An Examination of Social Inferencing Skills in Males and Females Following Traumatic Brain Injury

Dawn Neumann, PhD (corresponding author)
Associate Professor, Indiana University School of Medicine, Department of Physical Medicine and Rehabilitation, Indianapolis, IN
Research Director, Rehabilitation Hospital of Indiana
4141 Shore Drive
Indianapolis, IN 46254
Email: dmneuman@iupui.edu
Phone: 317-329-2188

Ryan Mayfield, B.S.
Indiana University School of Medicine, Department of Physical Medicine and Rehabilitation, Indianapolis, IN

Angelle M. Sander, PhD
Associate Professor and Director, Division of Clinical Neuropsychology and Rehabilitation Psychology, H. Ben Taub Department of Physical Medicine and Rehabilitation, Baylor College of Medicine and Harris Health System, Houston, Texas
Senior Scientist and Director of the Brain Injury Research Center, TIRR Memorial Hermann, Houston, Texas

Jeong Hoon Jang, PhD
Assistant Professor, Indiana University School of Medicine, Biostatistics Department, Indianapolis, IN

Surya Sruthi Bhamidipalli, MPH
Biostatistician, Indiana University School of Medicine, Biostatistics Department, Indianapolis, IN

Flora M Hammond, MD
Nila Covalt Professor and Chair, Physical Medicine and Rehabilitation, Indiana University School of Medicine, Indianapolis, IN
Chief of Medical Affairs, Rehabilitation Hospital of Indiana

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ABSTRACT

Objective: This study examines sex differences in social inferencing deficits after traumatic brain injury (TBI), and examines the odds of males and females being impaired while controlling for potential confounders.

Design: Cross-sectional survey.

Setting: Outpatient. .

Participants: One hundred five participants with TBI (60 males, 45 females) and 105 healthy controls (HC; 57 males, 48 females).

Interventions: Not applicable.

Main Outcome Measures: The Awareness of Social Inference Test (TASIT), which includes 1) Emotional Evaluation Test (EET), 2) Social Inference-Minimal (SI-M) test, and 3) Social Inference-Enriched (SI-E) test.

Results: Within the HC sample, males and females performed similarly on all three TASIT subtests. Within the TBI group, males had significantly lower scores than females on EET (P = 0.03), SI-M (P=0.01) and SI-E (P=0.04). Using impairment cutoffs derived from the HC sample, significantly more males with TBI (30%) were impaired on the EET than females(16.7%); impairment was similar between males and females on SI-M and SI-E. When adjusting for executive functioning and education, the odds of being impaired on the EET did not significantly differ for males and females (OR = 0.47; 95% CI: 0.16 - 1.40; P = 0.18).

Conclusions: While more males with TBI have emotion perception deficits than females, the difference appears to be driven by education and executive functioning. Research is needed in larger samples with more definitive norms to better understand social inferencing impairments in males and females with TBI, and translation to interpersonal behaviors.

Key Words: emotions, affect, social inferencing, brain injury, sex differences

Abbreviations

EET: Emotional Evaluation Test

HC: Healthy Control

PHQ-9: Patient Health Questionnaire-9

SI : Social inferencing

SIE: Social Inference Enrinched

SIM: Social Inference Minimal

STAI: State Trait Anxiety Inventory

TASIT: The Awareness of Social Inferencing Test

TBI: Traumatic Brain Injury

ToM: Theory of Mind

People do not often explicitly communicate their feelings or mental states (e.g., beliefs, intentions, expectations), making social inferencing a crucial skill for effectively and appropriately understanding and responding to others. Social inferencing is a process by which nonverbal cues (e.g., facial expressions, tone of voice), verbal cues, and other relevant information (e.g., social context, prior knowledge pertaining to the situation, social norms) are used to determine others' emotions and their mental states (also known as Theory of Mind [ToM]).[1,2] Problems with social inferencing (SI) are common after traumatic brain injury (TBI),[3-7] and have been associated with maladaptive social behavior and social integration.[8] Research is needed to understand who might be at greater risk for SI deficits after TBI.

In the last decade there has been a burgeoning interest in whether SI performance after TBI is influenced by one's sex.[9-13] Research in the general population suggests women are typically better than men at SI,[14-16] and as such, societal expectations and standards for these skills are often higher for women.[17,18] Due to differences in societal expectations for men and women, it is important to understand how males and females compare to one another on SI tasks after TBI, and whether sex influences their outcomes.

Turkstra and colleagues published a review article examining sex differences in SI performance in participants with TBI.[17] Findings were largely mixed. For example, they found significant sex differences with a video-based assessment of SI in a preliminary study;[11] however, they did not find significant sex differences with a subsequent replication sample.[13] Also, Rigon et al. did not find significant sex differences when using static facial expressions on tasks of emotion recognition[12], but did find differences with faces that morphed from one expression to another.[12] Rigon's results suggest the different types of stimuli used (e.g., still images vs dynamic) may partially account for some of the disparities. It was suggested by the authors of the review article that future studies should concentrate on using dynamic stimuli with multiple cues, as they may be more ecologically valid than static images with isolated cues.[17] Other limitations noted included small and imbalanced samples with more men

than women, not distinguishing biological sex from gender (socially constructed characteristics of men and women), and not controlling for potentially confounding variables (e.g., executive functioning).[17]

When it comes to examining sex differences in SI after TBI, an addtional limitation to the shortcomings highlighted by Turkstra et al described above,[17] is that prior studies only compared men and women with TBI based on group averages without considering whether performance was normal or impaired relative to their sex-matched healthy peers. Because rehabilitation aims to treat impairments, it is important to advance our knowledge of SI impairments after TBI that would require intervention, and whether these deficits are more prevalent in men or women.

The current study overcame some prior limitations by using a dynamic, video-based assessment[1] to examine *impaired* SI after TBI, and determine the influence of sex on these outcomes, while controlling for potentially confounding variables. Specifically, study aims were to 1) compare SI performance (emotion recognition and mental state attributions) between men and women with and without TBI; 2) determine the prevalence of impaired SI in men and women with TBI using healthy control (HC) data as a point of reference and compare the proportion of males and females with these deficits; and 3) examine the relative odds of SI impairments for males and females with TBI while controlling for variables that could confound the outcomes (e.g., cognition). Due to the lack of consistent findings in past studies and different assessments, a priori hypotheses were not defined.

METHODS

Study Design and Setting

This cross-sectional survey study was conducted at two TBI rehabilitation hospitals (Rehabilitation Hospital of Indiana and TIRR Memorial Hermann Rehabilitation Hospital) with community dwelling individuals with and without TBI.

Participants

Participants were 105 persons with TBI and 105 HC enrolled in a larger project on social

attribution.[19] Sample size was based on power calculations for the larger project.[19] Participants were recruited from patient databases, support groups, social media, flyers, and university newsletters. HCs were additionally recruited through family and friend referrals from participants with TBI. Recruitment aimed to frequency-match participants with TBI and HC's for sex and age. The study was approved by ethical review boards of both institutions. All participants provided informed consent.

Individuals met inclusion criteria for the parent project.[19] All participants were ≥18 years old; had adequate expressive language abilities to participate (as determined by interaction with the Research Assistant during screening); had good comprehension (minimum of 6/8 correct on a section of the Discourse Comprehension Test)[20]; spoke fluent English, and had no history of psychiatric disorders or developmental disability that could impact social cognition. Participants had complicated mild to severe TBI ≥six months prior to enrollment. Injury severity was classified as moderate-to-severe[21] based on meeting at least one of the following criteria: Glasgow Coma Scale score (GCS) <13 at time of injury, post-traumatic amnesia (PTA)≥24 hours, and/ or loss of consciousness (LOC) ≥30 minutes. Severity was classified as complicated mild if GCS 13-15, PTA <24 hours, LOC <30 minutes, with abnormality on neuroimaging. Classification was based on the worst severity indicator. HC denied any history of neurological disorders and acquired brain injury.

Measures

The Awareness of Social Inference Test (TASIT)[1] is a video assessment of affect recognition and ToM comprised of 3 subtests: 28-item Emotional Evaluation Test (EET) (scores range 0-28); 15-item Social Inference-Minimal (SI-M) (range 0-60); and 16-item Social Inference-Enriched (SI-E) (range 0-64). The sum of correct items for each subtest generate total substest scores. For EET, participants evaluate nonverbal cues to infer what emotions the actors are expressing in each video clip and select from a list of 7 options. SI-M and SI-E evaluate participants' ability to infer what the actors are trying to

Do, Say, Think, and Feel via Yes/No responses to statements that either accurately or falsely describe the characters' mental states. SI-M and SI-E differ in the type of exchanges between the characters and amount of context available. Exchanges in SI-M videos are either sincere or lies and offer minimal context. In contrast, SI-E exchanges are either lies or sarcastic and offer additional context for inferencing. All TASIT components have demonstrated reliability and validity (construct, concurrent, and discriminant).[1,5,22-25]

Stroop Color-word interference test[26,27] is a timed executive functioning test that evaluates attention and proneness to cognitive interference and disinhibition. Participants are shown shown a list of color words (e.g., "red") written in black ink, and are timed while reading the words aloud as quickly as possible. Next, they are shown a list of color words written in a color of ink that is different from the actual word (e.g. the word 'orange' written in green ink). Participants name the color of ink, and inhibit the word that they see. An interference score is calculated that indicates the ability to suppress or inhibit the automated word reading response. The interference score is transformed to a T-score, with a mean of 50 and a standard deviation of 10. A T-score of 50 reflects no interference.

Controlled Oral Word Association Test (COWAT)[28] evaluates verbal fluency. Participants are given one minute to produce as many words as they can that start with a specific letter. The total score is the number of words recalled across three trials.

State Trait Anxiety Inventory (STAI)[29] evaluates subjectively reported state and trait anxiety with two subscales. Participants rate the degree to which they have experienced anxiety-related symptoms on a 4-point Likert scale. Subscale scores range 20-80 and are converted into T-scores. Higher scores indicate greater anxiety. Only the Trait Anxiety Subscale scores were used. The STAI correlates well with other anxiety measures.[30]

Patient Health Questionnaire-9 (PHQ-9)[31] is a 9-item subjective assessment of depression. Scores range from 1-27, with higher scores indicate greater depression.

Data Analyses

Baseline demographic and clinical measurements were compared between males and females, stratified by TBI vs. HC. Variables measured on a continuous scale were compared between the groups with Wilcoxon rank sum test. Chi-square test or Fisher's exact test (if any cell was < 5) was employed for variables measured on the nominal scale. SAS software version 9.4 (SAS Institute Inc, Cary, NC) was utlized. All tests were two-sided with significance level of 0.05.

Wilcoxon rank sum tests were performed to compare mean TASIT EET, SI-M and SI-E scores, between participants with TBI and HCs in the entire sample and by sex within TBI and HC groups separately. The prevalence of SI impairments for each TASIT subtest were calculated for TBI participants, and compared between males and females. While the TASIT manual offers normative data, it was based on small Australian samples of HCs that differed significantly from the characteristics (sex, age) of our TBI sample. Therefore, we used HCs who were matched to our TBI sample on sex and age as the comparison group for determining impairment on the TASIT. Participants were classified as impaired if below a cutoff of mean-1.5*SD below that of the HCs for each of the subtests. A Chi-square test of independence or Fisher's exact test (cells ≤ 5) examined the relationship between sex and impaired SI in TBI. Logistic regression analysis was performed to assess the association between impaired SI status (impaired vs. non-impaired; dependent variable) and sex (primary independent variable), while adjusting for other clinical and demographical factors. Variables with significant univariate associations with TASIT outcomes (i.e., age, age at injury, years of education, race and TBI severity and Stroop score; $p<.05$) as well as variables that could theoretically interact with sex on the TASIT outcomes (i.e., years post-injury, verbal fluency duration, PHQ-9 and STAI) were included in the initial set of variables considered in the model. The final model variables were selected using the following procedure: 1) fit a univariate model for each predictor, and identify those significant at $p=0.2$; 2) fit a model for predictors selected in step 1, and use backward elimination to remove non-significant variables at $p=0.1$; 3) starting with model selected in step 2, consider each of the non-significant variables from step 1 using forward selection, with $p=0.1$; 4) create all possible interaction

terms between sex and the variables remaining in the model after step 3 and used a backward elimination procedure to remove those not significant at p = 0.10.

RESULTS

Differences in demographics between males and females with and without TBI

Table 1 summarizes the demographic and clinical characteristics of the TBI and HC groups by sex. In the TBI group, 57% were male and 43% female and both sexes had similar baseline characteristics except for education, where males had significantly more education years. Among HC participants, 54.3% were male and 45.7% female, and both sex groups were well-matched.

Differences in TASIT scores between males and females with and without TBI

Comparisons of mean TASIT EET, SI-M and SI-E scores between TBI and HC groups, as well as between males and females within the TBI and HC samples, are presented in Table 2. In the entire sample, participants with TBI had significantly lower TASIT EET, TASIT SI-M and SI-E mean scores than HC participants (all p-values < 0.05). In the TBI sample, males had significantly lower scores than females in all three TASIT subtests (P=0.03, 0.01, and 0.03 for EET, SI-M and SI-E, respectively). Among HCs, no significant difference was observed between males and females on all TASIT scores.

Relationship between impaired social inferencing and sex in TBI patients

Comparisons of the percentages of TBI participants with impaired social inferencing by sex are provided in Table 3. Based on the cutoff derived from HC TASIT EET, the percentage of males with impairments (30%) was significantly higher (P = 0.04) than females (16.7%). No signicant differences with cutoffs derived from TASIT SI-M and SI-E.

Table 4 presents the regression analysis results that examines the association between the EET impairment prevalence and sex among participants with TBI while controlling for other clinical and demographic variables selected by the three-step model procedure. Logistic regressions were not calculated for SI-M or SI-E since impairments did not differ by sex on these subtests. Although age at enrollment age at time of injury, years of education, PTA and Stroop were significantly associated with

TASIT EET in separate univariate association analyses, when jointly considered in the logistic regression model, only Stroop and education withstood the three step model selection process and were included in the final model along with sex. EET impairment status was the dependent variable (impaired vs. non-impaired). The odds of impaired emotion perception were 53% lower in females with TBI compared to males with TBI (odds ratio = 0.47; 95% confidence interval: 0.16 to 1.40), however, the association of impairment with sex was not significant when adjusting for Stroop and education.

DISCUSSION

It is clear from past research that on average, persons with TBI often perform significantly poorer on emotion perception and SI tasks compared to HC. The current study found the same to be true in our comparison of participants with and without TBI on all three TASIT subtests. However, less clear from the existing literature is whether emotion perception and SI abilities differ between men and women after TBI. The current study used the TASIT to extend our knowledge about sex differences in SI after TBI, and HC were included as a point of reference. When we compared sex differences within our TBI sample, we found women outperformed males on all three tasks. These findings are consistent with some prior studies, which also reported an advantage for females with TBI relative to males.[9,11,12] Among HCs, both sexes unexpectedly performed similarly on all three subtests of the TASIT. The absence of sex differences in our HC subjects contradicts findings from much of the research in the general population, which more frequently show women to have better SI skills.[14-16] This inconsistency may be a function of the TASIT assessment which was designed to identify broader SI problems in the TBI population compared to non-TBI individuals, and therefore may not be sensitive enough to capture sex differences in a general population. As discussed below, other factors beyond sex (education and executive functioning), appear to be contributing to differences between males and females in the TBI population.

Although our initial findings inidicated sex differences in emotion perception and mental state attribution after TBI, it was unclear from these group-based means how meaningful these differences

were and what would warrant clinical intervention, especially since societal expectations are generally lower for males in this area than women.[17] When we calculated SI impairments (1.5 *SD below that of our HC data),we found significantly more males with TBI (30%) were impaired compared to their female counterparts with TBI (13%) at emotion perception. However, when we calculated the odds of emotion perception impairment while controlling for education and Stroop scores, the odds of females with TBI being impaired at emotion perception (53%) was not significantly less than males with TBI. This suggests sex differences in emotion perception impairment following TBI might be due to differences in education and executive functioning. Prior findings suggest females with TBI may be better than males at executive functioning skills that involve problem-solving and the ability to use verbal feedback to guide responses.[32] Although some studies have not found a significant relationship between some executive functioning and tasks using simple emotion perception stimuli (e.g. facial expression in isolation),[6,12,33,34] this relationship must be explored with complex emotional stimuli (multiple dynamic, affective cues), such as the TASIT, which may have greater cognitive burden. It is possible that the Stroop, which in our study was related to emotion perception performance, more adequately represents performance-based executive function, and may therefore be more relevant to emotion perception than other executive function measures.

When examining impairments in ability to make inferences about others' intentions and beliefs from verbal and nonverbal cues (SI-M and SI-E), we found small percentages of participants were impaired (i.e., $\geq 1.5\ \mathrm{SD\ below\ HC\ means}$), and that the proportion of impairment on these SI tasks did not differ by sex. These results are consistent with one of Turkstra's studies, which also failed to identify sex differences on the *Video of Social Inferencing Tes*t (VSIT),[13] but inconsistent with findings from their earlier study[11], which did find a difference between males and females. The authors noted that sex differences were only found when males and females were not equivalent in level of education and tests of cognitive functioning. Of relevance, they also found VSIT was associated with working memory.[13] In conclusion, Turkstra and colleagues suggested education and cognition (particularly

working memory) may underlie or contribute to sex differences in SI after TBI.

The impairment results should be interpreted with caution due to the small number of participants classified as impaired and because the results were based on our modestly-sized HC sample. However, the impairment data underscore the importance of investigating actual impairment levels rather than mean sex differences. Sex differences between raw scores may not translate to clinically meaningful differenes for males and females with TBI. Because societal expectations differ between men and women for SI abilities, understanding impairment relative to a patient's sex and gender is important. Moreover, understanding when performance is sub-optimal is critical for determining the need for therapeutic intervention.

The results have implications for clinicians interested in assessing potential emotion perception and SI difficulties in persons with TBI. Both men and women with TBI perform worse on measures of emotion perception and on SI compared to HC, and this may contribute to decreased social integration and reduced quality of relationships following TBI. Addition of these measures to clinical assessment batteries may reveal impairments that interventions can target to directly address these important social skills. The full TASIT may be long for clinical purposes. A shortened 28-item version of the TASIT is available and has high correlation with the original TASIT.[35] Given that performance on the Stroop Test was related to impaired emotion perception in the current study, clinicians with limited time may use the Stroop Test as an initial screener for emotion perception deficits. If deficits are identified on the Stroop, more specific SI tests should be administered.

Limitations and Future Directions

Generalizability of the current results are limited to persons who are in the chronic stages of TBI (on average closer to a decade post-injury) and non-impaired discourse comprehension. Although participants with complicated mild-severe TBI was included, approximately 90% had a moderate-to-severe TBI, therefore results might not apply to indivuals with less severe injuries. Distinctions between sex versus gender identity were not examined. Prior researchers have suggested that gender identity,

which is not always consistent with one's biological sex, may be more related to SI than biological sex[17], and therefore should also be investigated in future studies. Exclusion of non-English speakers limits generalizability to persons of other cultural backgrounds, and cultural issues may impact emotion perception and SI. Findings should be interpreted with caution given the sample size, which may not be powered for this study's hypotheses, particularly for the logistic regression model, for which a small number of participants were impaired. Our definition of impairment was based on comparison with our own age- and sex-matched HC group, rather than a larger normative sample. Although 1.5 SD is a common impairment cutoff, it may be too large for the TASIT to detect meaningful differences. Our assessment of excutive functioning was limited. The Stroop measures only certain aspects of executive function (inhibition of automatic responding; speed of information processing), and there may be additional complex measures of executive function that may have a stronger relationship to emotion perception and SI. Future research should examine the relationship of other aspects of executive function (e.g., selective attention, working memory [as indicated by the Turkstra study[13]] problem-solving, and planning/organization) with complex assessments of SI that have ecological validity.

Further research is needed to advance the understanding of SI and sex differences after TBI. Sociatel expectations of men and women are likely to vary by culture, making it critical to determine and differentiate culturally appropriate sex and gender-based normative scores on SI tests. It is also important to identifiy cutoffs that indicate meaningful, functional impairments for males and females that translate to their interpersonal behaviors and social interactions. Establishing SI norms are necessary for interpreting test results in patients with TBI and determining the need for intervention. Also, more work is needed to understand the role of different executive functioning skills on SI performance, which remains unclear to-date due to mixed findings.

CONCLUSION

The current study is unique in using a video-based assessment of emotion perception and SI to

compare impairment in males and females with TBI, after controlling for other relevant variables. While a larger proportion of males with TBI had emotion perception deficits than females, the difference appeared to be driven by education and executive functioning. These findings are not conclusive and should be interpreted with caution. More work continues to be needed to establish a clearer understanding of sex differences in SI after TBI.

Conflicts of Interest/ Grant Funding:

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REFERENCES

1. McDonald S, Flanagan S, Rollins J, Kinch J. TASIT: A new clinical tool for assessing social perception after traumatic brain injury. *J Head Trauma Rehabil.* 2003;18(3):219-238.
2. Sullivan KW, E.; Hopfield, N. . How Children Tell a Lie From a Joke: The Role of Second Order Mental State Attributions. *British Journal of Developmental Psychology.* 1995;13:191-204.
3. Babbage DR, Yim J, Zupan B, Neumann D, Tomita MR, Willer B. Meta-analysis of facial affect recognition difficulties after traumatic brain injury. *Neuropsychology.* 2011;25(3):277-285.
4. McDonald S. Impairments in social cognition following severe traumatic brain injury. *J Int Neuropsychol Soc.* 2013;19(3):231-246.
5. McDonald S, Flanagan S. Social perception deficits after traumatic brain injury: Interaction between emotion recognition, mentalizing ability, and social communication. *Neuropsychology.* 2004;18(3):572-579.
6. Rosenberg H, Dethier M, Kessels RP, Westbrook RF, McDonald S. Emotion perception after moderate-severe traumatic brain injury: The valence effect and the role of working memory, processing speed, and nonverbal reasoning. *Neuropsychology.* 2015;29(4):509-521.
7. Williams C, Wood RL. Impairment in the recognition of emotion across different media following traumatic brain injury. *J Clin Exp Neuropsychol.* 2010;32(2):113-122.
8. Milders M. Relationship between social cognition and social behaviour following traumatic brain injury. *Brain Inj.* 2019;33(1):62-68.
9. Zupan B, Babbage D, Neumann D, Willer B. Sex Differences in Emotion Recognition and Emotional Inferencing Following Severe Traumatic Brain Injury. *Brain Impairment.* 2017;18(1):36-48.
10. Zupan B, Neumann D, Babbage D, Willer B. Sex-based differences in affective and cognitive empathy following severe traumatic brain injury. *Neuropsychology.* 2018;32(5):554-563.
11. Turkstra LS. Conversation-based assessment of social cognition in adults with traumatic brain injury. *Brain Inj.* 2008;22(5):397-409.
12. Rigon A, Turkstra L, Mutlu B, Duff M. The female advantage: sex as a possible protective factor against emotion recognition impairment following traumatic brain injury. *Cogn Affect Behav Neurosci.* 2016;16(5):866-875.
13. Turkstra L, Norman R, Mutlu B, Duff M. Impaired theory of mind in adults with traumatic brain injury: A replication and extension of findings. *Neuropsychologia.* 2018;111:117-122.
14. Hall JA, Matsumoto D. Gender differences in judgments of multiple emotions from facial expressions. *Emotion.* 2004;4(2):201-206.
15. Kessels RP, Montagne B, Hendriks AW, Perrett DI, de Haan EH. Assessment of perception of morphed facial expressions using the Emotion Recognition Task: normative data from healthy participants aged 8-75. *J Neuropsychol.* 2014;8(1):75-93.
16. Weisenbach SL, Rapport LJ, Briceno EM, et al. Reduced emotion processing efficiency in healthy males relative to females. *Soc Cogn Affect Neurosci.* 2014;9(3):316-325.
17. Turkstra LS, Mutlu B, Ryan CW, et al. Sex and Gender Differences in Emotion Recognition and Theory of Mind After TBI: A Narrative Review and Directions for Future Research. *Front Neurol.* 2020;11:59.

18. Stafslien EHD, Turkstra LS. Sex-based differences in expectations for social communication after TBI. *Brain Inj.* 2020;34(13-14):1756-1762.
19. Neumann D, Sander AM, Perkins SM, Bhamidipalli SS, Hammond FM. Negative Attribution Bias and Related Risk Factors After Brain Injury. *J Head Trauma Rehabil.* 2021;36(1):E61-E70.
20. Brookshire R, Nicholas L. Discourse comprehension test. *Tucson, AZ: Communication Skill Builders.* 1993:105-108.
21. Malec JF, Brown AW, Leibson CL, et al. The Mayo classification system for traumatic brain injury severity. *Journal of Neurotrauma.* 2007;24(9):1417-1424.
22. Bibby H, McDonald S. Theory of mind after traumatic brain injury. *Neuropsychologia.* 2005;43(1):99-114.
23. McDonald S, Flanagan S, Martin I, Saunders C. The ecological validity of TASIT: A test of social perception. *Neuropsychological Rehabilitation.* 2004;14(3):285-302.
24. McDonald S, Saunders J. Differential impairment in recognition of emotion across different media in people with severe traumatic brain injury. *Journal of the International Neuropsychological Society.* 2005;11(4):392-399.
25. McDonald S, Bornhofen C, Shum D, Long E, Saunders C, Neulinger K. Reliability and validity of The Awareness of Social Inference Test (TASIT): a clinical test of social perception. *Disability and rehabilitation.* 2006;28(24):1529-1542.
26. Stroop JR. Studies of interference in serial verbal reactions. *Journal of experimental psychology.* 1935;18(6):643.
27. Golden CJ, Freshwater SM. Stroop color and word test. 1978.
28. Spreen O, Strauss E. Controlled oral word association (word fluency). *Spreen O, Strauss E A compendium of neuropsychological tests Oxford: Oxford Univ Pr.* 1991:219-227.
29. Spielberger CD, Gorsuch RL, and , R.E. L. *Manual for the State-Trait Anxiety Inventory.* Palo Alto, CA: Consulting Psychologists Press; 1970.
30. Spielberger CD, Reheiser EC, Ritterband LM, Sydeman SJ, Unger KK. *Assessment of Emotional States and Personality Traits: Measuring Psychological Vital Signs, Clinical Personality Assessment: Practical Approaches.* In Butcher, J.N. (Ed.): New York: Oxford University Press; 1995.
31. Kroenke K, Spitzer RL, Williams JBW. The PHQ-9. *Journal of General Internal Medicine.* 2001;16(9):606-613.
32. Niemeier JP, Marwitz JH, Lesher K, Walker WC, Bushnik T. Gender differences in executive functions following traumatic brain injury. *Neuropsychol Rehabil.* 2007;17(3):293-313.
33. Spikman JM, Timmerman ME, Milders MV, Veenstra WS, van der Naalt J. Social cognition impairments in relation to general cognitive deficits, injury severity, and prefrontal lesions in traumatic brain injury patients. *J Neurotrauma.* 2012;29(1):101-111.
34. Yim J, Babbage DR, Zupan B, Neumann D, Willer B. The relationship between facial affect recognition and cognitive functioning after traumatic brain injury. *Brain Inj.* 2013;27(10):1155-1161.
35. Honan CA, McDonald S, Sufani C, Hine DW, Kumfor F. The awareness of social inference test: Development of a shortened version for use in adults with acquired brain injury. *The Clinical Neuropsychologist.* 2016;30(2):243-264.