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Patterns of impairment of narrative language in mild traumatic brain injury

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ABSTRACT

Mild traumatic brain injury (mTBI) represents a condition whose cognitive and behavioral sequelae are often underestimated, even when it exerts a profound impact on the patients' every-day life. The present study aimed to analyze the features of narrative discourse impairment in a group of adults with mTBI. 10 mTBI non-aphasic speakers (GCS > 13) and 13 neurologically intact participants were recruited for the experiment. Their cognitive, linguistic and narrative skills were thoroughly assessed. The group of mTBIs exhibited normal phonological, lexical and grammatical skills. However, their narratives were characterized by the presence of frequent interruptions of ongoing utterances, derailments and extraneous utterances that at times made their discourse vague and ambiguous. They produced more errors of global coherence [F (1; 21) = 24.242; p = .000; η_p^2 = 0. 536] and fewer Lexical Information Units [F (1; 21) = 7.068; p = .015; η_p^2 = .252]. The errors of global coherence correlated negatively with non-perseverative errors on the WCST (r = −.755; p < .012). The macrolinguistic problems made their narrative samples less informative than those produced by the group of control participants. These disturbances may reflect a deficit at the interface between cognitive and linguistic processing rather than a specific linguistic

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disturbance. These findings suggest that also persons with mild forms of TBI may experience linguistic disturbances that may hamper the quality of their every-day life.

1. Introduction

Individuals with traumatic brain injury (TBI) usually experience communicative impairments, which may vary in severity from subtle word-finding difficulties to frank aphasic symptoms. The ability to produce informative narratives, central to communicative success, poses a major challenge to them. Indeed, even those patients who do not exhibit evident microlinguistic (i.e., lexical or grammatical) difficulties may be communicatively inadequate and unable to deal with the macrolinguistic aspects of language processing (e.g., Glosser & Deser, 1991; Marini, Andreetta, Del Tin, & Carlomagno, 2011). These include pragmatic difficulties (e.g., in the production/comprehension of non literal expressions; Angeleri et al., 2008) and inefficacy in producing well-structured informative messages (e.g., Davis & Coelho, 2004). As a result, their contributions in conversation are usually described as confused and impoverished (e.g., Carlomagno, Giannotti, Vorano, & Marini, 2011).

The vast majority of the studies that analyzed discourse abilities in these persons have focused on severe and moderate forms of brain injury. These investigations have consistently reported poor topic management, tangentiality, difficulties in the use of cohesive markers and in dealing with the superstructural organization of their narratives (Body & Perkins, 2004; Coelho, 2002; Coelho, Liles, & Duffy, 1991, 1994; Groher, 1997; Marini, Galetto, et al., 2011; McDonald, 1993, 2000; Snow & Douglas, 2000; Turkstra, McDonald, & Kaufmann, 1996). For example, Coelho (2002) studied a cohort of fifty-five consecutive participants with TBI who were not aphasic on a story generation and a story retelling task. These individuals did not differ from a group of healthy participants in terms of sentence complexity and cohesive adequacy (i.e., proportion of complete cohesive ties) but introduced in their narratives more extraneous propositional content, suggesting problems in the organization of information at intersentential level. More recently, Carlomagno et al. (2011) on a narrative discourse production task found in 10 non-aphasic TBI adults normal microlinguistic abilities but impaired macrolinguistic processing in terms of errors of cohesion, local and global coherence. Interestingly, the occurrence of macrolinguistic errors correlated with the rating of language inaccuracy by naïve judges. These results further suggest that the impression of confused and impoverished language from non-aphasic individuals with TBI may depend on the reduced ability to organize information at the macrolinguistic level of processing rather than on difficulties in dealing with lexical and syntactic (i.e., microlinguistic) aspects of language production. The possibility of a problem in the global organization of information at the text level is supported by findings from studies focusing on story grammars. These refer to “the internal structure of stories which guide an individual’s comprehension and production of logical relationships, both temporal and causal, between agents and events” (Cannizzaro & Coelho, 2002, p. 1065). Indeed, these studies have highlighted the presence of problems in using story grammar knowledge to guide narrative discourse formulation (e.g., Body & Perkins, 2004; Brookshire, Chapman, Song, & Levin, 2000; Coelho, 2002; Le, Coelho, Mozeiko, Krueger, & Grafman, 2011a). This wide range of difficulties is likely linked to the diffuse nature of the injury (Adamovich, 1997; Davis, 2000; Stierwalt & Murray, 2002). Indeed, the available evidence from both structural and functional neuroimaging studies clearly shows that persons who have sustained a TBI may experience diffuse axonal damage and show frontal and/or temporal hypometabolism when engaged in highly-demanding tasks such as those assessing working memory, attention, and response inhibition (e.g., Graham, 1999; Mendez, Hurley, & Lassonde, 2005; Silver, McAllister, & Arciniegas, 2009; Stierwalt & Murray, 2002). Noteworthy, growing evidence highlights the importance of these areas also in discourse processing (e.g., Coelho, Le, Mozeiko, Krueger, & Grafman, 2012; Marini & Urgesi, 2012).

To the best of our knowledge, only few studies have focused on the communicative skills of individuals with mild TBI (mTBI; Stout, Yorkston, & Pimental, 2000; Tucker & Hanlon, 1998). This is striking when one considers the high incidence of mild traumas (approximately 80% of all brain traumas are of mild severity; Kraus & McArthur, 1996; Erez, Rothschild, Katz, Tuchner, & Hartman-Maeir, 2009). Moreover, even though the majority of individuals with mTBI will recover fully, a relevant minority develops chronic post-traumatic emotional impairments and mild cognitive problems. For example, several investigations showed the presence of reduced processing speed, problems with attention, memory, verbal fluency and executive functioning (Binder, 1997; Erez et al., 2009; Frencham, Fox, & Maybery, 2005; Vanderploeg, Curtiss, Luis, & Salazar, 2007). Furthermore, even persons with mild forms of TBI may experience word-finding difficulties and a certain difficulty in ordering their ideas when asked to produce well-structured and informative messages. In a seminal investigation on the argument, Tucker and Hanlon (1998) compared cognitive and narrative skills of eight individuals with mild TBI, five with moderate TBI, and a control group of neurologically healthy individuals. The participants were asked to produce narrative samples on a picture arrangement and description task. The narratives were scored for correct arrangement, presence of content essential information, correct story production, and ability to imply the meanings in the stories. Interestingly, both groups of participants with TBI were significantly less accurate in their story descriptions than the control group. Overall, the authors suggested that the cognitive impairments associated with mTBI might affect the quality of their narrative discourse. Similar results were reported by Stout et al. (2000) who examined the efficiency in discourse production of a group of 94 individuals with mild, moderate and severe TBI. The analyses showed that the narrative skills of persons with TBI were characterized by shorter narratives. These former studies suggest that persons with mTBI might experience macrolinguistic difficulties that resemble those observed in persons with severe forms of TBI. More recent, albeit indirect, investigations seem to support this conclusion, as difficulties in dealing with the pragmatic aspects of verbal communication have been recently reported by Parrish, Roth, Roberts, and Davie (2011) and Blyth, Scott, Bond, and Paul (2012). These difficulties might depend on the effects of the lesion on higher cortical functions important on tasks demanding cognitive flexibility such as that required to produce well-formed, informative messages (i.e., working memory and/or executive control – Ylvisaker, Szekeres, & Feeney, 2001; Whelan, Murdoch, & Theodors, 2006). It has been proposed that discourse impairments in these patients might reflect a dysfunction of working memory and/or executive control over macrolinguistic processes. Indeed, in a recent study Mozeiko, Le, Coelho, Krueger, and Grafman (2011) assessed narrative skills in a large group of TBI participants on a story retelling task showing a significant correlation between measures of story grammar organization and those of executive functioning.

Overall, the few studies conducted so far to explore the macrolinguistic skills of persons with mTBI suggest that they may experience problems in the conceptual and linguistic organization of their messages and that these difficulties may depend on the diffuse nature of the lesion leading to reduced cognitive efficiency. However, to the best of our knowledge, none of the available investigations explicitly included persons with mTBI without aphasic symptoms. Indeed, aphasic symptoms such as phonological difficulties, as well as lexical and/or phonological, lexical or morphosyntactic deficits may have biased the results from previous investigations by concealing the presence of higher-level difficulties in linguistic processing. Furthermore, too often the cognitive profile of the selected participants is not fully reported and this does not allow estimating whether macrolinguistic disturbances are related to more general cognitive impairments. Finally, in none of these investigations the authors have performed an accurate micro- and macrolinguistic analysis in parallel. Consequently, the current study was designed to quantify both microlinguistic and macrolinguistic skills in persons who have sustained a mild TBI on a picture description task that has been designed to elicit the production of samples of narrative discourse. Furthermore, as the participants were all non-aphasic, the analyses allowed us to detect potential macrolinguistic difficulties. Furthermore, the cognitive profile of the participants was analytically analyzed so to explore the possibility that such potential impairments might be related to more general cognitive difficulties. We hypothesized that even in persons with mild TBI we would find macrolinguistic deficits likely deriving from difficulties in the phases of message planning and organization of coherence across the narratives. Furthermore, we also hypothesized that these patients would have difficulties in dealing with cognitive tasks assessing executive functioning. Finally, we predicted that the production of macrolinguistic errors would correlate with their performance on tasks tapping their executive functions.

2. Methods

2.1. Participants

Twenty-three Italian-speaking participants were included in the study. They formed two groups matched for age and level of formal education (Table 1). The experimental group was formed by 10 individuals with mild Traumatic Brain Injury (Age – mean: 35.4; SD: 10.8; Level of formal education – mean: 10.5; SD: 2.9), with a Glasgow Coma Scale that, in the acute phase, had been higher than 13. In order to be included in the experimental group they had to be in the chronic phase (months post-onset – mean: 39.1; SD: 8.3; range: 26–53). Furthermore, the presence of aphasia was ruled out after a linguistic analysis of their conversational skills and the administration of the Aachener Aphasie Test (AAT, Italian version, Luzzatti, Willems, & DeBleser, 1991; see Table 2).

The control group was formed by 13 neurologically healthy controls (HC) (Age – mean: 34.9; SD: 5.8; Level of formal education: 12.3 SD: 1.8). Inclusion criteria for admission in the control group included normal range performance on Raven's progressive matrices (Raven, 1938) and normal performance on a series of neuropsychological tests (see the *Neuropsychological assessment* section and Table 4). None of the participants had a previous history of psychiatric or neurological illness, learning disabilities, nor hearing or visual loss.

The study received institutional ethics approval from the Ethical Committee of the IRCCS "E. Medea". All participants released their written informed consent to participate to the study after all procedures had been fully explained.

2.2. Procedures

2.2.1. Neuropsychological assessment

The cognitive profile of all participants was evaluated through a neuropsychological assessment, that focused on those cognitive functions necessary to complete the narrative task: phonological and semantic verbal fluency, phonological short-term memory (digit span), verbal learning (Rey's 15-word Immediate Recall and Delayed Recall; Rey, 1964), executive functioning (Wisconsin Card Sorting Test, WCST perseverative and non-perseverative errors; Heaton, Chelune, Talley, Kay, & Curtiss, 1993), and sustained and selective attention (Trail Making Test, Parts A and B, respectively; Reitan, 1992).

2.2.2. Assessment of narrative abilities

The assessment of narrative abilities was performed on story-tellings. Each participant was asked to produce a set of narratives elicited with the help of one single picture depicting a shot of a story (the scene of a "Picnic") and two cartoon stories with six pictures each presented on the same page (the stories of the "Flower Pot" and of a "Quarrel"). The single picture "Picnic" was taken from the Western Aphasia Battery (WAB; Kertesz, 1982). The two cartoon-picture sequences have been used by Huber and Gleber (1982) and by Nicholas and Brookshire (1993) respectively, for analyzing textual competence and discourse information content in persons with brain injuries. Each participant was asked to describe all three stories. The order of presentation was counterbalanced across subjects. In order to avoid poor performance due to short-term memory limitations, the picture or cartoon story remained

Table 1
Means (and standard deviations) of demographic and clinical characteristics of the groups of traumatic brain injured (TBI) and healthy control (HC) participants.

	TBI	HC
	Mean (SD) (range)	Mean (SD) (range)
Age	(35.4) (10.8) (20–52)	34.9 (5.8) (20–44)
Formal education (years)	10.5 (2.9) (5–13)	12.3 (1.9) (8–14)
Time after injury (months)	39.1 (8.3) (26–53)	–
GCS (score)	14.2 (0.66) (13–15)	–
Raven's progressive matrices	–	33.5 (2.4) (28–36)

Table 2
Performance on the AAT of the 10 participants with TBI.

Participant	Token	Repetition	Writing	Naming	Comprehension	Spontaneous language
TBI_1	64	71	65	73	68	22
TBI_2	69	65	65	71	70	23
TBI_3	66	64	72	73	77	21
TBI_4	63	67	68	65	70	23
TBI_5	77	73	77	72	74	25
TBI_6	73	67	66	74	68	24
TBI_7	66	67	72	77	71	21
TBI_8	74	71	77	77	74	25
TBI_9	69	71	65	67	65	23
TBI_10	73	73	68	77	73	23

visible until the speaker had finished his/her description. Each storytelling was tape-recorded, transcribed verbatim by two of the authors (AM, VG) and the transcription included phonological fillers, pauses, false starts and extraneous utterances.

These transcriptions underwent quantitative, in-depth linguistic and textual analysis focusing on five main aspects of linguistic processing: productivity, speech rate, lexical and syntactic encoding, textual organization and informativeness (Marini, Andreetta, et al., 2011) (see Appendix for a schematic description of the narrative measures).

Productivity measures included units, words, speech rate and mean length of utterance (MLU). A unit was formed by each word, non-word or syllabic false start uttered by the speaker. The total number of well-formed words with the exception of phonological fillers, phonemic paraphasias and phonetic errors was then computed. The number of words was used to obtain a measure of speech rate in terms of words per minute (Words/m′). For each story description, the total number of utterances was assessed following the criteria established in the Shewan Spontaneous Language Analysis System (Shewan, 1988) and further detailed in Marini, Andreetta, et al. (2011). The MLU was calculated by dividing the total number of words by the number of utterances.

Lexical processing was assessed in a two-step analysis. At step one the analysis concerned the lexeme level of word processing (Levelt, Roelofs, & Meyer, 1999). The participants' ability to retrieve phonologically well-formed words was assessed computing an index of phonological selection. This was obtained by dividing the number of words by the number of units (Marini, Carlomagno, Caltagirone, & Nocentini, 2005). At step two the lemma level was assessed in terms of proportion of semantic paraphasias or paragrammatic errors in the sample. The speaker's ability to select semantically appropriate words was analyzed in terms of his/her production of semantic paraphasias. When a target word was substituted by a semantically related word, a semantic paraphasia was counted. An example of semantic paraphasia is provided by the word "mother" in the sequence /here he's talking to his mother/, where the speaker implied "wife." Lexical-semantic processing was measured by the percentage of occurrences of semantic paraphasias on the total number of content words. Higher values represent more semantic errors per word. The speaker's ability to access morphological and morphosyntactic information relative to the selected word was assessed in terms of paragrammatic errors. These include grammatical errors with bound morphemes (e.g., /questo è una coppia [in English: "this [masculine] is a couple [feminine]"]/ where the pro- noun "questo" ends with the wrong bound morpheme-o, which indicates masculine gender instead of the appropriate morpheme-a in agreement with the feminine word "coppia") and function words (e.g., prepositions, conjunctions, or articles as shown in the following example: /batte da una porta [in English: /he is knocking from a door]/, where the wrong function word da has replaced the correct preposition a). The percentage of paragrammatic errors was calculated by dividing the total number of paragrammatic errors by the number of phonologically well-formed words and multiplying this value by 100. Therefore, higher values in the ratio of paragrammatisms in the connected speech samples represent more errors per word.

The identification of grammatically complete sentences provided a measure of grammatical organization. An index was calculated by dividing the number of grammatical sentences by the number of utterances (Saffran, Berndt, & Schwartz, 1989; Thompson, Schwartz, & Toga, 1996). A sentence was considered grammatically complete if all the arguments required by the verb were inserted correctly in the body of the sentence and if there were no omissions or substitutions of free or bound morphemes.

As for discourse organization at intersentential level, the macrolinguistic measures included indexes of local coherence and global coherence errors. Local coherence reflects the extent to which each utterance of the story is conceptually related to the preceding one. Local coherence errors included the production of words without a clear referent and erratic topic switching. Missing referents were counted whenever the referent of a pronoun or the implicit subject of a verb was not unambiguously clear. Consider the following example. In the sequence "/Qui stanno litigando furiosamente/Poi dice/" [in English: /Here they are quarrelling furiously/Then [implicit pronoun] says/], in the second utterance there is a missing referent as it is not clear whom the verb "dice" ("says") refers to. As to the second type of error of local coherence, an erratic topic switch was scored whenever an utterance was abruptly interrupted but the following utterance did not continue the flow of thoughts, therefore introducing new information. For example, in the sequence: /he's trying to…/these two girls are watching the dog/, the first utterance remains unfinished while the second utterance introduces new information. The percentage of local coherence errors was calculated by dividing the number of local coherence errors by the number of utterances and multiplying this value by 100. Global coherence refers to the ability to semantically relate remote utterances in the framework of a given discourse (Christiansen, 1995; Marini, Andreetta, et al., 2011). Consequently, errors of global coherence included the production of utterances that may be tangential, conceptually incongruent with the story, propositional repetitions, or simple fillers (see Marini, Andreetta, et al., 2011 for an extensive discussion of these measures). An utterance is considered tangential when it contains a derailment in the flow of discourse with respect to the information previously provided in preceding utterances as in the following sequence produced during the description of the Picnic picture: /It is a picnic/I like picnics/I have made several picnics in my life/. Here, the second and the third utterances are scored as tangential, as they provide irrelevant information triggered by a specific idea portrayed in the stimulus picture. An utterance is considered conceptually incongruent when it includes ideas not directly addressed by the stimulus. Let's consider the following sequence produced during the description of the Cookie Theft picture: /the children are trying to get the cookies/the TV is out/. In this example, the second utterance is scored as conceptually incongruent as in the picture stimulus there is no TV. A propositional repetition is a sequence where the speaker simply repeats ideas that have been already mentioned. Therefore, any new information is provided (e.g., the second utterance in the sequence: /the man is walking on the sidewalk/he is on the sidewalk/). Finally, a filler utterance is scored whenever the speaker produces an utterance that does not provide any additional information like in the following sequence: /the man and the woman are eating/my god, and now?/ah, yes, I get it/. The last two sequences are scored as filler utterances. The percentage of global coherence errors was calculated by dividing the number of global coherence errors by the number of utterances and multiplying this value by 100.

The information content of each narrative was assessed in terms of a percentage of thematic informativeness and percentage of informative words in the sample. A thematic unit is considered the main idea or detail in the story that has been identified in a previous study (Marini et al., 2005). The number of thematic units produced by each subject was considered an index of the participants' abilities to derive information from the picture stimuli. The second measure concerned the production of appropriate lexical information units (LIUs), i.e. those content and function words that were not only phonologically well-formed but also appropriate from a grammatical and pragmatic point of view (Marini et al., 2005). Therefore, all those words that were classified as semantic or verbal paraphasias, fillers, paragrammatic errors or forming tangential or extraneous utterances (i.e. utterances that were somehow deviating from the gist of the story) were excluded from the LIUs' count. An index of lexical informativeness was then obtained by dividing the number of LIUs by the number of words. This ratio (%LIUs) has proved adequate in measuring effectiveness in encoding information in speech in several neurologically impaired populations and neuropsychiatric conditions (e.g. right brain damaged subjects, Marini et al., 2005; schizophrenic patients, Marini et al., 2008). The scoring procedure was performed independently by two raters on the stories produced by the participants and then compared. High interjudge reliability for the story narrative analyses has been previously documented (Marini & Urgesi, 2012). An interrater reliability analysis using Kappa statistics was performed to determine consistency among raters (see Table 3). Acceptable interrater reliability was defined as $K \geq .70$ (Carletta, 1996; Landis & Koch, 1977). As can be seen in Table 3, the interrater reliability scores

Table 3
Details of the interrater reliability analysis performed on the narrative analysis conducted by two independent raters using the kappa statistic.

Variable	Cohen's *K*	*p*-Value
Words	$K = 1.000$	$p = .000$
Speech rate	$K = 1.000$	$p = .000$
MLU	$K = 1.000$	$p = .000$
% Lexical informativeness	$K = .783$	$p = .000$
% Phonological selection	$K = 1.000$	$p < .002$
% Semantic paraphasias	$K = 1.000$	$p < .002$
% Paragrammatic errors	$K = 1.000$	$p = .000$
% Complete sentences	$K = .780$	$p = .000$
% Local coherence errors	$K = 1.000$	$p = .000$
% Global coherence errors	$K = .783$	$p = .000$
% Thematic informativeness	$K = 1.000$	$p = .000$

for the two raters are constantly high. During the analysis in a few cases we needed to listen again to the audio recordings in order to face the residual minor issues that could be easily solved.

2.3. Statistical analyses

Group-related differences in neuropsychological scores were assessed with a series of One-Way ANOVAs with Group (1. TBI; 2. C) as fixed factor and Task (phonemic and semantic fluency, TM-A, TM-B, and Rey's 15-words immediate and delayed recall) as dependent variables. The narrative performance of the two groups of participants was analyzed performing a two-way ANOVA with repeated measures with *group* as between-subject factor and *story* as within-subject factor for each sample on eleven measures (words; speech rate; mean length of utterance; % phonological selection; % semantic/verbal paraphasias; % paragrammatic errors; % complete sentences; % local coherence errors; % global coherence errors; % thematic informativeness; % lexical informativeness). The analyses showed no story*group interaction in the descriptions of the two groups of participants. A correlation analysis was performed between neuropsychological and narrative scores in the group of participants with TBI.

3. Results

3.1. Cognitive and neuropsychological assessment

Neuropsychological scores are shown in Table 4. The performance of the TBI group did not differ from that of the group of healthy participants on the majority of the neuropsychological measures. However, they produced more non-perseverative errors on the Wisconsin Card Sorting Test ([$F(1; 22) = 27.331$; $p = .000$; $\eta_p^2 = .564$]) and remembered fewer words on the Rey's 15-word delayed recall ([$F(1; 22) = 7.454$; $p < .013$; $\eta_p^2 = .262$]). Of note, their production of perseverative errors on the WCST

Table 4
Means (and standard deviations) of the neuropsychological performance of the groups of traumatic brain injured (TBI) and healthy control (HC) participants. *Legend*: TMT-A: Trail Making Test A; TMT-B: Trail Making Test B; WCST: Wisconsin Card Sorting Test.

	TBI	HC	Level of significance	Effect size (partial η^2)
TMT-A (seconds)	37.2 (26.4)	53.9 (10.9)	$p < .053$	.166
TMT-B (seconds)	98.5 (68.05)	98.8 (30.1)	$p < .987$	.000
Phonemic fluency	33.4 (9.3)	32.6 (9.2)	$p < .844$	.002
Semantic fluency	23.4 (4.2)	22.6 (3.9)	$p < .657$	.001
WCST (pers err)	8.4 (14.9)	0.08 (0.3)	$p < .055$	.163
WCST (non-pers err)	11.3 (7.8)	0.08 (0.3)	$p = .000$	.564
Rey's 15-word immediate recall	49.9 (6.7)	45.7 (6.9)	$p < .160$	.092
Rey's 15-word delayed recall	11.5 (1.7)	9.4 (1.9)	$p < .013$	.262

approached significance ([$F(1; 22) = 4.117$; $p = .055$; $\eta^2_p = .163$]), as did their performance on the TMT-A ([$F(1; 22) = 4.192$; $p = .053$; $\eta^2_p = .166$]).

3.2. Assessment of narrative abilities

Results from the assessment of narrative abilities are reported in Tables 5 and 6. Overall, the participants with mild TBI did not show relevant microlinguistic problems. Indeed, even if they uttered their story descriptions with lower speech rate than controls ([$F(1; 21) = 4.406$; $p < .046$; $\eta^2_p = .177$]), their speech samples had normal length and MLU. Furthermore, they did not produce paraphasias (either phonological or semantic) or paragrammatic errors. Finally, they had normal levels of grammatical structuring. However, the macrolinguistic analysis showed a more stratified picture. Even though the speech samples produced by these participants were not abnormal in terms of local coherence, they produced significantly more errors of global coherence ([$F(1; 21) = 24.242$; $p = .000$; $\eta^2_p = .536$]) and fewer lexical information units (LIUs) ([$F(1; 21) = 7.068$; $p < .015$; $\eta^2_p = .252$]).

3.3. Correlations between neuropsychological scores and narrative performance in TBI participants

A series of correlations were performed between those neuropsychological variable scores (i.e., non-perseverative errors on the Wisconsin Card Sorting Test and Rey's 15-word delayed recall) and those measures of the narrative production that were found altered in the TBI participants (i.e., Speech Rate, % Global Coherence Errors and % Lexical Informativeness) (see Table 7). The results showed a significant negative correlation between the production of non-perseverative errors on the WCST and the quantity of lexical information units conveyed in the narrative sample ($r = -.755$; $p < .012$). Furthermore, we found that the scores obtained by the participants with TBI on the Rey's 15-word delayed recall task correlated negatively with the production of global coherence errors ($r = -.679$; $p < .031$) and positively with the production of LIUs ($r = .788$; $p < .007$).

4. Discussion

The current study was designed to analyze in detail the linguistic and narrative profiles of persons with mild TBI without aphasic symptoms. The narrative assessment included the analysis of both micro- and macrolinguistic aspects of language processing in speech samples elicited on a picture description task. The main results suggest the presence of reduced speech rate in the group of participants with mTBI and a deficit on the macrolinguistic dimension of processing as they produced narratives with more errors of global coherence and lower levels of lexical informativeness. In other words, they were inefficient in linking their utterances and in producing an adequate amount of information. This also suggests that persons with mild forms of TBI may experience linguistic disturbances that may hamper the quality of their every-day life.

These findings are in line with previous studies on persons with both severe and mild TBI (e.g., Marini, Galetto, et al., 2011; Stout et al., 2000; Tucker & Hanlon, 1998; Youse & Coelho, 2005) where the narratives produced by persons with TBI were reported as strongly impaired at the macrolinguistic level. For example, Youse and Coelho (2005) described a group of individuals with TBI who experienced difficulties

Table 5
Results of the microlinguistic analysis for the groups of TBI and healthy control participants. The table reports also significance level and partial effect size.

Microlinguistic analysis	TBI	HC	Level of significance	Effect size (partial η^2)
Words	96.4 (57.3)	81.9 (46.1)	$p < .471$	.025
Speech rate	108 (30.6)	129.5 (29.3)	$p < .046$	.177
MLU	7.1 (1.9)	7 (1.9)	$p < .769$	.004
% Phonological selection	99.8 (0.4)	99.6 (0.8)	$p < .158$	.093
% Semantic paraphasias	0.2 (0.4)	0.1 (0.4)	$p < .817$	.003
% Paragrammatic errors	0.5 (0.9)	0.2 (0.5)	$p < .155$	.094
% Complete sentences	63.1 (21.2)	70.9 (24.1)	$p < .306$	.050

Table 6
Results of the analysis of the macrolinguistic and informative aspects of narrative production for the groups of TBI and healthy control participants. The table reports also significance level and partial effect size.

Macrolinguistic and informative analysis	TBI	HC	Level of significance	Effect size (partial η^2)
% Local coherence errors	10.9 (19.3)	0.91 (2.5)	$p < .094$	.128
% Global coherence errors	5.6 (5.7)	3.6 (7.5)	$p = .000$	.536
% Lexical informativeness	75 (18.3)	85.1 (9)	$p < .015$	.252
% Thematic informativeness	56.2 (22.9)	59.1(18.2)	$p < .653$	.010

in the use of cohesion markers, produced fewer words, fewer content, and more inaccurate information compared to neurologically healthy individuals. Similarly, Le, Coelho, Mozeiko, Krueger, and Grafman (2011b) reported significant differences between TBI and healthy participants on a story retelling task, with non brain injured individuals achieving higher scores than those with TBI on measures assessing story organization and completeness. The participants with TBI framed fewer utterances in episodes and recalled fewer critical story elements. Interestingly, the results reported here on a group of participants with mild TBI replicate what found in Marini, Galetto, et al. (2011) in a group of persons with severe TBI on a picture-story description task. When evaluated on measures of verbal productivity and grammatical and lexical adequacy, the story narratives produced by the individuals with TBI had normal length (as measured in terms of uttered words and mean length of utterance), and showed no relevant phonological, morphological, semantic or syntactic deficits. However, their narratives teamed with violations of global coherence (e.g., derailments) that made their discourse vague and ambiguous and reduced the levels of informativeness. Interestingly, in that study the group of participants with TBI produced stories with reduced speech rate and this reduction was found linked to the frequent abrupt interruptions of ongoing utterances. In the present study, however, the participants with mild TBI did not experience problems in completing their utterances and therefore the reduced speech rate must have a different explanation. As they did not have additional phonological or lexical deficits, we may argue that the slowed production of words did not depend on articulatory or linguistic difficulties. Instead, we hypothesize that this symptom might be linked to a more general reduction in the amount of the cognitive resources usually employed in the process of lexical selection.

An important issue concerns the plausible reasons for the peculiar narrative behavior observed in the group of participants with mTBI. A possibility is that the macrolinguistic disturbances observed in the sample of persons with mTBI are due to a pure linguistic deficit. This, however, seems implausible, as problems with executive functions and attentional deficits have also been observed in patients with mild traumatic brain injury: indeed, even if cognitive and emotional symptoms of mTBI tend to be most evident in the acute stages after the injury and often completely resolve within few months (Binder, 1997), a subgroup of patients continues to experience cognitive and neurological deficits long after the time of their injury (Binder, 1997; Erez et al., 2009; Ruff, Camenzuli, & Mueller, 1996). Among these, difficulties in memory, attention and executive functions are often reported in these individuals (e.g., Body & Perkins, 2004; Body, Perkins, & McDonald, 1999; Stierwalt & Murray, 2002). These considerations have prompted the formulation of the "High Level Language Hypothesis" (Hincliffe, Murdoch, & Chenery, 1998), according to which the communicative deficits observed in patients with TBI may be considered as the outcome of more general cognitive difficulties rather than a direct effect of a primary linguistic deficit. In other words, these cognitive impairments might influence the conceptual organization of a narrative (Tucker & Hanlon, 1998) and may account for macrolinguistic deficits such as the difficulty to organize, plan and produce a

Table 7
Results from the univariate correlation analysis between linguistic (speech rate, % global coherence errors, and % lexical informativeness) and neuropsychological scores in the group of participants with TBI. Scores are presented as Pearson's *r*-indexes and (*p*-values). The asterisks highlight significant correlations. *Legend*: TMT-A: Trail Making Test A; TMT-B: Trail Making Test B; WCST: Wisconsin Card Sorting Test.

Neuropsychological variables	Speech rate	% Global coherence errors	% Lexical informativeness
WCST (non-pers err)	$r = .279$ ($p = .434$)	$r = .350$ ($p = .321$)	$r = -.755$ ($p = .012$)*
Rey's 15-word delayed recall	$r = .439$ ($p = .204$)	$r = -.679$ ($p = .031$)*	$r = .788$ ($p = .007$)*

discourse and to appropriately link the concepts that make up a coherent story. Consequently, it cannot be excluded that the difficulties in global coherence and the reduction in lexical informativeness observed in our mTBI sample are to be considered an epiphenomenon of other cognitive deficits affecting the specific task of story description. Several studies have explored this possibility. For example, Hartley and Jensen (1991), analyzing the narrative samples of 11 individuals with TBI, found a significant correlation between working memory skills and the ability to produce adequate cohesive links among utterances. More recently, Youse and Coelho (2005) investigated the conversational abilities in a group of 55 persons with TBI engaged on a cartoon-picture description task reporting a significant association between low performance on tests assessing attention and memory and insufficient linguistic performance. Other investigations have focused on the role potentially played by executive functions in narrative production tasks. Namely, it has been suggested that at least some narrative difficulties found in persons with TBI might depend on impaired executive control over cognitive and linguistic organizational processes (Coelho, 2002; Ylvisaker et al., 2001). According to Mozeiko et al. (2011) the three key executive functions identified by Miyake, Emerson, and Friedman (2000) (i.e., shifting, updating and inhibition) might play an important role in efficient discourse production. Shifting requires the ability to move forwards and backwards between multiple tasks, operations, or mental sets (e.g., Monsell, 1996) and as such might be involved in the generation of complete episodes within a narrative discourse and in the selection of informative words. Updating involves the ability to monitor and integrate incoming information with that already present in working memory. For this reason it might be required to recall former episodes or episodic contents for an accurate organization of the story. Finally, inhibition might be important for monitoring the production of extraneous comments and derailments while telling a story. Interestingly, one of the neuropsychological measures adopted in our study (e.g., WCST performance) is thought to tap the shifting component (Miyake et al., 2000). Coelho (2002) reported significant correlations between scores on the WCST and measures assessing discourse processing: higher performance on the WCST was associated with the production of more episodes in story retelling tasks and therefore to the ability to organize a story. Similarly, the correlational analysis performed in our study showed a statistically significant inverse association between the production of non-perseverative errors on the WCST and the percentage of lexical information units conveyed in the narrative sample. Furthermore, the participants' performance on the Rey's 15-word delayed recall task correlated negatively with the production of global coherence errors and positively with the production of LIUs. Overall, these findings support the High Level Language Hypothesis suggesting that mild difficulties in the ability to move forward and backward between multiple mental sets and in the ability to learn new words (i.e., impaired memory skills) may affect the process of discourse planning and, consequently, reduce the levels of informativeness of their narratives.

A final point of discussion concerns the reason why in some studies correlations between cognitive measures and macrolinguistic skills have not been found. Analyzing the narrative samples of a group of persons with severe TBI, Snow, Douglas, and Ponsford (1998) found a modest degree of statistical association between conversational discourse abilities and measures of attention (Trial Making part A and B; Reitan & Wolfson, 1992) and memory (Rey Auditory Verbal Learning Test; Rey, 1964) suggesting that care should be taken in attributing discourse changes after TBI to underlying cognitive disturbances. More recently, Marini, Galetto, et al. (2011), using the same neuropsychological tests and the same method of narrative analysis adopted in the present study, found no significant correlation between macrolinguistic and cognitive deficits in a group of persons with severe TBI. To explain these findings, the authors proposed the existence of a specific linguistic deficit, independent from other cognitive aspects, leading to a more generalized inability to coherently link concepts in a story format by controlling what has been said, integrating the latter with incoming information and inhibiting irrelevant behaviors and the production of tangential utterances. Spalletta, Spoletini, Cherubini, et al. (2010) hypothesized that these abilities might be subserved by a specific cortico-subcortical system, involving left nucleus accumbens and left frontal areas. One possible explanation for this divergence in results may be in the extent of the cerebral damage: in mild TBI, lesions may not be diffused enough to cause communication problems similar to those reported in persons with severe TBI. Consequently in this case the communicative failures may be explained as an epiphenomenon of a primary cognitive deficit involving attention, memory and executive functions. On the contrary, in severe TBI, where the cerebral damage is usually broader, it may be possible to hypothesize the presence of a general communication problem, partially independent from other cognitive functions, whose neural substrate may be the network hypothesized by Spalletta et al. (2010). Indeed, a lesion to this network may lead to a selective difficulty in coherently linking the concepts that form a story. Further research is required to directly compare the linguistic and narrative performance of persons with different degrees of TBI (i.e., mild, moderate, severe). Furthermore, investigations applying both structural and functional neuroimaging techniques may importantly advance our understanding of the functional sequelae of the neuronal damage after TBI.

Conflict of interest

No actual or potential conflicts of interest including any financial, personal or other relationships with other people or organizations that could inappropriately bias their work, is reported by any of the authors.

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Appendix

Microlinguistic analysis	Productivity	Words	Total number of well-formed words, i.e., all those units that were not scored as phonological errors.
		Speech rate	Number of well-formed words produced in a minute
		Mean length of utterance (MLU)	The mean number of words that make up the utterances produced by each participant
	Lexical & morphosyntactic processing	% Phonological selection	The percentage of phonologically well-formed words with respect to all uttered units (see text). It refers to the ability to retrieve phonologically well-formed words.
		% Semantic paraphasias	The percentage of words that were classified as semantic paraphasias. A semantic paraphasia consists in the substitution of a target word with another word which can be either semantically related or unrelated (i.e., "table" instead of "chair").
		% Paragrammatic errors	The percentage of words that were classified as paragrammatic errors. Paragrammatic errors include: the substitution of bound morphemes (i.e., "questo è una coppia" "this [masc in Italian] is a couple [fem]" – in Italian "questo" should be "questa") or function words (i.e., "batte da una porta" "he is knocking from a door" – in Italian "da" instead of "a").
		% Complete sentences	The percentage of grammatically well-formed utterances.
Macrolinguistic analysis	Informative content	% Lexical informativeness	The percentage of words that were scored as lexical information units, i.e., those words that were not only well-formed from a phonological point of view, but also grammatically and pragmatically accurate. This broad category includes all those words that were not scored as phonological errors, semantic paraphasias, or paragrammatic errors, and were not ambiguous, repeated, or forming tangential utterances.
	Textual organization	% Local coherence errors	The percentage of utterances that were not accurately connected because they presented local coherence errors. Local coherence errors include the use of words with unclear referents.
		% Global coherence errors	The percentage of utterances that were somehow violating global coherence rules. Global coherence refers to the semantic connectivity across long-distant sentences within a discourse. Global coherence errors include the production of tangential utterances.

Schema showing the major microlinguistic and macrolinguistic measures used in the narrative analysis (modifed from Marini & Urgesi, 2012).

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