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Impaired Executive Function in Concussed Athletes

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Abstract

Concussions are classified as mild traumatic brain injuries (mTBI). An individual that has sustained a concussion will experience symptoms such as nausea, possible memory loss, blurry vision, or loss of balance. Most symptoms subside within a few days, but a large pool of research raises concern for the recovery of executive function, specifically impulse control. Executive function relates to all tasks that require deliberate attention. Past research has shown adolescents record the highest number of sports concussions when compared to collegiate and professional athletes. The frontal lobe, which controls executive function, is not fully developed during the time of adolescence. Injured players of this developmental stage typically experience a prolonged recovery period. This study performed a battery of cognitive tests, well-recognized as effective means of testing impulse control, on both concussed and non-concussed athletes. Results of the Erikson Flanker and Color Stroop tests identified a permanent marker of concussion at 6 months post-injury. The data shows concussed individuals have impulse control problems and struggle to focus their attention. This behavior is characteristic of individuals diagnosed with ADD/ADHD. Evaluation of executive function prior to return to play is useful for the prevention and treatment of long-term consequences.

Keywords: Concussion, Executive Function, mTBI

INTRODUCTION

The Centers for Disease Control estimated that 1.6 to 3.8 million concussions occur in sports and recreational activities annually. Concussions are classified as mild traumatic brain injuries (mTBI). These injuries occur due to impact to the head, causing short term symptoms—and we believe they can cause long term impairments as well. The impact of a concussion causes the brain to move around at rapid speed inside the skull, leading to cognitive deficits in the brain.

An individual that has sustained a concussion will experience symptoms such as nausea, possible memory loss, blurry vision, or loss of balance. Most symptoms subside within a few days, but a large pool of research raises concern for the recovery of executive function. Executive function relates to all tasks that require our deliberate attention. "Executive function is the ability to resolve conflict as well as switch between tasks (Halterman, 2006)." It allows people to engage in one task, move their attention, and engage in another. Individuals with damage to their executive function have issues with impulse control. They react to things faster because of this impulsivity.

Through the use of the Erikson Flanker and Color Stroop tests, the authors of this study have identified a permanent marker of concussion at 6 months post-injury. Both of these tests are a well-recognized, effective means of testing impulse control. Each test paradigm has three trials:

neutral, congruent, and incongruent. Congruent trials have elements that work in favor of persons completing tasks correctly. Incongruent trials have additives that work against the ability to answer correctly. This study hypothesized that persons whom sustained a concussion will perform worse on incongruent trials when compared to the non-concussed participants.

METHODS

This study utilized a battery of cognitive tests well recognized for their effective means in testing impulse control. Response time, accuracy, and brain waves were measured for each subject. The first test was the Color Stroop test, first introduced in 1935; it is characterized by three trials: neutral, congruent, and incongruent. The Congruent task includes stimuli that will increase the subjects' chances of answering correctly. In the case of the Color Stroop test, the color the participant is instructed to report is also the word they are reading. The incongruent trial does just the opposite, containing stimuli to work against the participants success. More specifically, the color reported is different than the word used to display it.

Table 1. The Color Stroop test includes three tasks: neutral, congruent, and incongruent.

Neutral	**X X X** **X X X**
Congruent	**Red Blue Yellow** **Blue Red Green**
Incongruent	**Red Blue Yellow** **Blue Red Green**

The second test is the Erikson Flanker test, also containing neutral, congruent, and incongruent trials. Table 1 demonstrates the design of the test. Congruent trials contain stimuli aligned in the same direction as the point the subject is focused on. The incongruent trial contains stimuli arranged in the opposite direction from the point of focus.

Table 2. The Erikson Flanker Test requires subjects to report the direction in which the middle arrow is pointing. There are three trials: neutral, congruent, and incongruent which vary in difficulty.

Neutral	**X X → X X**
Congruent	→→→→→
Incongruent	←←→←←

This study included 53 participants with a mean age of 20.2 years. All of these individuals were Ursinus College athletes. Twenty-seven participants had no history of concussion. The non-concussed group was made up of thirteen males and fourteen females from the Ursinus soccer, lacrosse, and football teams. Twenty-six athletes were concussed, 13 male/13 female, and came from the following Ursinus College sports teams: football, soccer, lacrosse, rugby. The average time post-concussion was 73.4 days. Each participant of the concussed group had only one reported concussion.

RESULTS

A 2*3 mixed model ANOVA was run to test the interaction of condition and concussion status. Condition has 3 levels within it: neutral, congruent, and incongruent. Concussion status is categorized into concussed and non-concussed participants. A significant effect of condition was demonstrated: $F(2,102)=203.809$, $p<.001$ for the Stroop effect; $F(2,102)=60.039$, $p<.001$ for the Flanker test. All participants, regardless if they had a history of concussion, were slower on incongruent trials. Note the increase in both figures 1 and 2 on the incongruent trial. The slope of the line indicates the significant change in response time. The interaction between condition and concussion status was also significant: $F(2,102)=16.727$, $p<.001$ for Stroop effect; $F(2,102)=3.492$, $p<.001$ for the Flanker effect. Concussed individuals showed significant difficulties on the incongruent condition. Post hoc contrasts revealed the difference between congruent and incongruent response times was greater for concussed compared to non-concussed: $F(1,51)=23.388$, $p<.001$ for the Stroop effect; $F(1,51)=4.095$, $p<.001$. In figures 1 and 2, the response time for concussed athletes from congruent to incongruent trials shows a significant difference. The cost of switching between tasks is greater to individuals with a history of concussion. The level of impulse control required by the test taker is more difficult to execute for participants with a history of mTBI.

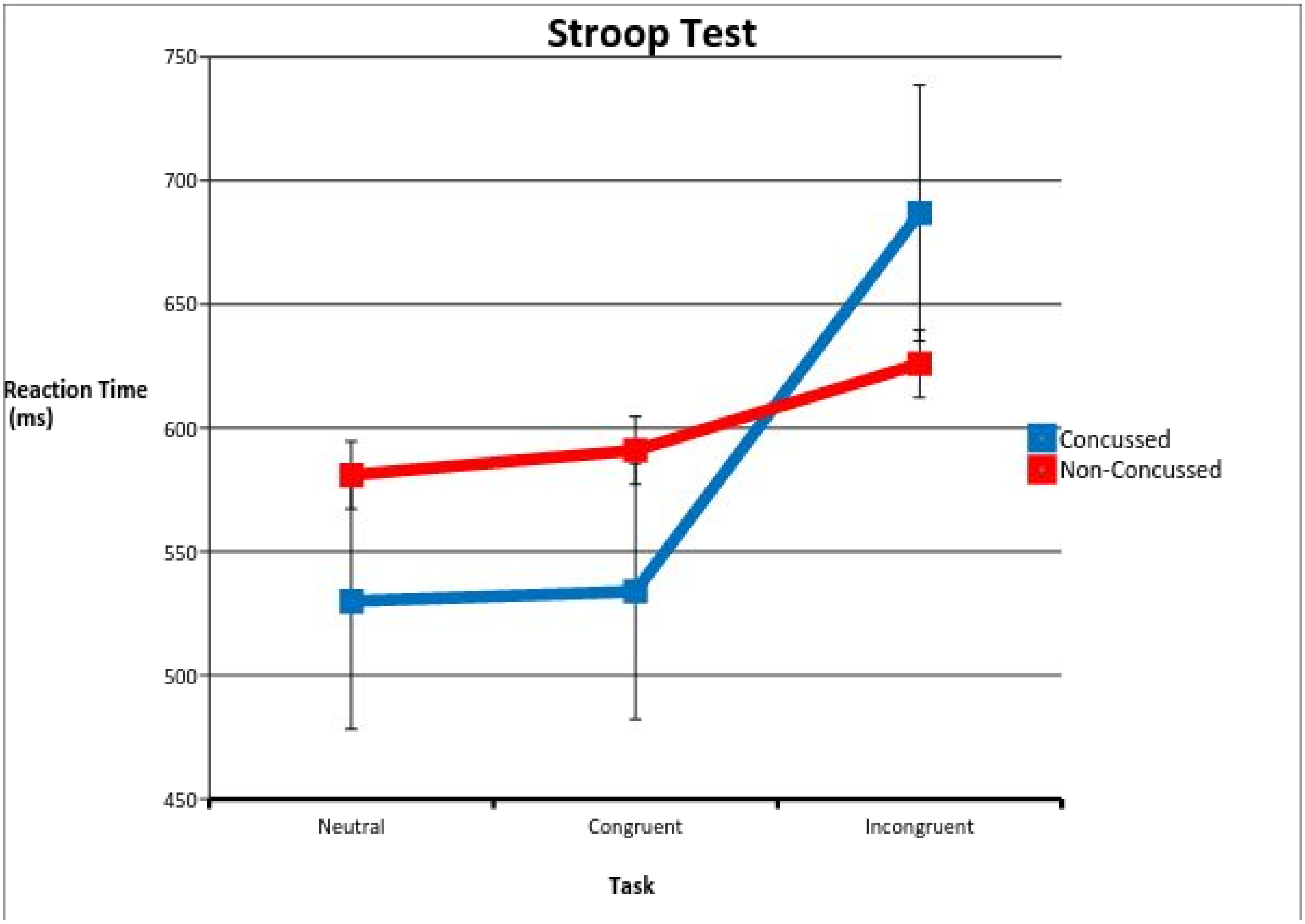

Figure 1. Twenty-six controls and 27 athletes were tested post-concussion. The Color Stroop Test shows a significantly delayed reaction time in concussed individuals. (The data presented in this graph was generated in Dr. Bish's lab at Ursinus College, Summer 2015.)

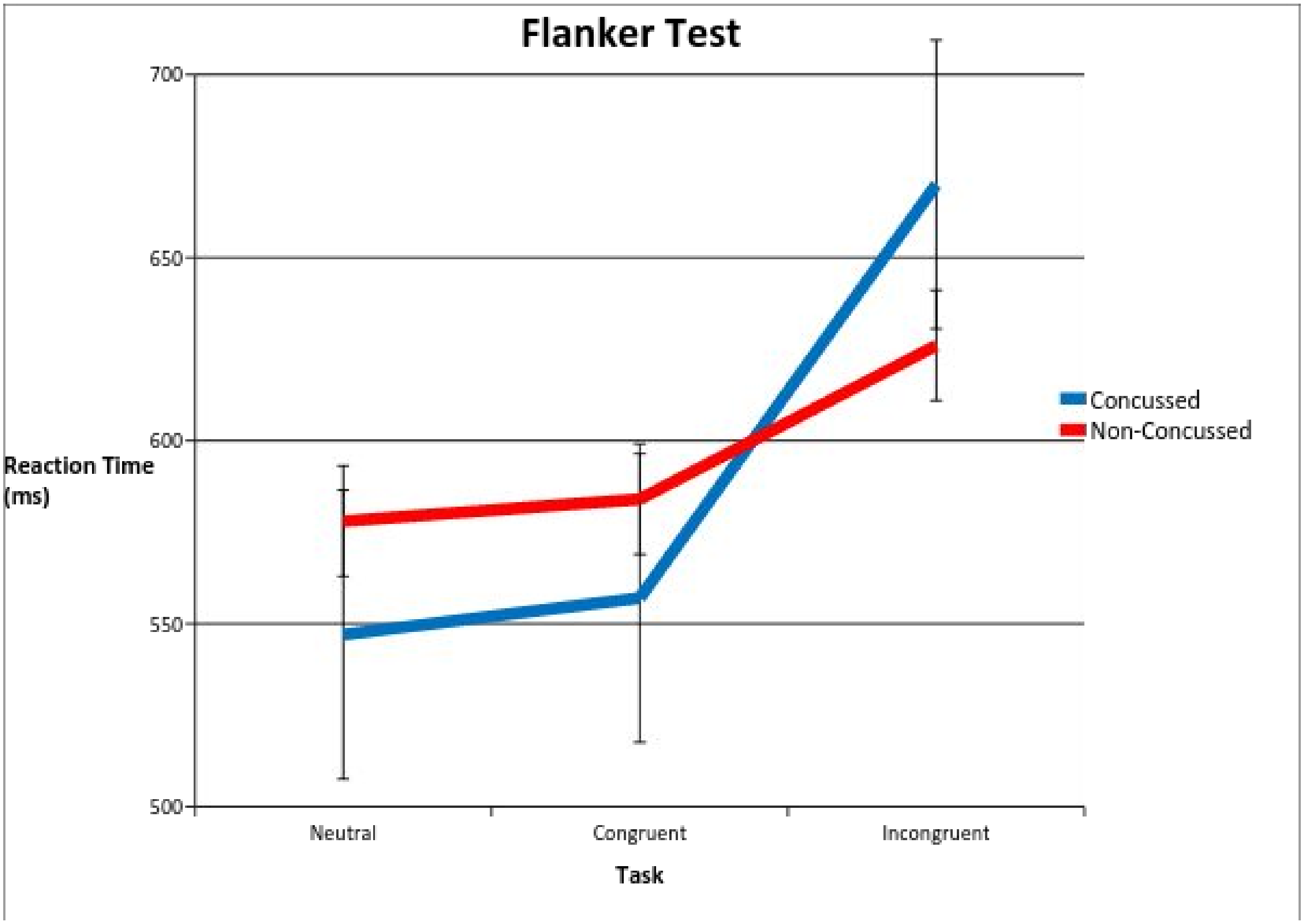

Figure 2. Twenty-six controls and 27 athletes were tested between one and 1 and 6 months post-concussion. The Flanker Test shows a significant delay in reaction time for concussed individuals. (The data presented in this graph was generated in Dr. Bish's lab at Ursinus College, Summer 2015.)

All concussed participants had a history of only one concussion. They were tested at varying timeframes post-concussion. Some were tested as early as 1 month post-injury, others not until 6 months post-injury. The correlation between time post-concussion and level of recovery is not significant; players are not getting better overtime. This reveals a marker of concussion at six months post-concussion because the results show cognitive deficits are still present at the six month period.

DISCUSSION

This study was an assessment of three variables: between subjects testing, within subjects testing, and condition effect. Participants were divided into both concussed and non-concussed groups. Each group was submitted to testing on both the Erikson Flanker and Color Stroop. On all assessments, there were three conditions: neutral, congruent, and incongruent.

The results of the Color Stroop and Erikson Flanker tests in this study demonstrate that concussed individuals are at a deficit when compared to non-concussed individuals. The duration of time between injury and testing varied for each participant. All persons in the concussed group were tested no earlier than one month and no later than six months. Each participant sustained only one concussion.

The data shows no correlation between the time since concussion and inhibition of problems. After data analysis, the authors of this study were able to identify a permanent marker of concussion. Persons tested at six months post-concussion were still experiencing cognitive deficits. Meaning, even at 6 months post-injury, the cognitive deficits brought on by concussion are still present. Other research conducted on this topic shows neurocognitive decrements are present in concussed athletes that no longer report their concussion related symptoms (Broglio 2007). Often, returns to play decisions are based on the athlete's report of how they are feeling. Although a player may feel as though they are healthy enough for return to play, the results show the brain may not be fully healed. More specifically, this study shows cognitive setbacks are present 6 months post-injury. Other studies have found negative effects present at 6 months (Baillargeon, 2012).

The results of the incongruent tests reveal that persons who sustained a concussion experience more difficulty with this task. They had worse reaction times throughout the testing. This deficit is related to the impairment of their executive function. This makes it more difficult to switch between tasks. Therefore, an incongruent trial preceded by a congruent trial elicits a longer reaction time. The incongruent test requires those tested to filter out the distracting material and focus in on what is important. A different study found that people who have suffered from a concussion experience difficulty ignoring irrelevant information (Howell, 2013). This conclusion is in agreement with what the authors of this study have found: concussed individuals experience greater difficulty focusing and filtering out distractions. Another research study found similar data, where concussed individuals had a decrease in executive function, still present after the 1 month (Halterman, 2006).

Characteristics of impaired executive function involve attention and task switching difficulties. This type of behavior is characteristic of individuals with ADD or ADHD. Results on the Erikson Flanker for the concussed variable were similar to adolescents with ADD/ADHD. A study by Alosco concluded that athletes with ADHD were more likely to report a past history of concussion than those without ADHD (Alosco, 2014). The association between ADHD and concussion history in athletes is important in the prevention and management of concussions. One major concern is the over diagnosis of ADD/ADHD. If these behavioral issues are due to the consequences of concussion, meaning the patients are misdiagnosed, taking these medications is more detrimental to their cognitive status. In the future, the authors of this study would like to test people within a few days after their injury. This way, once their symptoms subside, lasting damage in the brain can be looked at.

Another concern of these findings is if players are symptom free and they continue to play, cognitive deficits are still present. These declines in cognition can affect their impulse control. Decreases in impulse control can cause players to have different reaction times. If they are reacting in a less conscientious manner, they are putting themselves in more danger. This may look as if the impaired are better players, due to intensity and confidence on the field, but the long-term effects of this behavior show evidence of more setbacks than success for their cognitive well-being.

CONCLUSION

The results of this study reveal that concussed individuals struggle with impulse control. These individuals show greater reaction times on incongruent tasks. The authors of this study discovered a marker of concussion at six months post-injury. Athletes are showing these cognitive deficits up to six months post-concussion even after initial symptoms have subsided. Evaluation of executive control can be useful for return to play decisions as a cautionary step to prevent to long-term effects of mild traumatic brain injury.

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