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Distractions in Hearing: Measuring Impulsivity in Service Members with a mTBI

Kathleen Margaret Chopra

A dissertation submitted to the Graduate Faculty of

JAMES MADISON UNIVERSITY

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Disclaimer: The views expressed in this paper are those of the authors and do not reflect the official policy of the Department of the Army/Navy/Air Force, Department of Defense, or the U.S. Government.
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Part I
Abstract

One of the cognitive symptoms associated with the diagnosis of a mild traumatic brain injury (mTBI) is the degradation of focus and attention. This pilot study was designed to quantify examples of such capabilities in Service Members diagnosed with mTBI and to compare their abilities to peers without an mTBI diagnosis. Specifically, we compared participant groups on their false alarm rates and thresholds for contralateral and informational masking tasks to document the participants’ ability to focus and detect an auditory stimulus in the presence of distracting maskers. In this study, comparing the overall performance of Service Members, with and without a mTBI, did not yield significant group differences but did highlight the considerable variability associated with mTBI. The Service Members’ data were then compared to data from a group of civilian adults of a similar age whose data were previously published in two doctoral dissertations. This comparison found significant group differences, with the Service Members performing worse than the group of civilian adults, in informational and contralateral masking. Later work may incorporate subjective as well as objective measures to investigate the participants’ reported deficits and how they relate to behavioral responses.
Introduction

Traumatic brain injury (TBI) is the “signature injury” of Service Members who served in Operation Enduring Freedom (OEF), Operation Iraqi Freedom (OIF), and Operation New Dawn (OND) (McCrea, et al., 2009). Since 2000, there have been approximately 370,688 Service Members diagnosed with a TBI. Due to the complicated nature of combat, however, the reported number of TBIs may be significantly underestimated. In addition, if a Service Member has experienced multiple injuries, only one is included in the total number of injuries reported by the government. The Defense and Veterans Brain Injury Center (DVBIC) reports that the majority of brain injuries sustained by Service Members are mild (mTBI) and the number of recorded mTBIs between 2000 and 2017 is approximately 305,140. Generally, mTBIs do not include any type of penetrating injury, and imaging is typically normal. According to the DoD, mTBI is defined as a “confused or disoriented state which lasts last less than 24 hours; or loss of consciousness for up to 30 minutes; or memory loss lasting less than 24 hours” (Defense and Veterans Brain Injury Center, 2017).

Historically, mTBIs were classified as short-term injuries, and the recipients could expect quick and full recoveries. Now, it is understood that many individuals who have suffered an mTBI can experience chronic post-concussive symptoms. Several of the long-term symptoms following an mTBI include poor concentration, frustration, sleep disturbance, headache, dizziness, tiredness, depression, poor memory, irritability, tinnitus, photophobia, and blurred or double vision (Vander Werff, 2012).

A theoretical model of recovery has been proposed outlining three stages of recovery: acute, subacute, and chronic. The acute period lasts the first several days
following the injury, and during this time, the symptoms are the most severe and can impair daily function. Following the acute period, there is a subacute period where the majority of individuals start to become asymptomatic and can gradually begin physical exercise. Finally, the chronic period begins 30-days past the time of injury. Some individuals, but not all, experience long-term post-concussive symptoms into the chronic period. This model is important to consider in military settings because during the acute period, the Service Member may not be able to fulfill their duties and may be at risk for recurrent injuries, and vigorous physical activity could impede recovery or worsen the injury. Furthermore, this proposed model highlights the importance of a biopsychosocial approach as other co-morbidities such as post-traumatic stress disorder (PTSD), depression, or anxiety can complicate recovery and professionals can misinterpret co-morbidities as symptoms of the injury (McCrea et al., 2009).

There is a burgeoning body of literature examining the auditory and cognitive complaints following an mTBI. Altogether, the goal of these studies is to understand the relationship between reported deficits and behavioral measures in order to create appropriate intervention and treatment plans. Research has demonstrated that high-level blasts can lead to impairments in central processing. This was demonstrated with performance on multiple auditory processing tasks (Gaps in Noise [GIN], Staggered Spondaic Words [SSW], and the Masking Level Difference [MLD]) when comparing a group of blast-exposed participants to controls. This indicated that blast exposure can affect brainstem or cortical level function. The degree to which blast exposure can affect performance on various test measures is, however, highly variable across individuals. One important finding was that abnormal performance on auditory processing tasks often
correlates with reports of PTSD (Gallun et al., 2012; Saunders et al., 2015). In addition, Veterans with blast-exposure, but normal hearing sensitivity, reported deficits on the Functional Hearing Questionnaire (FHQ), and reported deficits often correlate with performance on behavioral measures associated with speech in noise, temporal resolution, binaural processing, gap detection, stream segregation, working memory, attention and other cognitive abilities. For instance, the Digits Span (DS) test, a test of working memory, correlated to reported difficulties following spoken instructions and following long conversations. Also, reported difficulties comprehending rapid speech or needing extra time to process speech, correlated to performance on the Time Compressed Speech Test (TCST). Lastly, problems following spoken instructions and recalling information correlated to performance on the Woodcock Johnson Story Recall test. While performance and subjective deficits correlated on several tasks, performance was variable across the various test measures and no clear pattern of performance was exhibited (Saunders et al., 2015).

Not all individuals with an mTBI demonstrate long-term deficits but those who perceive difficulties are more likely to exhibit deficits on related behavioral measures. Individuals diagnosed with an mTBI reported difficulties with speech understanding in noise and exhibited difficulties on related objective measures (Saunders et al., 2015). In addition, individuals with an mTBI demonstrate a higher rate of dysfunction on speech tests and psychophysical tests, compared to controls (Hoover, Souza, & Gallun, 2017). The data highlights the highly variable performance and that the reported deficits are different in each individual. Not all Veterans with blast-exposure exhibit any type of
deficit, indicating task specific deficit(s), rather than a deficit in global functioning (Saunders et al., 2015).

In addition to reported auditory complaints post-mTBI, Service Members frequently report cognitive symptoms. Deficits with attention, processing, and working memory have been reported following an mTBI. Working memory is the brain’s storage center of information and is required for cognitive function. The brain’s working memory circuit can be impacted by brain injuries. In general, individuals who have suffered an mTBI report working memory deficits more frequently than those without an mTBI diagnosis (McAllister et al., 2001).

Research has shown that the working memory circuit’s activation pattern differs significantly between individuals with a TBI and those without, but performance measures show no significant differences. McAllister et al. (2001) reported that functional magnetic resonance imagining (fMRI) show an increase in neural activation with an associated increase in working memory load. When comparing a group of participants with an mTBI to a group of matched controls, an increase from a moderate-load to a high-load task reveals a difference in activation patterns within the working memory circuit. The mTBI group showed a greater increase, compared to the controls, in their working memory circuit activation with an increase from a low- to a medium-level task and less activation from a medium- to a high-load task. The n-back task quantifies working memory abilities and the working memory “load” is varied by the difficulty level of the task. On all difficulty levels, the control and the mTBI groups’ performance on the various n-back tasks were not significantly different. These findings indicate that the regions of activation associated with working memory are impaired following an
mTBI but is either not significant enough to be measured behaviorally or the tasks used were not difficult enough to detect a significant difference between groups. The differences in required activation levels indicate that the working memory circuit can be disrupted, but that disruption may not translate to behavioral measures (McAllister et al., 2001).

Mild TBI is a highly variable and multi-faceted injury where some recipients experience quick and full recoveries but others experience long-term complications. To gain a better understanding of the cognitive complaints from Service Members diagnosed with an mTBI, the present study was designed to analyze impulsivity and distractibility with two non-sensory masking tasks. Non-sensory masking involves the presentation of a signal and masker where the masker does not physically obstruct the signal in the ear, and the interference from the masker is thus a central (brain) phenomenon, rather than peripheral. These tasks were utilized because Service Members returning from OIF, OEF, and OND, without measurable peripheral auditory deficits, describe difficulties with concentration and a degradation in focus and attention (Saunders et al., 2015; U.S. Department of Veterans Affairs, 2015). The reported cognitive symptoms post-mTBI (e.g. distractibility) are similar to symptoms reported with attention deficit hyperactivity disorder (ADHD). The test measures used in this study were used on children with ADHD as well as college age-controls, without any adverse effects, to quantify impulsivity (Gray, Breier, Foorman & Fletcher, 2002; Sanderson, 2014; Gray, Miller & Evans, 2012).

Children diagnosed with ADHD exhibit a greater number of false alarms on the contralateral masking task, when compared to the control participants (Gray, Breier,
Foorman & Fletcher, 2002; Gray, Miller & Evans, 2012). Based on these results, and due to the similarity in reported symptoms between mTBI and ADHD, it is hypothesized that Service Members will display higher false alarm rates on the contralateral masking task than the controls. Based upon personal reports, the prevalence of ADHD among active duty Service Members is low and before 2004, ADHD disqualified someone from Service; requirements regarding ADHD and military service are more vague now. The prevalence of ADHD among a random sample of American adults ranged from 3% to 16%, depending on the stringency of the criteria (Faraone & Biederman, 2005). We expect to see Service Members with a formal mTBI diagnosis exhibit a greater degree of impulsivity and distractibility than Service Member without an mTBI.
Materials and Methods

Participants

The participants included in this study had to be between the ages of 18 and 65 and were either active duty Service Members or recently retired from service. Participants’ date of birth were not required during data collection. In total, thirty Service Members were included and were split into two groups of 15. In the first group, all 15 participants had a formal mTBI diagnosis. The second group was composed of 15 Service Members who all reported that they had never been diagnosed with an mTBI. All but one participant was recruited through the Fort Belvoir National Intrepid Center of Excellence (NICoE) or through the hospital at Fort Belvoir. The participant who was not recruited through Fort Belvoir was local to Harrisonburg, VA and was encouraged by a family member to participate in the study. The participant from Harrisonburg was tested at James Madison University (JMU) in the Psychoacoustics Research Laboratory while the rest of the participants were tested at the NICoE. As compensation for participating in the study, most but not all of the participants were given a twenty dollar prepaid gift card. The participants who did not receive a gift card opted not to receive any type of compensation for participating. All testing procedures were reviewed and approved under JMU IRB #16-0130 and Fort Belvoir EIRB #874169. All participants were volunteers and provided signed informed consent.

Testing

Contralateral and informational masking were used to record the participants’ false alarm rates and thresholds. False alarms are when the participant indicates that the signal was present when it was not, and represents the participants’ “impulsivity.”
Thresholds designate the level that the participants were “maximally uncertain” whether the signal was present. The two groups of Service Members, those with an mTBI and those without, completed one session that lasted no longer than 45 minutes. The participants, except for the one local to Harrisonburg, VA completed the testing in a therapy room at the NICoE center. The therapy room was not sound proof but it was quiet and testing was performed while utilizing sound-attenuating circumaural headphones. The participant who was tested at JMU was tested in a double-walled sound booth.

Possible covariates were recorded for the 14 Service Members at NICoE in the mTBI group. These possible covariates included reported PTSD, type of injury (e.g. blast or non-blast), number of injuries, and age of first injury. These participants were asked if they are currently prescribed any medications for attention deficits.

Tympanometry was performed to screen middle ear function. If tympanometry was not completed, due to equipment issues, than the participant was asked if they had any history of middle ear infections, pressure equalization tubes, or ear surgery and their responses were recorded. Following tympanometry, each participant completed an automated audiogram on the test computer. Hearing loss was not a contraindication to participate but the hearing assessment was used to verify that the participant could hear the test stimuli.

The two auditory signal-detection measures, contralateral and informational masking, each involve brief, procedural training and a 40-trial adaptive task. These tests were the same between the two testing locations, JMU and Fort Belvoir. The test instructions were given verbally for contralateral masking while instructions for
informational masking were given verbally with a supplemental visual image. Each task was preceded by at least one training session to ensure understanding. If the participant reached 100% after the first training session, they would move onto the test session. If the participant did not reach 100% on the training on their first attempt than they repeated the training until they either reached 100% or were fully confident on the task and demonstrated understanding.

Following the procedural training, a 40-trial adaptive test for both the contralateral and informational masking tasks were completed to estimate real false alarm rates and thresholds. The participants completed the contralateral masking training and test session first because it was typically, easier to learn. Both contralateral and informational masking involve the detection of a 500 Hz signal tone in the presence of an unpredictable masker. These two tasks involve different levels of uncertainty and incorporate different forms of non-sensory masking. With contralateral masking, an 80 dB SPL, 500 ms octave-band masker centered at the signal frequency, which ranged from 354 Hz to 708 Hz, is presented on every trial while the 500 Hz signal is presented randomly on half of the trials. The masker was always presented to the contralateral ear of the signal and varied in terms of which ear it was presented to. With informational masking, the masker is an 80 dB SPL noise that is composed of 10 randomly selected tones between 1000 Hz and 2500 Hz and is presented to both ears on every trial and the signal is presented randomly on half of the trials to both ears.

Visual prompts on the computer cued the participants on how to learn and proceed through the tasks. First, the monitor displays the text “Ready” and then “Listen.” The masker, and possibly the signal, are presented and the display shows the text
“Decide.” This task involved a single-interval procedure where the participants were instructed to respond by pressing one of two keys on the computer representing, “Tone” or “No Tone.” The participants were instructed to listen for the signal tone in the presence of the masker and to press the “Tone” button on the keyboard whenever they heard the signal in the presence of the masker. When the signal tone was not detected, the participants were instructed to press the “No Tone” button. While participants were instructed to only press the “Tone” button when they could detect the signal tone, they were advised that the tasks are designed to find the point where they are maximally uncertain as to whether or not the signal tone is present. If the participant was correct in choosing “Tone” or “No Tone,” they would receive immediate feedback that would read “Correct.” If they were incorrect in their choice, they would see “Wrong.” In the event that the participant’s false alarm rose higher than 40%, the monitor would display the text “Do NOT press the tone key unless you are sure you heard the tone.” A 40-trial maximum likelihood adaptive track estimates the 60% point on the psychometric function to estimate thresholds while the twenty randomly interspersed non-signal trials estimated false alarm rates.
Results

Comparison of Service Members with and without mTBI

The data collected from the Service Members, with and without an mTBI diagnoses, were analyzed in a between-groups design to see if any group differences could be identified. Overall, the between-groups analysis, comparing mean false alarm rates and thresholds, for the Service Members with and without mTBI did not yield any significant differences in performance, negating the original hypothesis.

Independent samples t-tests were performed to compare the means of the Service Members with and without a mTBI to assess for any statistically significant performance differences on either of the masking tasks. First, for the informational masking task, the groups’ mean false alarms did not significantly differ, t(28)=-0.087, p=0.931, d=-0.032. Similarly, the group means for false alarms during the contralateral masking task did not reach significance, t(24.316)= 0.000, p=1.000, d=0.000. As indicated by these statistics and seen in Figure 1 below, the estimated means are identical (to the level of our measurements). The variances in the groups were likely different (p=0.06), leading to the altered degrees of freedom.
There was no significant difference in the groups’ masked thresholds: $t(28) = 1.168$, $p = 0.253$, $d = 0.426$, in the comparison of contralateral-masking thresholds; and $t(28) = 1.891$, $p = 0.069$, $d = 0.690$, in the comparison of informational masking thresholds. The difference in informational-masking thresholds is close to significant, the effect size is closer to 'large' than to 'medium', is in the predicted direction, and would be significant with a one-tailed test (not after applying Bonferonni correction for four comparisons: thresholds and false alarms in two different masking tasks). Power analysis (G-power 3.1.9.2) predicts that testing 27 Service Members in both the mTBI and no-TBI groups (less than doubling the size of our sample) would have an 80% chance of finding significant one-tailed difference at the 0.05 level in informational masking thresholds. Multivariate techniques show the threshold in informational masking to be a significant
predictor of mTBI in the two groups of Service Members (correctly classifying 62% of cases through logistic regression and explaining 16% of the variance in discriminant analysis, \( p=0.027 \) in both analyses).

Figure 2: Mean Thresholds for Informational and Contralateral Masking for Service Members with and without mTBI

All of the Service Members, except for one, with an mTBI provided information on several co-variates that related to the type of injury they had sustained as well as when the injury occurred. The Service Members reported if they had experienced blast or non-blast injuries, if the injury occurred before they were 25 years old, how many mTBI they had sustained and if they experience concomitant PTSD. Furthermore, they reported any prescribed medications for ADHD. Correlation analysis was performed for the fourteen Service Members with an mTBI to see if any significant relationships existed between
those specific co-variates and test performance. Table 1 illustrates those relationships between test performance and the various covariates.

<table>
<thead>
<tr>
<th></th>
<th>Blast mTBI</th>
<th>Non-blast mTBI</th>
<th>PTSD</th>
<th># of mTBI</th>
<th>mTBI &lt;25 yrs.</th>
<th>ADHD Rx</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMTH</td>
<td>r= -0.101</td>
<td>r= -0.210</td>
<td>r= -0.148</td>
<td>r= -0.172</td>
<td>r= 0.000</td>
<td>r= 0.192</td>
</tr>
<tr>
<td>CMFA</td>
<td>r= -0.279</td>
<td>r= -0.393</td>
<td>r= 0.101</td>
<td>r= -0.162</td>
<td>r= -0.184</td>
<td>r= 0.391</td>
</tr>
<tr>
<td>IMTH</td>
<td>r= 0.215</td>
<td>r= 0.235</td>
<td>r= -0.232</td>
<td>r= 0.072</td>
<td>r= 0.388</td>
<td>r= -0.285</td>
</tr>
<tr>
<td>IMFA</td>
<td>r= -0.128</td>
<td>r= -0.251</td>
<td>r= -0.007</td>
<td>r= -0.208</td>
<td>r= 0.055</td>
<td>r= 0.035</td>
</tr>
</tbody>
</table>

* Green designates a predictive direction while peach designates an opposite direction

Table 1

None of the correlations shown in Table 1 are significant (lowest p=0.16). Twenty-four correlations are evaluated so the appropriate Bonferroni correction requires significance be tested at a p value of 0.002, so a p value would need to be 2 orders of magnitude lower to reach significance. Only 25% of these correlations are in the predicted direction.

Comparison of Service Members to Civilian Adults

Since the initial analysis showed that performance was not significantly different between Service Members with and without an mTBI diagnoses, additional analysis was performed comparing the entire group of 30 Service Members to a group of 20 civilian adults. The civilian adults were enrolled in University classes during their data collection and their data was previously published in Gray, Miller and Evans (2012) and
Sanderson’s (2014) doctoral dissertation. First, for the informational masking task, the two groups’ means for false alarms were close to reaching significance, $t(48)=1.855$, $p=0.070$, $d=0.551$ while the groups’ mean false alarms during the contralateral masking task were not close to significant, $t(48)=0.427$, $p=0.671$, $d=0.126$. On the other hand, when the contralateral masking thresholds were compared they were significantly different between groups $t(48)=3.823$, $p<0.001$, $d=2.071$. Similarly, the two groups’ thresholds for informational masking also reached significance, $t(48)=7.164$, $p<0.001$, $d=1.178$.

**Figure 3:** Mean False Alarms for Informational and Contralateral Masking. Comparing Service Members to Civilian Adults.
Prior to the contralateral and informational masking training and test trials, each participant completed an automated audiogram on the test computer. Participants were instructed to press the space bar on the keyboard when they heard a tone. The program implemented the Hughson-Westlake algorithm to estimate absolute thresholds at octave frequencies between 250 and 8000 Hz in each ear separately. Among the tested frequencies are 500 Hz, the signal frequency, and 4000 Hz, the expected locus of hearing loss from noise exposure (Nandi & Dhatrak, 2008).
Figure 5: Range of Hearing Thresholds at 500 Hz. Comparing Service Members to Civilian Adults.

There was a significantly greater hearing loss at 500 Hz in the Service Members than civilian adults ($t_{47.5} = 6, p < 0.001$). All but one of the 30 Service Members had ‘normal’ hearing at 500 Hz (thresholds above 20 dB HL are ‘abnormal’). There was no difference in 500-Hz thresholds between Service Members with and without TBI ($t_{23.2} = 0.78, p = 0.45$), suggesting again that the important difference is unexpectedly between adults in the Military versus civilian adults, with no difference between Service Members with and without TBI.

Hearing loss from high intensity sound-damage occurs most predictably and noticeably from 3000 to 6000 Hz, centering at 4000 Hz (Nandi & Dhatrak, 2008). There is significantly more hearing loss at 4000 Hz in the Service Members compared to the civilian adults ($p = 0.001$), also more variance in this measure among the Service Members.
There was no difference in these high-frequency thresholds between the Service Members with and without mTBI ($p=0.28$). Noise exposure, due to blast or gunfire exposure, might affect one ear more severely than the other, inducing an asymmetrical hearing loss. Analysis of the absolute difference of thresholds at 4000 Hz between the ears showed a significantly greater asymmetry in the Service Members compared to civilian adults ($p=0.05$). Surprisingly, there was no difference between Service Members with and without TBI ($p=0.32$), but among 14 Service Members with mTBI (who volunteered information on possible covariates) there was a marginally significant difference between those who reported a blast injury versus those with TBI from a non-blast related event ($p=0.04$, one–tailed).

It is likely that hearing loss at the signal frequency would affect thresholds in both masking tasks, and we see this significant trend in the next two figures ($p<0.001$ for both tasks). If hearing thresholds alone predicted performance in the masking tasks then the individual points in the figures below would fall along the line of best fit, with points for both groups equally above and below the linear regression. This is not the case. For both informational and contralateral masking, Service Members tend to lie above the regression line while the civilian adults tend to lie below the regression. While the same trend is seen in both contralateral and informational masking, it only reached statistical significance with contralateral masking ($p=0.002$ in a comparison of the regression residuals between the groups of 30 Service Members and 20 civilian adults).
**Figure 5:** Relationship between Hearing Thresholds and Informational Masking Thresholds for the Service Members and Civilian adults

**Figure 6:** Relationship between Hearing Thresholds and Contralateral Masking Thresholds for the Service Members and Civilian adults
It is expected that when contralateral and informational masking is completed, that there will be a trade-off between false alarm rates and thresholds. With an increase in false alarm rates there is an expected decrease in thresholds. The signal detection-theory parameter beta measures participants’ response proclivity. By response proclivity, we mean that listeners might vary along a continuum from conservative to lax responders. Remember that in both masking tasks, the maximum likelihood method finds the participants’ threshold for detecting the signal. In other words, after the first few trials of the 40-trial tests, the computer has found the maximally ‘frustrating’ signal level: the level where the listener is most uncertain about whether the signal is present or not. Listeners can have different strategies or proclivities in how they respond under conditions that can require some guessing about whether the signal we present or not. A conservative responder will make sure they hear the soft signal before they indicate that the signal is present; they minimize false alarms at the expense of missing some weak signals. A lax observer in contrast responds somewhat impulsively making sure never to miss a signal and thus has a higher false alarm rate. If the participants varied in their intrinsic beta, there would be a trade-off between false alarm rates and thresholds. Conservative listeners would have low false-alarm rates and high thresholds. Lax observers would have the reverse, high-false alarm rates and lower thresholds. We would see a negative correlation between thresholds and false alarms. Figure 8 shows this trend, a significant regression with negative slope, in the informational masking data of the Service Members \((p=0.009)\). The trend, though negative, is not significant in the civilian adults \((p=0.28)\). The regression slopes are different \((t_{46}=8.5, p<0.001)\), showing that
Service Members, but not the civilian adults, adopt different listening strategies with informational masking. This trend is not seen in contralateral masking (Figure 9).

**Figure 8:** Relationship between Informational Masking Thresholds and False Alarms for the Service Members and Civilian adults

**Figure 9:** Relationship between Contralateral Masking Thresholds and False Alarms for the Service Members and Civilian adults
Returning to informational masking, as there are different trends in the relations between thresholds and false alarms, an alternate analysis would be to select only those Service Members with thresholds that fall in the same range of thresholds seen among the civilian adults. Then we test for a difference in false alarm rates in this matched subset of adults with similar informational-masking thresholds.

Figure 10: Overlap of hearing thresholds for the Service Members and Civilian adults

Figure 10 highlights the range of thresholds where the Service Members fall within the same range of thresholds as the civilian adults. Using only the ‘matched’ subset, the points within the box in Figure 10, there is a highly significant difference in false alarms ($t_{32}=3.2$, $p=0.002$, effect size is ‘very large’ with Cohen’s $d = 1.3$).
Finally, Logistic-regression is used to summarize these findings into one multivariate analysis. Logistic regression attempts to predict a binary outcome, in this case whether the listener was in the military or not, based on selected continuous variables. A forward stepwise binary logistic regression analysis identified three of our variables as significant predictors: threshold at 500 Hz, contralateral masking threshold, and informational masking false-alarm rate. These three variables can be combined to form a ‘logistic score’ that predicts with 90% accuracy whether our participants were in the military or were civilians ($x^2_p=41, p<0.001$). In summary, the Service Members had significantly worse thresholds at 500 and 4000 Hz than our sample of civilian adults. Among the Service Members, central masking thresholds were worse than predicted from their sub-clinical hearing loss alone, and informational masking false alarms were greater than predicted from their thresholds in this task.
Discussion

The purpose of this study was to quantify the impulsivity and distractibility of Service Members who have been diagnosed with an mTBI in terms of false alarm rates and thresholds. The results from this study do not support the original hypothesis: Service Members with an mTBI do NOT perform similarly to children with ADHD and do NOT exhibit a greater level of impulsivity and distractibility on the contralateral masking tasks, when compared to their peers without an mTBI diagnosis. A between-groups design was used and while no clear patterns were exhibited between the two groups of Service Members, significant trends were shown between the whole group of Service Members when compared to a group of civilian adults.

The Service Members performed similarly on the two masking tasks but there was a large amount of performance variance. The large degree of variance, especially in terms of false alarms within the two Service Member groups (Figure 1), could be attributed to extraneous variables that were not originally accounted for. Based on current literature, mTBI does not impact each recipient in the same manner and some individuals experience complete symptom resolution while others experience chronic symptoms years after the time of injury (Vander Werff, 2012). Variables such as active or retired from duty status, time of injury, and how much time has passed since the injury occurred could influence performance. For example, a retired Service Member who experienced an mTBI in their early twenties will likely be less symptomatic than an active duty Service Member who was recently on a tour overseas and experienced a combat related injury. It is also important to note that performance was not universally consistent in this study, which is consistent with data from other studies (Gallun et al., 2012). In addition, the
studies that investigated auditory deficits post-TBI as well as blast exposure did not report significant group differences on complex auditory processing and working memory tasks, even when deficits were reported (Gallun et al., 2012; Saunders et al., 2015; Hoover, Souza, & Gallun, 2017). Thus, impairments following an mTBI are heterogeneous in nature and inconsistent across individuals. In addition, when the participants within the mTBI and matched groups are re-organized in terms of reported difficulties, significant differences were found. For this reason, individual differences may be more meaningful than group differences (Hoover, Souza, & Gallun, 2017).

Military service was examined as a possible influence on the masking tasks by comparing Service Members, with and without an mTBI, to civilian adults. When performance on the informational and masking tasks were compared, the two groups’ thresholds were significantly different on both tasks (Figure 4). Next, contralateral and informational thresholds were compared to “hearing thresholds” for both groups to see if hearing sensitivity predicted performance. In Figures 6 and 7, we see the overall trend that the Service Members tend to fall above the line of best fit and the civilian adults typically fall below the line. This indicates that the Service Members typically perform worse than what is predicted by hearing sensitivity alone. Meaning, there appears to be an effect of Military service on distractibility as measured with the contralateral masking task.

With the contralateral and informational masking tasks we expect to see a trade-off between false alarm rates and thresholds. It is expected that with a “conservative” listener, false alarms will be few but thresholds will rise. This is because a “conservative” listener needs to be certain that they heard the signal before they indicate that they heard
it. On the other hand, a “lax” observer will respond that they heard the signal even if they are not confident that the signal was present. In Figure 8 and 9, we see that the rate of trade-off between false alarms and thresholds differ between the Service Members and civilian adults. In fact, with a decrease in false alarms, the informational masking thresholds rise more than three times faster with the Service Members than the civilian adults (Figure 8). Therefore, there trade-off in responses is different between the two groups. In other words, the Service Members have a greater increase in threshold by being a conservative listener than the civilian adults. In Figure 10, the region of overlap shows a significant difference in the false alarms between the two groups. This analysis suggests that Service Members produce more false alarms, than the civilian adults do, in order to achieve low thresholds. As shown in Figure 9, this same trend was not exhibited with contralateral masking. As a result, there is a difference in the two masking tasks when Service Members are compared to civilian adults. This difference may be attributed to Military training and the Service Members’ ability to ignore distracting maskers when the masker can be localized to one side. Compared to contralateral masking, the signal in informational masking cannot be localized and appears to be more distracting for Service Members. Based upon the findings of this study, it appears that Service Members, with or without an mTBI diagnoses, do not perform similarly to subjects with ADHD, even suggesting that ADHD is not present in these groups.

The literature highlights the wide range of reported difficulties made by Service Member with blast exposure and/or an mTBI diagnoses. The literature also emphasizes the fact that the symptoms reported by those diagnosed with an mTBI do not always translate to behavioral test measures. As demonstrated in McAllister et al., (2001)
performance on working memory tasks was not significantly different between the participants with and without mTBI diagnoses on the n-back tasks. It was discussed that perceptual deficits might not always translate to behavioral measures or that the behavioral tasks are not guaranteed to be sensitive enough to detect any differences. Similar to the McAllister study, future work with mTBI and impulsivity might incorporate imaging studies to investigate activation pattern variations that could indicate group differences.

Incorporating a subjective measure into the test protocol can provide insight on any specific deficits experienced by the participants and help to illuminate the long-term implications of an mTBI. One possibility would be to create a questionnaire where the participants rated their perceived difficulties in terms of focus and attention in various listening environments. Incorporating a questionnaire into future studies would also allow comparison between reported deficits and performance on the masking tasks and would help to illustrate if the tasks are sensitive enough to detect group differences and highlight the individuals who are experiencing related difficulties. Lastly, a questionnaire would be helpful to isolate reported difficulties that overlap with PTSD, mTBI and possibly ADHD to help guide professionals in developing treatment plans.

In summary, mTBI is a highly variable and multifaceted injury. While this study did not show the originally anticipated results, that Service Members with mTBI would perform like children with ADHD, it did shed light on the nature of inattention following a head injury. Perhaps the most important result of this study is seeing that the nature of inattention following mTBI is very different from ADHD, although the symptoms are described the same. This is an important finding in regards to clinical implications.
because Service Members with mTBI that experience inattention and difficulty with concentration should not be treated as though they have ADHD. Symptomatically, mTBI and ADHD are similar in regards to attention, but functionally they are very different.
Conclusion

The long-term goal of this research is to understand the chronic implications of an mTBI and create intervention strategies to help Service Members cope with these injuries. Specifically, this research study was designed to gain a better understanding of the difficulties associated with concentration and attention following an mTBI and develop a training protocol to help individuals be less distracted. While distractibility and impulsivity is a commonality between ADHD and mTBI, these two populations did not perform similarly on the same test measures. In fact, there was absolutely no difference in contralateral masking false alarms between the two groups of Service Members. Thus, any problems with attention and concentration post-mTBI are different from those in ADHD. On the other hand, contralateral masking thresholds were higher than predicted with hearing thresholds in the Service Members when compared to the civilian adults and informational masking false alarms were greater in the Service Member group, once informational thresholds were corrected for.

In conclusion, the difficulties with attention and focus that were detected in the Service Member population are different from those of civilian adults. This finding suggests that Military training and service affects the trade-off in false alarms and hits in a challenging listening situation. Future work should incorporate test measures that account for perceptual difficulties and take into account differences between the control and mTBI Service Members. For instance, we should learn more about the control group in terms of deployment, age, noise exposure, and any special training. Training is of unique importance because specialized training will likely influence a person’s response proclivity.
Part II. Appendices
Appendix A: Literature Review

Concussions and TBI are major health concerns and are the primary focus of health professionals and researchers throughout the world. Historically, mTBIs were classified as short-term injuries where the recipients could expect quick and full recoveries without any chronic post-concussive symptoms. However, many individuals who have suffered an mTBI experience post-concussive symptoms years after the time of injury. Some of the reported long-term symptoms following a mTBI include, but are not limited to, poor concentration and poor memory, frustration, sleep disturbance, headache, dizziness, tiredness, depression, sleep disturbances, irritability, tinnitus, photophobia, and blurred or double vision (Vander Werff, 2012).

The natural history and prognosis of mTBIs is not clearly understood and is complicated by the environment in which the injury occurred. One specific setting where mTBI occurs frequently is in military (Vander Werff, 2012). In fact, TBI has been termed the “signature injury” of Service Members who served in Afghanistan and Iraq (McCrea et al., 2009). The number of Service Members diagnosed with TBI since 2000 has reached an approximated 370,688. However, the number of military related TBIs could be underestimated due to the complicated nature of military environments. In addition, if a Service Member has experienced multiple injuries, only one is included in the total number of injuries recorded. According to the DVBIC, the vast majority of brain injuries sustained by Service Member are mild. The number of mTBIs between 2000 and 2017 has reached an estimated 305,140 (Defense and Veterans Brain Injury Center, 2017).

Mild TBI, because of blast exposure, combat, training, or accidents in garrison suffered by Veterans who served in OEF, OIF or OND is a serious public health issue.
Blast exposure, as well as mTBIs superimposed on the stress of active duty and combat situations, have effected a large number of Service Members who suffer life-altering morbidity because of those injuries (Mu, Catenaccio, & Lipton, 2017). Combat-related mTBIs, including the effects of blast, impact, and acceleration-deceleration injuries can have long lasting and debilitating effects (Saunders et al., 2015). The significance of this type of injury is partially attributed to the vast number of occurrences as well as the fact that the long-term implications are not fully understood.

The long-term implications of an mTBI are not universally consistent. Large numbers of returning Service Members from OEF, OIF, or OND with blast-exposure report post concussive symptoms, some of which can include headache, dizziness, poor memory, difficulties with speech in noise, and a difficulty with auditory memory and concentration years after the time of injury. There is professional dispute regarding the specific cause of the aforementioned symptoms as some professionals view them to be the direct result of blast-exposure, others view them to be the result of PTSD, or specific damage to the central auditory system (Saunders et al., 2015). The difficulty that surrounds mTBI is being able to measure and isolate the specific difficulties that are a result of the injury and to understand the natural history and the long-term effects to best design the most appropriate intervention.

A TBI occurs when an external force disrupts brain function. The degree of injury can range from mild to severe; with each degree of injury having associated diagnostic criteria. A common definition of mTBI, is from the American College of Rehabilitation, as cited by Vander Werff, and describes “an impact or forceful motion of the head [that] results in post-traumatic amnesia not exceeding 24 hours, loss of consciousness not
exceeding 30 minutes, and a Glasgow Coma Score rating between 13-15.” A low score on the Glasgow Coma Scale (e.g. 3) indicates a deep coma while a high score (e.g. 15) indicates a person that is fully awake (Vander Werff, 2012). According to the Department of Defense, an mTBI is characterized by a “confused or disoriented state which lasts less than 24 hours; or loss of consciousness for up to 30 minutes; or memory loss lasting less than 24 hours.” Typically, mTBIs do not include any penetrating type of injuries and imaging is often normal (Defense and Veterans Brain Injury Center, 2017). In military settings, the Military Acute Concussion Evaluation (MACE) is often used to assess acutely injured soldiers but due to the nature of combat, the time of injury, which is necessary information, is often incomplete. Lack of assessment at the initial point of injury is a major weakness when investigating service related mTBIs. Furthermore, the specific mechanisms of injury for blast-related versus impact or blunt mTBI may differ. Additionally, the situation in which the injury occurred, such as combat, could complicate the occurrence, as there could be an overlap between post-concussive symptoms and PTSD. Post-concussive symptoms can include emotional and/or behavioral problems and individuals may report depression, impulsivity, agitation, anxiety, fatigue or depression (Vander Werff, 2012). There are four main types of PTSD symptoms: reliving the event, situation avoidance, changes in beliefs or feelings, and hyper-arousal. Specifically, individuals with PTSD may experience, nightmares, flashbacks, situational avoidance, changes in behavior or emotions, anger, irritability, or difficulty sleeping and concentrating (U.S. Department of Veterans Affairs, 2015b). The overlap in post-concussive symptoms and PTSD can complicate and impede diagnosis and treatment (Mu, Catenaccio, & Lipton, 2017).
TBI is not a monolithic condition and can cause many associated cognitive and auditory deficits (Hoover, Souza, & Gallun, 2017). There are countless ways that damage can be inflicted on the auditory system from a head injury. Traditionally, an audiologic evaluation following a head injury focused on the peripheral auditory system, rather than the central auditory system, because the external, middle, and inner ear could all be damaged by external forces hitting the skull, especially if the temporal bone was the recipient of a direct impact. However, damage can occur beyond the peripheral auditory system and can affect the central auditory system and even high-level structures (Vander Werff, 2012).

The term “mild” TBI is a very broad classification in terms of pathophysiology and neurobiology. On one end of the spectrum, a mild injury can cause the individual to feel dazed for a brief period with a headache and some degree of dizziness and then experience symptom resolution within a few hours. The previously described type of injury affects the cellular physiology temporarily. On the other hand, an mTBI may also involve loss of consciousness for several minutes and induce hours of post-traumatic amnesia. The more intense injuries could be associated with visible evidence of damage on computed tomography (CT) scans such as a contusion as well as brain tissue abnormalities (McCrea, et al., 2009). There can be focal regions of damage from skull fractures, lacerations or hematomas or diffuse damage from the acceleration and deceleration of the brain within the skull (Vander Werff, 2012). Furthermore, damage may involve, but is not limited to, swelling, shearing, or stretching of the neural connections and inflammation of the tissue. Injuries that fall closer to the mild end of the spectrum are likely to involve low levels of axonal stretching (McCrea et al., 2009).
Damage can be so widespread and dispersed that it is not visible on imaging (Gallun et al., 2012).

Regions of the frontal and temporal lobes that are involved in cognition can be affected by an mTBI and the injury can influence the brain’s ability to process auditory input (Vander Werff, 2012). The widespread nature of damage that can occur from an mTBI results in unique profiles of injury, making understanding the challenges associated with the damage challenging for professionals (Gallun et al., 2012). Because the damage following a mTBI may be widespread highly variable, it is unclear whether the auditory complaints following an injury are due to central auditory, peripheral auditory, or even non-auditory cognitive factors. Some of the difficulties expressed from individuals diagnosed with mTBIs are difficulties listening in situations with background noise, following verbal instructions and processing rapid or degraded speech (Vander Werff, 2012). It could be that the auditory complaints associated with mTBIs, difficulty-understanding speech in noise, are associated with higher-level cognitive factors such as attention (Hoover, Souza, & Gallun, 2017).

To aid in the evaluation and management of military-related mTBIs, a theoretical model of recovery following an mTBI was proposed that was based on a summary of current literature. The theoretical model proposed by McCrea et al., describes an acute, subacute and chronic period of recovery following an uncomplicated mTBI without any focal or structural injury. First, the acute period lasts around 5 days post-injury and the symptoms are typically the most severe during this time and can disrupt daily function. In addition, during the acute period, functional neuroimaging can detect decreased neuronal activation and the brain is injured enough to create a neurometabolic crisis,
which could be worsened by physical exertion. Second, the subacute period is around 5 to 30 days post-injury and is characterized by an overlap between symptom recovery and cognitive and functional impairments. The majority of patients are expected to experience symptom resolution during the subacute period. Finally, the chronic period is the timeframe 30 days post-injury and presumably. It is estimated that only a small percentage of patients experience persisting symptoms during into the chronic period.

While some patients demonstrate persistent post-concussive symptoms into the chronic period, these symptoms can be exacerbated by non-injury-related factors. Co-morbidities such as depression, PTSD, anxiety, and chronic pain can influence recovery and the evaluation and management of persistent disability following an mTBI. This theoretical model was used to draw several parallels to aid in the evaluation and management of military related mTBIs. First, during first several days following an mTBI, the Service Members will experience significant symptoms that will impede function, impact their ability to fulfill their duties and could be more susceptible for recurrent injury. Vigorous exercise can make the injury worse and disrupt the recovery process. It is not until the individual is symptom free that they should gradually begin physical activity.

Furthermore, while the individual may be asymptomatic, that does not mean that cerebral function has fully recovered. Finally, this literature summary highlighted the importance of a biopsychosocial approach for management following an mTBI; especially, in military settings where PTSD, depression and other comorbidities complicate recovery.

Additional research is needed to fully understand the exact natural history of mTBIs to either confirm or refute the theoretical model presented in this review (McCrea et al., 2009).
To understand the root of the auditory complaints following mTBIs, there is a growing body of literature investigating auditory processing deficits following blast exposure. In Gallun et al. (2012), the purpose of the study was to determine whether there is evidence of central auditory dysfunction following exposure to high-level blasts. To examine this question, the study incorporated two participant groups, the experimental group and the controls. The experimental group included individuals who served in either Iraq or Afghanistan and had experienced a high-level blast exposure. The control group was matched to the experimental group with regards to age, sex, and audiometric configuration. The time of blast exposure was all within one year of study enrollment and if any of the participants had been diagnosed with TBI, none of the injuries was greater than a mild injury. In addition, none of the participants had a hearing loss greater than a 50 dB HL puretone average (500, 1000, and 2000 Hz). The test battery was used to detect difficulties processing simple and complex auditory stimuli and assessed the following auditory skill sets: temporal pattern perception, auditory temporal resolution, binaural processing and sound localization, and dichotic listening. Electrophysiological measures included an Auditory Brainstem Response (ABR) and the Long Latency Response (LLR). In this paper, several participants reported that they had experienced more than one blast event while others only reported experiencing one injury. While the researchers did not find any significant data regarding the number of injuries, it warrants further investigation (Gallun et al., 2012).

The behavioral tests utilized in the Gallun et al. (2012), paper were used in previous studies to assess central auditory processing abilities in several of populations with all different backgrounds. Etiologies of injuries involved in those previous studies
included concussive head injury from motor vehicle or sports accidents and even strokes or brain tumors. In those earlier studies, the experimental group had known lesions with localized regions of injury. Typically, those control groups included young, non-disabled subjects from diverse backgrounds. In contrast, the experimental group in Gallun et al. (2012), did not have localized regions of damage nor did they have confirmed pathologies but had all experienced exposure to a high-level blast during deployment. For this reason, a unique control group was established to account for any differences in demographics between the published normative data and the experimental group involved in this study (Gallun, et al., 2012).

The three tests that revealed the largest effects of blast exposure when comparing the experimental group to the controls were the GIN, SSW, and MLD tests. The central auditory processing tests were analyzed for the experimental and control groups and an abnormal performance was considered plus or minus two standard deviations from the control group’s mean. All participants underwent a full audiometric evaluation and while there was not a significant difference in performance on word recognition scores (WRS) there was a significant difference on the QuickSIN, indicating that speech understanding in complex auditory environments may be compromised following blast-exposure. Abnormal responses with the SSW and the GIN reflect damage to the cortex and the corpus callosum while abnormalities with MLD can reflect damage to the auditory brainstem. The correlation that was documented between exposure to a high-level blast and abnormal performance on the GIN and SSW tests indicate that the corpus callosum and the cortex are possibly involved when exposure to a blast occurs. The results of this study suggest that blast exposure can affect brainstem or cortical level function.
However, it is important to note that performance was not universally consistent and there were not any significant between-group differences, but a high degree of variability was noted (Gallun, et al., 2012).

The results of the Gallun et al. (2012) paper suggest that exposure to high-level blasts can lead to impairments in central processing, even when a formal mTBI diagnosis is absent. The results of this study indicate that blast exposure alone can lead to central auditory processing disorders. One important factor to note was that abnormal performance on the auditory processing tasks was significantly correlated to reports of PTSD and these reports should be investigated as a factor in auditory function/dysfunction (Gallun, et al., 2012).

In Saunders et al. (2015), data was collected from 99 Veterans with blast-exposure who had hearing that was within normal limits but reported auditory difficulties. The purpose of this study was to gain further insight into the reported difficulties hearing in various listening environments following blast exposure. For this study, some of the inclusionary criteria required that the participants have served as part of OIF, OEF or OND, have exposure from at least one blast event during combat, report difficulties with speech in noise, have symmetrical hearing and have age and educational level appropriate Mini Mental State Exam scores. Participants could not be included with any outer ear infections or conductive hearing loss, substance abuse issues, neurological or psychiatric disorders (except for PTSD), infection disease, auditory processing disorders or previous auditory training, to name a few. All of the participants reported blast exposure whether it was from a grenade, land mine, improvised explosive device (IED), or some other explosive event (Saunders et al., 2015).
The participants’ subjective hearing difficulties were recorded with the FHQ and the Speech, Spatial and Qualities (SSQ) questionnaires. The FHQ was designed to assess hearing difficulties with nine questions that are geared around nine different communication situations. The participants completed the FHQ by rating their difficulty in each of the nine environments, on a scale of one to four. Scores on the FHQ range from nine to thirty-six, with nine indicating no difficulties and thirty-six suggesting significant hearing difficulties. Next, reported difficulties with speech understanding, spatial hearing, and hearing quality were evaluated with the SSQ questionnaire. Together, results from the FHQ and the SSQ characterized specific hearing-related difficulties. Overall, the most common difficulty reported by the participants was a difficulty understanding speech in noise (>75%). In addition, over fifty percent of the participants reported difficulties following long conversations, talking on the phone, and understanding rapid speech (Saunders et al., 2015).

Next, behavioral measures were used to quantify the participants’ specific hearing abilities. The Hearing in Noise Test (HINT) was used to attain a speech reception threshold in noise (SRTN) and the data showed a performance deficit with understanding speech in noise in Service Members, when compared to the controls. Auditory segregation skills were assessed via the North American Listening in Spatialized Noise-Sentence test (NA LiSN-S) and the mean data showed that Veterans with blast exposure have deficits in binaural processing but not in the use of pitch cues. To assess temporal resolution, the Adaptive Tests of Temporal Resolution (ATTR) was performed and the participants’ gap detection thresholds were recorded by an adaptive two-interval forced choice paradigm. Gap detection is associated with central, compared to peripheral,
processing and performance on these tasks was poorer in the blast-exposed grouped, compared to the civilian adults. The TCST assessed the participants’ understanding of speeded speech but the only major take away from this measure was an exhibited high degree of variability. The SSW, a test of segregation with competing signals, showed a higher than average total number of errors when compared to age-appropriate averages but no specific pattern. With the SSW, because no pattern of performance could be distinguished, the general conclusion was that the participants exhibited an overall deficit in the ability to segregate speech in environments with competing speech. Auditory working memory and working memory for spoken language was quantified with the Digit Span Test (DS) and the Woodcock Johnson Story Recall subtest, respectively. Within the DS test, the DS-Forward subtest assessed short-term memory and auditory information while DS-Backward subtest has to do with the manipulation of verbal information while it is in temporary storage. The group scores for the Veterans with blast exposure were very similar to the normative data on the DS tests and indicated no measurable working memory deficits. In the same way, the Veterans did not exhibit any working memory deficits with spoken language when assessed with the Woodcock Johnson Story Recall. Finally, the Stroop Color and Word Test looked at attention and cognitive interference. Performance on this test measure was similar to the age-appropriate norms and suggested that the participants were capable of ignoring irrelevant stimuli (Saunders et al., 2015).

In the Saunders et al. (2015), paper, the Veterans with blast-exposure performed variably across the numerous test measures. Overall, none of the participants performed \( \geq 1 \) standard deviation (SD) from the mean on all of the test measures. Ten percent of the
participants scored $\geq 1$ SD below the mean on five measures while over half of the participants performed $\geq 1$ SD below the mean on three to five of the difference measures. Approximately one third of the participants scored $\geq 1$ SD on less than three measures. The researchers performed Pearson correlations to see whether the participants’ reported difficulties, as noted on the FHQ, corresponded with performances on the behavioral measures. Based off the Pearson correlation, there were several statistically significant correlations between FHQ items and behavioral measures (Saunders et al., 2015).

Several functional difficulties reported on the FHQ were associated with poorer performance on related behavioral measures. First, DS scaled scores, a test of working memory, correlated with reported difficulties following spoken instructions and following long conversations, both of which require the ability to store information and then recall it. In addition, performance on the TCST, a measure of speeded speech, correlated with reported difficulties comprehending rapid speech and needing extended time to process speech. Lastly, the Woodcock Johnson Story Recall was associated with reported problems following a series of spoken instructions. This task requires the ability to follow and recall spoken content. Altogether, the results of this study indicate that reported difficulties listening in difficult environments significantly correlated with demonstrated performance deficits on behavioral measures (Saunders et al., 2015).

As expressed on the FHQ questionnaire, reported difficulties are similar to those expressed by older individuals with hearing loss rather than those of the same age with normal hearing. The participants demonstrated deficits with measures of speech understanding in noise, binaural processing, speech segregation and temporal resolution
as exhibited on the HINT, NA LiSN-S Spatial advantage, SSW, and the ATTR, respectively. Not all of the participants demonstrated deficits, indicating task specific deficits rather than a deficit in global functioning. Results suggest that blast exposure can lead to damage to the central auditory system. A proposed drawback to this study was that blast-exposure and time of exposure was self-reported, and no behavioral measures were performed prior to blast-exposure. Since behavioral measures were not performed prior to blast-exposure, it is impossible to verify that the exhibited deficits are a direct result of blast exposure. Finally, PTSD symptoms were present in the majority of the participants and a formal PTSD diagnosis was present in over half of the participants, making it even more difficult to isolate the symptoms resulting from the blast-exposure (Saunders et al., 2015).

Hoover, Souza and Gallun examined auditory deficits associated with mTBI, specifically in relation to auditory processing and speech-in-noise deficits. Primarily, the goal of this study was to gain a better understanding of speech in noise deficits for those with a history of an mTBI and the relative contributions of auditory dysfunction and cognitive factors. The researchers were looking to differentiate between auditory processing, peripheral auditory components and non-auditory cognitive components. Participants were recruited from a community population and were sorted into three groups based on age, hearing sensitivity, and medical history. The first group was composed of 13 participants, all with “uncomplicated” mTBI diagnoses and any persistent cognitive or auditory deficits were classified as long-term. An “uncomplicated” TBI refers to an injury where peripheral damage and blast exposure do not exist. Two groups of controls who did not have any history of mTBI diagnoses or neurological
disorders in their medical history were also included. One control group was the young normal group that included nine listeners (aged 18-24) with hearing thresholds that were within normal limits and the second group was the Matched group to the mTBI participants with respect to age and hearing thresholds (Hoover, Souza, & Gallun, 2017).

The participants in the Hoover, Souza and Gallun paper completed objective and subjective test measures. Far more participants in the mTBI group reported difficulties with speech understanding in noise than the Matched control group. First, all of the participants reported their subjective hearing ability through an interview format and completed the SSQ. Behaviorally, monaural speech recognition in noise assessed whether subjective reports of speech-in-noise difficulties corresponded to measured signal-to-noise (SNR) losses on tests that had known psychometric properties. The QuickSIN was administered to estimate sentence recognition in four-talker background noise and each participant heard two lists of sentences presented to each ear to estimate their SNR loss. Word recognition in four-talker background noise was assessed with the Words-in-Noise (WIN) test and one list was administered to each ear. The QuickSIN and WIN scores were converted to an SNR loss and performance was compared to the young listeners group. Next, the participants’ ability to benefit from spatially separated sound sources was evaluated using spatial release from masking (SRM). SRM involves three structured sentences presented simultaneously under headphones and are presented in a spatially simulated environment. The listeners were instructed to focus on the signal (located at 0° azimuth) and ignore the background maskers that were either spatially separated at ±45 degrees azimuth or co-located. The target and the masker signals’ presentation preserved inter-aural timing cues but obscured any inter-aural level cues. The target signal was
presented at a fixed level of 50 dB SL, relative to the listener’s speech reception thresholds and the background masker level was varied in 2 dB increments from -10 to +10 target-to-masker ratio. In this scenario, spatial release was the 50% target-to-masker ratio between the co-located and spatially separated conditions (expressed in dB). This score represents the benefit the listener receives from the spatial separation of talkers (Hoover, Souza, & Gallun, 2017).

Performance on the behavioral measures was compared to psychophysical measures. The participants’ monaural temporal fine structure perception was evaluated by having them listen to a sequence of tones where the spacing of the harmonics within the signal was unchanged but the temporal fine structure and the place-pitch would deviate. The participants’ task was to detect a deviation from the standard stimulus. Next, the researchers incorporated spectral ripple reversal (SRR), a measure of spectral resolution within the auditory system, to offer insight on whether the dysfunction had a central or peripheral origin. A relationship between spectral resolution and speech-in-noise deficits post-mTBI would indicate a peripheral cause. Spectral modulation applied to the signal tone and was varied to find the highest rate where the participant could detect the reversal of the standard stimulus. Third, participants’ low-frequency temporal fine structure perception was quantified by measuring detection thresholds for interaural phase differences within a 500 Hz tone. This task was performed because it has been shown to demonstrate central auditory dysfunction following TBI. Finally, Temporal coding within the auditory system was assessed by measuring detection thresholds for a decrease in interaural coherence. The interaural coherence was adaptively adjusted to estimate threshold (Hoover, Souza, & Gallun, 2017).
Cognitive ability was evaluated in terms of attention, processing speed, and working memory with three different tasks. The purpose of these tasks was to emphasize any differences, in terms of cognition, between the mTBI group and the Matched group of controls. The three tasks were presented visually to gain a better understanding between non-auditory cognitive factors and auditory abilities. First, the Trail Making Test required the participants to mark numerically marked consecutive circles while being timed, testing their executive attention. Processing speed was evaluated with a timed digit-symbol coding task. Finally, visual working memory was assessed with a computer-based test that required the participants to read a passage and recall main words and also evaluate semantic validity (Hoover, Souza, & Gallun, 2017).

The performance of the civilian adults, Matched controls, and mTBI group was analyzed with a matched-groups design to examine any group differences. The mTBI group and Matched group participants were matched in terms of age and hearing sensitivity to allow the researchers to examine any specific deficit resulting from a TBI without influences from age or hearing loss. None of the young listeners reported trouble with speech in quiet or noisy environments. The controls in the Matched group reported that they did not have trouble with speech understanding in quiet environments and only one reported that they had difficulty in noisy environments. The participant in the Matched group who had difficulty in noise had a mild-to-moderate sensorineural hearing loss. Performance with speech recognition in the presence of background noise, as assessed with the QuickSIN and the WIN, indicated that the group performance for the Matched and mTBI groups were slightly elevated but did not yield any significant group differences. The results of the civilian adults in terms of SRM with co-located and spatial
separation was consistent with results from previous studies that were used to define normal performance and no significant findings were recorded when comparing the mTBI and the Matched groups. Results from this study were consistent with earlier studies in that no group effects were observed between listeners with a TBI and age-matched peers on complex auditory tasks but also that impairments following a TBI are heterogeneous in nature and inconsistent between individuals. For this reason, individual differences may be more meaningful than group differences. In addition, when the participants within the mTBI and Matched groups were re-organized in terms of reported difficulties, significant differences in speech-in-noise and SRM performances were found (Hoover, Souza, & Gallun, 2017).

Finally, Hoover, Souza and Gallun examined subjective reports of difficulty with speech in noise and objective measures to evaluate any existing relationships. Repeated measures ANOVA for the mTBI and Matched group data showed a significant interaction between recorded speech scores and stated reported deficits. This finding indicates that the individuals from the mTBI group and the individual from the Matched group who reported difficulties with speech understanding in noise exhibited a deficit on the related objective measures. The researchers also found that multiple individuals within the mTBI group demonstrated reduced SRM. Together, these findings show that while not all individuals with an mTBI demonstrate long-term auditory deficits, those who report difficulties are more likely to demonstrate deficits on objective test measures. Finally, none of the psychophysical tasks yielded significant differences between the civilian adults and the Matched and mTBI groups. Statistical analysis also showed that no
significant group differences were found between the mTBI and Matched groups for any of the three cognitive measures (Hoover, Souza, & Gallun, 2017).

For a broader analysis of the effects of mTBIs on auditory function, the researchers examined the rate of abnormal test results between groups. To do this, the number of abnormal results for each participant was tallied and the sum was converted to a proportion in order to compare the three groups. The test measures included were the speech tests and psychophysical tests. Comparison across groups showed a higher rate of dysfunction in the mTBI group (62%) (Hoover, Souza, & Gallun, 2017).

Hoover, Souza and Gallun used stepwise linear regression to determine the variance that could be explained by certain predictor variables for the various speech tasks. The stepwise linear regression found the predictor variable that accounted for the largest amount of variance and the other variables that accounted for any residual variance until the remaining variance was not significant. The predictor variables examined were age, PTAs, interaural phase difference, temporal fine structure, interaural coherence, spectral ripple reversal (SRR), working memory, attention, and processing speed. For the QuickSIN, puretone averages (PTA) and SRR accounted for about 50% of the variance. Both PTA and SRR represent peripheral auditory function. For the WIN, PTA and interaural phase difference (IPD) accounted for over 70% of the variance. IPD requires phase-locking and is considered a measures of temporal fine structure as well as binaural processing. Finally, the regression model that was computed for SRM, which was calculated by the difference between co-located and spatial separation, involved two factors, which contributed nearly 70% of the variance: working memory and PTA. Because none of the auditory processing variables explained a significant amount of
variance, SRM is seemingly more sensitive to unique listener characteristics when compared to the monaural speech-in-noise tasks. Thus, working memory was the primary factor in performance. From this, the researchers concluded that the greatest benefit from spatial separation correlates to the greatest working memory capacity in order to make use of the spatial difference. This analysis indicates that different variables influence performance on binaural versus monaural tasks. For instance, with the monaural tasks, the variance was best explained by peripheral factors such as threshold elevation. Elevated hearing thresholds were the most important factor with respect to speech-in-noise tests. Thus, additional research is necessary understand the relationship between mTBIs and pure-tone threshold elevation by including participants with pre-injury audiometric data (Hoover, Souza, & Gallun, 2017).

Many individuals who have suffered mTBI report cognitive symptoms following the injury. Deficits with attention and processing information are often reported and now, deficits with working memory are beginning to as well. “Working Memory” is the brain’s storage center for information that is required for cognitive function. Regions of the brain that are often sites of structural disruption following a traumatic injury overlap with regions of the working memory circuit. Thus, regions of the working memory circuit could be highly susceptible to damage following a TBI. This study hypothesized that the mTBI group would allocate the majority of their working memory resources for a moderate load condition and not have enough reserve for a higher load condition. An inability to allocate additional resources for an increase from a moderate to a higher-level task will result in a decrease in performance. The participants had an mTBI diagnoses and none of them had history of any other neurological disorders, significant systemic
medical illness, or a current diagnosis of psychiatric illness, other than substance abuse. On average, the mTBI patients were studied 26.9 days post-injury. The type of injuries varied from motor vehicle accidents, falls, to sports or recreational injuries. All of the participants were right-handed. Items that were not present prior to injury or ones that increased in intensity or frequency were attributed to the injury. The participants completed an 18-item self-rating memory scale to assess subjective memory function. Finally, that participants were administered a neuropsychological test battery to assess general intellectual function, speech and language, memory, attention and concentration, and executive function. No significant differences for relevant neuropsychological, demographic, and self-reported variables were noted (McAllister, et al., 2001).

Working memory performance was assessed with n-back tasks. The task involved the presentation of a sequence of stimuli and the participants were tasked to indicate when the stimulus being presented was the same as the one presented n steps before. There were four conditions used: 0-, 1-, 2-, and 3-back. Incorrect and correct responses were recorded. Functional MRIs were administered with a total scanning time of 384 seconds, and the functional whole-brain volume acquired every 3 seconds (McAllister, et al., 2001).

Performance on the working memory tasks was analyzed for 17 mTBI participants and 12 controls. The participants in the mTBI group reported significantly more difficulties with memory, compared to the controls. The mTBI group self-rated their working memory skills as worse than controls on all 18 items on the self-rating scale, 14 items reached statistical significance. Cognitive symptoms were reported frequently from the mTBI participants than the control group; specifically, memory and
concentration difficulties. While the mTBI participants reported significant difficulties, they performed well on the neuropsychological battery. The mTBI group performance only differed from the controls with speed on the Continuous Performance test as well as a letter fluency test. The neuropsychological test battery included: Wisconsin Card Sorting Test, Trail Making Test, California Verbal Learning Test, Facial Memory Test, and the Stroop Interference Test. None of the neuropsychological tests evaluating attention, memory, or executive function yielded significant between-group differences. In addition, the two groups did not differ significantly on the four n-back tests. However, the researchers did observe a significant difference in activation patterns with an increase in working memory load. For example, with the moderate working memory load (2-back task) there was a greater amount of neural activation for the mTBI group but less of an increase with the harder task (3-back), compared to the controls. The observed activation patterns were consistent with the researchers’ hypothesis but they did not observe any performance differences, as they had expected. In summary, with an increase in working memory load, the controls and mTBI groups showed different amounts of activation. A possible explanation of this difference is that the working memory capacity is impaired in the mTBI group but the tasks used to measure the deficits was not challenging enough to display any significant group differences. Furthermore, while performance was similar, the mTBI group perceived more difficulty allocating the necessary resources for the behavioral task. In the end, there was a significant discrepancy between perceived abilities and actual performance. Further work should be performed to assess whether the activation patterns, as shown on the fMRI, persist a year past the time of injury (McAllister, et al., 2001).
The present paper investigates the impact of an mTBI on attention capabilities to better understand the reports of impulsivity and distractibility. Similar to mTBI, impulsivity is a hallmark symptom of ADHD. This impulsivity has been quantified using two non-sensory masking tasks, informational and contralateral masking. Both tasks involve the detection of an adaptively adjusted, 500 Hz signal in the presence of an unpredictable masker. False alarm rates and thresholds were compared between a group of control children to a group of children with ADHD for informational masking and in quiet. Data from a previous study was used to compare performance on contralateral masking. The data showed that all the children performed similarly on informational masking but children with ADHD are more impulsive, when compared to age appropriate controls, when completing the contralateral masking task. Contralateral masking involves a lower level of uncertainty, than informational masking, so children with ADHD tend to become more impulsive with lower levels of unpredictability than controls (Gray, Breier, Foorman, & Fletcher, 2002). Based on the shared symptom, we would expect a group of individuals with an mTBI to perform similarly to the children with ADHD.

In summary, there are a myriad of potential cognitive and auditory implications from an mTBI and the evaluation necessary to understand these effects goes well beyond evaluation for a sensorineural hearing loss. Subjective reports and behavioral measures are both imperative assessment tools because each injury is unique and there are not any clearly identified long-term global deficits. To understand the implications of an mTBI and the resulting auditory and cognitive complaints, a complete evaluation of the auditory system must be conducted and the test battery should include speech-in-noise tasks and psychophysical test measures. Professionals can take the information gained from the
assessment process and incorporate it into the rehabilitation process and work to address the specific needs of the individual with a head injury (Hoover, Souza, & Gallun, 2017).
Appendix B:
Data Collection Form

Participant ID: **SM** __ __ **FM** __ __ **CG** __ __
Staff Member: _________________
Date: _________________

Tympanometry: ____ Normal  ____ Abnormal (testing will still continue)
If abnormal, please explain:

__________________________________________________________________________

__________________________________________________________________________

Injury type: ____ Blast  ____ Non-blast  ____ Not applicable

Post-traumatic stress: Yes ______ No _____

Number of mild TBIs: ______ or ______ Not applicable

First mild TBI at age 25 or less? ____ Yes ____ No ____ Not applicable

Are you currently on a prescription for attention deficits?
____ Yes ____ No ____ Not applicable (no attention deficits)

If yes, what medications? ____________________________
Informed Consent

**Fort Belvoir Community Hospital**

**CONSENT TO PARTICIPATE IN RESEARCH**

**PROTOCOL TITLE:** A simple hearing test to assess attention and focus problems as well as distractibility by background sound in Service Members, Caregivers and FBCH Beneficiaries with or without mild traumatic brain injury

You may be eligible to take part in this research study. This form gives you important information about the study.

Please take time to review this information carefully. You should talk to the researchers about the research study and ask them any questions you have. You may also wish to talk to others (for example, your friends, family, or your personal physician) about your participation in this study. If you decide to take part in this research study, you will be asked to sign this document. Before you sign this document, be sure you understand what the research study is about, including the risks and possible benefits to you.

Please tell these researchers if you are taking part in another research study.

You do not have to take part if you do not want to. You may also leave the research study at any time. If you choose not to take part in this research study or if you leave the study before it is finished, there will be no penalty.

Your decision will not affect your future care at Fort Belvoir Community Hospital.

**1. WHAT IS THE PURPOSE AND DURATION OF THIS RESEARCH AND WHO WILL TAKE PART?**

You are being asked to be in this research study because you are between the ages of 18 and 65, and 1) you have served in the armed forces and have either blast or non-blast mTBI; or 2) you have served in our armed forces and have not had an mTBI, or 3) you are a family member or caregiver of a Service Member with mTBI (and have not had an mTBI yourself).

We are interested in the extent to which you might or might not be distracted by background sounds. You will attempt to decide if a very soft tone is present at the same time as two types of noises of moderate loudness. These noises are somewhat unpredictable in different ways. One but not the other of these noises distracts control listeners. Many other volunteers (both children and adults) have taken these hearing tests with no adverse effects.
The duration of participation per visit is less than one hour.

A total of 15 Service Members with or without mTBI seen at the NICoE Satellite at Ft. Belvoir plus 15 family members plus 15 Service Members at Ft. Belvoir without TBI are expected to take part in this study.

2. SCREENING PROCESS TO QUALIFY FOR PARTICIPATION IN THIS STUDY

Before you can take part in this study, you will need to have some tests and provide some information so that the Investigator can confirm that you qualify for the study. This is called the "Screening Process". These tests may have been done or this information collected as a part of your regular medical care.

3. WHAT WILL HAPPEN IF YOU DECIDE TO BE IN THIS RESEARCH?

As a subject, you will undergo the following procedures:

The testing session may last less than an hour. Before the tests a small device may be put in your ear that will make a soft low-frequency sound and change the pressure in your ear much like going up an elevator. This is a common clinical test called tympanometry. This test indicates whether there may be anything that might obstruct the transmission of sound, if there are any holes in your eardrum, or present ear infections. Next we will ask you to wear headphones and sit at a computer, for a hearing screening. You will simply press the space bar when you hear a tone.

There will be short training exercises to make sure you understand the next two hearing tests. You will hear a noise and sometimes (not always) a tone. You will either press the 'tone' button to indicate that the soft tone was present or the 'no tone' button to indicate that the tone was absent. After successful training, the final exercises will each be 40 trials. The computer has been programmed to try and make you get several of these trials wrong, so don't be upset if the computer gives you feedback that you are incorrect, please just try to relax and do your best.

4. WHAT ARE THE RISKS OR DISCOMFORTS FROM BEING IN THIS RESEARCH?

There may be minor risks, discomforts, and inconveniences associated with any research study. These deserve careful thought. You should talk with the study investigator if you have any questions.

There is no known risk in this study. No sound will be loud enough to cause any hearing damage. It is unlikely, but possible, that you might find wearing the padded headphones to be uncomfortable.
You might experience some frustration during the hearing tasks. The hearing test is challenging as you are trying to detect a soft tone in background noise. If you experience any discomfort or frustration during these tasks you can pause the task and take a break or withdraw from the study at any time.

5. WHAT ARE THE POSSIBLE BENEFITS FROM THIS RESEARCH?

There are no direct benefits to you for taking part in the study. However, others may benefit in the future from the information learned during this study. The possible benefits to others are assisting hearing professionals learn about the effects of mTBI on attention and distractibility.

6. WHAT ARE THE ALTERNATIVES TO TAKING PART IN THIS RESEARCH?

Your alternative is not to participate in this research.

7. IS THERE COMPENSATION FOR YOUR PARTICIPATION IN THIS RESEARCH?

Yes, for your participation, if eligible you will receive $20.00 in the form of a gift card after completion of your part of this study from the JMU collaborator. If you are active duty or civilian on duty, you will not be eligible for this compensation per DOD regulations.

8. ARE THERE COSTS FOR PARTICIPATING IN THIS RESEARCH?

No, there are no costs to you for taking part in this research study.

9. WHO IS CONDUCTING THIS RESEARCH?

This project is being conducted by James Madison University and Fort Belvoir Community Hospital.

10. STUDY SPONSOR (the organizations or persons who oversee the study and are responsible for analyzing the study data):

Name and Rank: Cynthia Zmroczek, M.S., CCC/SLP
Department: Speech Language Pathology
Phone Number: 571-231-1210

11. SOURCE OF FUNDING:

This study is being funded by the Madison Trust at James Madison University.
12. **PRINCIPAL INVESTIGATOR** (the person(s) responsible for the scientific and technical direction of the study):

Cynthia Zmrozek  
National Intrepid Center of Excellence: Intrepid Spirit One (NICoE/ISO)  
Fort Belvoir Community Hospital  
Building 1259  
5980 9th Street  
U.S. Army Garrison, Fort Belvoir, VA 22060

13. **LOCATION OF THE RESEARCH:**

National Intrepid Center of Excellence: Intrepid Spirit One

14. **DISCLOSURE OF FINANCIAL INTERESTS AND OTHER PERSONAL ARRANGEMENTS:**

There are none.

15. **WHO WILL SEE MY INFORMATION (PRIVACY) AND HOW WILL IT BE PROTECTED (CONFIDENTIALITY)?**

Records of your participation in this research study may only be disclosed in accordance with state and federal law, including the Federal Privacy Act, 5 U.S.C. 552a, and its implementing regulations. DD Form 2005, Privacy Act Statement - Military Health Records, contains the Privacy Act Statement for the records. A copy of DD Form 2005 can be given to you upon request, or you can read on-line at:  

Procedures to protect the confidentiality of the data in this study include but are not limited to: coded data and the removal of personal information, all documents will be computer password protection and stored in a locked room in locked drawers.

Researchers will make every effort to protect your privacy and confidentiality; however, there are risks of breach of information security and information loss.

By signing this document, you give your permission for information gained from your participation in this research study to be published in literature, discussed for educational purposes, and used generally to further science. You will not be personally identified; all information will be presented as anonymous data.
Complete confidentiality cannot be promised for military personnel, because information regarding your health may be required to be reported to appropriate medical or command authorities to ensure the proper execution of the military mission, including evaluation of fitness for duty.

The principal investigator will keep your research records. These records may be looked at by staff from the FBCH Department of Research Programs, the JMU Institutional Review Board (IRB), and the DoD Higher Level Review.

Those listed above will have access to your records and agree to safeguard your protected health information by using and disclosing it only as permitted by you in this consent or as directed by state and federal law.

16. WHAT HAPPENS IF YOU ARE INJURED AS A RESULT OF THIS RESEARCH?

If you think that you have a research-related injury, notify your Principal Investigator immediately at 571-231-1210.

If you are injured because of your participation in this research and you are a DoD healthcare beneficiary (e.g., active duty military, dependent of active duty military, retiree), you are authorized space-available medical care for your injury within the DoD healthcare system, as long as you remain a DoD healthcare beneficiary. This care includes, but is not limited to, free medical care at DoD hospitals or DoD clinics.

If you are injured because of your participation in this research and you are not a DoD healthcare beneficiary, you are authorized space-available medical care for your injury at a DoD hospital or an DoD clinic; medical care charges for care at a DoD hospital or a DoD clinic will be waived for your research-related injury. If you obtain care for research-related injuries outside of a DoD or DoD hospital or clinic, you will not be reimbursed for those medical expenses.

For DoD healthcare beneficiaries and non-DoD healthcare beneficiaries: Transportation to and from hospitals or clinics will not be provided or paid for by DoD. Unless you are covered by TRICARE, no DoD reimbursement is available if you incur medical expenses to treat research-related injuries. No compensation is available for research-related injuries. You are not waiving any legal rights.

Although research that uses your samples may lead to the development of new inventions, products, or discoveries (some that might be patented and licensed), there are no plans to pay you for them.

17. WHAT HAPPENS IF I WITHDRAW FROM THIS RESEARCH?

You may withdraw your consent at any time and stop participating in this research study without affecting your eligibility for care or any other benefits to which you are entitled. Should you choose to withdraw, you must notify a study staff member.
Please note that withdrawing your consent to participate in this research does not fully revoke your HIPAA Authorization Form to use/disclose your protected health information. To make that revocation, please send a letter to the principal investigator as discussed in the HIPAA Authorization Form.

The principal investigator of this research study may terminate your participation in this research study at any time if she determines this to be in your best interest, if you are unable to comply with the procedures required, or if you no longer meet eligibility criteria.

18. VOLUNTARY PARTICIPATION.

The decision to take part in this research study is completely voluntary on your part. You will be informed if significant new findings develop during the course of this research study that may relate to your decision to continue participation.

19. INCIDENTAL FINDINGS

There is a possibility that while reviewing your test results we may see an abnormality that we did not expect to see in this study. This is what is called an "incidental finding."

We will let you know if we see such an incidental finding. Depending on the type of incidental finding, we may contact you by phone. In the case of a potential serious emergency, the researcher will inform you right away.

You do not have an option to decline receiving information about an incidental finding. A qualified person (usually a member of the research team) will talk to you if there is an incidental finding.

We will also give information about this incidental finding to your primary doctor or we will refer you to an appropriate doctor for further evaluation.

• An incidental finding may cause you to feel anxious
• Since an incidental finding will be part of your medical record, you could face greater difficulty in getting health or life insurance

The costs for any care that will be needed to diagnose or treat an incidental finding would not be paid for by this research study. These costs would be your responsibility. If you are a DoD beneficiary, you will have access to care through standard Military Health System and TRICARE procedures.
20. Purpose of this Document

An Authorization is your signed permission to use or disclose (release) your health information. The Health Insurance Portability and Accountability Act (HIPAA) Privacy Rule, as implemented by the Department of Defense (DoD), requires that an Authorization contain certain core elements and required statements.

NOTE TO PARTICIPANT: Please read the information below and ask questions about anything you do not understand before deciding to give permission for the use and disclosure (release) of your health information.

A. What health information will be used or disclosed (released) about you?
For this research study, we will be collecting the following information (as applicable):

a. Name  
b. Age  
c. Injury date  
d. History of mild traumatic brain injury/injuries  
e. History of posttraumatic stress disorder  
f. History of select psychiatric diagnoses  
g. Far damage

B. Who will be authorized to use or disclose (release) your health information?

The members of the research team will have access to your health information in order to find out if you qualify to participate in this study, to administer research procedures, to monitor your progress, and/or to analyze the research data. Additionally, your PHI may be made available to groups such as the Department of Research Programs and the Institutional Review Board.

C. Who may receive your health information?

Records may be looked at by the Collaborator at James Madison University (JMU), the JMU IRB, the DOD Higher Level Review, the Food and Drug Administrative, the Department of Health and Human Services Office for Human Research Protections, and the HHS Office for Civil Rights.

D. What if you decide not to sign this authorization?

The MHS will not condition (withhold or refuse) treatment that is not part of this study, payment, enrollment, or eligibility for benefits on whether you sign this Authorization.

E. Is your health information requested for future research studies?

No, your health information is not requested for use or disclosure (release) in future research studies.

F. Can you access your health information during the study?
You may have access to your health information at any time unless your identifiers are permanently removed from the data.

G. Can you revoke this authorization?
   - You may change your mind and revoke (take back) your Authorization at any time except to the extent that the MHS has already acted in reliance on your Authorization. Even if you revoke this Authorization, any person listed above who received your Authorization for purposes of the research study may still use or disclose (release) any already obtained health information as necessary to maintain the integrity or reliability of this research.
   - If you revoke this Authorization, you may no longer be allowed to participate in this research study.

If you want to revoke your Authorization, you must write to: Cynthia Zmroczek, 5980 9th Street, U.S. Army Garrison, Fort Belvoir VA 22060.

H. Does this authorization expire?
   - [ ] No, it does not expire
   - [x] Yes, it expires at end of the research study
   - [ ] Yes, it expires on the following date or event: ____________________________

I. What else may you want to consider?
   - No publication or public presentation about the research described above will reveal your identity without another signed Authorization from you.
   - If all information that does or can identify you is removed from your health information, the remaining deidentified information will no longer be subject to this Authorization and may be used or disclosed (released) for other purposes.
   - Once your health information is shared or disclosed (released) outside of the MHS, the privacy of your health information cannot be guaranteed and it may no longer be protected by the Federal privacy laws (such as the HIPAA Privacy Rule).

21. CONTACT INFORMATION:

   Principal Investigator (PI)
   The Principal Investigator or a member of the research staff will be available to answer any questions throughout this study.

   Principal Investigator: Cynthia Zmroczek
   Phone: 571 231 1210
Mailing Address: 5980 9th Street, Fort Belvoir VA 22060

Institutional Review Board (IRB) Office
If you have any questions about your rights as a research participant or if you have concerns or complaints about the research study, please contact the JMU IRB Office at 540-568-2318, the FBCH DRP office at 571-231-2537, or the FBCH Office of the Command Staff Judge Advocate, Sunrise Pavilion, at 571-231-2887.

IF THERE IS ANY PORTION OF THIS DOCUMENT THAT YOU DO NOT UNDERSTAND, ASK THE INVESTIGATOR BEFORE SIGNING. YOU MAY CONSULT WITH YOUR PERSONAL PHYSICIAN OR LEGAL ADVISOR, IF YOU WISH.

A signed and dated copy of this document will be given to you.

---

**SIGNATURE OF PARTICIPANT**

________________________________________
Printed Name of Participant

________________________________________
Signature of Participant

__
Date

---

**SIGNATURE OF INDIVIDUAL ADMINISTERING CONSENT**
(Can only be signed by an investigator or staff approved to administer consent)

________________________________________
Printed Name of Administering Individual

________________________________________
Signature of Administering Individual

__
Date
Protocol Application Signature

Principal Investigator's Department Chief

I have considered this protocol and am able to approve the personnel and resources necessary
to complete it. I have also reviewed the research timeline and believe it to be realistic given the
investigator's other responsibilities within this department. I understand that I will be the point
of contact for correction of deficiencies should the principal investigator fail to meet the
requirements agreed to in the Principal Investigator Agreement.

[Signature]

[Date] 6/14/16

Maulik Purushot, MD, MPH
Chief of Research and Medical Services, Neurorehabilitation and Traumatic Brain Injury
TBI/ICU at Intrepid Spirit One, Fort Belvoir Community Hospital
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