

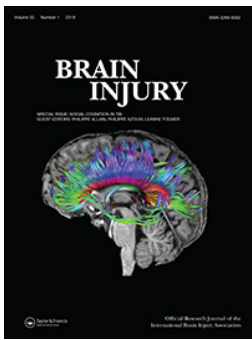
## PDF hosted at the Radboud Repository of the Radboud University Nijmegen

The following full text is a publisher's version.

For additional information about this publication click this link.

<http://hdl.handle.net/2066/199745>

Please be advised that this information was generated on 2020-09-10 and may be subject to change.



## Participation after traumatic brain injury: the surplus value of social cognition tests beyond measures for executive functioning and dysexecutive behavior in a statistical prediction model

Herma J. Westerhof- Evers, Luciano Fasotti, Joukje van der Naalt & Jacoba M. Spikman

To cite this article: Herma J. Westerhof- Evers, Luciano Fasotti, Joukje van der Naalt & Jacoba M. Spikman (2019) Participation after traumatic brain injury: the surplus value of social cognition tests beyond measures for executive functioning and dysexecutive behavior in a statistical prediction model, *Brain Injury*, 33:1, 78-86, DOI: [10.1080/02699052.2018.1531303](https://doi.org/10.1080/02699052.2018.1531303)

To link to this article: <https://doi.org/10.1080/02699052.2018.1531303>



© 2018 The Author(s). Taylor & Francis Group, LLC



Published online: 16 Oct 2018.



Submit your article to this journal [↗](#)



Article views: 1137



View related articles [↗](#)



View Crossmark data [↗](#)



Citing articles: 2 View citing articles [↗](#)

# Participation after traumatic brain injury: the surplus value of social cognition tests beyond measures for executive functioning and dysexecutive behavior in a statistical prediction model

Herma J. Westerhof- Evers<sup>a,b</sup>, Luciano Fasotti<sup>c</sup>, Joukje van der Naalt<sup>d</sup>, and Jacoba M. Spikman<sup>a,d</sup>

<sup>a</sup>Department of Clinical and Developmental Neuropsychology, University of Groningen, Groningen, The Netherlands; <sup>b</sup>Department of Rehabilitation Medicine, University of Groningen, University Medical Center Groningen, The Netherlands; <sup>c</sup>Donders Institute for Brain, Cognition and Behaviour, Radboud University, Donders Institute for Brain, Cognition and Behaviour, Nijmegen, The Netherlands; <sup>d</sup>Department of Neurology, University of Groningen, University Medical Center Groningen, Groningen, The Netherlands

## ABSTRACT

**Objective:** This study evaluates the contribution of measures for social cognition (SC), executive functioning (EF) and dysexecutive behavior to the statistical prediction of social and vocational participation in patients with traumatic brain injury (TBI), taking into account age and injury severity.

**Method:** A total of 63 patients with moderate to severe TBI participated. They were administered a semi-structured Role Resumption List for social (RRL-SR) and vocational participation (RRL-RTW). EF was measured with planning- and switching tasks. Assessment of SC included tests for facial affect recognition and Theory of Mind (ToM). Dysexecutive behavior was proxy-rated with a questionnaire. Additionally, healthy controls were assessed with the same protocol.

**Results:** Patients with TBI performed significantly worse on tests and had significantly more behavioral problems compared to healthy controls. Hierarchical multiple regression analyses for the TBI group revealed that SC accounted for 22% extra variance in RRL-RTW and 10% extra variance in RRL-SR, which was significant over and above the amounts of variance explained by EF, dysexecutive behavior, age and injury severity.

**Conclusions:** Our findings underline the added value of measures of SC and dysexecutive behavior in the prediction of social and vocational participation post-TBI. In particular, impairments in ToM, and dysexecutive behavior were related to a lower participation making them important targets for rehabilitation.

## ARTICLE HISTORY

Received 4 January 2018  
Revised 15 September 2018  
Accepted 27 September 2018

## KEYWORDS

Traumatic brain injury (TBI); social cognition; dysexecutive behavior; participation; return to work; outcome

## Introduction

Traumatic brain injury (TBI) is a major cause of mortality and disability (1,2), with worldwide 10 million new cases annually (3). In particular moderate to severe TBI results in a wide range of emotional, cognitive and behavioral sequelae (4–6), with a negative impact on long-term participation (7,8). Participation refers to people's societal roles, including the maintenance of social relationships and vocational functioning (9). Many patients who have sustained moderate to severe TBI encounter problems in the resumption of social and vocational roles and may become socially isolated (10,11). Therefore, it is important to find the predictors of an unfavorable outcome and to identify patients at risk for participation problems at an early stage. Such a prediction entails an analysis of clinically relevant variables in regression models, with the purpose of allowing the prediction of forthcoming problems. This allows timely intervention treatment or counseling aimed at preventing an unfavorable outcome.

The majority of the studies investigating long-term outcome following TBI have focused on personal and environmental predictors like age, pre-injury unemployment, pre-injury

substance abuse, or injury severity (12,13). These variables have been found to be significant predictors of outcome in regression models (14,15). Adding cognitive measures of information processing speed, memory and executive functioning (EF) to injury severity and demographic predictors was found to significantly increase the strength of outcome prediction models (8,16,17). In particular, deficits in executive function have been identified as important barriers to work and societal participation post-TBI (16,18,19). Since executive functions are crucial for effective goal-setting, planning and switching, they enable adaptation to novel and complex everyday life situations (20). Two studies reported that EF explained a unique part of the variance in work and functional outcome post-TBI (16,18), as well as in social integration (21). There is increasing evidence that in addition to cognitive and executive deficits, impairments in social cognition (SC) are also frequent in moderate to severe TBI (22–25). SC refers to the processing of social information and includes the ability to perceive social cues, for instance facial emotional expressions. It also entails the understanding of the mental states of others, that is, their thoughts, feelings and intentions, also referred to as Theory of Mind (ToM) (26,27). Both, emotion recognition and ToM can be measured with

specific tests. In a growing number of studies it has been found that social cognitive information processing skills, measured with tests for emotion recognition and ToM, are related to inadequate psychosocial behavior following TBI (28–30). Hence, it seems plausible that the presence of such behaviors may also influence work and societal participation negatively. To date, only one study investigated the impact of SC deficits on participation. Ubukata and colleagues found that impaired ToM was a significant predictor of incomplete self-reported functional outcome (31). However, studies that investigate the extent to which different aspects of SC are related to different domains of participation (work, social reintegration), and in particular, that compare the predictive value of these measures to usual measures of EF, are lacking.

Furthermore, Struchen and colleagues (2011) found that self-perceived social communication and behavioral problems contribute significantly to self-reported poor functional and social integration outcome after TBI (21). This suggests that in addition to tests for EF or SC, measures of problematic daily life behaviors may also be relevant indicators of participation problems. Baddeley and Wilson (1988) introduced the term ‘dysexecutive syndrome’ which describes the behavioral changes that used to be associated with damage to prefrontal brain areas (32). The dysexecutive syndrome includes both, difficulties in planning and organization that are likely the result of EF impairments, as well as changes in social and interpersonal behavior that might be a consequence of impaired SC. In particular, behavior can be described by excess and by default. Damage to the frontal convexity might be at the root of egocentricity, lack of initiative, and planning deficits whereas orbitofrontal damage gives rise to emotion regulation deficits, resulting in agitation, disinhibition, irritability, and loss of social norms (33,34). A well-known instrument to measure these dysexecutive behaviors is the Dysexecutive Questionnaire (DEX) (35). The DEX consists of a self-report and proxy-rated version. As poor self-awareness is frequently seen in patients with TBI, including ratings of the patients’ dysexecutive behavior in everyday life by a significant other seems crucial (36,37).

The present study was conducted to investigate the predictive value of tests for EF and SC as well as of a questionnaire for dysexecutive behaviors, for social and vocational participation in the chronic stage after moderate to severe TBI. Our aim was to establish whether measures of emotion recognition and ToM had added predictive value beyond the value of measures of proxy-rated dysexecutive behavioral problems and EF, after controlling for age and injury severity.

## Methods

### Ethics statement

This study was part of a prospective multicenter randomized controlled trial (RCT) aimed at evaluating behavioral changes following TBI, approved by the medical ethical committee of the University Medical Center Groningen, the Netherlands (METc2011.094) and registered with study ID ISRCTN81350364. All participants gave informed written consent prior to study inclusion, granting permission to use

personal information for research purposes, and were treated in accordance with the declaration of Helsinki.

### Participants and procedure

The patient group consisted of 63 participants with TBI (51 males, 12 females). A total of 52 of them had previously been admitted to the Neurology or Rehabilitation department at the University Medical Center Groningen (UMCG) and 11 had been treated in two other Dutch rehabilitation centers. Neurologists or rehabilitation physicians referred patients with behavioral problems or suspected SC impairments as part of a routine follow-up after neuropsychological testing. Eligible candidates (a) had an age between 18 and 65 years, (b) had sustained a moderate to severe TBI, (c) were outpatients in the subacute and chronic phase, (d) had no severe cognitive comorbidity (i.e., amnesic syndrome, global aphasia, neglect or dementia), (e) had no serious psychiatric disorders (i.e., depression) or other neurological diagnoses, (f) were eligible for rehabilitation treatment and (g) suffered from impairments in SC as indicated by defective scores on the FEEST and/or behavioral changes as indicated by proxy-ratings on the Dysexecutive Questionnaire (35). All patients underwent neuropsychological assessment at the hospital or rehabilitation center. This assessment included a semi-structured interview with a neuropsychologist, measuring the levels of social and vocational participation, tests for SC and EF, and a questionnaire for dysexecutive behavioral functioning. A proxy of the patient (life partner, family member, or friend) completed the Dysexecutive questionnaire. The participants with TBI were classified according to the Mayo classification (38). This classification is either based on the Post-traumatic amnesia (PTA) duration, initial Glasgow Coma Scale score (GCS) or imaging data. The imaging data had been used to help identify patients with a suspected mild TBI, for whom no reliable PTA or GCS score was available and who had to be excluded from this study. Using these criteria, 24 patients with TBI were classified as moderate and 39 as severe. For 57 patients data about the duration of the Post Traumatic Amnesia (PTA) were available; mean PTA duration was 32.4 days (SD 41.1), with a range from 1 to 182 days. To classify the 6 patients without a PTA score, GCS scores or imaging data (interpreted by a neurologist) were used for classification. Of all patients, 43 had survived a traffic accident (68%), 19 a fall (30%) and 1 a non-violent external force (2%). Mean time since injury was 105 months (SD = 103) on average, ranging from 6 months to 35 years. The TBI group had a mean age of 42 years (SD = 13, range 18–64). Median educational level was 5 (39%) on a scale ranging from 1 (primary school drop-out) to 7 (university degree) (39).

In order to assess whether patients had impairments in SC, EF and dysexecutive behavior we tested for differences between the scores of patients with TBI and the scores of two separate healthy control groups who had taken part in earlier studies at our department (40,41). Exclusion criteria for these healthy controls were (a) the presence (or history) of severe neurological or psychiatric disorders, (b) being a psychology student. The two healthy groups were separately matched with the patients for age, education and gender. The first group consisted of 72 healthy controls, for whom test scores for SC and proxy-ratings on the

DEX questionnaire were available; these controls had a mean age of 45.0 (SD 15.4), mean educational level of 5.2 (SD 1.3) and a male/female ratio 68/32. Chi-square and  $t$  tests showed no significant differences with the TBI patients with respect to: male/female ratio  $X^2 = 0.42$ ;  $p = .52$ , age  $t(134) = -.91$ ,  $p = 0.36$ , educational level  $t(134) = 1.27$ ,  $p = 0.21$ . In the second healthy control group, 45 controls had completed the tests for EF. In this group, mean age was 47.1 (SD 11.8), mean educational level 5.3 (SD 0.9) and male/female ratio 67/33. Again, no differences were found with the TBI patients for male/female ratio  $X^2 = 2.75$ ;  $p = .10$ , age  $t(106) = -1.85$ ,  $p = 0.07$  and educational level  $t(106) = -1.50$ ,  $p = 0.14$  respectively.

## Measures

### Social and vocational participation

The Role Resumption List (RRL) (42), assesses changes in the amount and the quality of roles in different domains of everyday life. It is based on a semi-structured interview. In the present study, we used two RRL sub-scales: Return To Work (Participation RTW) (43) and Social Roles (Participation SR). Both domains were rated by an assessor who was blind for test and questionnaire results. For Participation RTW ratings were given on a 5-point scale (0 = full return to former job/study, 1 = return to former job/study, but with lower demands (i.e. less tasks, less working hours), 2 = working on a lower level, 3 = working in a protected environment, and 4 = no work or study at all). Participation SR ratings were also given on a 5-point scale with the following steps: 0 = no change at all in social relations, 1 = no change in social relations, but with lower intensity or frequency, 2 = some change or loss in social relations and, 3 = poor ability to maintain social relations and serious loss of social relations, 4 = inability to maintain social relations at all.

### Social cognition

**Emotion recognition.** The Facial Expressions of Emotion: Stimuli and Tests (FEEST) (44), is a test for facial emotion recognition (happiness, anger, surprise, fear, disgust, and sadness). A total of 60 pictures are shown for 3 seconds each. Sub-scores for each emotion can range from 0 to 10 and the overall score ranges from 0 to 60.

**Theory of mind.** The Cartoon Test (CT) (45) is a test for ToM measuring the ability to infer mental states. The participant is asked to describe the joke that the cartoonist intended to convey in the pictures. The ability to understand first (non-ToM cartoons) and second order beliefs (ToM cartoons) is assessed. Answers are rated on a 4-point scale (0–3 points), with a total score ranging from 0 to 36.

The short version of the Faux Pas (FP) test (23,46) measures the detection of a “faux pas” (a social blunder) in 10 short stories, of which 5 contain a faux pas. Discovering whether a faux pas was committed (and if so, recognizing by whom) is scored and forms the FP detection score, ranging from 0 to 10.

### Executive function

**Planning.** The Zoo Map Test, a subtest of the Behavioral Assessment of Dysexecutive Syndrome (BADS) (47),

measures planning and problem-solving (48,49). The Zoo Map Test is ecologically valid and predicts executive daily life behavior (48,50). Participants are instructed to plan a visit to specific locations on a map. The test requires the generation of complex planning strategies and must be carried out following several restricting rules. The maximum score is 16 and the minimum score can be lower than zero.

**Switching.** The Controlled Oral Word Association Test (COWAT) is a verbal task intended to measure verbal fluency and executive control (51). Participants are asked to generate as many words as possible that begin with a specific letter (D-A-T, K-O-M or P-G-R), while in the meantime they have to comply to three rules. Abwender and colleagues (2001) have stressed the importance of switching ability in verbal fluency tasks since it includes the ability to create clusters, alter search criteria and switch from one cluster to the next (52). The total number of words generated across three trials (1 minute per trial) was calculated.

The Trail Making Test (TMT) is a paper and pencil task for EF. Completion time for Part B (TMT-B) was used as a measure of cognitive flexibility (53). In TMT-B, numbered as well as lettered circles have to be connected in ascending sequence while alternating between the two, by drawing lines (54).

### Dysexecutive behavior

To measure dysexecutive behavior, a proxy-questionnaire for participants' behavioral functioning in everyday life was administered. The Dysexecutive Questionnaire (DEX) (35) measures the presence of executive and social behavioral symptoms in everyday life. Answers are given on a five-point Likert-type scale, from 0 = “never” to 4 = “very often” (range 0–80). The proxy-questionnaire was filled-in by life partners, family members or friends, for the patients with TBI as well as for healthy controls. A prerequisite for filling in the DEX-proxy was frequent contact with the participant, preferably on a daily base.

### Statistical analysis

Spearman correlation coefficients (two-tailed) were calculated to examine the relationships between predictor and outcome variables and to examine the relationship between time since injury (TSI) and measures for SC and dysexecutive behavior. Univariate statistics (means and standard deviations for continuous variables and frequencies and percentages for categorical variables) were used to describe the participants' sociodemographic characteristics. Chi-square tests were used to test whether social and vocational participation differed across gender. To test for differences between the group with TBI and the healthy groups, T-Tests were used when assumptions for parametric tests were met, whereas Mann–Whitney U tests were performed in case of skewed distributions. Subsequently, to reduce the number of variables, composite scores were created by calculating Z-scores, correcting these for direction and adding the transformed Z-scores for the two EF-Switching tasks (Letterfluency, TMT-B), resulting in a single EF-Switching variable. The same procedure, without correction for direction, was applied to two tests for ToM (Cartoons Test, Faux Pas Test), resulting in the variable SC-ToM. Spearman correlation coefficients were calculated to analyze the relationship between

tests within the SC domain and between tests within the EF domain. Two separate series of hierarchical multiple regression analyses were conducted for the outcome variables (RRL-RTW, RRL-SR). For each outcome variable in the first block, injury-severity (dummy variable, 0 = moderate TBI, 1 = severe TBI) and age were entered. In the second block the EF predictors were added, whereas in the third block dysexecutive behavior (DEX-proxy) and in the fourth block SC (emotion recognition, SC-ToM) were entered.

## Results

### Differences between patients with TBI and healthy controls

Patients with TBI performed significantly poorer than healthy controls on all measures of SC and EF (Table 1). Further, proxies of patients with TBI reported significantly more behavioral problems on the DEX compared to the proxies of healthy controls.

### Correlations between TSI and test results, and within the SC and EF domain

In the patient group, time since injury was significantly correlated with the FEEST ( $R_s$  0.26,  $p = 0.04$ ), but not with the other measures: Cartoons Test ( $R_s$  -0.12,  $p = 0.35$ ), Faux Pas Test ( $R_s$  -0.06,  $p = 0.62$ ), DEX-proxy ( $R_s$  0.13,  $p = 0.32$ ), Letterfluency ( $R_s$  0.16,  $p = 0.22$ ), Zoo Map Test ( $R_s$  -0.24,  $p = 0.06$ ) or TMT-B ( $R_s$  0.20,  $p = 0.12$ ).

Within the SC domain, scores on the FEEST were significantly correlated with the Faux Pas Test ( $R_s$  0.35,  $p < 0.01$ ), but not with the Cartoons Test ( $R_s$  0.17,  $p = 0.19$ ). The Cartoons Test was significantly correlated with the Faux Pas Test ( $R_s$  0.32,  $p = 0.01$ ). Within the EF domain, the Letterfluency was significantly correlated with the TMT-B ( $R_s$  -0.27,  $p = 0.04$ ), but not with the Zoo Map Test ( $R_s$  0.22,  $p = 0.09$ ). Scores on the Zoo Map Test were not significantly correlated with the TMT-B ( $R_s$  -0.19,  $p = 0.13$ ).

### Level of participation

Percentages for Participation RTW levels per score were as follows: 0 = 11%, 1 = 19%, 2 = 16%, 3 = 11%, 4 = 43%, with a median score of 3 (IQR 3). Eighty-nine percent of the patients with TBI did not return to their former level of work or study. For Participation SR the median score was 2 (IQR 0), with the following percentages per score: 0 = 0%, 1 = 19%, 2 = 59%, 3 = 22%, 4 = 0%. Not a single patient returned to the previous level of social functioning.

### Correlations between participation and relevant measures

As shown in Table 2, there were significant positive correlations between Injury severity and both participation measures, indicating that having sustained a severe TBI was related to a lower social and vocational participation score. A poor SC-ToM score and more behavioral problems, as rated by DEX-proxy, were both found to be significantly correlated with lower social and

**Table 1.** Means, standard deviations and independent samples T- tests, for the patient group with TBI and healthy controls on tests for EF and SC, and behavioral ratings.

Measure	Patient group	Control group	T/Z	p (two-tailed)
	M (SD)	M (SD)		
<b>SC</b>				
FEEST <sup>a</sup>	44.0 (7.3)	47.9 (4.9)	-4.28	<.001
Cartoons Test <sup>a</sup>	18.0 (6.6)	23.1 (6.4)	-5.69	<.001
Faux Pas Test <sup>a</sup>	8.8 (1.3)	9.3 (0.9)	-2.27	.025
<b>EF</b>				
Zoomap Test <sup>b</sup>	11.4 (4.4)	13.2 (3.2)	2.11	.035
Letter fluency <sup>b</sup>	32.1 (10.8)	41.7 (11.9)	-4.38	< .001
TMT-B <sup>b</sup>	77.2 (27.8)	55.7 (17.1)	-4.28	< .001
<b>Dysexecutive behavior</b>				
DEX-proxy <sup>b</sup>	33.3 (10.4)	16.01 (10.7)	9.51	< .001

Note. FEEST: Facial Expressions of Emotion Stimuli and Tests. DEX-proxy: Dysexecutive Questionnaire- proxy ratings. TMT-B: Trailmaking Test- part B. <sup>a</sup> patient group  $n = 63$ ; healthy controls  $n = 72$ , <sup>b</sup> patient group  $n = 63$ ; healthy controls  $n = 45$ .

**Table 2.** Spearman correlations between injury severity, age, SC, behavior, EF and both participation measures.

	RRL-RTW	RRL-SR
Injury Severity	0.31*	0.29*
Age	0.14	-0.06
FEEST	-0.29*	-0.07
SC-ToM	-0.41**	-0.44**
DEX-proxy	0.26*	0.31*
EF-switching	-0.13	-0.19
EF-planning	0.07	-0.07

Note. FEEST: Facial Expressions of Emotion Stimuli and Tests. SC-ToM; Theory of Mind (Cartoons Test and Faux Pas test), DEX-proxy: Dysexecutive questionnaire – proxy rated. EF-switching: Executive functioning-Switching (TMT-B and Letterfluency), EF-planning: Executive functioning – planning (Zoomap Test), RRL-RTW: Role Resumption List – subscale Return To Work (Rs), RRL-SR: Role Resumption List – subscale Social Relations (Rs). \*  $p < 0.05$ , \*\*  $p < 0.01$ .

vocational participation. Age and EF measures showed no significant correlations with both participation measures.

### Multiple regression analyses

In Table 3, the results of the hierarchical multiple regression analyses with vocational participation (RRL-RTW) as dependent variable are displayed. In block 1, injury severity and age were entered in the regression model, accounting for 13% of the variance. In block 2, both EF variables were added to the model, accounting for 2% additional variance. In block 3, DEX-proxy was added, accounting for a significant 10% extra variance. In block 4, the full model, the SC measures FEEST and SC-ToM were added. These predictors accounted for an additional significant 21% of the overall explained variance in vocational participation (RRL-RTW). In sum, this full model explained 46% of the variance in the patients' level of vocational participation ( $F_{[7,55]} = 6.718$ ,  $P = < 0.001$ ). Significant predictors in this full model were SC-ToM, Age, DEX-proxy, Injury Severity and EF-planning. Injury severity appeared to be a stable predictor, accounting for a significant amount of variance across the four blocks. The predictors Age and EF-planning accounted for a unique significant part of variance only when entered together with the SC and behavioral variables (block 4). Patients with a higher SC-ToM score, lower DEX-proxy score, younger age, moderate TBI and lower EF planning score had a lower RRL-RTW score indicating better vocational functioning.

Table 4 shows the results of the hierarchical multiple regression analyses with social participation (RRL-SR) as dependent variable. In block 1, injury severity and age were entered, accounting for 9% of the variance. In block 2, EF-planning and EF-switching were added, accounting for an additional 5% of variance. In block 3, DEX-proxy was added, accounting for an extra significant 8% of the variance. In the full model (block 4), when FEEST and SC-ToM were added, 10% of additional significant variance in social participation was accounted for. In sum, the full model explained 32% of the variance ( $F_{[7,55]} = 3.610$ ,  $P = .003$ ). The only significant predictors in this full model were the scores on SC-ToM and DEX-proxy. Injury severity was the only predictor that accounted for a unique significant part of the variance in the first and second block, whereas it did not contribute significantly to the final model when social cognitive and behavioral measures had been entered. So, a higher SC-ToM score and a lower DEX-proxy score predict a lower RRL-SR score, indicating a higher level of social participation.

### Discussion

To date, this is the first study revealing that social cognitive impairments as well as dysexecutive behavioral problems are significant predictors of lower social and vocational participation in patients with a moderate to severe TBI in the subacute and chronic stage. Strikingly, the full prediction model, including ToM and behavioral predictors, added a unique significant

**Table 3.** Hierarchical multiple regression analysis on vocational participation (RRL-RTW), by injury severity, age, EF, behavior and SC.

Blocks of predictors	Model 1			Model 2			Model 3			Model 4		
	B	$\beta$	p<	B	$\beta$	p	B	$\beta$	P	B	$\beta$	p<
1st block:												
Injury severity	1.03	0.34	0.006	1.04	0.34	0.007	0.99	0.33	0.006	0.73	0.24	0.029
Age	0.02	0.18	0.140	0.02	0.18	0.163	0.04	0.32	0.018	0.04	0.35	0.004
2nd block: EF												
EF-planning <sup>a</sup>				0.18	0.13	0.303	0.19	0.14	0.244	0.31	0.23	0.038
EF-switching <sup>b</sup>				-0.08	-0.09	0.496	-0.03	-0.04	0.774	0.22	0.24	0.059
3rd block:												
DEX-proxy							0.66	0.34	0.009	0.65	0.33	0.003
4th block:												
FEEST										-0.21	-0.17	0.140
SC-ToM <sup>c</sup>										-0.42	-0.47	0.001
$\Delta R^2$ (R2 change)	13.4%, p < 0.05			15% (2%), p < 0.05			25% (10%), p < 0.01			46% (21%), p < 0.001		

Note. <sup>a</sup> Zoomap Test, <sup>b</sup> composite score TMT-B and Letterfluency, FEEST: Facial Expressions of Emotion Stimuli and Tests, <sup>c</sup> SC-ToM: Theory of Mind (composite score Happé Cartoons and Faux Pas test), DEX-proxy: Dysexecutive questionnaire – proxy rated.

**Table 4.** Hierarchical multiple regression analysis on social participation (RRL-SR), by injury severity, age, EF, behavior and SC.

Blocks of predictors	Model 5			Model 6			Model 7			Model 8		
	B	B	p<	B	$\beta$	p<	B	$\beta$	P	B	$\beta$	p<
1st block:												
Injury severity	0.38	0.29	0.023	0.38	0.29	0.024	0.36	0.27	0.026	0.22	0.17	0.174
Age	-0.01	-0.32	0.797	-0.01	-0.10	0.437	0.01	0.03	0.845	0.01	0.05	0.708
2nd block: EF												
EF-planning <sup>a</sup>				-0.02	-0.04	0.768	-0.02	-0.03	0.816	0.03	0.05	0.663
EF-switching <sup>b</sup>				-0.08	-0.21	0.119	-0.06	-0.16	0.216	-0.01	-0.01	0.988
3rd block:												
DEX-proxy							0.26	0.31	0.020	0.27	0.32	0.012
4th block:												
FEEST										0.02	0.04	0.781
SC-ToM <sup>c</sup>										-0.16	-0.40	0.007
$\Delta R^2$ (R2 change)	9%, p = 0.065			13% (5%), p = 0.078			21% (8%), p = 0.016			32% (10%), p = 0.003		

Note. <sup>a</sup> Zoomap Test, <sup>b</sup> composite score TMT-B and Letterfluency, FEEST: Facial Expressions of Emotion Stimuli and Tests, <sup>c</sup> SC-ToM: Theory of Mind (composite score Happé Cartoons and Faux Pas test), DEX-proxy: Dysexecutive questionnaire – proxy rated.

amount of variance over and above models with biographical and injury related variables (age, injury severity) and EF measures only. Several studies have reported that executive dysfunction is the major predictor for poor productivity or long-term outcome (16,18,19), but we found that adding measures for proxy-rated dysexecutive behavior and SC (in particular ToM) each significantly increase the amount of variance explained. This underlines the importance of including such measures of SC and behavioral problems in neuropsychological assessment, as they are likely to be relevant indicators of a negative long-term outcome.

Our TBI group had impairments in SC and EF, performing significantly worse than healthy controls on all tests. This result is consistent with earlier findings (23). As expected, proxy-ratings for behavioral problems were significantly higher in the patient group than in healthy controls. Thus, we found that our group of patients with moderate to severe TBI was seriously impaired on all aspects of EF, SC and dysexecutive behavior. In the TBI group, there were no systematic effects for time since injury as we only found a weak correlation with emotion recognition. With regard to the composite scores, significant correlations were found between the tests for ToM and between the tests for switching, which justified both aggregates. Furthermore, scores on the participation measure (the RRL) showed that 89 % of the patients had not fully returned to their previous vocational level and nobody in the patient group had attained to their previous level of social functioning. However, for both measures there was some variability with regard to the extent of incomplete vocational or social participation.

So far as vocational participation is concerned, we found that adding measures for ToM and for dysexecutive behavior accounted for a significant proportion of variance. It seems likely to assume that an inadequate understanding of the thoughts and feelings of others, as well as the presence of inadequate or inappropriate behavior may contribute to interpersonal conflicts in work situations (55,56). Yeates and colleagues (2016) for instance, recently reported that patients' ability for mentalizing was a crucial factor for obtaining appraisal from work colleagues (57). In addition, executive functioning, in particular planning skills, emerged as a significant predictor in the full model as well. However, in the regression formula high scores on this variable were associated with lower levels of vocational participation. This seemingly contradictory result cannot be interpreted in isolation but should be combined with the effect of other predictors. Moreover, EF-planning was not a significant contributor when combined with Age and Injury severity only. Nevertheless, some previous studies have found significant effects of EF measures in the prediction of participation, but until now these effects have never been compared with the predictive value of measures for SC and behavioral problems (16,18,19). Our findings strongly suggest that measures of SC and behavioral problems are more powerful predictors of vocational participation than measures of EF. This is an important finding, given that the ability to return to a previous vocational level is a crucial component of overall participation and is of paramount importance in the relatively young TBI population (58–60). This means that measures of SC, in particular ToM, and dysexecutive behavior, should be incorporated in early neuropsychological assessment.

This may allow the identification of eventual risk factors for low vocational participation. Further, we found that severity of injury was a significant predictor of lower vocational participation across all regression blocks, as may be expected. Age has repeatedly been found to be a significant predictor of outcome as well (12,13). In our study, however, age was non-significant in the first blocks for prediction of vocational participation. It only reached significance in the full model, where it can be conceived as a moderator of the effects of tests for EF and SC, both known to be influenced by age differences.

As for social participation, we found that it was also significantly predicted by SC and dysexecutive behavior, accounting for a unique portion of variance beyond age, injury severity and EF. This finding is as relevant as the findings regarding vocational participation, given that social participation is one of the most important aspects of community integration (61). This is not surprising, since social cognitive abilities and appropriate behavior are prerequisites for successful engagement in social contacts and the maintenance of relationships. These are in turn important aspects of quality of life and experienced caregiver burden. Ryan and colleagues (2016), for instance, report that victims of a TBI with an impaired ability to understand other people's mental and emotional states are experienced by their proxies as more distressing (62). This is in line with our finding that both a negative judgement by proxies of patients' behavior as well as an impaired ability of the patient to understand others, are negative determinants of patients' ability to resume social roles and relationships. Facial affect recognition, however, was not significantly correlated with social participation, nor a significant predictor in the multiple regression analysis. Although it is wellknown that the ability to recognize facial emotional expressions is an important aspect of SC, we conclude that this ability is not decisive in social participation after TBI. Apparently, the ability to use this information to understand others (ToM) is more essential. This is in line with results from studies that found training of emotion recognition to be effective in itself, though it did not result in better social outcomes (63,64). Furthermore, injury severity was a significant variable in the first and second block of the prediction of social participation, indicating poorer social participation for the patients with a severe TBI, in line with previous studies. Wells and colleagues (2009), for instance, found that injury severity accounted for 15% of the variance in social participation outcomes when analyzed together with age and environmental factors as predictors (13). However, in our study, after entering the behavioral and SC variables neither injury severity nor EF were significant predictors anymore. Again, this finding suggests that measures of ToM and dysexecutive behavior are the most powerful predictors of social participation and should always be included in neuropsychological assessment, to allow early identification of risk factors for successful social participation.

The present study has some limitations. Relevant injury data were not available for all patients, i.e. for some patients initial GCS scores were lacking, for others PTA durations were not available and imaging data were incomplete. However, by applying the Mayo criteria (38), we were able to classify our patients according to their available injury related variables into severity



categories and to distinguish moderate from severe traumatic injuries. In this study, we selected participants based on SC impairments or social behavioral problems, narrowing the possible range of relevant predictors. Therefore, the explained variance might have been larger in a more heterogeneous group of patients with TBI. Further, it should be kept in mind that while hierarchical multiple regression analysis allows for testing several steps within the model, it does not allow to draw conclusions regarding causality. The analyses only test relations between variables in a given model which is based on correlations. Finally, there are other demographic predictors that may influence outcome after TBI, for instance time since injury, gender and educational level. Our small sample size restrained the number of potentially relevant predictors. Besides that, a larger patient sample would have allowed for a more comprehensive regression analysis, measuring the predictive power of SC and executive behavior beyond measures of attention, memory, mood or fatigue that might also have been of influence on either social or vocational participation.

Nevertheless, based on our present findings we conclude that TBI survivors with SC deficits and behavioral difficulties are at risk for poor social and vocational participation, a clinically relevant finding. When neuropsychological assessment is possible at an early stage after injury, we strongly recommend to incorporate such tests for SC and questionnaires for dysexecutive behavior. Timely identification of social cognitive or behavioral risk factors allows early counseling or treatment, aimed at the prevention of an unfavorable long-term outcome.

## Disclosure Statement

The authors report no declarations of interest.

## Funding

This work was supported by the Hersenstichting [F2008-1-18].

## References

- Hyder AA, Wunderlich CA, Puvanachandra P, Gururaj G, Kobusingye OC. The impact of traumatic brain injuries: A global perspective. *NeuroRehabilitation*. 2007;22(5):341–53.
- Thornhill S, Teasdale GM, Murray GD, McEwen J, Roy CW, Penny KL. Disability in young people and adults one year after head injury: prospective cohort study. *BMJ*. 2000;320(7250):1631–35.
- Langlois JA, Rutland-Brown W, Wald MM. The epidemiology and impact of traumatic brain injury - A brief overview. *J Head Trauma Rehabil*. 2006 Sep-Oct;21(5):375–78.
- Spikman JM, Timmerman ME, Coers A, van der Naalt J. Early CT frontal abnormalities predict long term neurobehavioral problems but not affective problems after moderate to severe TBI. *J Neurotrauma*. 2015;1;33(1):22–28. doi:10.1089/neu.2014.3788.
- Benedictus MR, Spikman JM, van der Naalt J. Cognitive and Behavioral Impairment in Traumatic Brain Injury Related to Outcome and Return to Work. *Arch Phys Med Rehabil*. 2010 Sep;91(9):1436–41. doi:10.1016/j.apmr.2010.06.019.
- Novack TA, Bush BA, Meythaler JM, Canupp K. Outcome after traumatic brain injury: pathway analysis of contributions from premorbid, injury severity, and recovery variables. *Arch Phys Med Rehabil*. 2001 Mar;82(3):300–05. doi:10.1053/apmr.2001.18222.
- Pepin M, Dumont C, Hopps S. Relationship between cognitive capabilities and social participation among people with traumatic brain injury. *Brain Inj*. 2000 Jun;14(6):563–72.
- Tate RL, Broe GA. Psychosocial adjustment after traumatic brain injury: what are the important variables? *Psychol Med*. 1999;29(3):713–25.
- Levasseur M, Richard L, Gauvin L, Raymond E. Inventory and analysis of definitions of social participation found in the aging literature: proposed taxonomy of social activities. *Soc Sci Med*. 2010 Dec;71(12):2141–49. doi:10.1016/j.socscimed.2010.09.041.
- Kersel DA, Marsh NV, Havil JH, Sleigh JW. Psychosocial functioning during the year following severe traumatic brain injury. *Brain Inj*. 2001;15(8):683–96. doi:10.1080/02699050010013662.
- Tomberg T, Toomela A, Ennok M, Tikk A. Changes in coping strategies, social support, optimism and health-related quality of life following traumatic brain injury: A longitudinal study. *Brain Inj*. 2007;21(5):479–88. doi:10.1080/02699050701311737.
- Willemse-van Son AHP, Ribbers GM, Verhagen AP, Stam HJ. Prognostic factors of long-term functioning and productivity after traumatic brain injury: a systematic review of prospective cohort studies. *Clin Rehabil*. 2007 Nov;21(11):1024–37. doi:10.1177/0269215507077603.
- Wells R, Minnes P, Phillips M. Predicting social and functional outcomes for individuals sustaining paediatric traumatic brain injury. *Dev Neurorehabil*. 2009;12(1):12–23. doi:10.1080/17518420902773109.
- Willemse-van Son AHP, Ribbers GM, Hop WCJ, Stam HJ. Community Integration Following Moderate to Severe Traumatic Brain Injury: a Longitudinal Investigation. *J Rehabil Med*. 2009 Jun;41(7):521–27. doi:10.2340/16501977-0377.
- Husson EC, Ribbers GM, Willemse-van Son AHP, Verhagen AP, Stam HJ. Prognosis of Six-Month Functioning After Moderate to Severe Traumatic Brain Injury: a Systematic Review of Prospective Cohort Studies. *J Rehabil Med*. 2010 May;42(5):425–36. doi:10.2340/16501977-0566.
- Spitz G, Ponsford JL, Rudzki D, Maller JJ. Association Between Cognitive Performance and Functional Outcome Following Traumatic Brain Injury: A Longitudinal Multilevel Examination. *Neuropsychology*. 2012 Sep;26(5):604–12. doi:10.1037/a0029239.
- Bercaw EL, Hanks RA, Millis SR, Gola TJ. Changes in Neuropsychological Performance after Traumatic Brain Injury from Inpatient Rehabilitation to 1-Year Follow-Up in Predicting 2-Year Functional Outcomes. *Clin Neuropsychol*. 2011;25(1):72–89. doi:10.1080/13854046.2010.532813.
- Struchen MA, Clark AN, Sander AM, Mills MR, Evans G, Kurtz D. Relation of executive functioning and social communication measures to functional outcomes following traumatic brain injury. *Neurorehabilitation*. 2008;23(2):185–98.
- Green RE, Colella B, Hebert DA, Bayley M, Kang HS. Prediction of return to productivity after severe traumatic brain injury: investigations of optimal neuropsychological tests and timing of assessment. *Arch Phys Med Rehabil*. 2008;89(12):51–60. doi:10.1016/j.apmr.2008.09.552.
- Lezak MD. The problem of assessing executive functions. *Int J Psychol*. 1982;17(1–4):281–97. doi:10.1080/00207598208247445.
- Struchen MA, Pappadis MR, Sander AM, Burrows CS, Myszyka KA. Examining the contribution of social communication abilities and affective/behavioral functioning to social integration outcomes for adults with traumatic brain injury. *J Head Trauma Rehabil*. 2011 Jan-Feb;26(1):30–42. doi:10.1097/HTR.0b013e3182048f7c.
- Milders M, Fuchs S, Crawford JR. Neuropsychological impairments and changes in emotional and social behaviour following severe traumatic brain injury. *J Clin Exp Neuropsychol*. 2003 Apr;25(2). doi:10.1076/jcen.25.3.297.13805.
- 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):101–11. doi:10.1089/neu.2011.2084.
24. Henry JD, Phillips LH, Crawford JR, Ietswaart M, Summers F. Theory of mind following traumatic brain injury: the role of emotion recognition and executive dysfunction. *Neuropsychologia*. 2006;44(10):1623–28. doi:10.1016/j.neuropsychologia.2006.03.020.
  25. 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):277–85. doi:10.1037/a0021908.
  26. Adolphs R. The neurobiology of social cognition. *Curr Opin Neurobiol*. 2001;11:231–39.
  27. Amodio DM, Frith CD. Meeting of minds: the medial frontal cortex and social cognition. *Nat Rev Neurosci*. 2006;7:268–77. doi:10.1038/nrn1884.
  28. Spikman JM, Milders MV, Visser-Keizer AC, Westerhof-Evers HJ, Herben-Dekker M, van der Naalt J. Deficits in facial emotion recognition indicate behavioral changes and impaired self-awareness after moderate to severe traumatic brain injury. *PLoS One*. 2013;8(6):e65581. doi:10.1371/journal.pone.0065581.
  29. May M, Milders M, Downey B, Whyte M, Higgins V, Wojcik Z, Amin S, O'Rourke S. Social Behavior and Impairments in Social Cognition Following Traumatic Brain Injury. *J Int Neuropsychol Soc*. 2017;23(5):400–11. doi:10.1017/S1355617717000182.
  30. Saxton ME, Younan SS, Lah S. Social behaviour following severe traumatic brain injury: contribution of emotion perception deficits. *Neurorehabilitation*. 2013;33(2):263–71. doi:10.3233/NRE-130954.
  31. Ubukata S, Tanemura R, Yoshizumi M, Sugihara G, Murai T, Ueda K. Social cognition and its relationship to functional outcomes in patients with sustained acquired brain injury. *Neuropsychiatr Dis Treat*. 2014;10:2061–68. doi:10.2147/NDT.S68156.
  32. Baddeley A, Wilson B. Frontal amnesia and the dysexecutive syndrome. *Brain Cogn*. 1988;7(2):212–30.
  33. Levin H, Kraus MF. The Frontal Lobes and Traumatic Brain Injury. *J Neuropsychiatry Clin Neurosci*. 1994;6(4):443–54. doi:10.1176/jnp.6.4.443.
  34. Luria AR. Higher cortical functions in man. London: Tavistock; 1966.
  35. Burgess PW, Alderman N, Evans J, Emslie H, Wilson BA. The ecological validity of tests of executive function. *J Int Neuropsychol Soc*. 1998;4(6):547–58.
  36. Kelley E, Sullivan C, Loughlin JK, Hutson L, Dandah MN, Long MK, Schwab KA, Poole JH. Self-Awareness and Neurobehavioral Outcomes, 5 Years or More After Moderate to Severe Brain Injury. *J Head Trauma Rehabil*. 2014 Mar-Apr;29(2):147–52. doi:10.1097/HTR.0b013e31826db6b9.
  37. Spikman JM, van der Naalt J. Indices of Impaired Self-Awareness in Traumatic Brain Injury Patients with Focal Frontal Lesions and Executive Deficits: implications for Outcome Measurement. *J Neurotrauma*. 2010 Jul;27(7):1195–202. doi:10.1089/neu.2010.1277.
  38. Malec JF, Brown AW, Leibson CL, Flaada JT, Mandrekar JN, Diehl NN, Perkin PK. The Mayo classification system for traumatic brain injury severity. *J Neurotrauma*. 2007 Sep;24(9):1417–24. doi:10.1089/neu.2006.0245.
  39. Verhage F. Intelligentie en leeftijd: onderzoek bij Nederlanders van twaalf tot zeventenveertig jaar. Assen: Van Gorcum; 1964.
  40. Westerhof-Evers HJ, Visser-Keizer AC, McDonald S, Spikman JM. Performance of healthy subjects on an ecologically valid test for social cognition: the short, Dutch Version of The Awareness of Social Inference Test (TASIT). *J Clin Exp Neuropsychol*. 2014 Nov;36(10):1031–41. doi:10.1080/13803395.2014.966661.
  41. Vlagsma TT, Koerts J, Tucha O, Dijkstra HT, Duits AA, van Laar T, Spikman JM. Objective Versus Subjective Measures of Executive Functions: predictors of Participation and Quality of Life in Parkinson Disease? *Arch Phys Med Rehabil*. 2017;98(11):2181–87. doi:10.1016/j.apmr.2017.03.016.
  42. Spikman JM, Boelen DH, Lamberts KF, Brouwer WH, Fasotti L. Effects of a multifaceted treatment program for executive dysfunction after acquired brain injury on indications of executive functioning in daily life. *J Int Neuropsychol Soc*. 2010 Jan;16(1):118–29. doi:10.1017/S1355617709991020.
  43. van Zomeren AH, van Den Burg W. Residual complaints of patients two years after severe head injury. *J Neurol Neurosurg Psychiatry*. 1985;48:21–28. doi:10.1136/jnnp.48.1.21.
  44. Young A, Perrett D, Calder A, Sprengelmeyer R, Ekman P. Facial Expressions of Emotion: stimuli and Tests (FEEST). Bury St. Edmunds, UK: Thames Valley Test; 2002.
  45. Happe F, Brownell H, Winner E. Acquired 'theory of mind' impairments following stroke. *Cognition*. 1999 Apr;70(3):211–40.
  46. Stone VE, Baron-Cohen S, Knight RT. Frontal lobe contributions to theory of mind. *J Cogn Neurosci*. 1998 Sep;10(5):640–56.
  47. Wilson B, Evans J, Emslie H, Alderman N, Burgess P. The development of an ecologically valid test for assessing patients with a dysexecutive syndrome. *Neuropsychol Rehabil*. 1998;8:213–28. doi:10.1080/713755570.
  48. Norris G, Tate RL. The Behavioural Assessment of the Dysexecutive Syndrome (BADS): ecological, Concurrent and Construct Validity. *Neuropsychol Rehabil*. 2000 Jan;10(1):33–45. doi:10.1080/096020100389282.
  49. Hendry K, Ownsworth T, Beadle E, Chevignard MP, Fleming J, Griffin J, Shum DH. Cognitive Deficits Underlying Error Behavior on a Naturalistic Task after Severe Traumatic Brain Injury. *Front Behav Neurosci*. 2016;10(190). doi:10.3389/fnbeh.2016.00020.
  50. Allain P, Nicoleau S, Pinon K, Etcharry-Bouyx F, Barre J, Berrut G, Dubas F, Le Gall D. Executive functioning in normal aging: A study of action planning using the zoo map test. *Brain Cogn*. 2005;57:4–7. doi:10.1016/j.bandc.2004.08.011.
  51. Schmand B, Groenink SC, Van Den Dungen M. Letterfluency: psychometrische eigenschappen en Nederlandse normen. *Tijdschr Gerontol Geriat*. 2008;39:64–76. doi:10.1007/BF03078128.
  52. Abwender DA, Swan JG, Bowerman JT, Connolly SW. Qualitative analysis of verbal fluency output: review and comparison of several scoring methods. *Assessment*. 2001;8(3):323–38. doi:10.1177/107319110100800308.
  53. Arbuthnott K, Frank J. Trail Making Test, Part B as a Measure of Executive Control: validation Using a Set-Switching Paradigm. *J Clin Exp Neuropsychol*. 2000;22(4):518–28. doi:10.1076/1380-3395(200008)22:4;1-0;FT518.
  54. Reitan RM. Validity of the Trail Making test as an indicator of organic brain damage. *Percept Mot Skills*. 1958;(8):271–76. doi:10.2466/pms.1958.8.3.271.
  55. Sveen U, Mongs M, Roe C, Sandvik L, Bautz-Holter E. Self-rated competency in activities predicts functioning and participation one year after traumatic brain injury. *Clin Rehabil*. 2008;22(1):45–55. doi:10.1177/0269215507080768.
  56. Ruffolo CF, Friedland JF, Dawson DR, Colantonio A, Lindsay PH. Mild traumatic brain injury from motor vehicle accidents: factors associated with return to work. *Arch Phys Med Rehabil*. 1999;80(4):392–98.
  57. Yeates G, Rowberry M, Dunne S, Goshawk M, Mahadevan M, Tyerman R, Salter M, Hillier M, Berry A, Tyerman A. Social cognition and executive functioning predictors of supervisors' appraisal of interpersonal behaviour in the workplace following acquired brain injury. *Neurorehabilitation*. 2016;38(3):299–310. doi:10.3233/NRE-161321.
  58. Corrigan JD, Bogner JA, Mysiw WJ, Clinchot D, Fugate L. Life satisfaction after traumatic brain injury. *J Head Trauma Rehabil*. 2001;16(6):543–55.
  59. Steadman-Pare D, Colantonio A, Ratcliff G, Chase S, Vernich L. Factors associated with perceived quality of life many years after traumatic brain injury. *J Head Trauma Rehabil*. 2001 Aug;16(4):330–42.
  60. Wehman PH, Kreutzer JS, West MD, Sherron PD, Zasler ND, Groah CH, Stonnington HH, Burns CT, Sale PR. Return to Work for Persons with Traumatic Brain Injury - a Supported Employment Approach. *Arch Phys Med Rehabil*. 1990 Dec;71(13):1047–52.
  61. McColl MA, Carlson P, Johnston J, Minnes P, Shue K, Davies D, Karlovits T. The definition of community integration:

- perspectives of people with brain injuries. *Brain Inj.* 1998 Jan;12(1):15–30.
62. Ryan NP, Catroppa C, Beare R, Silk TJ, Crossley L, Beauchamp MH, Yeates KO, Anderson VA. Theory of mind mediates the prospective relationship between abnormal social brain network morphology and chronic behavior problems after pediatric traumatic brain injury. *Soc Cogn Affect Neurosci.* 2016 Apr;11(4):683–92. doi:10.1093/scan/nsw007.
63. Bornhofen C, McDonald S. Comparing strategies for treating emotion perception deficits in traumatic brain injury. *J Head Trauma Rehabil.* 2008 Mar-Apr;23(2):103–15. doi:10.1097/01.HTR.0000314529.22777.43.
64. Neumann D, Babbage DR, Zupan B, Willer B. A Randomized Controlled Trial of Emotion Recognition Training After Traumatic Brain Injury. *J Head Trauma Rehabil.* 2015 May-Jun;30(3):E12–E23. doi:10.1097/HTR.000000000000054.