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EXAMINING THE VALIDITY OF AN AFFECTIVE VERBAL LEARNING TEST IN A COLLEGE ATHLETE SAMPLE

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Abstract

Concussion is a form of mild traumatic brain injury (TBI) that is prevalent in the college athlete population. Research has demonstrated that verbal memory tests are sensitive to concussion and that concussion may lead to transient changes in affect as well. This study was designed to measure the validity of the Affective Verbal Memory Test (AVLT) as an indicator of both verbal memory and affective state. The AVLT was administered to 237 non-injured college athletes at baseline, as part of a neuropsychological test battery. The AVLT is a verbal list-learning task, in which 15 affectively-loaded words are presented aurally. Immediate and delayed recall were assessed. The HVLT-R, RBMT, ImPACT Verbal Memory Composite, VIGIL, Stroop Test, and BDI-Fast Screen were consulted to establish convergent and discriminant validity. Analyses revealed that the AVLT immediate and delayed recall indices exhibited medium to large correlations with indices of verbal learning (ranging from $r=.24$, $p<.001$ for the RBMT story memory test to $r=.51$, $p<.001$ for the ImPACT Verbal Memory Composite), and non-significant to medium correlations with tests of attention (ranging from $r=.03$, $p=.63$ for the PSU Cancellation Task to $r=.24$, $p<.001$ for the Vigil). The AVLT immediate and delayed affective bias ratings exhibited small to medium correlations with athletes' rating of motivation ($r=.18$, $p<.005$) and anhedonia ($r=-.21$, $p<.005$). These results suggest the AVLT is a valid measure of verbal memory, and a promising indicator of emotional state. A measure that can provide information about both cognitive and affective consequences of head-injury would prove useful in analyzing the severity of a concussion and the recovery progress of an athlete.

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Introduction

Introductory statement

Concussion, defined as "any traumatically induced brain dysfunction, with or without loss of consciousness," is a topic of growing focus in both the medical and sports realm. The risk of sustaining a concussion, a type of mild traumatic brain injury (mTBI), is especially high for athletes, and has been identified as one of the leading causes of death and disability for the young population with incidence peaking during adolescence (Giza & Hovda, 2004). Moser et. al (2007) suggest that the 300,000 athletes per year who sustain a concussion as estimated by the Centers for Disease Control and Prevention (CDCP) does not even come close to accurately representing the true prevalence of this injury. This CDCP tally does not take into account concussions that occur without loss of consciousness (LOC), which is around 90% of all concussions. This popular notion that LOC must occur for the injury to be considered a concussion is one of the main underlying factors resulting in the gross underreporting of concussions. For example, Delaney et al. (2002) found that, although 70% of football players in their study experienced a set of symptoms indicative of concussion, only 23% had even realized that a concussion had occurred. There are other reasons explaining why concussions often go unreported. The growing attention given to and dissemination of information about concussions may help coaches and trainers identify many of these injuries that were previously going unreported, but many athletes may still feel pressure not to report a concussion if doing so might result in a loss of playing time or they feel it will negatively impact their team.

Although concussions frequently result in clearly recognizable short-term impairments in domains such as memory, attention, reaction time, and information processing speed, the damage to the brain is more difficult to pinpoint. For this reason, neuropsychological testing is an

important tool used to determine exactly which domains are impaired and to then track the recovery of the patient's level of function in those domains. Many universities and even some high schools have begun testing programs for their athletics programs where all athletes who participate in sports where they are at risk for concussion undergo baseline testing. If athletes do end up sustaining a concussion as a result of their participation in sports, then their performance on the test battery following the concussion can be compared with their performance at baseline to determine their level of impairment and to track their recovery. (Echemendia et al., 2001).

Purpose of study

This study is a test of the validity of one of the components of the test battery used as a part of the Penn State Concussion program. This measure, the Affective Verbal Learning Task (AVLT), was designed by Dr. Peter Arnett and Fiona Barwick, M.S. at Pennsylvania State University. The AVLT is a task designed to measure both verbal memory and affect. It is well-established that memory is one of the domains most affected by concussion. What is also becoming clear is that concussion often results in changes in patients' affect as well. These changes in affect provide insight into the severity of the injury and could have implications in treatment and return-to-play decisions (Borgaro & Prigatano, 2002). The AVLT consists of 16 affectively-loaded words that are presented aurally to the participant. After the word list is read, the participants are asked to repeat back as many of the words as they can remember, in whatever order they come to mind. The test consists of three immediate recall trials and one delayed recall trial.

The present study will assess the validity of this measure by determining its convergent and discriminant validity with other measures currently used in a typical neuropsychological battery use for sports concussion assessment. Convergent validity will be established for both

memory and affect separately since these are two different domains. This will be done by correlating the AVLT with other measures of memory and affect that are known to be valid. To establish discriminant validity, the AVLT will be correlated with components of the concussion battery that are not intended to measure either memory or affect.

What follows is a review of the epidemiology, symptomatology, and diagnosis of concussion, as well as some background on the tests used in the neuropsychological battery. A more in-depth explanation of the AVLT will be provided as well. Finally, the hypotheses for the research questions in this study will be discussed.

Background: Concussions

Definition and Epidemiology

Although there is not one agreed-upon definition about what exactly qualifies as a concussion, there is a set of typical pathophysiological and symptomatological qualities that characterize the outcome of a concussion (Rosenbaum, Arnett, Bailey, & Echemendia, 2006). All concussions involve a blow to the head or another action that causes the brain to rapidly accelerate and decelerate within the skull (Moser et al. 2007). This acceleration/deceleration of the brain within the skull causes the brain tissue to make contact with the skull, resulting in the damage and associated deficits seen in concussed individuals. Despite the fact that the brain is violently colliding with the inside of the skull, 90% of concussions do not result in LOC, thus it is important not to use this as an inclusionary criterion for defining concussive injury.

Neurometabolic Cascade

The hallmark of concussive injury is the neurometabolic cascade which takes place afterwards. This neurometabolic cascade, as described by Giza & Hovda (2004), encompasses a

number of complex mechanisms that affect the cells of the brain in a various ways. The damaged cells will eventually either recover or die off, depending on the level of damage incurred.

The movement of the brain during concussion results in axonal stretch and the subsequent efflux of K^+ ions, depolarizing the neuron and causing it to fire. The release of glutamate, an excitatory neurotransmitter, results in the activation of NMDA and AMPA receptors which further depolarizes the cell. To restore the membrane potential of the cell, the Na^+-K^+ ATPase uses additional ATP, requiring an immediate increase in glycolysis following TBI. The problem for the cell is that its ability to use oxidative phosphorylation, the method that produces the vast majority of ATP in cells, is impaired following TBI. The situation that results is one in which the cells are demanding increased energy in the form of ATP, while they are impaired and cannot meet that need; thus an energy crisis exists. The cerebral blood flow (CBF) during the period following concussion is also reduced. This drop in CBF may continue for several days following a concussion and is thought to put individuals at serious risk if they sustain another head injury during that time. In addition to the issues created by this energy crisis, the activation of NMDA receptors results in the influx of Ca^+ ions. This influx results in further disruption of the cell's ability to use oxidative phosphorylation, degradation of elements of the cytoskeleton, and, in some cases, activation of proteases that cause cell death. After the brain's immediate response, hyperglycolysis, it has been found that cortical energy production decreases well below baseline levels for quite some time. While this might intuitively seem to be disadvantageous for the brain, emerging research seems to indicate that glucose may not be the best source of energy for the injured brain. Instead, the utilization of ketone bodies for energy seems to be tied to better behavioral outcomes following concussion (Giza & Hovda, 2011).

Symptomatology

The symptoms of concussion can be classified into three categories: cognitive, affective, and physical. The cognitive symptoms of concussion include deficits in memory, information processing speed, attention, "mental fogginess," and difficulty concentrating (Rosenbaum et al. 2006). The affective symptoms indicative of concussion are depression or decreased mood and anxiety (Rosenbaum et al. 2006). Physical symptoms include nausea, dizziness, headache, vomiting, fatigue, and balance problems. Depending on the severity of the concussion and individual factors, the rate of recovery can vary greatly. It has been found, however, that almost all individuals are symptom-free within one month post-concussion, with the large majority recovering in around seven days (Moser et al. 2007). It is crucial to note that once an individual has been concussed, their risk for experiencing subsequent concussions is greatly increased. Guskiewicz et al. (2003) found that once an athlete has sustained one concussion, they are four to six times more likely to experience a concussion in the future in comparison with those who do not have a history of concussion. In addition, there is mounting evidence that for individuals who have experienced three or more concussions, the recovery time and acute impairments as a result of the injury are more severe. Finally, in extreme and rare cases, concussion can result in severe brain damage or death. This can occur in individuals who experience concussions in succession, while their brain is still recovery. This phenomenon, known as second impact syndrome, is likely linked to the previously-discussed effects of the neurometabolic cascade, and is much more commonly seen in children and adolescents than adults.

Diagnosis and Neuropsychological (NP) Testing

The measures currently used in concussion testing range from paper-and-pencil tests like those comprising a typical neuropsychological test battery, to MRI and other imaging techniques.

Research has shown that certain neuroimaging techniques are useful in the diagnosis and treatment of concussion. CT scanning can be used to detect severe conditions such as internal hemorrhaging of the brain. A more relevant type of neuroimaging for concussion is MRI testing. An MRI can detect anatomical signs of atrophy and damage, structural indications of long-term consequences for athletes who have sustained more than one concussion over their career. It is for this reason that Sedney et al. (2011) recommend using MRI testing to make recommendations to concussed athletes contemplating retirement to avoid the consequences of subsequent head injuries.

Genetic testing appears extremely promising in its potential to assess the risk of future development of dementia in individuals who have sustained a concussion. Although genetic testing in concussion research is still in its infancy, it has been shown that individuals who are either heterozygous or homozygous in the ApoE3 or ApoE4 gene are three to nine times more like to develop dementia after concussion (Sedney et al., 2011).

Neuropsychological testing is the most commonly-employed technique used to diagnose and evaluate the effects of concussion. The most common method of neuropsychological testing is to administer a baseline assessment exam to athletes prior to their participation in sports to establish their functioning level in various domains when their brain is functioning without impairment. Then, after a concussion occurs, the athlete can return to the clinic and take the same battery of tests at baseline so the results can be compared. This baseline / post-concussion assessment method is much more effective than simply testing athletes after they are injured because it allows the athlete's post-concussion performance on tests to be compared to an accurate and descriptive evaluation of their baseline functioning (Moser et al. 2007). Doing so

helps account for each individual's natural strengths and weaknesses in the domains being assessed.

The neuropsychological evaluation process used in concussion testing is somewhat time-intensive and contains a multitude of tests. These tests aim to tap into the domains most-affected by concussion, namely attention, information-processing speed, memory, and reaction time. Prior to participation in athletics, the athlete is administered the test battery. Then, if the athlete experiences a concussion as the result of participation in sports, they will return to the clinic and receive post-concussion testing. The output of the testing is analyzed by a neuropsychologist and can be compared to performance at baseline. If the athlete's results indicate significant reduction from baseline as a result of their concussion, it can be recommended that they refrain from participation in sports until they are back to their neurocognitive baseline.

Description of Neuropsychological Tests

The Penn State Sports Concussion Program testing battery consists of both paper-and-pencil and computer-based testing components and requires about two hours to complete. For the present study, the tests that were used to establish convergent validity for the memory component of the AVLT were: the Hopkins Verbal Learning Test-Revised (HVLT-R) a word-list task that measures verbal memory (Brandt & Benedict, 2001); the RBMT, a test designed to measure memory problems as they would present in everyday life (Wilson et al. 1985); and the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) Test Battery, which contains a verbal memory section (Lovell, Collins, Podell, Powell, and Maroon, 2000). Tests that were used to establish discriminant validity with the memory component were: the VIGIL, a test of attention and information-processing speed (Cegalis and Bowlin, 1991); the PSU Cancellation Task, a test of attention and information-processing speed; and the Stroop Color-Word Test,

which measures attention, information processing speed, and visual tracking (Echemendia et al. 2001);

The tasks used to establish convergent validity for the affect-measuring aspect of the AVLT were: the Beck Depression Inventory Fast Screen (BDI-FS), used to measure depression (Beck, Steer, & Brown, 2000); Self-Motivation Rating; and Experimenter Motivation Rating.

The AVLT will be the primary focus of this study. This test was designed by Peter Arnett and Fiona Barwick at Pennsylvania State University with the intention of creating a measure that simultaneously measures both verbal memory and affect. Such a task would be a valuable addition to a neuropsychological battery for various reasons. Many athletes undergoing testing in a clinic may be reluctant to acknowledge symptoms of depressed affect on a face-valid measure such as the BDI-FS. This motivation is likely heightened during a post-concussion evaluation when an athlete goes in knowing that if they prove that "everything is okay," they will be allowed to return to play. In this case, detecting depressed affect in comparison to baseline would indicate that it is likely that the athlete has not fully recovered.

Along similar lines, certain athletes could be termed "minimizers" based on their level of positive or negative bias displayed on the AVLT. For example, if an athlete displays a high level of negative bias on the AVLT, indicating depressed mood, but is simultaneously responding on self-report measures that they are experiencing no symptoms of depression and no other physical or mental problems, it is very possible they are minimizing their self-report of symptoms. With this knowledge in hand, a neuropsychologist could look at the athlete's responses in other areas of the testing battery to pinpoint questions where the athlete is also likely to be "minimizing."

Some athletes might lack insight into their depression altogether, another factor that would result in the reporting of no symptoms of depression on an overtly face-valid test such as

the BFI-FS. This may have been the case for University of Pennsylvania football player Owen Thomas who tragically committed suicide in April, 2010. The autopsy revealed that Thomas had developed chronic traumatic encephalopathy (C.T.E.), a brain disease resulting from repeated sub-concussive blows to the head. Researchers speculate that C.T.E. could produce changes in behavior and mood underlying this incident. Since Thomas never reported a concussion or any symptoms of a concussion, he likely would not have attributed any changes in mood to receiving blows to the head as a result of playing football (Schwarz 2010).

Finally, if athletes display depressed affect as a result of sustaining a concussion, it would likely impact their overall performance on the test battery by potentially resulting in decreased motivation, lack of energy, and difficulty focusing. In this instance, depressed affect can be viewed as both a consequence of concussion and a potential cause of decline in cognitive performance on the test battery in comparison to baseline.

Predictions

Hypothesis 1: The AVLT will be a valid predictor of verbal memory and will be correlated with other measures of verbal memory used in the testing battery

The AVLT should be a valid predictor of verbal memory because it requires the athletes to recall elements of a 16 word list. This task is similar to the HVLT, a widely-used measure of verbal memory that has been shown to be sensitive to concussion. By analyzing the convergent validity of AVLT and measures such as the HVLT-R, ImPACT verbal memory component, and the RBMT, the extent to which the AVLT is a valid predictor of verbal memory will be assessed.

Hypothesis 2: The AVLT will not be highly correlated with measures not designed to assess either affect or verbal memory

The AVLT is not designed to measures domains such as information processing speed or reaction time and therefore should correlate less than verbal memory measures with components of the testing battery designed to assess these domains. The Stroop, Vigil, and PSU Cancellation Task will be used to establish discriminant validity.

Hypothesis 3: The AVLT will be a valid predictor of affective state and will be correlated with other measures of affect used in the concussion battery

The 16 words that comprise the word list are affectively loaded and therefore should allow for the detection of positive or negative affective state. There should be moderate correlations between the AVLT and other measures used to assess affect. The measures used to determine convergent validity will be the BDI-FS, subject motivation rating, and experimenter motivation rating.

Method

Participants

The participants in the current study were 237 Penn State athletes who were administered the neuropsychological test battery between July 2007 and August 2010. A more detailed description of the participants can be found in Tables 1 and 2 of Appendix A. The study included data from both male and female athletes from a wide variety of sports.

These participants were administered the Penn State Sports Concussion Program testing battery. This battery consists of a both paper-and-pencil and computerized tests and takes about two hours total to complete. The baseline testing is done prior to the athlete's participation in sports at the collegiate level, while post-concussion testing typically occurs within 48-72 hours following injury. The tests administered are designed to measure various domains of functioning including information processing speed, memory, attention, affect, and reaction time. The battery contains the tests described below as well as other measures, all of which are designed to assess areas that may be affected following a concussion.

Description of Neuropsychological Tests

Hopkins Verbal Learning Test – Revised (HVLT–R; Brandt & Benedict, 2001)

The HVLT-R is a test designed to measure verbal memory. This measure consists of a list of 12 words that are read aloud to the athlete. Athlete repeat back as many of the words as they can remember in any order, and the number of perseverations, intrusions, and a cluster score are tallied. Three immediate recall trails are conducted, followed by a delayed recall trial about 20 to 30 minutes later. Total recall across the three immediate trials and total recall at the delayed trial were used as independent variables in the current study.

Rivermead Behavioural Memory Test (RBMT) (Wilson, Cockburn, Baddeley, and Hiorns, 1989).

The Rivermead Behavioural Memory Test is designed to assess verbal memory. The task involves the administrator reading a story of about five or six lines to the athlete and the athlete repeating back as much of the story as they can remember. The athlete is also asked to recall the content of the story about 20-30 minutes later in the test battery.

The Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) Test Battery (Lovell, Collins, Podell, Powell, and Maroon, 2000)

The ImPACT consists of three separate sections; collection of demographic information, post-concussion symptoms assessment, and a series of neuropsychological tests. The neuropsychological testing component of this measure allows for the assessment of the same domains as many of the other measures included in the Penn State Sports Concussion testing battery. These domains are reaction time, memory, attention, and information processing speed. The tests allow for four composite scores to be compiled; reaction time, visual-motor speed, visual memory, and verbal memory. This study will use only the results of the verbal memory composite score.

Vigil Continuous Performance Test (VIGIL) (Cegalis and Bowman, 2001))

The VIGIL is a test of reaction time and attention. This computerized task requires an athlete to observe the computer screen while a series of letters of the alphabet appear and disappear quickly. The athletes are instructed to hit the space bar when they see the letter "K" but not for other letters.

The Stroop Color-Word Test (Trenerry, Crosson, DeBoe, & Leber, 1989)

The Stroop Color-Word Test is used to measure information processing speed and attention. The task requires the athlete to read the names of a series of colored words, while the actual color of the ink for each word does not match the name of the color that is written. Then,

the reverse is done, with the athlete reading the colors of the ink of the words, ignoring the written word. The athletes read through the lists as quickly as possible and the number of corrected and uncorrected errors is tallied.

Pennsylvania State University Cancellation Task

The PSU Cancellation task is a test of attention and reaction time. The athlete visually scans a sheet containing various symbols, putting a line through any symbols which match the target symbol at the top of the page. The task takes 90 seconds to complete and requires sustained focus for the duration.

The Beck Depression Inventory—Fast Screen (BDI-FS; Beck, Steer, & Brown, 2000)

The BDI-FS is used to measure depression and anhedonia. This measure consists of 7 questions, each with a scale of 0-3. The total score on the measure ranges from 0 to 21, with a higher score indicating higher levels of depression.

Subject Motivation Rating

The Subject Motivation Rating consists of a simple 0-7 scale where the athletes indicate how motivated they were during the testing process. A higher number on the scale represents a greater degree of motivation.

Experimenter Motivation Rating

The Experimenter Motivation Rating consists of a simple 0-7 scale where the test administrator rates how hard they feel the athlete was trying during the testing battery. The test administrator uses verbal and nonverbal cues to determine the rating for their rating for this measure.

Description of the AVLT

The AVLT aims to measure both verbal memory and affect simultaneously. The measure is comprised of 16 affectively-loaded words such as “peace,” “bad,” “joy,” and “vile.” The measure is administered aurally and the athlete waits until the entire list is read to respond. After the administrator finishes reading the list, the athletes repeat back as many of the words as they can recall. This is done a total of three times, followed by a recall trial approximately 20 minutes after the initial recall trials.

The degree to which the athlete shows a preference for either the positive affectively-loaded words or the negative affectively-loaded words is used to determine their affective bias. Affective bias, the difference between the number of positive words recalled and the number of negative words recalled, is thought to be related to the athlete’s underlying emotional state.

Although numerous measures exist that assess either verbal memory or affect, prior to the development of the AVLT, there was not a measure that assessed both at the same time in the sports concussion context. If the AVLT is found to be a valid measure of these constructs, it would prove useful as a result of its ability to assess both of these domains simultaneously. Another possible benefit of the AVLT lies in its ability to assess affect without this intention being overtly known to the participant. This is important because post-concussion testing often occurs under circumstances where athletes are motivated to minimize the outward appearance of their symptoms. This would especially be the case when the athlete has the goal of returning to play as soon as possible. On overt measures of affect such as the BDI-FS, athletes could easily conceal any changes in affect that they may be experiencing because the questions are very clearly asking about mood, motivation, and depression. If the AVLT is able to tap into these domains without the participant realizing it, the clinical utility of the assessment would be increased.

Description of Statistical Analyses

The descriptive statistics concerning the participants involved in this study can be found in Tables 1 and 2 of Appendix A. All of the participants were administered the complete test battery, including all of the measures that were considered as part of the statistical analyses in this experiment. Correlational analyses were performed to assess the convergent and discriminant validity of the AVLT.

The analyses performed were two-tailed and significance was assessed at the $p < .05$ and $p < .01$ levels. In order to interpret the directions of the correlations in this study, it is necessary to understand how the bias portion of the AVLT is calculated. A higher score on bias would indicate that an athlete recalled a greater amount of positively loaded words than negative words. Likewise, a lower score indicates that the athlete displayed a negative bias and recalled more of the negative loaded words than positively loaded words. Another scoring method which is important to note is that of the BDI-FS. A higher score on the BDI-FS indicates more symptoms of depression.

Results

The data used in this study were analyzed using the Statistical Package for the Social Sciences (SPSS) version 17.0. This software was used to organize data and conduct correlational analyses. Information detailing the characteristics of the athletes who participated in this study can be found in Tables 1 and 2 of Appendix A. The athlete sample in this study consisted of both males and females, and encompassed a wide variety of sports, with football being the most common. The mean age of participants was 18.2 years as most of the athletes in this sample were tested during the freshman year, prior to participation in sports at Penn State.

Convergent validity was assessed using correlational analyses (Table 3). Both the immediate and delayed recall scores for the AVLT were strongly correlated with other measures of verbal memory, as indicated by the significance of all of these correlations at the $p < .01$ level. The correlations also show that the delayed AVLT scores are slightly more correlated with other measures of verbal memory than are the immediate recall scores for the AVLT. Overall, the AVLT shows good convergent validity with other measures of verbal memory.

Discriminant validity was also assessed using correlational analyses (Table 4). The AVLT was found to be significantly negatively correlated with a few of the measures used to test for discriminant validity ($p < .01$). Scores on other measures such as the PSU Cancellation task were found to be unrelated to scores on both the immediate and delayed recall AVLT. It is important to note that, overall, the correlations tend to be stronger with the delayed recall AVLT scores than the immediate recall AVLT scores. Also, the strengths of the correlations between the AVLT and measures used to assess discriminant validity were lower than those between the AVLT and the measures used to assess convergent validity.

Further correlational analyses were conducted to assess the AVLT's validity as a predictor of affect (Table 5). The results of these analyses show that subject motivation rating was found to be related to AVLT immediate bias ($p < .01$) and delayed bias ($p < .05$). Experimenter motivation rating was found to be related to AVLT delayed bias ($p < .05$). The BDI-FS anhedonia item and BDI-FS Total Score were found to be correlated with AVLT immediate bias scores at the $p < .01$ and $p < .05$ levels respectively.

Discussion

This study was designed to assess the validity of the Affective Verbal Learning Test (AVLT). The AVLT is currently one of many measures used in the Penn State Sports Concussion testing battery. The validity of the AVLT both as a measure of verbal memory and affect was assessed in this study. The convergent and discriminant validity of the AVLT as an indicator of verbal memory was assessed to assess the degree to which it is related or unrelated to measures designed to measure verbal memory as well as measures aimed at measuring domains other than verbal memory.

The first hypothesis, that the AVLT would be a valid predictor of verbal memory and would thus display positive correlations with other measures of verbal memory was supported. Both the immediate and delayed scores for the AVLT displayed strong, positive correlations with all of the measures of verbal memory used to assess convergent validity. All of these correlations were significant at the $p < .01$ level, showing that the AVLT was a valid measure of verbal memory.

The second hypothesis, that the AVLT would not be highly correlated with measures not designed to assess verbal memory, was also mostly supported. The results show that the AVLT immediate and delayed recall scores were correlated with some of the measures used to assess discriminant validity, but not all of these measures. In addition, the correlations that were found, although significant, were typically weaker than those between the AVLT and measures used to assess convergent validity.

The third hypothesis, that the AVLT would be a valid predictor of affective state, was also somewhat supported by the results of this study. The results indicate that the AVLT was correlated with subject motivation rating, experimenter motivation rating, the BDI-FS anhedonia item, and the BDI-FS Total Score. The strength of the correlations varied, but either the AVLT immediate bias or delayed bias was correlated at either the $p < .05$ or $p < .01$ level with all of these measures.

Limitations and Future Research

There were various limitations of this study that open up opportunities for future research. First, this study found that, although the AVLT was correlated with measures of affect, these relationships were not as strong as one would hope. It would therefore be useful to find out ways in which this promising measure can be adapted, allowing it to be a more robust better predictor of affect. This would increase the clinical utility of the instrument and allow it to be used more effectively as a determinant in making return-to-play decisions post-concussion.

A major limitation of this study is that all of the data comes from athletes at baseline. This could be problematic when assessing a domain such as affect that theoretically should display less deviation from the norm at baseline than post-concussion. This study has shown that the results of the AVLT are linked to other known, reliable measures of affect when assessing

athletes at baseline, but little is known as to whether this holds true after concussion. One might even hypothesize that the AVLT would be more sensitive to changes in affect post-concussion when greater deviations from typical affect tend to be seen. This hypothesis is one that needs to be tested before it can be said for certain that the AVLT is a valid measure of affect in concussed athletes.

Another relationship that requires further exploration is the one between the AVLT and some of the concussion battery measures used to assess discriminant validity. Although the correlations were not overwhelming strong or consistent across measures, it was somewhat surprising to see that any moderately strong correlations existed at all. It would be useful to explore the mechanism through which these relationships are occurring to get a better idea of what the AVLT is measuring in this case. It may be that, because memory measures are attentionally demanding, the AVLT was correlated with measures of attention as well as memory.

This study did not assess whether certain words or the positive or negative words as a whole proved to be more or less difficult to remember. Ideally, the AVLT would include positive and negative words which are equally likely to be recalled when administered to a sample of athletes with neutral affect. If this is not the case, and some of the words are more or less difficult to recall than others, the outcome would be results that indicate biases in affect which may not reflect reality.

Conclusions

On the whole, this study was effective in demonstrating that the AVLT is a valid measure of verbal memory and a promising measure of affect. The results indicate that performance on the AVLT is correlated to performance on other measures of verbal memory such as the HVLT-

R, RBMT, and ImPACT Verbal Memory Composite. Importantly, the results also indicate that affective bias scores on the AVLT are correlated to measures of emotional state such as subject motivation rating, experimenter motivation rating, and the BDI-FS.

Through further testing and adaptation of this measure, the AVLT could provide a very useful tool in the assessment of the effects of concussion. If the validity of the AVLT as a measure of affect can be improved such that the correlations between the AVLT affective bias and other measures of affect are stronger and better established, the AVLT would be uniquely useful in the diagnosis and recovery of concussions in athletes. Having a measure such as the AVLT, which would allow for simultaneous measurement of verbal memory and emotional state, would provide a way for neuroscientists to gain insight into an aspect of concussion diagnosis and recovery which is currently lacking. This measure would allow for neuroscientists to gain knowledge about an athlete's affect without the athlete having to knowingly provide this information. This is beneficial and relevant in many of the cases of concussion that occur in the college athlete population. A measure such as the AVLT would be able to identify changes in affect both in athletes who lack insight into their depression or mood changes following a concussion, as well as athletes who may try to mask any changes in affect in order to be allowed to return to play as soon as possible. With further research and development, the AVLT has the potential to be a very useful measure for neuroscientists aiming to improve their ability to diagnose and evaluate concussed athletes.

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Appendix A: Tables

Table 1

Participant Characteristics

	N	Mean (SD)
Age	237	18.26 (.713)

Table 2

Sex	N	Percentage
Male	176	74.3
Female	61	25.7
Total	237	100

Table 3

Convergent Validity

	AVLT Immediate	AVLT Delayed
HVLT Immediate	0.36**	0.44**
HVLT Delayed	0.36**	0.51**
RBMT Immediate	0.24**	0.24**
RBMT Delayed	0.28**	0.27**
ImPACT Verbal Memory	0.35**	0.51**

****. Correlation is significant at the 0.01 level (2-tailed).**

***. Correlation is significant at the 0.05 level (2-tailed).**

Table 4

Discriminant Validity

	AVLT Immediate	AVLT Delayed
Vigil Omissions	-0.02**	-0.24**
Vigil Average Delay	-0.08	-0.21**
Stroop 1 Time	-0.12	-0.18**
PSU Cancellation Task	-0.03	0.05

****. Correlation is significant at the 0.01 level (2-tailed).**

***. Correlation is significant at the 0.05 level (2-tailed).**

Table 5

Relationships to Affect

	AVLT Immediate Bias	AVLT Delayed Bias
Subject Motivation	0.12**	0.13*
Experimenter Motivation	0.05	0.16*
BDI Fast Screen	-0.15*	-0.10
BDI Fast Screen Anhedonia	-0.21**	-0.12

****. Correlation is significant at the 0.01 level (2-tailed).**

***. Correlation is significant at the 0.05 level (2-tailed).**

Academic Vita

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Education:
Pennsylvania State University, University Park, PA 2007-2011
Expected Bachelor of Science in Psychology, 2011
Enrolled in Schreyer Honors College

Academic Accomplishments:
2008 President's Freshman Award ● 2009 President's Sparks Award 2010 ● Evan Pugh Scholar Award ●
2011 Evan Pugh Senior Scholar Award ● 2008-2009 and 2009-2010 Penn State Liberal Arts Scholarship
2008-2009 Penn State Montgomery County Scholarship

Post-Graduation Experience:
Teach for America (Bay Area, CA)
Will be teaching secondary mathematics in a severely underserved school in the Bay Area, CA for the next two years. Responsible for getting at-risk students to invest in their education and future while being a role model inside and outside the classroom.

Extracurricular Experience:
PSU Clinic Volunteers Program (University Health Center, University Park, PA)
Take blood pressure, respiratory rate, peak flow, pulse, height, and weight of patients who come into the clinic and enter the information into the computer system used by University Health Services. Responsible for relaying important information to doctors and nurses.
Shadowing
Shadowed ER Physician for 15 hours (Allentown, PA), Pulmonologist for 10 hours (Philadelphia, PA), General Internist for four hours (University Park, PA), and Cardiologist for four hours (Phoenixville, PA).
KidsPeace Sarah's Smile Summer Internship 2010 (Bethlehem, PA)
Position: One on One Aide
Worked as a "One on One" aide with a client with autism, ADHD, and aggression-management issues. Aimed to positively shape the behaviors of children with autism and other related behavioral issues. Worked with the rest of the clients in the classroom during times when primary client was occupied.
Volunteering
Volunteered for 25 hours at Chestnut Hill Hospital in the ER for the summer volunteer program. Participated in Penn State Dance Marathon (THON) in 2009, 2010, and 2010 which raised between $7,000,000 and $9,500,000 each of those three years to fund pediatric cancer treatment and research.

Research Experience:

Neuroscience Laboratory Research Assistant 2008-present (University Park, PA)

Administered concussion assessments to athletes to gather information necessary to make return-to-play decisions. Entered and analyzed data. First authored a poster at INS conference in Boston, MA on the results of a validity assessment of the Affective Verbal Learning Test (AVLT) in concussions testing. Completing my thesis for Schreyer Honors College by evaluating the validity of the AVLT.

Leadership Experience:

Starfinder/Penn State Partnership Program 2009-2010 (Leader of Program 2010-2011)

Lead partnership between the Philadelphia non-profit Starfinder and PSU. Responsible for organizing activities to introduce inner-city youth to the opportunities available at college and providing information about how to achieve the goal of attending college. Responsible for planning Starfinder's yearly visit (~15 people) to PSU as well as summer meet-up. Requires booking a hotel, scheduling events, planning activities, and recruiting ~10 Penn State students to participate.

SHO Time Mentor 2009 and 2010

Was responsible for leading 10-15 incoming Schreyer Honors College freshman during orientation week both years.

Towamencin Baseball Head Coach for 18-23yr. old team (2009 League Champions)

Coached local baseball team while also participating as a player. Organized practices, scheduled games, and managed game situations and player relations.

Other Volunteer Experience:

Volunteers for Peace (Scafa, Italy 2010 Trip) ● Bronx Pen Pal Program ● Habitat for Humanity Spring Break 2009 Service Trip