mild traumatic brain injury's (mTBI) are of particular interest since elderly are at a higher risk of falling. Many ailments, which will be discussed further on, contribute and even heighten their risk of a fall. Management of mTBI is crucial to the long term cognitive-communicative well being of seniors.

Given the heightened risk of falling in this population, it is important to understand the neurological changes that occur when a concussion is sustained post-fall. A mTBI is the result of a biomechanical force in which an individual experiences some sort of "shake" to the brain, such as in a coup contrecoup injury. Some of the symptoms include dizziness, confusion, disorientation, visual disturbances, headaches, and mood changes (Giza & Hovda, 2001).

The most misunderstood concept in identifying a concussion is whether or not the individual must suffer loss of consciousness (LOC) in order to be considered concussed (Giza & Hovda, 2001). Research has shown that an individual does not have to sustain LOC in order to have sustained a concussion (Giza and Hovda, 2001). In other words, LOC may or may not occur when a concussion is sustained, therefore, it should not be exclusively used to diagnose a concussion. Concussions may have a variety of symptoms that immediately follow the injury. McCrory, Meeuwisse, Johnston, Dvorak, Aubry, & Cantu (2009) discussed the process that takes place when a mTBI occurs as a rapid onset of neurological impairments that are short lived and resolve spontaneously. In more severe cases, skull fractures are likely to occur due to weakness in bone structure, increasing the chance of an intracranial injury when a TBI occurs (McCrory et al., 2009). Pentland, Jones, Roy and Miller (1986) conducted a study that compared TBI severity between younger and older subjects and found that skull fractures may lead to epidural and/or subdural bleeding after a TBI has occurred; this was found to contribute to a poorer functional outcome post-injury in seniors.

Dementia

Dementia is an umbrella term for several degenerative cognitive impairments that may affect an individual's memory, attention, and persona (Brookshire, 2007). The Diagnostic and Statistical Manual of Mental Disorders, 3rd Edition Revised (1987) summarized the cognitive effects dementia has as "...[an] impairment in short- and long-term memory, associated with impaired judgment, other disturbances of higher cortical function, or personality change". Dementia affects both short and long-term memory ultimately affecting cognitive-communicative behavior. Dementia with Lewy bodies has been defined as a "...gait/balance disorder, [with] prominent hallucinations and delusions, sensitivity to traditional antipsychotics,

and fluctuations in alertness” (Knopman et al., 2001). Mixed dementia is the most commonly seen as the symptoms of more than one syndrome present at the same time (Knopman et al., 2001). In another study, Luukinen et al., (1999) assessed a large cohort of adults; each assessment was 30 months apart. Results indicated head injuries sustained as an adult (number and severity) were useful in predicting an earlier onset dementia.

TBI leads to an increased vulnerability in developing Alzheimer’s disease. Lye & Shores (2008) conducted a meta-analysis to ascertain whether TBI affects the development of dementia. A close relationship was found between TBI and the development and early onset of dementia (Alzheimer’s Disease). Satz (1993) described the Threshold Theory which was used to define the relationship between several factors and dementia. First, this theory dictates that neural loss caused by TBI reduces available brain reserve capacity (executive function). Second, factors that affect the development of dementia include: genetic, biochemical, and level of education (Satz, 1993). These factors and TBI may co-exist in different combinations. These combinations account for dementia occurring at various ages to individuals with differing educational and genetic backgrounds.

Fall related injuries in which TBIs are sustained are the most detrimental health-related issues for seniors. Herrmann, Rapoport, Sambrook, Hebert, McCracken and Robillard (2006) conducted a prospective study that investigated the relationship between performance on the Mini-Mental State Exam and driver performance. Cognitive decline in patients with dementia was deemed an important predisposing factor in predicting motor vehicle accidents (e.g. driver mistaking gas for brake, resulting in a motor vehicle accident) and the likelihood of falling.

Effects on cognitive-communicative skills

Falls, TBI, and dementia affect the cognitive-communicative abilities of senior citizens. Cognitive- Communicative skills involve the use of executive processes (language) and expressive/receptive abilities.

The American Speech-Language and Hearing Association (ASHA, 2005) defined cognitive-communication as a multi-faceted concept that includes; cognitive processes (e.g., memory) and language domains (e.g., phonetics, morphology, syntax, semantics, pragmatics) and their relationship with neuro-anatomical structures. These processes may be affected by intrinsic (e.g. education, cultural background, psychological) and extrinsic factors (e.g. TBI, stroke, tumor, encephalopathy, degenerative disorders).

Seniors have an increased risk of sustaining cognitive-communicative deficits after sustaining a TBI. Leblanc (2005), via the use of his TBI prevention program, conducted a retrospective study on functional outcome and TBI in senior citizens. Outcomes following a mild to moderate TBI in seniors were much worse than those of young and middle aged individuals. Senior performance on the communication portion of The Functional Independence Measure (FIM) rating scale was significantly lower than scores obtained from younger controls. Seniors may acquire dysarthria, impaired speech production caused by stroke, degenerative disease, or TBI. Dysarthria arises from damage to the nerve cells that control the musculature necessary for speech production (Brookshire, 2007). Behavioral/pragmatic changes are most commonly seen in individuals diagnosed with a TBI. Perkins (1998) defined pragmatics as, “the emergent consequence of interactions between linguistic, cognitive, and sensorimotor processes which take place both within and between individuals”. Perkins (1998) indicated that the relationship between pragmatics and TBI are irrevocable and stated that pragmatic deficits in the

TBI community should be classified as a disability. TBI related pragmatic impairments affect how the listener perceives the speaker due to disruptions caused by the chemical changes in the structure and coherence of the message (Adams, Lloyd, Aldred, & Baxendale, 2006).

Douglas (2010) stated, “TBI participants experienced difficulties with the amount and the relevance of information that they provided in conversation as well as how they conducted the conversation”. This may cause the unaffected person to disengage in conversation with the pragmatically deficient individual since he or she may be perceived as rude or inappropriate (Adams et al., 2006).

Assessing the extent of a TBI has proven to be a challenge with this population. The severity of the injury to the brain is based upon a model of senior cognitive-communicative functioning that is general at best and that requires more evidence-based research.

The use of the Immediate Post-Assessment and Cognitive Test (ImPACT) in this preliminary study is an attempt to ascertain whether this test of cognitive-communicative status with collegiate norms is sensitive enough to be used on a senior population. Several memory components are measured on the ImPACT, therefore, a clear differentiation between these processes must be made.

Baddeley's working memory model

Baddeley's Working Memory Model is the main framework concerning working memory and will be used as the theoretical basis for this study. Aspects from other memory models have also been used to add clarity to this memory model so the relationship between memory and the ImPACT test can be made (e.g. processing, inhibition, distracter).

An understanding of memory and how possible co-morbidities may impact memory is necessary. Memory may be affected by multiple ailments and accidents such as dementia, Parkinson's disease, stroke, depression, vision problems, and vertigo (Kannus et al., 2005). Also, use of medication for different ailments has been known to impact a senior's muscular strength and perception of his/her surroundings (Mayo Clinic, 2011). As a result, a senior with dementia that is on medication may forget to use his/her cane or walker which may result in a fall and potentially sustain an mTBI (Kaye, et al. 2000). A mTBI, post-fall may further disrupt executive functioning of a demented individual, further increasing the risk of falling (Lamoueux et al., 2008).

Monitoring cognitive performance across time is crucial to the management and prevention of further cognitive problems as well as mTBI. Baddeley's Working Memory Model (Baddeley, 2000, 2004) outlines several hypothetical memory constructs that facilitate the understanding of memory.

Central executive control

The central executive is the hypothetical construct in which information from the phonological loop and visuospatial sketch pad is combined (Baddeley, 2004). Inhibition (part of executive central executive) is the ability to differentiate between information that is relevant and/ or irrelevant to content that is being processed at any given moment (Baddeley, 2004; Van der Linden, et al., 1999). For example, when reading a book, the semantic component of the text is held within the working memory through inhibition. The font and color of the book's pages are not stored since the reader's intention is not to analyze the book's aesthetics.

Fortunately, cognitive decline is not immediately detectable for years when traditional neurocognitive tests are administered. Hickman, Howieson, Dame, Sexton & Jeffrey (2000) conducted a study that compared the cognitive performance of elderly individuals between the ages of 65 and 80. No statistically significant changes were observed within a 4 year age interval although “some mild decline was observed”. Decline in executive functioning is gradual with the senior population so long as no co-morbidities exist.

Phonological loop

The phonological loop requires the use of visual (non-verbal) and auditory (verbal) inputs (Baddeley, 2004). These inputs are sent to the central executive for integration. Visual and auditory inputs are required in order to apply semantic meaning to sensory input. Semantic knowledge is retrieved and meaning is added to these inputs through the central executive.

Auditory and visual input enables individuals to make sense of the world around them by accessing their declarative memory. Verbal communication would not be possible if one of these components were missing. In a study conducted by Keller, Morton, Thomas, & Potter (1999) patients of lower functional status were administered a whisper test and Folstein Mini Mental State Exam (MMSE) in an outpatient clinic. Working memory was found to overcompensate in those with moderate to severe hearing loss as indicated by their performance on the MMSE. Working memory was found to have an increased load as it was attempting to decipher a weakened auditory signal. This reduced the amount of working memory available for motor processing, increasing the likelihood of a fall (Keller et al, 1999; Kaye, et al. 2000)

Visuospatial sketch pad

The visuospatial sketch pad (visual memory) manipulates and stores visual stimuli. Visual memory is required in everyday scenarios, such as walking to and from the kitchen and stepping over or around objects that are in the way. Lamoueux et al. (2008) conducted a study in which senior citizens were given an eye exam and completed a questionnaire about falls. Results from the study indicated that seniors with visual problems had double the risk of falling. Visual memory processes several communication modalities, such as gestures and body language. A break down in this type of visual feedback may keep the individual from understanding the true meaning of the message at hand (e.g. ability to understand sarcasm requires the ability to understand body language).

Working memory studies

The following are several hypothetical constructs described in the literature from other memory models.

Several studies have attempted to define the concept of working memory (Perfect, Riby, & Stollery, 2004; Bittner & Crowe 2007). The general consensus is as follows; working memory temporarily stores and manipulates new information received from sensory input. Working memory may also be viewed as the place where intermediate and final products of memory are created and modified before storage occurs. Just and Carpenter (1992) explained that within working memory resides “the pool of operational resources that perform symbolic computations and thereby generate the intermediate and final products [of a memory].”. Memories are therefore retrieved, compared, and modified; executive functioning is combined with these processes in working memory to determine what sensory inputs should be kept and disposed of.

Working memory capacity (load that can be managed and processed) increases through childhood and reaches its peak by early adulthood (Just & Carpenter, 1992). Working memory capacity in early adulthood allows individuals to process larger amounts of visual and auditory feedback and filter through the executive process Riby, Perfect & Strollery (2004). The ability to multitask is at its greatest at this time and gradually decreases as the individual ages.

Declarative memory (knowledge base)

Declarative memory stores what we know about everyday concepts. Declarative memory can be further divided into episodic, semantic, and retrospective memory (Brookshire, 2007; Just & Carpenter, 1992). Episodic and retrospective memory contain information of events that have been experienced through life. This memory is what dictates an individual's persona and self-perception. Semantic memory contains most of what is learned through the educational process and basic world concepts (e.g. red octagon means stop, green means go). Concepts such as numbers and the alphabet are also considered to be a part of semantic memory since they have meaning associated with them (Shivde & Anderson, 2011). Bittner & Crowe (2006) investigated the relationship between working memory, processing speed, and verbal comprehension via the use of several cognitive scales. Verbal fluency performance was found to be impacted by verbal intelligence, working memory and processing speed.

Retention span is the amount of information that can be stored in memory after the initial exposure, such as when words, letters and even geometric shapes are presented. The ability to measure retention span provides valuable information as to the status of the individual memory. Retention span has two integral components: immediate retention and short-term retention (Brookshire, 2007). Immediate retention is tested by presenting a stimulus, removing it, and ascertaining whether the participant can recall the stimulus. Short-term retention is measured by

imposing a delay after exposure to a stimulus for a few minutes. Clune-Ryberg et al. (2011) conducted a study that measured retrospective memory via the use of an unnamed neurocognitive test in patients with moderate to severe TBI. These participants were compared to an age-matched control group. About 50% of the TBI group failed to complete at least two out of six memory tasks.

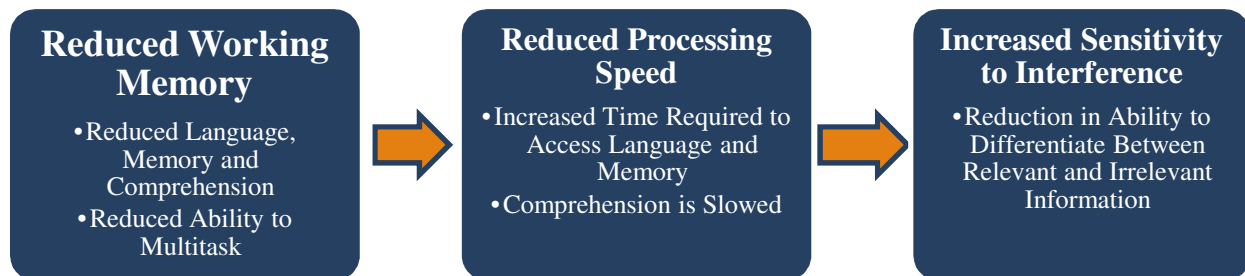
Procedural Memory

Procedural memory consists of concepts that have been over learned (e.g. showering, hand washing, opening/closing door). These actions occur automatically and require no effort on the individual's part to perform. Depending on the diagnosis after a fall, different components of memory could be affected. Procedural memory has been found to remain intact post-TBI. This, of course, is dependent on the locus and severity of the injury (Bittner & Crowe, 2006).

Working memory and the aging process

As the aging process takes its course and working memory capacity declines, individuals are likely to produce semantic and syntactically simpler responses when engaged in verbal communication. In one study, Kemper, Herman, and Liu (2004) presented a variety of nouns and verbs to the participants and required them to respond. When three words were presented, both the younger and older participants scored comparably; when four or more words were required, the older participants took longer to respond. Participant responses were of reduced complexity when the word stimuli were not well understood. Responses were found to be syntactically simpler than those of the younger adults. As the number of words and the semantic and syntactic complexity increased, verbal fluency was found to have decreased. The Bittner et al. (2007) study found that following a TBI, working memory and processing speed changes impacted performance on verbal fluency measures.

Van der Linden & Hupet et al.. (1999) defined several processes related to working memory; they found age-related differences in processing speed, working memory, and inhibition. Any reduction in working memory reduces language and memory available for use at any given moment, reduction in these processes leads to increased difficulty when attempting to comprehend new stimuli, reduced working memory capacity reduces processing speed. Van der Linden et al. defined processing speed as the time needed to integrate and comprehend new stimuli. This increased load on an already reduced working memory decreases the working memory's ability to inhibit relevant information. The following chart outlines this relationship.



For example, personal computers run on this same concept; all information is stored on the computer's hard drive (long-term memory). When something is opened from the hard drive, it is temporarily stored in its random access memory (working memory). Within random access memory these files are updated or deleted then restored onto the hard drive. If the amount of random access memory available is reduced or if the load on random access memory is greater than what it can handle (reduced processing speed), then the computer may slow down, freeze, and even store corrupted files back onto the hard drive.

Multi-tasking

Riby et al. (2004), conducted a meta-analysis on whether older adults found dual-tasking problematic. Autonomic control (executive), motor, and dual processing as defined by Riby et al. (2004) is as follows.

Autonomic processing (procedural memory) occurs when over learned processes, such as opening a door or flipping on a light switch, take place. These processes put the lightest load on working memory (Bittner et al, 2006).

Controlled processing, or central executive control as defined by Baddeley (2000), occurs when executive functioning is required to complete a task. When one or more tasks draw on this type of processing, older adults experience greater difficulty in processing.

Motor processing (visuospatial sketchpad, phonological loop) requires the use of the sensorimotor system and proprioceptive abilities (vision, hearing). Motor processing is the most demanding of the three processes, especially when controlled processing is needed (walking through a densely populated park). Working memory load is at maximum when these two processing tasks coincide; increasing the possibility of falls (Riby et al., 2004; Van der Linden et al., 1999).

Lindenberger, Marsiske, & Baltes (2000) argued that balance and gait are in constant need of additional working memory resources as an individual ages. Older adults experience difficulty when engaged in controlled processing activities while walking. Examples of controlled processing activities include memorization of a written text and tracking via visual input and walking while given specific verbal commands via auditory input. Sensory acuity,

posture, balance, and gait have less working memory available to process efficiently due to breakdown in inhibitory functions.

Neurocognitive tests

The Immediate Post Assessment and Cognitive Test (ImPACT) (Lovell, Collins, Podell, Powel, & Maroon, 2005) has been used to manage and track sports related concussions in high school and collegiate athletes. It is easily accessible via the internet and requires little training in its administration. The ImPACT measures several cognitive abilities via its 6 modules. Approximately 5 composite scores are created, each measures verbal memory, visual memory, reaction time, visual motor speed, impulse control, and cognitive efficiency (relationship between reaction time and accuracy). Composite scores are derived from several modular subtests.

After a concussion is sustained, this test facilitates the evaluation process allows professionals to make judgments on the cognitive abilities of the concussed. Cognitive recovery is also monitored by conducting serial reassessments with this test. At the Concussion Management Clinic at the University of Texas at El Paso, collegiate athletes that participate in sports related activities are administered a baseline ImPACT test at the beginning of the season. Serial reassessment of these athletes is conducted by administering a post-concussion ImPACT test which allows for the management potential sports related concussion. Returns to play protocols are established in accordance with the athlete's performance on the test.

The ImPACT test is robust in nature given that it incorporates concepts from several different neurocognitive tests that measure memory, reaction time, processing speed, and impulse control based on the test takers performance, all of which have been available independently for quite some time. According to Randolph, McCrea, & Barr (2005), many

neurocognitive tests of this nature suffer from poor validity, reliability, and sensitivity post-concussion. Fortunately, the ImPACT test incorporated the most valid and reliable neurocognitive tests available. Lau, Collins & Lovell (2010) pointed out that the implementation of all the test modules together contribute to increased sensitivity of the ImPACT.

Establishing validity with these tests has encountered several problems: (1) the test must measure what it claims to measure and (2) memory tests must correlate with results that have been generated by other well established tests. Test re-test reliability is crucial to tracking cognitive performance through time. Test-retest reliability for the dependent variables on the CogSport (CogState, 2012) computerized exam was found to be variable ($p=.30 - .87$) and deemed unreliable (Maruff, Kakkissi, McCrory, McStephen, Darby, 2003). Sensitivity must also be established to differentiate between a concussed and a normal individual. An exploratory study conducted by Schatz, Pardini, Lovell, Collins, Podell (2005) found sensitivity on the ImPACT to be at 81.9%. Neurocognitive tests that correlate with the ImPACT tests modules will be discussed.

The following neurocognitive tests will be discussed due to their similarities with the ImPACT test and its modules: Hopkins Verbal Learning Test (HVLTL), Brief Visuospatial Memory Test (BVMT), Wechsler Adult Intelligence Scale-III Digital Sub-Test (WSST), Symbol Digit Modalities Test (SDMT), Trail Making Test (TMT), Stroop Color Word Test (SCWT), and WAIS-III Digital Span Test (WDST).

Hopkins verbal learning test (HVLTL)

The HVLTL equivalent on the ImPACT test is module one. These modules will be discussed further on. The HVLTL contains a list of twelve words that are repeated four times to

the test taker. This is set in place to test the individual's ability to immediately recall the words. After this portion of the test is completed, a delay is implemented in the form of a different task. After the delay task has been completed, the test taker is then asked to remember the words that were shown before the distracter task was implemented. This test measures verbal memory. Hogervorst, Combrinck, Lapuerta, Rue, Swales & Budge (2010) studied the sensitivity and specificity of the HVLT on a group of senior citizens and found test sensitivity to be 87% sensitive and specificity at 98%. The HVLT has been shown to be a reliable test.

Brief visuospatial memory test (BVMT)

The BVMT equivalent on the ImPACT test is the module 2. The BVMT has three learning trials in which the test taker is asked to watch the visual stimuli presented and attempt to recall those items after a delay or delay task has been imposed. The test taker is asked to recall at least six of these designs before concluding the test. Visual memory is measured on this test. Jeffrey, Gavett, Lynch et al. (2008) found that the BVMT sensitivity was adequate to track age related changes in patients with Alzheimer's disease versus unaffected normal individuals.

Trail making test (TMT)

The TMT equivalent on the ImPACT test is module three. The TMT presents multiple O's that contain a letter or a number within. The test taker must then draw a line between each of these items in numerical order. The objective of this test is to complete the line in the correct sequence as quickly as possible. This test measures working memory and processing speed. Ashendorf, Jefferson, O'Connor, Chaisson, Green, & Stern (2008) found the TMT to be highly sensitive in measuring the processing speed (working memory and executive functioning) in older adults.

Wechsler adult intelligence scale-III digital sub-test (WDSST) & symbol digit modalities test (SDMT)

The WDSST and SDMT's equivalent on the impact test is module 4. The WDSST was designed to measure the test taker's memory (immediate and delayed retention) and visual processing speed. The test taker is presented with a series of boxes that contain a symbol within and an assigned number underneath the box. The target symbol is then shown and must be selected by selecting the number underneath the symbol. The symbols within the boxes ultimately disappear; therefore, the test taker must remember where each of the target symbols was presented by remembering the number that was associated with the target symbol from earlier in the test. Iverson, Lovell, Collins (2005) found a high correlation between the SDMT and ImPACT test on processing speed measurement.

Stroop color word test (SCWT)

The SCWT equivalent on the ImPACT test is module five. The SCWT presents the colors red, blue, and green in a timed test. This test measures reaction time and response inhibition. The colors appear on words that are the names of the colors being tested. The test taker must be able to discriminate between the color of the letters and the actual color name spelled out in the form of a word. Therefore, the test taker must discriminate between these two stimuli and select the word that is the color that is being asked for regardless of the word itself. The total number correct is calculated. Van der Elst, Van Boxtel, and Van Breukelen (2006) conducted a study on age and the implementation of the SCWT. Executive functioning was found to decline the older the participants were. The effects of aging were found to be even more profound in individual of lower SES.

WAIS-III digit span test (WDST)

The WDST equivalent on the ImPACT test is module six. A subtest on the WDST presents a sequence of numbers. The amount of numbers (string length) presented each time increases as the test progresses. The test taker is asked to remember these sequences and later verbally reproduce after a delay has been imposed. The length of the sequences remembered is scored. This test measures working memory and visual-motor speed. Module six on the ImPACT test uses letters instead of numbers. This is not significant since number and letter sequences are concepts that have been over learned and accessing either is just as simple. Ryan, Sattler, & Lopez (2008) conducted a study in which age effects were studied using this test. They found that fluid intelligence, or the ability to use new information to solve real world tasks, showed more of a decline versus crystallized intelligence (use of memorized knowledge, experience).

Significance

As a clinician and researcher, it is important to know and understand all factors that are commonly found in the senior population. The senior population is growing substantially that is highly susceptible to TBI as the result of a fall. Many diagnoses common within this population that further exacerbate this likelihood. In order to better serve this population, a cognitive test that is robust in nature that has the ability to monitor cognitive function across time is needed; the ImPACT may fulfill this need.

The modules within the ImPACT contribute to the tests ability to detect changes in collegiate athletes. The modules have been found to be highly sensitivity and specific in detecting cognitive performance changes in collegiate athletes; the test has the potential to do the

same for seniors given that the modules are derived from cognitive tests that are capable of this when administered independently.

Preventing falls in the senior population requires a collaborative effort including medical treatment, rehabilitation, and environmental modification. Medical assessment of a senior after a fall is designed to treat the potential conditions associated with the fall, such as broken limbs and trauma to the head resulting in a mild traumatic brain injury (mTBI). If a senior citizen sustains an mTBI, there is currently no standardized test or protocol accepted across health care facilities to track the cognitive-communicative recovery of these patients. Therefore, this study will investigate the hypothesis of whether there is a difference in performance on the ImPACT test between a senior and a collegiate group.

Purpose

The purpose of this study was to collect data on healthy senior individuals via the use of the ImPACT test and compare it to collegiate student baseline data obtained from UTEP's Concussion Management Clinic.

Research question: Is there a difference in performance on the ImPACT test between the senior and collegiate groups on the ImPACT test?

Null Hypothesis: There is no statistically significant difference between the senior group and the normative data for the collegiate athletes on the ImPACT.

Chapter 2: Methods

Design

A group comparison was conducted in this study. Means, standard deviations, and t-test values were calculated and compared between the senior group recruited from the Golden Age Program at the University of Texas at El Paso (UTEP) and collegiate baselines from the Concussion Management Clinic (CMC) at UTEP. Senior baseline data was collected on a one-time basis and compared to available collegiate baselines from the CMC.

Independent Variable

The senior and collegiate groups were the independent variables. Baseline ImPACT results were obtained from the pre-existing Concussion Management Clinic (CMC) dataset. A random sample of 25 baseline tests was chosen from this pre-existing dataset via the use of SPSS. Baseline results used in this study were created between 2007 and 2011.

Dependent Variable

Performance on the following ImPACT composite scores was the dependent variable: Verbal Memory Composite (VeMC), Visual Memory Composite (ViMC), Reaction Time Composite (RTC), Visual Motor Speed Composite (VMSC), Impulse Composite Control (ICC), and Cognitive Efficiency Index (CEI). Please see Table 1 for detailed information on each composite score.

Participants

Comparative Group (Senior)

A total of 27 participants that engaged in physical fitness were recruited from the Golden Age program at UTEP. Senior group data analysis consisted of 25 out of 27 participants. Two

were not included in this analysis due to PI intervening during baseline testing. These participants lacked basic computer operating skills necessary for the completion of the ImPACT test. Table 1 contains the participants' demographic information and the group designation.

Criteria for participation in this study was the following; must be a non-nursing home resident, literate, knowledge of basic computer skills (operation of mouse and keyboard), capable of attending to the ImPACT test without assistance and capable of independent living. All individuals in this study engaged in physical activity for at least two hours a week, twice a week. Participation in this study was voluntary. Participants ranged in age between 65 and 80.

Comparative Group (College)

A total of 25 collegiate baselines were randomly selected from the pre-existing Concussion Management Clinic database. Valid UTEP and EPCC baselines were used because they are considered to be collegiate athletes given that they were actively participating in a sport at the time of their BL testing. All male and female participants were between the ages of 18 to 25. The data collected from this control group was used to assess the cognitive performance of the senior group. Data was compared at baseline for both groups.

It is important to point out that scores generated from the ImPACT test were derived from the same set of norms, regardless of the language (English/Spanish) of the test.

Table 1: Control and Experimental Group Demographic Information

Group	N	Age	Male	Female	Education	History of Concussion	Physical Activity
Collegiate CMC Baselines	25	18-25	12	13	Enrolled in high school or college	No prior concussions as reported on ImPACT	Active in high school or college athletics program
Senior Participants	25	65-80	12	13	Attended college for at least 2 years	Self reported: No concussion within the last 10 years	Engage in physical activity twice a week for 1 hour.

Procedures for Senior Group

The approach used for this part of the study was two-pronged: (1) create a comparative database for a group (senior) that has none available and (2) compare the results to baseline data (collegiate baselines) that has normative data available from the Concussion Management Clinic (CMC) at the University of Texas at El Paso.

A clinical interview was conducted prior to the administration of the test to establish whether the patients had recently sustained a concussion and if other co-morbidities were present. Baseline data was collected via the use of the ImPACT test. On the test, participants had the option of choosing from any one of the thirteen languages provided on the test. All participants chose either English or Spanish. The principal investigator (PI) guided the participants in responding to the demographic questions provided on the test. Once this was completed, the participants were instructed to read the instructions, as thoroughly, before each of the test modules began. The PI answered any questions that arose at that time then instructed the participants to begin the test.

Setting and Materials

Participants were made as comfortable as possible by providing a cushioned chair. The PI adjusted the monitor, mouse, or table as needed for each participant. All participants were tested at the Ross Moore Gym in a sound treated room to eliminate as many distractions as possible from outside the room. Participants received a brief tutorial to establish whether they knew how to operate the mouse and keyboard. The same mouse, keyboard, computer, and computer monitor were used for all the participants.

Assessment Instrument

The Immediate Post Assessment and Concussion ImPACT test requires that the following information be provided every time the test is taken. Participants must respond to a set of demographic questions before beginning the test. Once this has been completed, the participants are instructed to thoroughly read through the instructions provided before each test module begins, shortly thereafter, the test begins. The PI guided the participants through the test instructions at the beginning of each module.

Baseline Testing Protocol

- 1) Answer any questions the participant might have about the consent form. Review and sign consent forms.
- 2) Educate participants on the purpose of the study and potential of the data collected in the future.
- 3) Provide tutorial on how to operate the mouse and the keys what will be necessary to complete the test.
- 4) Set up test
 - a. Access impacttestionline.com/colleges
 - b. Select Texas
 - c. Launch baseline test

- 5) Guide participants through demographics portion of exam.
- 6) Instruct participants to thoroughly read each section of the test before beginning. Answer any questions the participant might have during the test.
- 7) Test begins.
- 8) Download the test results. Place in the participant folder.
- 9) Folder will have pt. number, which is placed on the folder.
- 10) Participant name and number entered in the CMC log.

Statistical Analysis

Independent sample t-tests were conducted on all of the following composite scores: verbal memory, visual memory, visual motor procession, reaction time, and impulse control composite. Statistically significant differences were found in these composite scores. Further analysis was necessary to ascertain the nature of these differences; independent t-tests were conducted on the individual subtests scores used to calculate the composite score.

Dependent Variables on ImPACT

Dependent variables are the performance on each of the following composite scores derived from their corresponding module scores.

Table 2: Composite Score Break Down

Composite Score		
Verbal Memory Composite (VeMC)	Word Memory- Total Percent Correct	WMTPC
	Symbol Match- Total Correct Hidden /9x100	SMTCH
	Three Letters- Total Sequence Correct /5x100	3LTSC
Visual Memory Composite (ViMC)	Design Memory- Total Percent Correct	DMTPC
	X's and O's- Total Correct Memory /12 x100	X&OTCM
Visual Motor Speed Composite (ViMSC)	X's and O's- Total Correct Interference /4	X&OTCI
	Three Letters-Average Counted Correctly x3	3LACC
Reaction Time Composite (RTC)	X's and O's- Average Correct Reaction Time Interference	X&OACRTI
	Symbol Match- Average Correct Reaction Time Visible /3	SMACRTV
	Color Match- Average Correct Reaction Time	CMACRT
Impulse Control Composite (ICC)	X's and O's- Total Incorrect Interference	X&OTII
	Color Match- Total Commissions	CMTC
Cognitive Efficiency Index (CEI)	Symbol Match Total Correct Visible	SMTCV
	Symbol Match Average Correct Reaction Time Visible	SMACRTV
Total Symptom Score (TSS)	Total of all reported symptoms	TSS

Table 3: ImPACT Modules

Modules	
1	Word memory evaluates the participant's attention and ability to recognize and discriminate between verbal/ word stimuli.
2	Design memory evaluates the participant's attention and ability to visually recognize and discriminate between visual stimuli.
3	X's and O's measure the participant's visual processing speed as well as visual working memory. A reaction time distracter test is also used in this test.
4	Symbol matching measures the participant's visual processing speed as well as their ability to learn and retain information.
5	Color match measures reaction time, impulse control, and the participant's ability to inhibit their responses.
6	Three letter memory measures the participant's working memory and visual-motor response speed.

Chapter 3: Results

Statistically significant differences were found between the two groups. Independent samples t-test were conducted to compare composite score performance between collegiate and senior group.

Table 4: Composite Score Means, Standard Deviations, t-test scores

Composite Scores	Group	Mean	Standard Deviation	t-test for Equality of Means (2-tailed)	Statistically Significant Difference (yes/no)
Verbal Memory Composite	Collegiate	84.16000	11.48434	p<.003	Yes
	Elderly	69.920	19.25037		
Visual Memory Composite	Collegiate	77.5200	10.81712	p<.000	Yes
	Elderly	53.8800	8.74795		
Visual Motor Speed Composite	Collegiate	38.590	4.41706	p<.000	Yes
	Elderly	25.5657	4.63484		
Reaction Time Composite	Collegiate	.5756	.07366	p<.000	Yes
	Elderly	.8908	.15443		
Impulse Control Composite	Collegiate	4.9600	3.46987	p<.003	Yes
	Elderly	2.1600	2.82371		
Total Symptom Score	Collegiate	4.7600	8.34306	p >.671	No
	Elderly	5.5800	6.80515		
Cognitive Efficiency Index	Collegiate	.3275	.13878	p<.000	Yes
	Elderly	.0276	.12882		

Summary of Composite Score Results

A statistically significant difference was found in the following composite scores: Verbal Memory Composite (VeMC), Visual Memory Composite (ViMC), Visual Motor Speed Composite (ViMSC), Reaction Time Composite (RTC) and Impulse Control Composite (ICC). The results from the Impulse Composite Score (ICC) were not statistically significant. VeMC scores in the collegiate (M=84.2, SD=11.5) and senior (M=69.9, SD=19.3) groups; $t(48) = 3.176$, $p = .003$. The seniors performed significantly poorer on the word, symbol, and the letter memorization component of the test. They ranked borderline on the collegiate normative data provided by the ImPACT test.

ViMC scores in the collegiate (M=77.5200, SD=10.81712) and senior (M=53.880, SD=8.74795) groups; $t(48) = 8.5$, $p = .000$. The senior's ability to memorize abstract concepts such as designs and letters was significantly poorer than the CMC group. The x's and o's as well as the designs presented different each time via visuospatial manipulation. They ranked borderline on the collegiate normative data provided by the ImPACT test.

ViMSC scores in the collegiate (M=38.6, SD=4.4) and senior (M=25.6, SD=4.6) groups; $t(48) = 10.2$, $p = .000$. The seniors performed significantly poorer than the CMC group in processing speed. They ranked borderline on the collegiate normative data provided by the ImPACT test.

RTC scores in the collegiate (M=.58, SD=0.07) and senior (M=.90, SD=0.15) groups; $t(48) = -9.211$, $p = .000$. Senior reaction time was significantly slower than the CMC group, even more so than the prior scores. They ranked impaired on the collegiate normative data provided by the ImPACT test.

ICC scores for the collegiate group ($M=4.96$, $SD=3.46987$) and senior ($M=2.16$, $SD=2.82371$) group ($t(48)=3.1$, $p=.003$) indicate that seniors are less impulsive than their younger counterparts.

The TSS is not indicative of performance on the test between these two groups, at this time. TSS in the collegiate ($M=4.5$, $SD=8.3$) and senior ($M=5.6$, $SD=6.8$) groups; $t(48)=-.42$, $p=.671$. The Postconcussion scale is used to measure the symptoms the test taker presents with at the time of the test (Lovell & Collins, 1998). The seniors had a slightly higher TSS, although not statistically significant. They ranked normal on the collegiate normative data provided by the ImPACT.

The CEI score represents the relation reaction time and accuracy have on the symbol match task in the collegiate ($M=.32$, $SD=.14$) and senior ($M=.03$, $SD=.13$) groups; $t(48)=7.057$, $p=.000$. Seniors performed significantly poorer on this index score. Investigation of the subtest scores used in the CEI for reaction time and accuracy is needed.

Senior group performance was ranked between borderline and impaired when interpreted with athlete normative data available for the ImPACT. No CEI ranking has been established for the ImPACT at this time.

Table 5: ImPACT Senior Rankings with Athlete Norms

Verbal Memory Composite	Borderline
Visual Memory Composite	Borderline
Visual Motor Speed Composite	Borderline
Reaction Time Composite	Impaired
Impulse Control Composite	Impaired
Total Symptom Score	Normal
Cognitive Efficiency Index	No Ranking

The ImPACT publishers state the average CEI score is .34 with a range between .00 and .70. A score above .34 indicates the test taker is both accurate and prompt in making the appropriate selection on this task (Lovell, Collins, Podell, Powell & Maroon, & 2005).

These results suggest that age does play a role on performance on the ImPACT test as indicated by the VeMC, ViMC, ViMSC, RTC and ICC scores. No further analysis of the TSS will be made; a statistically significant difference was not found. Furthermore, the TSS is not indicative of cognitive performance on the ImPACT between these the senior and collegiate groups.

Further analysis of the subtests used to calculate each of the composite scores was completed to investigate the underlying component that contributed to the senior group's lower performance scores.

Table 6.1: Composite Score Sub-Test Means, Standard Deviations, t-test scores

Verbal Memory Composite (VeMC)	Group	Mean	Standard Deviation	Sig. (2-tailed) t-test	Statistically Significant Difference (yes/no)
Word Memory Total Percent Correct (WMTPC)	Collegiate	93.78	6.12556	p >.071	No
	Senior	84.7628	23.60087		
Symbol Match Total Correct Hidden (SMTCH)	Collegiate	6.08	2.17792	p <.014	Yes
	Senior	4.52	2.12368		
3Letter Total Sequence Correct (3LTSC)	Collegiate	4.32	0.9	p >.114	No
	Senior	3.68	1.77294		
Visual Memory Composite (ViMC)	Group	Mean	Standard Deviation	Sig. (2-tailed)	Statistically Significant Difference (yes/no)
Design Memory Total Percent Correct (DMTPC)	Collegiate	78.88	2.13508	p <.003	Yes
	Senior	67.16	2.09518		
X&O Total Correct Memory (X&OTCM)	Collegiate	9.16	0.43466	p <.000	Yes
	Senior	4.88	0.30725		
Visual Motor Speed Composite (ViMSC)	Group	Mean	Standard Deviation	Sig. (2-tailed)	Statistically Significant Difference (yes/no)
X&O Total Counted Incorrect (X&OTCI)	Collegiate	117.2800	6.34114	p <.000	Yes
	Senior	93.3200	20.61294		
3Letters Average Counted Correct (3LACC)	Collegiate	15.9520	2.78285	p <.000	Yes
	Senior	8.9680	2.45878		

Table 6.2: Composite Score Sub-Test Means, Standard Deviations, t-test scores

Reaction Time Composite (RTC)	Group	Mean	Standard Deviation	Sig. (2-tailed)	Statistically Significant Difference (yes/no)
X&O Average Correct Reaction Time Interference (X&OACTRI)	Collegiate	.4768	.05344	p <.000	No
	Senior	.7184	.16504		
Symbol Match Average Correct Reaction Time Visible (SMACRTV)	Collegiate	1.4348	.05344	p <.011	Yes
	Senior	3.5368	3.985203		
Color Match Average Correct Reaction Time (CMACRT)	Collegiate	.7748	.10576	p <.000	Yes
	Senior	1.0128	.29496		
Impulse Control Composite (ICC)	Group	Mean	Standard Deviation	Sig. (2-tailed)	Statistically Significant Difference (yes/no)
X&O Total Interference Incorrect (X&OTII)	Collegiate	4.52	3.07029	p <.001	Yes
	Senior	1.88	2.24202		
Color Match Total Correct (CMTC)	Collegiate	0.44	0.65064	p >.524 NS	No
	Senior	0.28	1.06145		
Cognitive Efficiency Index (CEI)	Group	Mean	Standard Deviation	Sig. (2-tailed)	Statistically Significant Difference (yes/no)
Symbol Match Total Correct Visible (SMTCV)	Collegiate	27.0000	.00000	p >.077 NS	No
	Senior	26.8800	0.33166		
Symbol Match Average Correct Reaction Time Visible (SMACRTV)	Collegiate	1.4348	0.38213	P <.011	No
	Senior	3.5368	3.95203		

Summary of Composite Score Subtests Results

Composite scores on the ImPACT are derived from individual subtest scores from each of the modules. Individual t-tests were conducted on all subtest scores.

Statistically significant differences were found throughout the modular composite scores. No statistically significant differences were found in the symbol match total correct visible (SMTCV), color match total counted correct (CMTCC), three letter total sequence correct (3LTSC), and word memory total percent correct (WMTPC) subtest scores. Each of these subtests scores corresponded to a different module with the exception of the SMTCV and CMTCC scores.

VeMC All variables for the *VeMC* score were poorer for the seniors. The significantly larger standard deviation for the WMTPC score for the senior group indicates greater variability in their performance on this particular subtest, however, no statistically significant differences were found between the two comparative groups of this subtest. Means were similar between comparative groups on the 3LTSC score; no statistically significant differences were detected between the two comparative groups on this subtest. WMTPC and 3LTSC measure word and number recall. SMTCH measures the ability to recall a stimulus after it has been associated with another stimulus (number). Seniors performed poorer on these subtests; standard deviations are comparable on this subtest between the senior and collegiate baseline groups.

ViMC DMTPC score appears age appropriate given the small standard deviation within the senior group, at this time. Also, standard deviations are comparable for both the senior and collegiate baseline groups. The X&OTCM mean score was significantly poorer for the senior group which indicates increased difficulty in recalling the correct stimulus.

ViMSC Mean scores for both 3LACC and X&OTCI, indicative of poorer performance in the senior group; X&OTCI was significantly lower for the senior group. This indicates seniors were slower in recalling the visuospatial location and shape of stimulus.

RTC Reaction time scores were all lower for the senior group. The SMACRTV score was particularly interesting since it calculates how long it takes for the test taker to match a symbol to a number. Mean scores and standard deviations were significantly lower on this subtest when compared to the X&OACRTI and CMA CRT scores.

ICC The X&OTII score indicated the seniors selected fewer incorrect stimuli on the x's and o's task. The CMTM score for the senior indicated that fewer color commissions were made on the color matching task; standard deviation for the seniors was also larger—greater variability within the sample.

CEI SMTCV means and SD were significantly similar, indicative of comparable accuracy between the two comparative groups. Statistically significant differences were found on the SMACRTV score, this is indicative of slower reaction time in the senior group when compared to the collegiate baselines.

A running timer was kept running for each participant for the duration of the test. It took the senior an average of 50 minutes to complete the ImPACT. Before beginning the test, the test taker has to provide demographic information before beginning the test (name, age, height, weight, nationality, etc.). This in itself took the senior a significant amount of time to complete and provides no relevant information in regards to verbal memory, visual memory, reaction time, impulse control and processing speed. Unfortunately, no data on the time it took the seniors to complete the demographic section was kept. According to the ImPACT publishers, 30-35

minutes are required to complete the test, along with the demographics section, when taken by athletes (Lovell, Collins, Podell, Powell & Maroon, & 2005).

Chapter 4: Discussion

Currently, no other data set exists for the senior population on the ImPACT test. The preliminary data collected from this comparative study has provided some insight regarding seniors' performance on the ImPACT test.

All participants were recruited from the Golden Age program at UTEP. The seniors in this study engaged in physical fitness in Golden Age program at UTEP. All individuals attended this program at least twice a week for one to two hours. Two baseline tests were not included in the analysis since the principal investigator during baseline testing. These two participants lacked basic computer operating skills necessary for taking the ImPACT test.

The senior group's performance scores were compared to the pre-existing CMC dataset obtained from student athletes (18-25 years of age) at the University of Texas at El Paso. The findings from this comparison revealed the senior group had poorer performance scores, independent t-tests revealed statistically significant differences throughout the ImPACT.

Several statistically significant differences were found in the following composite scores: Verbal Memory Composite (VeMC), Visual Memory Composite (ViMC), Visual Motor Speed Composite (ViMSC), Reaction Time Composite (RTC) and Impulse Control Composite (ICC). The results from the Total Symptom Score (TSS) composite were not statistically significant.

Memory, reaction time, and processing speed were measured by the ImPACT test. Baddeley's working memory model helps define which of these processes were affected. In this case, it pinpointed changes that have been seen in individuals of advanced age.

Verbal Memory Composite (VeMC)

The senior group performed significantly poorer when compared to the collegiate group on the word, symbol, and the letter memorization component of the VeMC. Inhibitory processes (part of executive control) were needed to solve the tasks on each of the this section (Van der Linden, Hupet, Feyereisen, Schelstraete, Bestgen, Bruyer, Lories, El Ahmadi, & Seron,1999). The participant is exposed to a stimulus then is required to hold it in short term working memory (inhibition) until the recall of this stimulus is needed again. This required higher executive processes which imposes an increased load on short term working memory. Within this composite score lay three subtests, all similar in nature. Findings for each of the subtests are as follows.

Verbal Memory Composite (VeMC) Subtests

No statistically significant difference was found between the collegiate and senior groups on the Word Memory Total Percent Correct score (WMTPC) and the Three Letter Total Sequence Correct (3LTSC), which will be discussed later. The WMTPC score represents the number of words the participant was able to recall after exposure to the word stimuli at the beginning and at the end of the test. For example, participants were required to progress through module 2, 3, 4, and 5 before recall of the stimulus words was necessary again.

Word stimuli used on the test are semantically simple and common in the English language. The same can be said about the stimulus words provided in Spanish. The simplicity of the stimulus words facilitated their retrieval at the end of the test. For example, exposure to a shape requires the participant to remember the lines and curves of the shape. Word stimuli require access to basic concepts within semantic memory. When a participant sees the word “doctor”, semantic memory is retrieved and all prior knowledge associated with the word is

made available. This information is then inhibited within short-term working memory and inhibited until it is needed.

The Three Letter Total Sequence Correct (3LTSC) score from the VeMC also showed no statistically significant differences between the senior and collegiate groups. This task required seniors to memorize 3 letters, perform a distracter task (count from 25-0), then key in the 3 letters that were shown before the distracter task. The distracter task puts an extra load on working memory and tests the individual's ability to inhibit the three letter sequence until it is needed.

Short-term working memory capacity is then measure by the participant's ability to recall the 3 letter sequence. Some of the participants were observed to either forget the first or last letter in the sequence when recall was necessary. As described in the Gothe, Oberauer & Kliegl (2007) study, seniors were found to have sacrificed performance on one task (distracter) for greater accuracy in the other (letter sequence memory). Greater emphasis was placed on the memorization of the 3 letter sequence; this reducing the speed in which the participants responded to the distracter task since. Interestingly, as the sub-test progressed, retrieval of the 3 letter sequence appeared to be easier.

Another compensatory strategy was observed; participants verbally recited the 3 letter sequence even after the distracter task had already begun. Recital of the stimulus words activated the phonological loop. This occurs when visual (letters) and auditory (recital of letters) input is received by working memory. Baddeley's memory model states that these two inputs are required to add semantic meaning to stimulus making the three letter sequence easier to retrieve from working memory. Accuracy on the 3 letter task was observed to have improved as the test progressed.

The Symbol Match Total Correct Hidden (SMTCH) was the only test used to calculate the VeMC score that was statistically significant. The SMTCH requires the use of cognitive processes that have not been over learned, in this case symbols. The symbols presented on the test require the use of executive processes along with visuospatial processing since memorization symbols was required. Both of these processes impose a greater load on working memory. Riby, Perfect and Strollery (2004) stated that seniors experience increased demands on their working memory when controlled (executive) and motor processing tasks occur together. When a certain threshold is met, working memory's dual tasking abilities begins to decrease. This threshold is considerably lower for seniors.

As seen in the Kemper et al. (2004) study, as dual-tasking demands increase, accuracy in the task decreases (reduced inhibition). As an example, a reduction in inhibition could cause an individual to forget where to step while climbing down the stairs when holding a conversation with a loved one. Performance on this sub-test alone could be used to determine the risk of falling in the senior population since it measures the individual's ability to merge both executive processing and motor processing; integration of executive and proprioception is needed for ambulation.

Visual Motor Composite (ViMC)

The ViMC tests the individual's ability to retain visual stimuli in working memory via the use of executive control. In these tests, a stimulus is presented and followed by a distracter task. The location of stimuli must be recalled after the distracter task. Executive control uses its inhibitory process to retain visual images and their location and inhibit the visual stimuli when performing the distracter task (selecting a red or blue box with a mouse). Visuospatial location of the stimuli presented before the distracter must then be recalled after the distracter task has been

performed (x's and o's). The inhibition of visuospatial stimuli in working memory coincides with the description of several memory models cited in the literature (Van der Linden, Hupet, Feyereisen, Schelstraete, Bestgen, Bruyer, Lories, El Ahmadi, & Seron, 1999; Just & Carpenter, 1992).

The two subtests that involved memorization of the visuospatial location of letters and abstract designs were both statistically poorer for the senior versus the collegiate group as indicated by the ViMC score.

The X & O Total Correct (X&OTC) stimulus was presented before and after a distracter task (clicking either the g or h key depending on the stimuli). Three of the x's and o's were illuminated when initially presented. Upon completion of the distracter task, recall of the visuospatial location of the three prior symbols was necessary. Storage of this type of stimulus requires the use of the visuospatial sketch pad (Baddeley's working memory model). On top of having to memorize location, participants were also required to recall whether the symbols were x's and o's.

Interestingly, the participants did not immediately notice that the symbols were illuminated when the distracter stimuli were initially presented. Memorization of two components is necessary to complete this task. This multitasking process has been found to decrease in the senior population. Van der Linden et al., (1999)

Imposing a distracter task with the x's and o's task would require the individual to inhibit what is learned from on the x's and o's task until its recall is needed again. Increased loads on executive control (inhibitory processes) have been found to be increasingly difficult for older individuals and would account for their performance on this task (Riby, Perfect and Strollery, 2004).

The Design Memory Total Percent Correct (DMTPC) required that both the design and orientation of the stimulus be memorized. Again, the scores from this subtest coincide with what Riby, Perfect, and Stollery (2004) found in their meta-analysis. Dual-tasking, specifically when executive processes are involved, put increased demands on an already overloaded working memory. The deficits experienced were seen when the participants struggled to remember the design and/or orientation of the stimulus.

Visual Motor Speed Composite (ViMSC)

Statistically significant differences were found in both subtest scores on the ViMSC X&OTCI and 3LACC scores between groups. Results from these scores indicate these tests were sensitive in detecting age related differences in visual processing speed (Ashendorf, et al., 2008) in the senior population. X&OTCI measured the ability to select the appropriate target via the use of a keyboard when a visual stimulus is presented. The 3LACC uses this same concept; 3 letters are presented and the average recall time of the 3 letter sequences was measured.

Visual stimuli were temporarily stored in the visuospatial sketch pad; motor processing occurs immediately afterwards, when a response is needed. Motor processing is the most demanding of memory processes since it requires the use of central executive processes and motor processing (Van der Linden, 1999).

Reaction Time Composite (RTC) & Cognitive Efficiency Index (CEI)

Statistically significant differences were found in all subtest scores on the RTC X&OACRTI, SMACRTV, and CMACRT between groups. The X&OACRTI, SMACRTV, and CMACRT required the use of the central executive which then elicited semantic memory (Shivde & Anderson, 2011). Keep in mind that the SMACRTV is also used in the CEI score.

Motor processing is slow given limited is the most demanding of memory processes since it requires the use of central executive processes and motor processing (Van der Linden, 1999). Working memory has been found to be reduced in seniors; this led to an increase in processing time when recognition of the stimulus is required which leads to increased reaction times when a response elicited (Van der Linden, 1999; Kemper, Herman, and Liu 2004).

The CEI uses the Symbol Match Average Correct Reaction Time Visible (SMACRTV) and the Symbol Match Total Correct Visible (SMTCV) subtest scores to measure the relationship speed and accuracy, respectively. No statistically significant differences were found on the SMTCV scores. The SMTCV was easier for seniors versus the symbol match task correct hidden use in the VeMC. One possible explanation for this is as follows: matching stimulus to stimulus is easier for seniors since working memory does have to inhibit the visuospatial location and shape of the symbol stimulus upon recall. Matching symbol to symbol requires less working memory since the visuospatial location of the stimulus does not need to be memorized. SMACRTV means and SD were significantly different, indicative of slower reaction time in the senior group versus the collegiate group. This score was also used on the RTC and the same argument applies.

Impulse Control Composite (ICC)

The x and o total incorrect interference (X&OTI) and color match total commissions (CMTC) measures the test takers response inhibition. Scores on the X&OTI indicate that seniors had difficulties selecting the appropriate responses on that task. Seniors were observed to have struggled significantly during the test itself. A reduced working memory in turn reduces the senior ability to process the visuospatial location of the x's and o's. Furthermore, this task shows the stimuli for less than five seconds. This is not enough time for working memory to store the

stimuli's visuospatial location, increasing senior sensitivity to interference (the x's and o's that were not correct).

Also, comments regarding memory were made by most participants. The CMTC scores between the two groups indicate performance was comparable to younger norms. This test score and the SMTCV 3LTSC, WMTPC scores use semantic memory and imposes a minimal load on working memory.

Chapter 5: Conclusion

Currently, there is *no* standardized test or protocol accepted across all health care facilities that tracks the cognitive-communicative recovery of elderly patients like the ImPACT. This test is easily accessible as long as an internet connection and a personal computer are available.

The results from this study demonstrate that the ImPACT test is a tool that has the potential to track the cognitive-communicative status of senior citizens. This study established that the ImPACT can be completed by a group of senior individuals.

Also, the results from this study are consistent with the literature on senior working memory. The likelihood of a fall has been found to increase when two processing tasks coincide, increasing the possibility of falls (Riby et al., 2004; Van der Linden et al., 1999). In the Lamoueux et al. (2008) study, they found that elderly that have vision problems are high risk fallers. Impaired vision or hearing has been found to be taxing on working memory, decreasing the amount of memory resources dedicated to the act of walking (Keller et al., 1999; Kaye, et al. 2000; Perfect, Riby, & Strollery, 2004; Bittner & Crowe 2007).

The combination of subtests within the ImPACT contributes to the test's sensitivity (81.9%) and specificity (89.4%) in the ability to detect changes in collegiate athletes (Collins & Lovell, 2010; Schatz, Pardini, Lovell, Collins, Podell, 2005). Also, the modular subtests on the ImPACT have been found to be highly reliable within the neurocognitive literature. The HVLT (module 1) sensitivity was found to be 87% and specificity was deemed at 98% and the BVMT (module 2) was found capable of tracking cognitive-communicative changes in elderly patients. The TMT also had strong sensitivity in tracking processing speed (Lynch et al., 2008; Swales &

Budge, 2010; Ashendorf, Jefferson & O'Connor et al., 2008). Also, the SCWT (module 5) and WDST (module 6) were found capable of tracking executive functioning and fluid intelligence, or declarative memory (Van der Elst, Van Boxtel, and Van Breukelen, 2006; Ryan, Sattler, & Lopez, 2008). This is evidence that the ImPACT is capable of tracking communicative-cognitive in differences across age groups.

Interestingly, independent t-tests on the following subtests indicated there was no statistically significant differences were found on the SMTCV, CMTCC, 3LTSC, and WMTPC test scores between the senior and collegiate groups. Repeated exposure to these concepts (symbol, colors, letters, and words) throughout life facilitated their ability to perform (Brookshire, 2007; Van der Linden et al., 1999). Declarative (semantic) memory or crystallized intelligence as defined by Ryan, Sattler, & Lopez (2008) remains easy to access through short-term working memory, regardless of age. For example, on the color matching task, seniors performed well since the color of the box and the word stimulus were presented during each interval appeared.

Also, memorization of letters and words imposed lighter load on working memory since they are given that they are stored in declarative memory. Letters and words (as well as colors and symbol recognition) are domains that have been learned since childhood as seen by the easier recall of those stimuli (Riby et al., 2004). Memorization and retrieval of letter and word stimuli is use autonomic memory, imposing the lightest load on the participants working memory (Brookshire, 2007). This data suggests declarative memory remains intact as the aging process takes its course.

Limitations

The ImPACT test has several limitations that would prove to make the implementation of this test on the senior population difficult but not impossible

First, this is a preliminary study. The differences found between the elderly and collegiate group may not hold up if a larger group of elderly's baseline data is collected. A larger group of elderly baselines is needed to form a comprehensive normative data set before the implementation of this test across the nation. Given the nature of the study, factors such as socioeconomic status and level of education were not taken into consideration. The meta-analysis conducted by Lye & Shores (2008) indicated that individuals of a lower socioeconomic status typically have a lower education level which has been found to increase the likelihood on earlier onset of dementia. In other words, cognitive performance is bound to be highly variable given the stratification that exists within this population. Currently, it is unknown whether individuals of low socioeconomic status are capable of completing the test. Furthermore, it is unknown whether the test would be capable of detecting the performance of these individuals.

Also, a running timer was kept running for each participant in order to track the time it took to complete the ImPACT from beginning to end (demographics, symptoms, & test). It took seniors an average of 50 minutes to complete the ImPACT test. It is important to note that before beginning the test, the test taker must provide demographic information before beginning the test (name, age, height, weight, nationality, etc.). This in itself took seniors a significant amount of time to complete.

Finally, t-tests were used for all the subtests on the ImPACT. Given the large number of t-tests, some statistically significant differences on the test scores may have been found by

chance. Future analysis of this data will use a more appropriate statistical analysis. Repeated measures Analysis of Variance (ANOVA) would be better suited to compare means within and between three or more groups in this study.

Future Directions

This test maybe appropriate for use in a nursing home setting where patient falls is a significant problem. If this test is to be of value in identifying individuals who's cognitive status puts them at risk for falling the test must be administered to a patient upon admission to the facility and re-administered if they fall. The natural progression of this study should include the administration of the ImPACT to a group of nursing home residents since the likelihood of fall related mTBI in this population is high.

Cognitive function of nursing home residents, upon admission would provide the following: (1) baseline ImPACT data to ascertain the cognitive functioning of the resident at that time, (2) would provide an indicator of risk for falls upon admission, and (3) provide health care staff with information that may potentially facilitate in the modification of the residents environment.

If a fall related TBI is sustained, the resident would be reassessed and post-concussion performance could be compared to their performance at admission. This comparison would help in the process of determining the severity of the fall on the resident's cognitive-communicative functioning. Furthermore, the resident could be assessed serially to determine the nature of recovery from a mTBI and when the resident's recovery stabilizes. This would provide a nursing home staff with an instrument that would significantly add to the prevention of falls and the consequences of mTBI on nursing home residents.

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Vita

Kevin van den Bogaard was born and raised in the city of El Paso, Texas and raised by his mother. He grew up in a multicultural home that consisted of his grandmother, grandfather and younger brother. Throughout his childhood, he was exposed to a variety cultures and exposed to multiple languages through his grandfathers business in Mexico. This formed the foundation to his eventual interest in the field of speech-language pathology. In his collegiate career, he obtained the Jimmie Vokes Bernard scholarship, amongst others. He was accepted and entered graduate school at the University of El Paso in 2010.

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