Communicative-pragmatic disorders in traumatic brain injury: The role of theory of mind and executive functions

DOI:10.1016/j.bandl.2017.01.007

Brain and Language xxx (2017) xxx-xxx

Contents lists available at ScienceDirect

Brain and Language

journal homepage: www.elsevier.com

Communicative-pragmatic disorders in traumatic brain injury: The role of theory of mind and executive functions

Francesca M. Bosco[a, b], Alberto Parola[a, *], Katiuscia Sacco[a, b], Marina Zettin[c], Romina Angeleri[d]

[a] Center for Cognitive Science, Department of Psychology, University of Turin, Italy
[b] Institute of Neurosciences of Turin, Italy
[c] Centro Puzzle, Turin Italy
[d] Department of Psychology, University of New Mexico, NM, United States

ARTICLE INFO

Article history:
Received 29 June 2016
Received in revised form 19 October 2016
Accepted 23 January 2017
Available online xxx

Keywords:
Communication
Pragmatics
Irony
Deceit
Non-verbal
Theory of mind
Executive functions
Cognitive flexibility
Working memory
Planning

ABSTRACT

Previous research has shown that communicative-pragmatic ability, as well as executive functions (EF) and Theory of Mind (ToM), may be impaired in individuals with traumatic brain injury (TBI). However, the role of such cognitive deficits in explaining communicative-pragmatic difficulty in TBI has still not been fully investigated. The study examined the relationship between EF (working memory, planning and flexibility) and ToM and communicative-pragmatic impairment in patients with TBI. 30 individuals with TBI and 30 healthy controls were assessed using the Assessment Battery of Communication (ABaCo), and a set of cognitive, EF and ToM, tasks. The results showed that TBI participants performed poorly in comprehension and production tasks in the ABaCo, using both linguistic and extralinguistic means of expression, and that they were impaired in EF and ToM abilities. Cognitive difficulties were able to predict the pragmatic performance of TBI individuals, with both executive functions and ToM contributing to explaining patients' scores on the ABaCo.

1. Introduction

A number of studies have confirmed that traumatic brain injury (TBI) is associated with communicative-pragmatic impairments (Angeleri et al., 2008; Bara, Tirassa, & Zettin, 1997; Bosco, Angeleri, Sacco, & Bara, 2015; Johnson & Turkstra, 2012). The aim of this paper is to investigate the relationship between this well–established communication disorder and the underlying cognitive components that might be responsible for such impairment. In particular, we focused our attention on two domains of cognitive functioning, usually found to be impaired after TBI, i.e. Theory of Mind (ToM) and executive functions (EF), (e.g., Ashman, Gordon, Cantor, & Hibbard, 2006; Dikmen et al., 2009). The role of these cognitive abilities in pragmatic performance after TBI is still unclear and difficult to disentangle (Honan, McDonald, Gowland, Fisher, & Randall, 2015; Martin & McDonald, 2003; McDonald, 2013; McDonald et al., 2014). This paper will contribute to improving the understanding of this issue.

A wide number of definitions exist to explain the notion of pragmatics (see Levinson, 1983). They include the study of meaning in relation to the use of language, as the relationship between signs and their users; the ability to use language and other means of expression, such as gestures and paralinguistic indicators, to convey communicative meaning; the ability to manage conversations and discourse analysis (Bara, 2010; Cummings, 2005). In the present investigation we focus on linguistic and extralinguistic (non-verbal) abilities to convey meaning in a social context.

Communicative-pragmatic abilities of individuals with TBI may be impaired, making it difficult for them to manage communicative interactions at various levels: their understanding of the non-literal meaning of utterances is often incorrect or incomplete (e.g., Winner & Gardner, 1977), they often have difficulty grasping the pragmatic implications of sentences, as in the case of understanding sarcasm (Channon et al., 2007; McDonald, 1992; McDonald & Pearce, 1996), humor (Braun, Lissier, Baribeau, & Ethier, 1989; Docking, Murdoch, & Jordan, 2000), or commercial messages involving inferential reasoning (Pearce, McDonald, & Coltheart, 1998). Pragmatic impairment is not limited to linguistic comprehension, but also extends to the production of communicative acts. For example, individuals with TBI are reportedly poor at negotiating efficient requests (McDonald & Van Sommers, 1993), and at giving the right amount of information to their interlocutor (McDonald, 1993).

Interestingly, difficulties have also been documented for the extralinguistic modality, which represents the ability to communicate

* Corresponding author at: Dipartimento di Psicologia, Via Po 14, 10123 Torino, Italy.
Email address: alparola@unito.it (A. Parola)

http://dx.doi.org/10.1016/j.bandl.2017.01.007
0093-934/

through gestures, facial expressions, and body posture (Bara, Cutica, & Tirassa, 2001; Rousseaux, Vérigneaux, & Kozlowski, 2010). Individuals with TBI often suffer from a general difficulty in managing social interactions in their everyday life (e.g., Struchen, Pappadis, Sander, Burrows, & Myszka, 2011), also characterized by conversational problems, such as managing turn taking (Murphy, Huang, Montgomery, & Turkstra, 2015), and narrative disorders (Dardier et al., 2011; Marini, Zettin, & Galetto, 2014; Marini et al., 2011).

In recent decades the cognitive aspects underlying pragmatic impairment have also been the subject of growing interest (e.g., Bambini et al., 2016; Cummings, 2009, 2014; Perkins, 2000; Stemmer, 1999). Even if the specific pattern of deficits resulting from traumatic brain injuries may differ widely depending on the lesion site, the type of damage, and the time after injury, individuals with TBI usually suffer from damage to the frontal lobes, resulting in deficits in executive functions, the construct used to describe the ability to manage goal-directed behavior (e.g., Miyake et al., 2000). Executive functions include abilities crucial to the efficient use of communication, such as self-regulation, organization, and planning; some authors have proposed that executive dysfunction is the main cause of pragmatic impairment in TBI (Channon & Watts, 2003; Douglas, 2010; McDonald & Pearce, 1998). Channon and Watts (2003) found TBI individuals to be impaired in the comprehension of indirect speech acts, as well as in executive tasks indexing working memory, inhibition and multitasking. The authors found that only inhibitory processes provided a significant contribution for explaining pragmatic performance in patients with TBI, while no association was found between working memory, multitasking and pragmatic tasks. Douglas (2010) evaluated pragmatic-communication difficulties in TBI individuals using the *La Trobe Communication Questionnaire* (LCQ; Douglas, O'Flaherty, & Snow, 2000), and she also provided different measures of executive skills, i.e. verbal fluency, the ability to maintain and manipulate information, and the speed of verbal processing. The author found that executive skills, in particular verbal fluency, were able to explain approximately a third of the variance in pragmatic performance of TBI individuals.

Communicative-pragmatic impairment in individuals with TBI has also been linked to a deficit in ToM, i.e. the ability to infer others' mental states, such as beliefs and intentions (Premack & Woodruff, 1978). Some authors have argued that ToM plays a critical role in human communication: understanding another person's mental state is essential in order to modify it and to achieve a specific communicative effect, i.e. to induce the partner to believe or to do something (Bosco, Bono, & Bara, 2012; Cummings, 2015; Happé & Loth, 2002; Tirassa, Bosco, & Colle, 2006a, 2006b). Several studies have reported poor comprehension of ToM tasks in individuals with TBI (Bibby & McDonald, 2005; Geraci, Surian, Ferraro, & Cantagallo, 2010; Martín-Rodríguez & León-Carrión, 2010; Milders, Ietswaart, Crawford, & Currie, 2006; Muller et al., 2010; Spikman, Timmerman, Milders, Veenstra, & van der Naalt, 2012), and some authors have suggested that this difficulty may be crucial to understanding their pragmatic impairment (Happé, Brownell, & Winner, 1999; Havet-Thomassin, Allain, Etcharry-Bouyx, & Le Gall, 2006; Martin & McDonald, 2003).

McDonald and Flanagan (2004) assessed a group of individuals with TBI using the Awareness of Social Inference Test (TASIT, McDonald, Flanagan, Rollins, & Kinch, 2003). The authors found that the ability to understand conversational meaning was closely related to the ability to interpret speakers' intentions, when measured by second-order ToM tasks (but not by first-order ones). First-order ToM tasks investigate a person's ability to infer the mental state of another person (Wimmer & Perner, 1983); second-order ToM tasks investigate the ability to comprehend what a person thinks, knows and or believes about another person's mental state, and they require a greater cognitive load in order to be understood (Perner & Wimmer, 1985). In line with these results, Channon, Pellijeff, and Rule (2005) reported that individuals with closed head injury performed poorly in understanding sarcasm, and that their difficulties were related to their mentalizing abilities, in particular to the incorrect or inadequate appreciation of the mental states of the characters involved in their tasks. Byom and Turkstra (2012) also showed that individuals with TBI used a reduced pattern of mental-state term types, compared to their peers, when conversing with friends about intimate topics.

Very few studies have examined the relationship between ToM and EF in individuals with TBI and tried to disentangle the unique contribution of ToM or executive functions to their communicative-pragmatic performance. Martin and McDonald (2005), for example, found that ToM deficits were not able to predict impaired irony comprehension, while physical inferential reasoning, i.e. the ability to comprehend complex non-mental inferences applying the principles of physical causation to a sequence of events, was a strong predictor. They also measured other cognitive components (including conceptual reasoning, cognitive flexibility and working memory). However, none of them was able to predict participants' ability to comprehend irony.

In a recent study, McDonald et al. (2014) investigated the contribution of executive functions (cognitive flexibility and inhibition) and ToM in TBI individuals, by administering a speech production task in which the patients were presented with different sets of photographs that they had to describe to a partner. The authors found that both executive functions and ToM had a unique effect on the speech production task, but also that cognitive flexibility was the best predictor of pragmatic performance. Moreover, ToM difficulties were able to predict poor performance by patients in language production tasks but only when the tasks implied strong inhibition, such as when participants were asked to think about a specific event from their own perspective, and then inhibit that perspective and switch to someone else's perspective. This result suggests a critical role of inhibition abilities in ToM reasoning (see also Leslie, Friedman, & German, 2004). These findings seem to indicate that theory of mind does play a role in communication, but also that this role tends to decrease when the contribution of executive functions is controlled; the idea of a domain-specific contribution of ToM in predicting pragmatic deficits in individuals with TBI is thus not well supported. In a more recent study, Honan et al. (2015) studied individuals with severe TBI, comparing their performance in everyday conversation with that of healthy controls. In particular, the study, using everyday conversation tasks, investigated whether impaired executive functions could predict ToM deficits. Participants with TBI were compared with controls in tasks demanding low or high ToM in four different experimental conditions: (i) high working memory (WM) (ii) high flexibility (iii) high inhibition and (vi) low cognitive load. The results showed that TBI individuals only performed less well than the control group in high-ToM tasks in the high WM condition. The authors suggested that ToM impairments in everyday communication in individuals with TBI may be attributable to higher demands on WM.

To conclude, there is still a lack of conclusive evidence regarding the nature of the relationship among ToM, executive functions, and pragmatic abilities, and more empirical work is needed.

1.1. The present study

The purposes of this study were to investigate the ability of patients with TBI to understand and produce linguistic and extralinguistic communicative-pragmatic tasks, and to examine the role of cognitive components, in particular EF and ToM, in explaining their performance. We expected that individuals with TBI perform worse than healthy controls in comprehension and production on the linguistic and extralinguistic scales of the Assessment battery for Communication (Angeleri, Bara, Bosco, Colle, & Sacco, 2015; Angeleri, Bosco, Gabbatore, Bara, & Sacco, 2012; Angeleri et al., 2008; Bosco, Angeleri, Zuffranieri, Bara, & Sacco, 2012). We also expected that patients with TBI perform worse than controls in the cognitive tasks administered: i.e. background neuropsychological functions - attention and long-term memory-, EF - planning, cognitive flexibility and working memory-, and ToM. Finally, we conducted hierarchical regression to evaluate the role of background neuropsychological functions, EF and ToM in explaining the severity of patients' pragmatic deficits.

2. Method

2.1. Participants

Thirty individuals with TBI (23 male; 7 female) and 30 healthy individuals (23 male; 7 female) took part in the present study. The age of TBI participants ranged from 20 to 68 years ($M = 37.13$; $SD = 11.36$); education ranged from 5 to 18 years of schooling ($M = 11.1$; $SD = 3.29$). The control group consisted of 30 healthy participants, closely matched to the experimental group in terms of sex (23 male; 7 female), age ($M = 37.03$, SD = 11.45) and years of education ($M = 11.8$, SD = 3.17). None of them had any previous history of brain damage or neurological disorders. The control group did not differed from the experimental one in age (*T*-test; t = 0.034, p = 0.97) and years of education (*T*-test; t = 0.83, p = 0.41).

Participants had to meet the following criteria: (1) be at least 18 years of age; (2) be Italian native speakers; (3) provide their informed consent. Participants with TBI had also to: (4) be at least 3 months post-brain injury; (5) have sufficient cognitive and communication skills to participate in the study, as resulting from the achievement of a cut-off score in a set of well-established neuropsychological tests: the MiniMental State Examination (MMSE, Folstein, Folstein, & McHugh, 1975; cut-off: 24/30); the denomination scale of the Aachener Aphasie Test (AAT, Huber, Poeck, Weniger, & Willmes, 1983; cut-off: no deficit), and the Token Test (De Renzi & Vignolo, 1962; cut-off: 5/6). Exclusion criteria for both TBI participants and healthy individuals were prior history of TBI or other neurological disease, neuropsychiatric illness or communication problems, pre-morbid alcohol or drug addiction.

The clinical characteristics of the participants with TBI are reported in Table 1. The time after onset ranged from 3 to 252 months ($M = 60.1$; $SD = 64.21$). All participants had been injured in road traffic accidents, resulting in diffuse brain injury. Most of the participants also suffered from focal damage in different brain areas, as indicated by MRI. At the time of the study, all participants with TBI were living at home with their caregiver (partners or relatives), and were in the post-acute phase. None of the individuals with TBI had a history of neurological disease, psychiatric illness, previous head injury, stroke, antipsychotic medication use or substance abuse disorder. All participants were right handed and able to provide their informed consent. Finally, scores on the Glasgow Coma Scale (GCS) ranged from 5 to 9, indicating that participants had sustained moderate to severe TBI (as defined by Teasdale & Jennett, 1974).

2.2. Materials

In order to examine the participants' pragmatic abilities we used the linguistic and extralinguistic evaluation scales derived from the

Table 1
Demographic and neurological details of TBI individuals.

Subject	Sex	Age	Education (years)	Time post-onset (months)	Lesional area
TBI1	M	33	13	138	Right fronto-parietal
TBI2	M	37	8	46	Right fronto-temporal
TBI3	F	26	18	30	Right fronto-parieto-temporal
TBI4	M	45	13	74	Right fronto-parietal
TBI5	M	21	8	32	Right fronto-temporo-parietal
TBI6	M	49	11	64	Right fronto-temporo-parietal
TBI7	M	20	8	41	Frontal-diffuse injury
TBI8	M	36	10	252	Right parieto-temporal
TBI9	M	27	8	35	Left frontal
TBI10	M	32	13	51	Right fronto-temporo-parietal
TBI11	M	32	11	23	Left temporal-bilateral parietal
TBI12	F	23	13	19	Bilateral fronto-temporal
TBI13	M	31	11	120	Left frontal
TBI14	M	68	5	3	Right fronto-temporal
TBI15	M	59	11	7	Left fronto-temporal
TBI16	F	37	8	15	Right fronto-parieto-temporal
TBI17	F	42	13	18	Right fronto-temporal
TBI18	M	54	18	48	Left fronto-temporal
TBI19	F	35	8	228	Bilateral frontal
TBI20	M	29	13	3	Right fronto-temporal
TBI21	M	39	8	3	Bilateral frontal
TBI22	F	36	13	34	Right fronto-temporal
TBI23	M	32	10	62	Right parietal
TBI24	M	53	18	36	Right fronto-parieto-temporal
TBI25	M	24	8	21	Right fronto-parietal
TBI26	M	45	13	17	Right temporo-parietal
TBI27	M	41	8	65	Right temporal
TBI28	F	38	8	66	Left fronto-temporal
TBI29	M	42	13	192	Right frontal
TBI30	M	28	13	60	Left fronto-temporal

ABaCo (Assessment Battery for Communication; Angeleri et al., 2012, 2015; Bosco et al., 2012; Sacco et al., 2008), a clinical battery designed to evaluate communicative-pragmatic ability in acquired brain injury (Gabbatore et al., 2014; Parola et al., 2016) or psychiatric disorders (Angeleri, Gabbatore, Bosco, Sacco, & Colle, 2016; Colle et al., 2013). Both the linguistic and extralinguistic scales are divided into two subscales, i.e. comprehension and production subscales. A battery of cognitive tests was also administered to examine participants' background neuropsychological functions (long-term memory and attention), executive functions (working memory, planning and cognitive flexibility) and theory of mind abilities.

2.2.1. Pragmatic assessment

Pragmatic abilities were assessed using the linguistic and extralinguistic scales of the ABaCo, described below. Examples for each type of task are reported in Appendix A.

2.2.1.1. Linguistic scale

The linguistic scale includes two subscales, i.e. linguistic comprehension and linguistic production. The linguistic comprehension subscale comprised a total of 12 tasks assessing the comprehension of communicative acts expressed mainly through language. The comprehension tasks were comprised of 4 standard (2 direct and 2 indirect) communicative acts, 4 deceitful communicative acts, and 4 ironic communicative acts. The linguistic production subscale comprised a total of 12 tasks assessing the production of communicative acts expressed mainly through language. The production tasks comprised 4 standard (2 direct and 2 indirect) communicative acts, 4 deceitful communicative acts, and 4 ironic communicative acts.

The tasks consisted in short videos that were presented to the participants one at a time; they portrayed two characters involved in a communicative exchange in a typical everyday situation. The number of words in each utterance was controlled (7 ± 2) in order to maintain a constant memory and attention requirement. In the comprehension tasks, participants had to understand the communicative exchange shown in the videos, while in the production tasks they had to complete the communicative exchange with an appropriate communication act.

2.2.1.2. Extralinguistic scale

The extralinguistic scale includes two subscales, i.e. extralinguistic comprehension and extralinguistic production. Each subscale comprised the same communication acts listed above: a total of 24 tasks divided into 12 tasks for the comprehension subscale (4 standard - direct and indirect - communicative acts, 4 deceitful communicative acts, and 4 ironic communicative acts) and 12 tasks for the production subscales (4 standard - direct or indirect- communicative acts, 4 deceitful communicative acts, and 4 ironic communicative acts). The extralinguistic tasks investigated the comprehension and production of communicative acts expressed through the gesture modality only.

The tasks were similar to the linguistic ones, except for the communicative modality used: the two characters depicted in the videos were in this case communicating using gestures or body movements only. As for the linguistic tasks, in the extralinguistic comprehension tasks, participants had to understand the communicative exchange, while in the production tasks they had to complete it with an appropriate communicative gesture.

2.2.1.3. Scoring

The sessions of pragmatic assessment were video-recorded for later coding. Two research assistants, blind to the hypothesis of the study, coded the videotapes. For each pragmatic task the rater can assign 1 point if the participant's answer is correct, and 0 point if the participant's answer is incorrect. The score for each subscale was then calculated as the ratio between the correct responses and the total number of answers to be given for that subscale. The coding system for the pragmatic tasks was that described in Sacco et al. (2008), and employed in Angeleri et al. (2008) and in Bosco, Angeleri, Colle, Sacco, and Bara (2013), see also Angeleri et al. (2015). The agreement between the two raters was calculated using the Intraclass Correlation Coefficient (ICC), a measure of inter-rater concordance calculated as the ratio of variability between subjects to the total variability comprising subject variability and error variability. The ICC calculated for our scores was 0.88, that according to Altman (1991) indicates a value of high inter-rater agreement.

2.2.2. Cognitive assessment

In order to examine cognitive performance as a predictor of pragmatic abilities, in line with previous studies (e.g., Honan et al., 2015) the participants had undergone neuropsychological evaluation. The evaluation included the assessment of the basic cognitive abilities generally involved in the performance of pragmatic tasks (for example, attention and memory), executive functions, and theory of mind abilities. Appendix B details the tests used; the tasks were selected due to their wide use and well-known robustness. Task scores were in a number of different formats, as detailed below. Some tasks had raw scores (RS), while others were converted into *equivalent scores*. Equivalent scores (ES) are distribution-based scores that range from 0 to 4. The cutoff between 0 and 1 corresponds to the 5th percentile of the score distribution in healthy controls; the cutoff between 3 and 4 corresponds to the median of the distribution; and the cutoffs between 1 and 2 and between 2 and 3 are equally spaced between 1 and 4 (Capitani & Laiacona, 1997). Equivalent scores are widely used for neuropsychological assessment in Italy, as they describe the patient's approximate level of performance better than standardized scores. Finally, some of the tests involved a single pass-fail decision (PF). To aggregate different types of tasks into composite scores, all scores were converted to a scale from 0 (minimum possible score) to 1 (maximum possible score) and then averaged.

2.2.2.1. Background neuropsychological tasks

The background cognitive functions we assessed were *long-term memory* and *attention*. Long-term memory was evaluated with the Deferred Recall test (RS; Spinnler & Tognoni, 1987). Attentional capacities were assessed with the Attentional Matrices (ES; Spinnler & Tognoni, 1987).

2.2.2.2. Executive function tasks

To assess executive functions, we constructed three composite scores: (a) *Planning,* defined as the ability to plan a series of actions or thoughts in a sequential order in a goal directed fashion (Smith & Jonides, 1999; Sullivan, Riccio, & Castillo, 2009; Thomas, Snyder, Pietrzak, & Maruff, 2014). The planning ability composite score was obtained by averaging scores on the Tower of London task (ES; Shallice, 1982) and the Elithorn's Maze Test (ES; Elithorn, 1955). (b) *Flexibility*, defined as the ability to switch attention and thinking in response to the demands set by a specific situation (Arbuthnott & Frank, 2000; Johnco, Wuthrich, & Rapee, 2013; Kortte, Horner, & Windham, 2002). Flexibility was assessed by performance on the Trail Making Test Part B – Part A (ES; Reitan, 1958). (c) *Working memory.* The working memory composite was obtained by averaging scores on the Disyllabic Word Repetition Test (ES; Spinnler & Tognoni, 1987), the Corsi's Block-Tapping Test (ES; Spinnler & Tognoni, 1987) and the Immediate Recall test (RS; Spinnler & Tognoni, 1987).

2.2.2.3. Theory of mind tasks

The Theory of Mind composite was obtained by averaging scores on the Smarties Task (PF; Perner, Frith, Leslie, & Leekam, 1989), Sally & Ann Task (PF; Baron-Cohen, Leslie, & Frith, 1985), and a selection of six Strange Stories (RS; Happé, 1994; we excluded items testing communicative aspects, such as irony and metaphor).

2.3. Procedure

The participants with TBI were tested at their rehabilitation center, where they regularly attended outpatient services, while the control participants were tested at home. The study was performed during three individual experimental sessions, each lasting about one hour. The study was approved by the Ethics Committee of the Department of Psychology, University of Turin, Italy.

Each participant was tested in three sessions. Neuropsychological tasks were administered by two of the authors. Pragmatic tasks were administered by the same authors with the help of three trained research assistants.

2.4. Data analysis

To analyze differences in performance on the four subscales of the ABaCo (linguistic comprehension, extralinguistic comprehension, linguistic production, extralinguistic production) between patients and controls, we performed a 2 × 2 × 2 repeated measure analysis of variance (ANOVA) with Factor 1 (patients vs. control) as between-subjects factor, Factor 2 (linguistic vs. extralinguistic) and Factor 3 (comprehension vs. production) as within-subjects factors.

In order to compare the cognitive performance of participants with TBI with that of healthy controls, scores on cognitive tasks were analyzed with independent samples *T*-Tests. The comparisons were performed separately for each cognitive domain investigated (i.e., working memory, long-term memory, attention, cognitive flexibility, planning and overall theory of mind tasks).

Finally, in order to investigate the causal role of background neuropsychological functions - attention and long-term memory (LTM) – EF - working memory, cognitive flexibility and planning - and overall ToM tasks, on the pragmatic performance of patients with TBI, we created a three-stage hierarchical regression model. These variables were entered as predictors into the regression model in hierarchical order of their possible increasing support for impacting on pragmatic performance – that is comprehension and production subscales on the linguistic and extralinguistic scales. We entered the background neuropsychological functions in Model 1 of the analysis. Then we inserted executive functions - working memory, planning and cognitive flexibility - Model 2 - and overall theory of mind - Model 3 – respectively, in two different consecutive stages, in order to consider their single distinctive effect on the dependent variables. We included EF in the regression analysis first and then ToM, since some authors have argued (Bloom and German, 2000) and empirically reported (Honan et al., 2015; McDonald et al., 2014) that executive functions may play a role in solving ToM tasks.

3. Results

3.1. Pragmatic performance

Descriptive statistics for the linguistic and extralinguistic scales are reported in Table 2.

The repeated measure ANOVA revealed that the main effect of Factor 1 (patients vs. controls) was significant ($F_{(1,58)} = 65.12$; $p < 0.0001$; $\eta^2_p = 0.53$), indicating that participants with TBI performed significantly worse than healthy controls on the ABaCo. The main effect of Factor 2 (linguistic vs. extralinguistic) was also significant ($F_{(1,58)} = 26.22$; $p < 0.001$; $\eta^2_p = 0.31$), indicating poorer performance on the extralinguistic than on the linguistic scales. These main effects were qualified by a significant Factor 1 × Factor 2 interaction effect ($F_{(1,58)} = 5.33$; $p < 0.05$; $\eta^2_p = 0.08$). The planned comparisons revealed that the effect of Factor 2 (linguistic vs. extralinguistic) was only significant in the group of TBI individuals ($F_{(1,58)} = 27.59$; $p < 0.001$; $\eta^2_p = 0.32$), indicating that only patients, but not controls, performed worse in extralinguistic tasks than in linguistic ones. The main effect of Factor 3 (comprehension vs. production) was not significant ($F_{(1,58)} = 0.091$; $p = 0.76$; $\eta^2_p = 0.002$), indicating that no differences were found in performance in comprehension vs. production tasks. To exclude the possibility that differences in post-onset time of TBI individuals are responsible for individual differences in the performance on the ABaCo, we calculated Spearman's correlation coefficient with months post-onset and scores on the comprehension and production subscales of the ABaCo linguistic and extralinguistic scales of the. No significant correlation was found ($0.234 < r_s < 0.284$, $0.129 < p < 0.214$).

Table 2
Mean and standard deviation of Linguistic and Extralinguistic scales, in both comprehension and production subscales.

	TBI	Controls
Linguistic Comprehension	0.72 (0.17)	0.91 (0.09)
Extralinguistic Comprehension	0.62 (0.22)	0.83 (0.12)
Linguistic Production	0.68 (0.20)	0.92 (0.11)
Extralinguistic Production	0.57 (0.21)	0.92 (0.07)

3.2. Cognitive performance

3.2.1. Comparison between participants with TBI and healthy controls

Table 3 shows data on cognitive tasks for participants with TBI and healthy controls. The comparisons were significant for all the cognitive functions examined ($2.47 < t < 9.07$; $0.0001 < p < 0.016$).

3.3. Explanatory role of executive functions and theory of mind

To explore the possible causal role of cognitive deficit in communicative-pragmatic ability, we conducted four multiple regression analyses using as dependent variable TBI participants' pragmatic performance on the linguistic and extralinguistic scales, considering comprehension and production subscales separately.

Table 4 displays the adjusted regression coefficients (R^2_{Adj}) for each predictor variable, the change in R^2 after the addition of executive functions and theory of mind variables (R^2_{Change}), the change in F (F_{Change}) and its significance value ($Sig.F_{Change}$).

Cognitive difficulty seems to have an important role in explaining TBI participants' pragmatic performance on the linguistic and extralinguistic scales. *Model 1* explains a proportion of variance of pa-

Table 3
Mean and standard deviation of neuropsychological tests: Attention (Attentional Matrices), Long term memory (Differed recall test), Working Memory (Disyllabic Word Repetition Test, Corsi's Block-Tapping Test, Immediate recall test), Cognitive flexibility (TMT B-A Test), Planning (Tower of London, Elithorn's Maze Test), overall Theory of mind (Smarties' Task, Sally & Ann Task, Strange Stories).

	TBI	Controls	*t*	*p*
Attention	0.39 (0.27)	0.87 (0.13)	9.07	0.0001
Long term memory	0.26 (0.22)	0.67 (0.13)	8.72	0.0001
Working memory	0.47 (0.27)	0.63 (0.23)	2.47	0.016
Cognitive flexibility	0.52 (0.39)	0.96 (0.10)	5.91	0.001
Planning	0.54 (0.28)	0.89 (0.10)	6.35	0.0001
Overall ToM	0.80 (0.24)	0.97 (0.08)	3.65	0.001

Table 4
Hierarchical regression analysis for variables predicting TBI performance on linguistic and extralinguistic scale, in both comprehension and production subscales: Model 1 (Attention, Long term memory), Model 2 (Working memory, Planning, Cognitive flexibility), Model 3 (overall Theory of Mind).

DVs	IVs	R^2_{Adj}	R^2_{Change}	F_{Change}	Sig. F_{Change}
Linguistic scale					
Comprehension	Model 1	−0.035	0.037	0.51	0.603
	Model 2	0.156	0.265	3.03	**0.049**
	Model 3	0.359	0.190	8.61	**0.007**
Production	Model 1	−0.052	0.021	0.289	0.751
	Model 2	0.151	0.276	3.14	**0.044**
	Model 3	0.294	0.143	5.85	**0.024**
Extralinguistic scale					
Comprehension	Model 1	−0.018	0.52	0.74	0.487
	Model 2	0.206	0.291	3.54	**0.030**
	Model 3	0.292	0.095	3.91	0.060
Production	Model 1	0.03	0.072	1.05	0.365
	Model 2	0.161	0.234	2.69	0.069
	Model 3	0.395	0.215	10.31	**0.004**

tients' pragmatic performance that was similar on the 4 different subscales, less than 10% of the explained variance: attention and long-term memory were involved in each of the pragmatic tasks examined, although their contribution remained at best very modest. The amount of explained variance tended to increase significantly when *Model 2* (executive functions) was included in the regression analysis: the change in R^2 after the addition of executive functions was significant in linguistic comprehension ($F_{(1,21)} = 5.92$; $p = 0.009$), linguistic production ($F_{(1,21)} = 3.97$; $p = 0.034$) and extralinguistic comprehension ($F_{(1,21)} = 4.80$; $p = 0.038$). The inclusion of *Model 3* (overall ToM tasks) into the regression analyses contributed to better explaining patients' pragmatic performance: the introduction of theory of mind produced a significant change in R^2 in linguistic comprehension ($F_{(1,20)} = 8.15$; $p = 0.010$), linguistic production ($F_{(1,20)} = 4.97$; $p = 0.037$) and extralinguistic production ($F_{(1,20)} = 10.6$; $p = 0.003$).

Considering the pragmatic performance of healthy controls, *Model 1* explains a very limited proportion of variance of less than 11%. No significant changes in R^2 were observed upon introducing *Model 2* and *Model 3* into the regression analyses (F_{Change}: $0.015 < F < 3.84$; $0.063 < p < 0.98$).

4. Discussion

In the present research we investigated the role played by background neuropsychological functions – attention and LTM - executive functions - WM, planning and cognitive flexibility - and overall ToM (first and second order) in explaining communicative-pragmatic difficulty in TBI individuals. The novelty of the present research consisted in studying the role of these cognitive factors in explaining TBI participants' communicative-pragmatic ability in terms of both comprehension and production, using linguistic and extralinguistic expressive means.

In line with our first expectation and with the relevant literature (Dardier et al., 2011; Murphy et al., 2015; Rousseaux et al., 2010) we found that TBI participants' performance, in both comprehension and production subscales on both the linguistic and extralinguistic scales of the ABaCo, was significantly worse compared with that of the control group (Angeleri et al., 2008, 2012; Bosco et al., 2012). Overall, we also found performance on the extralinguistic (comprehension + production subscales) scale to be poorer than that on the linguistic scale (comprehension + production subscales). This result is not surprising since the linguistic means of expression is the one more often used to communicate.

We also administered a series of tests to TBI individuals and controls investigating background neuropsychological functions (LTM and attention), EF (WM, planning and cognitive flexibility) and overall ToM (first and second order). As expected according to the relevant literature (Bibby & McDonald, 2005; Happé et al., 1999; Havet-Thomassin et al., 2006; Martin & McDonald, 2003) individuals with TBI performed less well in all the investigated components.

Finally, in order to investigate the contribution of EF and ToM to pragmatic performance, we performed a series of multiple regression analyses, considering as dependent variable TBI participants' performance on the linguistic and extralinguistic scales in both comprehension and production subscales (see Table 4), and using the EF investigated (WM, planning and cognitive flexibility) and overall ToM tasks as predictors.

As reported in Table 4, we controlled first for the role of background neuropsychological functions - Model 1 (attention and LTM). We then included as predictor variables executive functions - Model 2 (WM, planning and cognitive flexibility) - and overall theory of mind abilities - Model 3 (first and second order ToM tasks), which were considered separately in order to take their single distinctive effect on pragmatic performance into account. These variables were included in the regression model in their hierarchical order of possible increasing contribution to pragmatic performance, that is, first background neuropsychological functions (attention and LTM), then executive functions (WM, planning and cognitive flexibility) and finally overall ToM tasks.

Our analysis revealed that cognitive impairment plays a role in pragmatic performance. Background neuropsychological functions – attention and LTM - were able to explain a proportion of variability in communicative performance on all our subscales. This seems coherent with the idea that those background neuropsychological functions support communicative ability, even though their contribution remains at best very modest. The percentage of explained variance increased significantly with the inclusion of executive functions in the second stage of the analysis and theory of mind in the third stage on both the linguistic subscales, i.e. comprehension and production subscales. As regards the extralinguistic scale, we found that for the comprehension subscale the percentage of explained variance increased significantly for EF and not for ToM, while for the production subscale it was possible to observe the opposite, i.e. the percentage of explained variance increased significantly for ToM and not for EF. However, since in both cases the p-values were not far from significance (p ranging from 0.060 to 0.069), we suggest that the overall trend observed here is in line with those detected on the linguistic scale. For exploratory purposes we conducted the same analysis in the control sample, but in this case the insertion of our predictors variable into the regression model did not significantly increase the proportion of explained variance in pragmatic performance. Considered as a whole, these results seem to support the specific role of a deficit in both EF and ToM in explaining the communicative-pragmatic deficits shown by the TBI individuals who took part in the present research.

Honan et al. (2015) found that the relationship between ToM deficits and pragmatic impairments in individuals with TBI may in fact be mediated by WM demands set by the ToM tasks. McDonald et al. (2014) also reported that in patients with TBI executive demands are able to explain a large part of the relationship between ToM and pragmatic ability, with the exception of ToM tasks in which participants have to inhibit their own self-perspective, in order to switch to other people's perspectives; the difficulty shown by patients in this task was not accounted for by executive demands, suggesting a distinctive role of ToM, but only when the task also requires high inhibitory control. In line with these studies, our results confirmed the role that EF, in particular WM, cognitive flexibility and planning, may play in explaining pragmatic difficulties in TBI individuals. However, differently from these studies we found that the role of theory of mind is not accounted for by executive demands, as it persists even after controlling the contribution of EF. These data are in line with Muller et al. (2010) who reported a correlation between the comprehension of indirect speech acts and theory of mind ability, but did not find any relation between the EF measured (verbal fluency, inhibitory control and cognitive flexibility) and ToM tasks. Our results therefore confirm the role of ToM in explaining pragmatic impairments in individuals with TBI, and that its role cannot be reduced to those of other background neuropsychological functions – long-term memory and attention - or high-order executive functions – planning, cognitive flexibility, working memory.

A limit of the present investigation is that it only considered a limited number of EF, i.e. WM, planning and cognitive flexibility, while in the current literature other executive abilities such as inhibitory control, set shifting, and self-regulation have been reported to have a role in pragmatic impairment in TBI individuals (Douglas, 2010; Honan et al., 2015).

Despite this limitation our results may be helpful in order to better comprehend the nature of communicative-pragmatic deficits in patients with TBI and may have a role in improving rehabilitation programs (see for example Bosco, Gabbatore, Gastaldo, & Sacco, 2016; Gabbatore et al., 2015; Sacco et al., 2016) in order to remediate such difficulties.

Appendix A. Sample items from the pragmatic tasks

Scale	Sub-scale	Task	No. of items	Example
Linguistic	Comprehension	Standard	4	Sarah and David are at home. Sarah asks him: "Did you work out today?" David replies: "I worked out for an hour." − *What did the boy say to the girl*? − *Did the boy work out?*
		Deceit	4	Ryan is playing with a ball in the living room; he hits a vase, which falls and breaks. He immediately runs to the sofa, and starts cuddling his dog. The mom enters the room and asks him: "Who broke the vase?" Ryan replies: "It was Fido" − *What did the boy say to the mom*? − *Did the boy tell the truth*? − *Why did he say that*?
		Irony	4	Laura and Alex are in a fitting room, where Laura is trying a dress that is too tight for her. Laura hesitantly asks Alex: "How does it fit me?" Alex replies: "Your diet is really working!" − *What did the boy say to the girl?* − *Did he mean what he said?* − *Why did he say that?*
Linguistic	Production	Standard	4	Paul is sitting in the backyard. Beatrice comes out and asks him: "What would you like for dinner?" − *What could the boy say to the girl?*
		Deceit	4	Kevin is sit at the dining table, greedily eating some cupcakes. After a while, Janet arrives and asks Kevin: "Where are the cupcakes for grandma?" − *The boy doesn't want to be caught. What could he say to the girl?*
		Irony	4	Sandra is trying a green face-mask, which she has rubbed all over her face. Tim enters the room, sees her, and makes an amused expression. Perplexed, Sandra asks Tim: "Do you think it's going to work?" − *Imagine that the boy wants to make fun of the girl. What could he say?*
Extralinguistic	Comprehension	Standard	4	Daniel has just made some coffee and is pouring it into his cup. Julia comes into the kitchen, dressed in her coat and carrying a bag, ready to go out. Daniel gestures to her with the hand he is holding the coffee pot in, as if to ask her if she would like a cup too. Julia looks at the clock, then at Daniel, pulling a face, as if to say "It's late!", and turns to leave. − *What did the girl want to say to the boy?* − *Will the girl have the coffee?*
		Deceit	4	Christina is sitting at her desk, intent on studying. Behind her is Martha, wrapped only in a bath towel, who, stealthily, without being seen, picks up a sweater that belongs to her sister from the back of a chair and takes it into the bathroom. Immediately afterwards Christina enters the bathroom, picks up the sweater and, looking a bit cross, puts one hand on her hip and looks at her sister as if to say: "Did you take my sweater?" Martha shakes her head, with an innocent face. − *What did the girl want to say to her sister?* − *Did the girl tell the truth?* − *Why did she make that gesture?*
		Irony	4	The scene opens with Peter and Alice in the kitchen, sitting at a table that has been laid. Alice gets up to fetch a pan, which she brings to the table, and pours a ladle of soup into the dishes. They taste a spoonful and both pull a disgusted face, as if the soup were uneatable. Alice looks questioningly at Peter, who takes his fingers to his mouth and kisses his fingertips with an expression as if to say "Delicious!" − *What did the boy want to say to the girl?* − *Did he mean it?* − *Why did he make that gesture?*
Extralinguistic	Production	Standard	4	Diego is sitting on the sofa reading a book. Madeline enters the room and indicates the book questioningly, as if to ask "What's it like? It's good, isn't it?" − *What gesture could the boy answer with?*
		Deceit	4	James eats the last chocolate on a tray on the table. Stella arrives, looks at the tray and holds it out to James looking slightly annoyed, as if to ask him if he ate the last chocolate. − *The boy doesn't want to be found out. What gesture can he make?*
		Irony	4	Robert is playing at building a tower with some colored wooden blocks. Charlotte comes in and sits next to him and adds a brick, making the whole tower collapse. − *Imagine the boy wants to make fun of the girl. What gesture can he make*?

Appendix B. Neuropsychological tasks

Cognitive domain	Test	Description	Reference
Attention	Attentional Matrices	This task measures selective visuo-perceptual attention. The experimenter asks the participant to cross out target digits in three different matrices (1-digit, 2-digit, and 3-digit targets). Each matrix is made up of 11 rows of 10 digits each; the participant has 45 s to complete each matrix	Della Sala, Nespoli, Ronchetti, and Spinnler (1984) and Spinnler and Tognoni (1987)
Working memory	Disyllabic Word Repetition Test	The task measures the span of verbal working memory. The examiner reads a list of disyllabic words of increasing length (2 words, 3 words, 4 words, and so on). The participant has to repeat the words in the same order	Spinnler and Tognoni (1987)

	Corsi's block tapping test	This task measures visuo-spatial short term working memory. The participant observes the examiner as s/he taps a sequence of up to nine square blocks positioned on a wooden board, and is then asked to reproduce the sequence	Spinnler and Tognoni (1987)
	Story Recall Test (immediate recall)	This task measures immediate and deferred recall. The experimenter reads a story that comprises 28 mnemonic units (twice). To assess immediate recall, the participant is asked to recall the story immediately after hearing it	Novelli, Papagno, Capitani, and Laiacona (1986)
Long-term memory	Story Recall Test (deferred recall)	To assess deferred recall, the participant is asked to recall the story after 15 min, during which s/he has been involved in unrelated non-verbal tasks	Novelli et al. (1986)
Flexibility	Trail Making Test (B-A)	The task measures cognitive flexibility in a visual-motor sequencing task. The task is divided in two parts; both parts consist of 25 circles distributed over a sheet of paper. In Part A, the circles are numbered from 1 to 25, and the participant is asked to draw lines to connect the circles/numbers in ascending order. In Part B, the circles include both numbers (from 1 to 13) and letters (from A to L); the participant is required to draw lines to connect the circles in an ascending order, but in this case alternating between the numbers and letters. The difference in completion time between the two parts (B-A) is used as an index of cognitive flexibility (switching)	Reitan (1958)
Planning	Tower of London	This task measures planning abilities. Task materials comprise three wooden pegs of different lengths mounted on a base; the participant is asked to move three colored balls (blue, red, and green) between the pegs to reproduce an end state shown in a picture. A problem is accurately solved when the end state is reproduced in the prescribed number of moves	Shallice (1982)
	Elithorn's Maze Test	This test measures spatial planning abilities using six rectangular and two triangular mazes. The experimenter asks the participant to trace a path starting from the bottom of each maze in an upward direction, keeping to the lines, and passing through a target number of dots	Elithorn (1955, 1964) and Spinnler and Tognoni (1987)
Theory of mind	Smarties Task	This task assesses false-belief understanding. The participant is shown a Smarties box that contains a pencil rather than the expected candy. The participant is then asked what another person—who has not seen the actual content—will think is inside the tube before it is opened	Perner et al. (1989)
	Sally & Ann Task	This task is a location-change task that assesses false-belief understanding. The participant is shown a scenario in which a doll (Sally) puts a marble in a basket and then leaves. While she is gone, another doll (Anne) moves the marble from the basket to a box. The participant is asked where Sally will look for her marble when she comes back	Baron-Cohen et al. (1985)
	Strange Stories	The Strange Stories assess theory of mind abilities. Participants are asked to explain the motivations of story characters who at the end of each story produce an utterance (e.g., pretence, double-bluff). The participant is asked if what the character said was true, and why the character said that	Happé (1994)

References

Altman, D. G. (1991). Inter-rater agreement. *Practical statistics for medical research*, *5*, 403-409. Angeleri, R., Bara, B.G., Bosco, F.M., Colle, L., Sacco, K., 2015. Batteria per l'assessment della comunicazione (ABaCo). Giunti O.S., Bologna, IT.

Angeleri, R., Bosco, F.M., Gabbatore, I., Bara, B.G., Sacco, K., 2012. Assessment battery for communication (ABaCo): Normative data. Behavior Research Methods 44, 845–861.

Angeleri, R., Bosco, F.M., Zettin, M., Sacco, K., Colle, L., Bara, B.G., 2008. Communicative impairment in traumatic brain injury: A complete pragmatic assessment. Brain and Language 107, 229–245.

Angeleri, R., Gabbatore, I., Bosco, F.M., Sacco, K., Colle, L., 2016. Pragmatic abilities in children and adolescents with Autism Spectrum Disorder: A study with the ABaCo battery. Minerva Psichiatrica 57, 93–103.

Arbuthnott, K., Frank, J., 2000. Trail making test, part B as a measure of executive control: Validation using a set-switching paradigm. Journal of Clinical and Experimental Neuropsychology 22, 518–528.

Ashman, T.A., Gordon, W.A., Cantor, J.B., Hibbard, M.R., 2006. Neurobehavioral consequences of traumatic brain injury. The Mount Sinai Journal of Medicine 73, 999–1005.

Bambini, V., Arcara, G., Martinelli, I., Bernini, S., Alvisi, E., Moro, A., … Ceroni, M., 2016. Communication and pragmatic breakdowns in amyotrophic lateral sclerosis patients. Brain and Language 153, 1–12.

Bara, B.G., 2010. Cognitive pragmatics: The mental processes of communication. MIT Press, Cambridge, MA.

Bara, B.G., Cutica, I., Tirassa, M., 2001. Neuropragmatics: Extralinguistic communication after closed head injury. Brain and Language 77, 72–94.

Bara, B.G., Tirassa, M., Zettin, M., 1997. Neuropragmatics: Neuropsychological constraints on formal theories of dialogue. Brain and Language 59, 7–49.

Baron-Cohen, S., Leslie, A., Frith, A.M., 1985. Does the autistic child have a "Theory of Mind?". Cognition 21, 37–46.

Bibby, H., McDonald, S., 2005. Theory of mind after traumatic brain injury. Neuropsychologia 43, 99–114.

Bloom, P., & German, T. P. (2000). Two reasons to abandon the false belief task as a test of theory of mind. *Cognition*, *77*(1), B25-B31.

Bosco, F.M., Angeleri, R., Colle, L., Sacco, K., Bara, B.G., 2013. Communicative abilities in children: An assessment through different phenomena and expressive mean. Journal of Child Language 40, 741–778.

Bosco, F.M., Angeleri, R., Sacco, K., Bara, B.G., 2015. Explaining pragmatic performance in traumatic brain injury: A process perspective on communicative errors. International Journal of Language and Communication Disorders 50, 63–83.

Bosco, F.M., Angeleri, R., Zuffranieri, M., Bara, B.G., Sacco, K., 2012. Assessment battery for communication: Development of two equivalent forms. Journal of Communication Disorders 45, 290–303.

Bosco, F.M., Bono, A., Bara, B.G., 2012. Recognition and repair of communicative failures: The interaction between theory of mind and cognitive complexity in schizophrenic patients. Journal of Communication Disorders 145, 181–197.

Bosco, F.M., Gabbatore, I., Gastaldo, L., Sacco, K., 2016. Communicative-pragmatic treatment in schizophrenia: A pilot study. Frontiers in Psychology 7.

Braun, C.M.J., Lissier, F., Baribeau, J.M.C., Ethier, M., 1989. Does severe traumatic closed head injury impair sense of humor?. Brain Injury 3, 345–354.

Byom, L.J., Turkstra, L., 2012. Effects of social cognitive demand on Theory of Mind in conversations of adults with traumatic brain injury. International Journal of Language and Communication Disorders 47, 310–321.

Capitani, E., Laiacona, M., 1997. Composite neuropsychological batteries and demographic correction: Standardization based on equivalent scores, with a review of

published data. Journal of Clinical and Experimental Neuropsychology 19, 795–809.
Channon, S., Pellijeff, A., Rule, A., 2005. Social cognition after head injury: Sarcasm and theory of mind. Brain and Language 93, 123–134.
Channon, S., Rule, A., Maudgil, D., Martinos, M., Pellijeff, A., Frankl, J., … Shieff, C., 2007. Interpretation of mentalistic actions and sarcastic remarks: Effects of frontal and posterior lesions on mentalising. Neuropsychologia 45, 1725–1734.
Channon, S., Watts, M., 2003. Pragmatic language interpretation after closed head injury: Relationship to executive functioning. Cognitive Neuropsychiatry 8, 243–260.
Colle, L., Angeleri, R., Vallana, M., Sacco, K., Bara, B.G., Bosco, F.M., 2013. Understanding the communicative impairments in schizophrenia: A preliminary study. Journal of Communication Disorders 46, 294–308.
Cummings, L., 2005. Pragmatics: A multidisciplinary perspective. Edinburgh University Press, Edinburgh, Scotland, UK.
Cummings, L., 2009. Clinical pragmatics. Cambridge University Press, Cambridge, UK.
Cummings, L., 2014. Pragmatic disorders. Springer, Dordrecht, NL.
Cummings, L., 2015. Theory of mind in utterance interpretation: The case from clinical pragmatics. Frontiers in Psychology 6, 1286.
Dardier, V., Bernicot, J., Delanoe, A., Vanberten, M., Fayada, C., Chevignard, M., … Dubois, B., 2011. Severe traumatic brain injury, frontal lesions, and social aspects of language use: A study of French-speaking adults. Journal of Communication Disorders 44, 359–378.
De Renzi, E., Vignolo, L.A., 1962. The Token Test: A sensitive test to detect receptive disturbances in aphasics. Brain 85, 665–678.
Della Sala, S., Nespoli, A., Ronchetti, E., Spinnler, H., 1984. Does chronic liver failure lead to chronic mental impairment?. In: Kleinberger, G., Ferenci, P., Riederer, P., Thaler, H. (Eds.), Advances in hepatic encephalopathy and urea cycle diseases. S. Karger, Base, CH, pp. 448–455.
Dikmen, S.S., Corrigan, J.D., Levin, H.S., Machamer, J., Stiers, W., Weisskopf, M.G., 2009. Cognitive outcome following traumatic brain injury. Journal of Head Trauma Rehabilitation 24, 430–438.
Docking, K., Murdoch, B.E., Jordan, F.M., 2000. Interpretation and comprehension of linguistic humor by adolescents with head injury: A group analysis. Brain Injury 14, 89–108.
Douglas, J.M., 2010. Relation of executive functioning to pragmatic outcome following severe traumatic brain injury. Journal of Speech, Language and Hearing Research 53, 365–382.
Douglas, J.M., O'Flaherty, C.A., Snow, P.C., 2000. Measuring perception of communicative ability: The development and evaluation of the La Trobe Communication Questionnaire. Aphasiology 14, 251–268.
Elithorn, A., 1955. A preliminary report on a perceptual maze test sensitive to brain damage. Journal of Neurology, Neurosurgery and Psychiatry 18, 287–292.
Elithorn, A., 1964. Intelligence perceptual integration and the minor hemisphere. Neuropsychologia 2, 327–332.
Folstein, M., Folstein, S., McHugh, P., 1975. Mini-Mental State: A practical method for grading the cognitive state of patients for the clinicians. Journal of Psychiatric Research 12, 189–198.
Gabbatore, I., Angeleri, R., Bosco, F.M., Cossa, F.M., Bara, B.G., Sacco, K., 2014. Assessment of communicative abilities in aphasic patients. Minerva Psichiatrica 55, 45–55.
Gabbatore, I., Sacco, K., Angeleri, R., Zettin, M., Bara, B.G., Bosco, F.M., 2015. Cognitive pragmatic treatment: A rehabilitative program for traumatic brain injury individuals. The Journal of Head Trauma Rehabilitation 30, E14–E28.
Geraci, A., Surian, L., Ferraro, M., Cantagallo, A., 2010. Theory of mind in patients with ventromedial or dorsolateral prefrontal lesions following traumatic brain injury. Brain Injury 24, 978–987.
Happé, F.G.E., 1994. An advanced test of theory of mind: Understanding of story characters' thoughts and feelings by able autistic, mentally handicapped, and normal children and adults. Journal of Autism and Developmental Disorders 24, 129–154.
Happé, F.G.E., Brownell, H., Winner, E., 1999. Acquired theory of mind impairments following stroke. Cognition 70, 211–240.
Happé, F.G.E., Loth, E., 2002. 'Theory of mind' and tracking speakers' intentions. Mind and Language 17, 24–36.
Havet-Thomassin, V., Allain, P., Etcharry-Bouyx, F., Le Gall, D., 2006. What about theory of mind after severe brain injury?. Brain Injury 20, 83–91.
Honan, C.A., McDonald, S., Gowland, A., Fisher, A., Randall, R.K., 2015. Deficits in comprehension of speech acts after TBI: The role of theory of mind and executive function. Brain and Language 150, 69–79.
Huber, W., Poeck, K., Weniger, D., Willmes, K., 1983. Der aachener aphasie test (AAT). Hogrefe, Göttingen, DE.
Johnco, C., Wuthrich, V.M., Rapee, R.M., 2013. The role of cognitive flexibility in cognitive restructuring skill acquisition among older adults. Journal of Anxiety Disorders 27, 576–584.
Johnson, J.E., Turkstra, L.S., 2012. Inference in conversation of adults with traumatic brain injury. Brain Injury 26, 1118–1126.
Kortte, K.B., Horner, M.D., Windham, W.K., 2002. The trail making test, part B: Cognitive flexibility or ability to maintain set?. Applied Neuropsychology 9, 106–109.
Leslie, A.M., Friedman, O., German, T.P., 2004. Core mechanisms in 'theory of mind'. Trends in Cognitive Sciences 8, 528–533.
Levinson, F.C., 1983. Pragmatics. Cambridge University Press, Cambridge, UK.
Marini, A., Galetto, V., Zampieri, E., Vorano, L., Zettin, M., Carlomagno, S., 2011. Narrative language in traumatic brain injury. Neuropsychologia 49, 2904–2910.
Marini, A., Zettin, M., Galetto, V., 2014. Cognitive correlates of narrative impairment in moderate traumatic brain injury. Neuropsychologia 64, 282–288.
Martin, I., McDonald, S., 2003. Weak coherence, no theory of mind, or executive dysfunction? Solving the puzzle of pragmatic language disorders. Brain and Language 85, 451–466.
Martin, I., McDonald, S., 2005. Evaluating the causes of impaired irony comprehension following traumatic brain injury. Aphasiology 19, 712–730.
Martín-Rodríguez, J.F., León-Carrión, J., 2010. Theory of mind deficits in patients with acquired brain injury: A quantitative review. Neuropsychologia 48, 1181–1191.
McDonald, S., 1992. Differential pragmatic language loss after closed head injury: Ability to comprehend conversational implicature. Applied Psycholinguistics 13, 295–312.
McDonald, S., 1993. Viewing the brain sideways? Right hemisphere versus anterior models of non-aphasic language disorders. Aphasiology 7, 535–549.
McDonald, S., 2013. Impairments in social cognition following severe traumatic brain injury. Journal of the International Neuropsychological Society 19, 1–16.
McDonald, S., Flanagan, S., 2004. Social perception deficits after traumatic brain injury: Interaction between emotion recognition, mentalizing ability, and social communication. Neuropsychology 18, 572–579.
McDonald, S., Flanagan, S., Rollins, J., Kinch, J., 2003. TASIT: A new clinical tool for assessing social perception after traumatic brain injury. Journal of Head Trauma Rehabilitation 18, 219–238.
McDonald, S., Gowland, A., Randall, R., Fisher, A., Osborne-Crowley, K., Honan, C., 2014. Cognitive factors underpinning poor expressive communication skills after traumatic brain injury: Theory of mind or executive function?. Neuropsychology 28, 801–811.
McDonald, S., Pearce, S., 1996. Clinical insight into pragmatic theory: Frontal lobe deficits and sarcasm. Brain and Language 61, 88–104.
McDonald, S., Pearce, S., 1998. Requests that overcome listener reluctance: Impairment associated with executive dysfunction in brain injury. Brain and Language 61, 88–104.
McDonald, S., Van Sommers, P., 1993. Pragmatic language skills after closed head injury: Ability to negotiate requests. Cognitive Neuropsychology 10, 297–315.
Milders, M., Ietswaart, M., Crawford, J.R., Currie, D., 2006. Impairments in theory of mind shortly after traumatic brain injury and at 1-year follow-up. Neuropsychology 20, 400–408.
Miyake, A., Friedman, N.P., Emerson, M.J., Witzki, A.H., Howerter, A., Wager, T.D., 2000. The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. Cognitive Psychology 41, 49–100.
Muller, F., Simion, A., Reviriego, E., Galera, C., Mazaux, J.M., Barat, M., Joseph, P., 2010. Exploring theory of mind after severe traumatic brain injury. Cortex 46, 1088–1099.
Murphy, A., Huang, H., Montgomery, E.B., Turkstra, L.S., 2015. Conversational turn-taking in adults with acquired brain injury. Aphasiology 29, 151–168.
Novelli, G., Papagno, C., Capitani, E., Laiacona, M., 1986. Tre test clinici di memoria verbale a lungo termine: Taratura su soggetti normali. Archivio di Psicologia, Neurologia e Psichiatria 47, 278–296.
Parola, A., Gabbatore, I., Bosco, F.M., Bara, B.G., Cossa, F.M., Gindri, P., Sacco, K., 2016. Assessment of pragmatic impairment in right hemisphere damage. Journal of Neurolinguistics 39, 10–25.
Pearce, S., McDonald, S., Coltheart, M., 1998. Interpreting ambiguous advertisements: The effect of frontal lobe damage. Brain and Cognition 38, 150–164.
Perkins, M.R., 2000. The scope of pragmatic disability: A cognitive approach. In: Müller, N. (Ed.), Pragmatics and clinical applications. John Benjamins, Amsterdam, NL, pp. 7–28.
Perner, J., Frith, U., Leslie, A.M., Leekam, S.R., 1989. Exploration of the autistic child's theory of mind: Knowledge, belief and communication. Child Development 60, 689–700.
Perner, J., Wimmer, H., 1985. "John thinks that Mary thinks that…": Attribution of second-order beliefs by 5- to 10-year-old children. Journal of Experimental Child Psychology 39, 437–471.
Premack, D., Woodruff, G., 1978. Does the chimpanzee have a theory of mind?. Behavioral and Brain Sciences 1, 515–526.
Reitan, R.M., 1958. The validity of the Trail Making Test as an indicator of organic brain damage. Perceptual and Motor Skills 8, 271–276.
Rousseaux, M., Vérigneaux, C., Kozlowski, O., 2010. An analysis of communication in conversation after severe traumatic brain injury. European Journal of Neurology 17, 922–929.

Sacco, K., Angeleri, R., Bosco, F.M., Colle, L., Mate, D., Bara, B.G., 2008. Assessment Battery for Communication – ABaCo: A new instrument for the evaluation of pragmatic abilities. Journal of Cognitive Science 9, 111–157.
Sacco, K., Gabbatore, I., Geda, E., Duca, S., Cauda, F., Bara, B.G., Bosco, F.M., 2016. Rehabilitation of communicative abilities in patients with a history of TBI: Behavioral improvements and cerebral changes in resting-state activity. Frontiers in Behavioral Neuroscience 10.
Shallice, T., 1982. Specific impairments of planning. Philosophical Transactions of the Royal Society of London, Series B 298, 199–209.
Smith, E.E., Jonides, J., 1999. Storage and executive processes in the frontal lobes. Science 283, 1657–1661.
Spikman, J.M., Timmerman, M.E., Milders, M.V., Veenstra, W.S., van der Naalt, J., 2012. Social cognition impairments in relation to general cognitive deficits, injury severity, and prefrontal lesions in traumatic brain injury patients. Journal of Neurotrauma 29, 101–111.
Spinnler, H., Tognoni, G., 1987. Standardizzazione e taratura italiana di test neuropsicologici. The Italian Journal of Neurological Sciences 6 (Suppl. 8).
Stemmer, B. (Ed.), 1999. Special Issue on Pragmatics. Brain and Language, Vol. 68(1).
Struchen, M., Pappadis, M., Sander, A.M., Burrows, C., Myszka, K.A., 2011. Examining the contribution of social communication abilities and affective/behavioral functioning to social integration outcomes for adults with traumatic brain injury. Journal of Head Trauma Rehabilitation 26, 30–42.
Sullivan, J.R., Riccio, C.A., Castillo, C.L., 2009. Concurrent validity of the tower tasks as measures of executive function in adults: A meta-analysis. Applied Neuropsychology 16, 62–75.
Teasdale, G., Jennett, B., 1974. Assessment of coma and impaired consciousness. A practical scale. Lancet 2, 81–84.
Thomas, E., Snyder, P.J., Pietrzak, R.H., Maruff, P., 2014. Behavior at the choice point: Decision making in hidden pathway maze learning. Neuropsychology Review 24, 514–536.
Tirassa, M., Bosco, F.M., Colle, L., 2006. Rethinking the ontogeny of mindreading. Consciousness and Cognition 15, 197–217.
Tirassa, M., Bosco, F.M., Colle, L., 2006. Sharedness and privateness in human early social life. Cognitive Systems Research 7, 128–139.
Wimmer, H., Perner, J., 1983. Beliefs about beliefs: Representation and constraining function of wrong beliefs in young children's understanding of deception. Cognition 13, 103–128.
Winner, E., Gardner, H., 1977. Comprehension of metaphor in brain damaged patients. Brain 100, 717–729.