The Role of Cognitive Functions in Communication: The Case of Traumatic Brain Injury

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Abstract

The aim of the present study was to examine the relationship between cognitive functions such as attention, working memory, long-term memory, planning, i.e. executive functions, theory of mind, and pragmatic deficits resulting as a consequence of traumatic brain injury (TBI). Communicative disorders represent a typical outcome in TBI patients, even if their linguistic abilities remain virtually intact. We empirically investigated the role played by the possible cognitive deficits in patients' communicative performance. In addition to the factors mentioned in the current literature, such as planning and theory of mind, our results show the importance of considering the increasing complexity of the mental representations underlying different pragmatic phenomena in order to better understand the communicative outcomes after TBI.

Introduction

Traumatic brain injury (TBI) results in a wide range of communicative deficits, even if linguistic ability is usually conserved; patients affected by TBI do not display classical aphasic symptoms and their syntactical and lexical abilities are often adequate (McDonald, 1993). According to the current literature, it is possible to identify three principal cognitive components for explaining the communicative deficits in TBI: executive functions, theory of mind (ToM), and inferential processes. Theories based on the first two factors provide for a global explanation of the deficit, without fine differentiation between different pragmatic phenomena. Theories based on inferential processes provide a more articulated differentiation but, from our perspective, they underestimate the role of specific cognitive processes, namely the complexity of mental representations, in explaining TBI patients' communicative ability.

The present research is an exploratory investigation aimed at clarifying the role played by the different cognitive functions in pragmatic outcomes after TBI. In our opinion, different cognitive functions are involved in explaining patients' communicative deficits, from the more basic, such as working memory and attention, to the more sophisticated ones, such as theory of mind; however, our proposal is that in order to adequately comprehend TBI patients' pragmatic deficits it is also important to take into account the complexity of the mental representations activated during a communicative exchange. In order to establish this relationship, we compared patients' pragmatic performance with their performance on a series of neuropsychological and ToM tests. Thus, we referred to our previous recent study (Angeleri *et al.*, 2008), in which we investigated a wide range of pragmatic phenomena, and we compared those results with the performance showed by the same patients in different neuropsychological and ToM tests.

The paper is organized as follows. (1) We briefly examine the communicative impairments in the TBI population. (2) We review the current literature that is focused on the relationship between cognitive functioning and communication. (3) We present our theoretical framework, with the intent of specifying how mental representations of increasing complexity can affect different levels of ability in communicative tasks. (4) We present our experimental materials, procedures, and results. (5) The paper ends with a general discussion of our findings and their relevance in understanding communicative impairments in TBI.

Communicative ability in TBI

TBI patients show a series of communicative difficulties, loading on all the dimensions that characterize satisfying communicative interactions. TBI patients show several difficulties at various levels in comprehension tasks, i.e. they cannot go beyond the literal meaning of sentences (Winner & Gardner, 1977), they don't understand implicatures and sarcastic utterances (McDonald & Pearce, 1996), and commercial messages which require inferential processes in order to be understood (Pearce, McDonald & Coltheart, 1998). Moreover, TBI patients may show different forms of linguistic production impairment, such as in producing clear requests (McDonald & Van Sommers, 1993) or giving complete information to interlocutors (McDonald, 1993). Not only the linguistic dimension can show pragmatic impairments, but also the *extralinguistic*

modality may be affected and, consequently, patients may show a pronounced difficulty in communicating through gestures (Bara, Cutica & Tirassa, 2001). In order to assess patients' linguistic and extralinguistic pragmatic abilities, we analyzed the results published in a recent study by our group (Angeleri *et al*., 2008), correlating them with new unpublished data referring to the performance of the same patients in different neuropsychological and ToM tests. The results (briefly summarized below) showed widespread impairment in all of the investigated communicative dimensions, which reaffirms the importance of understanding the cognitive basis of communicative competence, which is not restricted at the areas that are involved in linguistic performance.

Cognitive functions and communication

In recent years, there has been increasing interest in the cognitive aspects underlying pragmatic impairment (i.e., Perkins, 2000). In particular, some authors have suggested that cognitive abilities, such as executive functions and theory of mind, play a central role in the pragmatic performance of brain-damaged subjects (Happé, Brownell & Winner, 1999; Martin & McDonald, 2003). TBI patients often suffer damage in the frontal lobe, the brain area involved in executive functioning - the construct used to describe the goal-directed behavior - and some authors explain the pragmatic deficit displayed by these individuals as being caused mainly by executive function impairment (McDonald & Pearce, 1998). *Theory of Mind* is the ability to ascribe mental states to oneself and to other people and to use such knowledge to interpret one's own as well as other people's behaviors. Some authors highlight the role of the ToM in human communication (Happé & Loth, 2002; Tirassa, Bosco & Colle, 2006). A developed and intact capacity to mindread is necessary to comprehend a partner's communicative intention. The relation between ToM and communicative ability is particularly apparent in the autistic pathology. Baron-Cohen, Leslie and Frith (1985) explained how the social and communicative problems, which are typically demonstrated by these patients, are caused by a ToM deficit. Only a few studies in the literature have investigated the relationship between TBI and ToM, but a possible link has been established (Bibby & McDonald, 2005), and for this reason it is important to clarify whether the pragmatic deficits in TBI patients are caused by their difficulties in ToM abilities.

We suggest that impaired executive functions or ToM skills are not sufficient to fully explain communicative deficits in TBI patients. In our perspective, more specific cognitive processes are responsible for interpreting communicative exchanges (see the paragraph on Cognitive Pragmatics theory).

Cognitive Pragmatics theory

Most authors within the pragmatic domain (Airenti, Bara & Colombetti, 1993; Bara, 2008; Searle, 1975; Sperber & Wilson, 1995) point out that communicative understanding concerns the expression and interpretation of the speaker rather than the literal meaning. Such authors highlight the role of inferential processes underlying communicative interaction. Within the general inferential domain, the Cognitive Pragmatics theory identifies specific mental cognitive processes, namely the complexity of mental representations, which allow interlocutors to interpret communicative exchanges. Cognitive Pragmatics (Airenti *et al.*, 1993; Bara, 2008) is a theory of the cognitive processes underlying human communication that holds both for linguistic and extralinguistic communication, distinguishing between different kinds of communicative phenomena – standard communication acts, deceit, irony– on the basis of the mental representations involved in their comprehension and production. In particular, the theory explains and predicts the difficulty in the comprehension of different communication acts in typical development (Bucciarelli, Colle & Bara, 2003) and in autistic children (Bara, Bucciarelli & Colle, 2001), and it offers a plausible account for the decay of pragmatic performance in brain-damaged patients (Bara, Tirassa & Zettin, 1997).

Within the framework of the Cognitive Pragmatics theory, Bucciarelli *et al.* (2003) provided a fine-grained theoretical explanation of the cognitive factors underlying the comprehension of standard, deceitful, and ironic speech acts. In standard communication, default rules of inference govern the comprehension of a communicative act (Reiter, 1980); in *standard communication,* such as direct and indirect speech acts*,* what the actor says is in line with his private beliefs. In terms of mental representations, to comprehend a standard communicative act the partner has only to refer the communicative act proffered by the interlocutor to the *behavioral game*[1] shared with him. By contrast, *non-standard communication* involves the comprehension and production of communicative acts via the blocking of default rules and the occurrence of more complex mental representations. In particular, in deceit the actor's communicative intention is in conflict with his private mental states but it does not contrast with the knowledge that he share with the partner; consequently, in the case of disclosed deceit, the partner recognizes the difference between the mental states that are expressed and those that the actor privately entertains. Finally, in irony the actor's communicative intention is again in conflict with his private mental states, but it also contrasts with the knowledge that he share with the partner: this makes an ironic communicative act more difficult to perform than a deceitful one. The increasing trend of difficulty in the comprehension of standard, deceit and irony has been experimentally validated in studies on children (Bucciarelli *et al*., 2003; Bosco *et al*., 2004) and the same trend has been found for the production of communicative acts as expressed both through linguistic and extralinguistic means in TBI patients (Angeleri *et al*., 2008).

[1] A behavior game is the stereotyped action plan mutually shared between the participants involved in a communicative interaction (see Airenti *et al.*, 1993; Bara, 2008).

Experiment

The present research aims to investigate the role of cognitive functions in the communicative abilities of TBI patients. From our perspective, cognitive functions support communication, but are not enough by themselves to explain the whole of TBI communicative outcomes. Rather, specific mental representations, such as those pointed out by the Cognitive Pragmatics theory, are required to modulate communicative ability. Regarding cognitive functioning, we expect TBI patients to perform worse than normal controls in all the cognitive tasks proposed, involving short and long-term memory, attention, planning, and theory of mind. Moreover, in the TBI group, we will explore the relationship between cognitive functions and pragmatic deficits, evaluated through our experimental protocol. We predict that deficits in cognitive functioning are involved in the pragmatic performance, but also that they don't play a strict causal role in determining the communicative outcomes.

Material and Procedure

Communicative abilities. The experimental protocol consists of 2 different evaluation scales: (1) Linguistic, and (2) Extralinguistic. The protocol comprises a total of 48 items, based on videotaped scenes. Each scene lasts 20-25 seconds and presents a controlled number of words (7±2). Each scale includes both comprehension and production tasks. In more details, the linguistic scale assesses the comprehension and production of communication acts expressed primarily through linguistic means, whereas the extralinguistic scale assess the same pragmatic phenomena but are only expressed through extralinguistic means. The phenomena evaluated in those two scales are: standard communicative acts, deceits, and ironies.

All TBI participants and normal controls were videotaped. Subjects' performance was coded offline from the videotape by two independent judges blind to the aim of the research and to the subject's identity (TBI vs. control). For each task, subjects could obtain a score of 0 or 1, corresponding to a correct (1 point) or incorrect (0 point) answer. The inter-rater agreement was calculated using Intraclass Correlation Coefficient (ICC), estimated on the means of the total scores for each pragmatic phenomenon. The ICC was 0.87, indicating almost perfect agreement (Altman, 1991).

Cognitive functions. A series of neuropsychological tests were administered to both TBI patients and normal controls in order to assess the most important cognitive functions, with two main goals: (1) to compare the TBI performance with that of the controls and (2) to investigate, in the TBI group, the possible relationship between cognitive impairment and pragmatic performance revealed through our protocol. The subjects were administered the Trail Making Test and the Attentive Matrices for *attention* abilities; the Verbal and Spatial Span for *working memory* and the Immediate and Deferred Recall test for *long-term verbal memory*; the Elithorn's Maze Test and the Tower of London for *planning* abilities; finally, the Smarties' Task, the Sally & Ann Task and a selection of six Strange Stories (excluding those testing communicative phenomena such as irony, metaphor, and social appropriateness) for *theory of mind* abilities.

Participants

The TBI group consisted of 21 TBI patients (5 female/16 male) ranging in age from 20 to 68 yrs (M = 36.9; SD = 12.5); their education ranged from 5 to 18 yrs of schooling (M = 10.9; SD = 3.3). The patients were recruited through different rehabilitation centers in Geneva and Turin. The time after onset ranged from 3 to 252 months (M = 59.5; SD = 69.8); all patients had sustained their individual injury in a road traffic accident. All patients were Italian native speakers; initial exclusion criteria were prior history of TBI or other neurological disease, neuropsychiatric illness or communication problems, pre-morbid alcohol or drug addiction. TBI patients had to pass a series of neuropsychological tests to rule out the possibility of being too seriously cognitively impaired. The screening battery included the Mini-Mental State Examination, Raven's Coloured Progressive Matrices, and the denomination scale of the Aachener Aphasie Test. In the control group, there were 33 healthy participants, matched to the patients group for age, sex, and years of education.

Results

We briefly summarize the communicative performance of TBI patients in Table 1 (for a more detailed analysis, see Angeleri *et al.*, 2008), in order to illustrate their performance on the different pragmatic phenomena that we examined.

Table 1: Communicative abilities, mean of correct responses (TBI vs. controls). *p < .05

		TBI (SD)		**Controls** (SD)	
Linguistic Comprehension	*Standard	.86	(.16)	.98	(.06)
	*Deceit	.75	(.3)	.96	(.11)
	*Irony	.63	(.34)	.94	(.14)
Extralinguistic Comprehension	*Standard	.94	(.13)	.98	(.06)
	*Deceit	.54	(.32)	.88	(.18)
	*Irony	.51	(.33)	.83	(.16)
Linguistic Production	*Standard	.91	(.16)	1.00	(.000)
	*Deceit	.80	(.23)	.94	(.14)
	*Irony	.21	(.28)	.64	(.31)
Extralinguistic Production	*Standard	.82	(.19)	.97	(.1)
	*Deceit	.65	(.24)	.92	(.14)
	*Irony	.24	(.35)	.55	(.37)

As shown in Table 1, the TBI group overall performed worse than the control group in all of the scales (T Test:

4.54 < t < 5.73; p < .0001). To investigate the patients' performance in comprehension and production of standard, deceitful and ironic communication acts, we conducted ANOVAs with one between-subjects factor (*type of subjects*, with two levels: patient and control) and one within-subjects factor (*type of phenomenon*, with three levels: standard, deceit and irony), both for linguistic and extralinguistic scales. Those analyses confirmed that TBI patients performed significantly worse than controls in all tasks, and revealed that there was a main effect of the type of pragmatic phenomenon in linguistic comprehension ($F_{(2,102)}$ = 7.89; p = .001; η^2 = .13), extralinguistic comprehension ($F_{(2,102)}$ = 31.32; p < .0001; η^2 = .38), linguistic production ($F_{(2,102)}$ = 95.14; p < .0001; η^2 = .65) and extralinguistic production ($F_{(2,102)}$ = 71.84; p < .0001; η^2 = .58). We introduced a linear contrast in each ANOVA analysis, which revealed a linear decrease in scores depending on the type of pragmatic phenomenon (13.69 < F < 141.21; .001 < p < .0001; .21 < η^2 < .73): standard communication acts were the easiest, followed by deceits, and finally by ironies, the most difficult task. In the present paper, we present new data about patients' cognitive performance in order to investigate the possible relationships between cognitive functions and pragmatic performance. To investigate the patients' performance in neuropsychological tests we used a paired T Test with the aim of comparing the TBI and control groups. The difference was significant in all five cognitive functions being investigated: attention, working memory (WM), long term memory (LTM), planning and ToM (T Test: 4.49 < t < 12.8; p < .0001). The results obtained by TBI patients and controls are summarized in Figure 1:

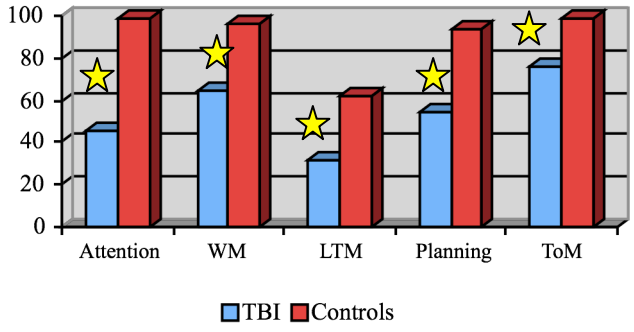

Figure 1: Cognitive functions, mean percentages of correct responses (TBI vs. controls). ☆ p < .0001

For the TBI group, multiple regression analyses were used to determine the contribution of different cognitive abilities to communicative performance. In Model 1 we considered the basic cognitive abilities (*attention*, *WM* and *LTM*) together; because they constantly underlie each task (the items were created maintaining constant the attention and memory requirement). Then, we created a hierarchical model of multiple regression analysis, also including as predictor variables *planning* – Model 2 – and *theory of mind* abilities – Model 3 -, considered separately in order to consider their unique effect on the dependent variable, i.e. patients' communicative performance. These variables were included in the regression model in order of their hierarchical increasing support for impacting performance, that is: first attention, WM and LTM, next planning, and finally ToM. Table 2 shows the adjusted determination coefficients (R^2_{Adj}) for each predictor variable, the change in R^2 after the addition of planning and theory of mind variables (R^2_{Change}), the change in F (F_{Change}) and its significance value (Sig. F_{Change}).

Table 2: Multiple Regression analysis

DVs	IVs	R^2_{Adj}	R^2_{Change}	F_{Change}	Sig. F_{Change}
Linguistic Comprehension					
Standard	Model 1	.17	=	=	=
	Model 2	.24	.001	.02	.89
	Model 3	.13	.15	2.59	.13
Deceit	Model 1	.14	=	=	=
	Model 2	.1	.007	.16	.69
	Model 3	.39	**.27**	8.98	**.009**
Irony	Model 1	.16	=	=	=
	Model 2	.39	**.27**	7.44	**.015**
	Model 3	.37	.02	.51	.49
Extralinguistic Comprehension					
Standard	Model 1	.14	=	=	=
	Model 2	.31	**.18**	5.15	**.037**
	Model 3	.47	**.16**	6.18	**.025**
Deceit	Model 1	.03	=	=	=
	Model 2	.03	.001	.03	.867
	Model 3	.25	**.26**	7.11	**.02**
Irony	Model 1	.11	=	=	=
	Model 2	.39	**.27**	8.75	**.009**
	Model 3	.48	.1	3.95	.07
Linguistic Production					
Standard	Model 1	.14	=	=	=
	Model 2	.25	.13	3.49	.08
	Model 3	.21	.003	.09	.77
Deceit	Model 1	-.09	=	=	=
	Model 2	-.13	.03	.51	.48
	Model 3	-.07	.1	1.84	.19
Irony	Model 1	.09	=	=	=
	Model 2	.16	.1	2.44	.14
	Model 3	.11	.005	.1	.75
Extralinguistic Production					
Standard	Model 1	-.08	=	=	=
	Model 2	-.02	.1	1.97	.18
	Model 3	-.05	.03	.54	.47
Deceit	Model 1	-.08	=	=	=
	Model 2	-.14	.009	.16	.69
	Model 3	.24	**.34**	8.83	**.009**
Irony	Model 1	.04	=	=	=
	Model 2	.16	.14	3.41	.08
	Model 3	.1	.000	.001	.9

As shown in Table 2, the overall pragmatic performance appears to be affected by various cognitive functions, but this influence seems not enough to explain the patients' performance. Attention, WM and LTM are involved, to a certain extent, in every task: their predictor role remains

nearly constant throughout the tasks, at less than 17% of the explained variance. The percentage of the explained variance tends to increase with the inclusion of planning abilities in all our tasks; however, the change in R^2 is only significant for the comprehension of linguistic irony ($F_{(1,16)}$ = 7.44; p = .015) and for the comprehension of both extralinguistic standard communication acts ($F_{(1,16)}$ = 5.15; p = .04) and irony ($F_{(1,16)}$ = 8.75; p = .009). The percentage of explained variance tends to increase in *Model 3* for all our tasks, but the role of theory of mind abilities as a predictor of pragmatic performance is only significant for the linguistic comprehension of deceit ($F_{(1,16)}$ = 8.98: p = .009), for the extralinguistic comprehension of both standard communication acts ($F_{(1,16)}$ = 6.18; p = .025) and deceit ($F_{(1,16)}$ = 7.11; p = .02), and for the extralinguistic production of deceit ($F_{(1,16)}$ = 8.83; p = .009).

Conclusions

The aim of the present study was to investigate the relationship between cognitive functioning and pragmatic performance after TBI. According to our theoretical framework, it is important to consider the complexity of the mental representations underlying a different kind of pragmatic phenomena in order to adequately understand the patients' performance. In particular, Cognitive Pragmatics Theory (Airenti *et al.*, 1993) posits that standard communication acts involve easier mental representations, whereas deceits and ironies involve more sophisticated ones. In line with those predictions, in our recent study, which was focused on TBI patients' performance (Angeleri *et al.*, 2008), we found a trend of increasing difficulty in the comprehension and production of standard, deceitful and ironic communication acts. In our opinion, cognitive deficits in ToM and executive functions are not enough to explain this peculiar trend of difficulty. In order to investigate this relationship, we referred to our previous results (Angeleri *et al.*, 2008) in a TBI population. In addition, we present new data referring to the administration of a selection of neuropsychological and ToM tests to the same patients and controls. In particular, we administered tests investigating working memory, long-term memory, attention, planning, and theory of mind in order to enable the study of the role held by different cognitive functions in the patients' communicative deficits.

As expected from the relevant literature (Happé, Brownell & Winner, 1999; Martin & McDonald, 2003; Bibby & McDonald, 2005; Havet-Thomassin *et al.*, 2006) TBI patients performed worse in all the five cognitive areas investigated. For the TBI group, we performed a multiple regression analysis directed at exploring the possible causal role of the cognitive deficit in communicative ability. In the first model of the analysis we considered the basic cognitive abilities (*attention, WM and LTM*) together as being equally involved in all our tasks, and then created a hierarchical model of multiple regression, also including *planning* – Model 2 – and *theory of mind* abilities – Model 3 – as predictor variables, considered separately in order to assess their unique effects on the dependent variable, i.e. patients' communicative performance. These variables were included in the regression model following their increasing hierarchical support for impacting performance. Our analysis reveals that cognitive impairment plays a role in explain communicative deficit, - patients perform worse than the controls in all the communicative tasks - but it is not sufficient to explain the whole TBI communicative outcomes, which is to explain the patient's increasing trend of difficulty in the comprehension and production of standard, deceitful and ironic communication acts. Some cognitive functions – i.e. attention, WM and LTM – are able to explain a proportion of the variability in communicative performance in all the communication tasks. This seems consistent with the idea that these basic cognitive functions support the comprehension and production of each communicative act, and for this reason we controlled these parameters in our assessment battery (such as the length of the sentence or the duration of each scene) in order to require the same degree of these basic cognitive functions. The percentage of explained variance tends to increase with the inclusion of planning abilities in all the pragmatic tasks; however, the change of explained variance is only significant for a few phenomena, i.e. comprehension of linguistic and extralinguistic irony, and comprehension of both extralinguistic standard communicative acts.

In particular, we were interested in the role of Theory of Mind, since some authors have suggested that in children (Winner & Leekman, 1991) as well as in right hemisphere brain-damaged patients (Winner, Brownell, Happé, Blum & Pincus, 1998) that the increasing role of a more sophisticated theory of mind ability may be the causal factor in the emergence of difficulty in the comprehension of verbal irony. We thus performed a multiple regression analysis investigating the role of the theory of mind in our various communicative tasks. The results show that deficits in theory of mind tasks can explain a small proportion of the variability of patients' performance, and that they are not enough to account for the specific communicative impairment as revealed in our previous study. In particular, how theory of mind underlies a specific task is explained by the change in variance; this effect is only significant for linguistic and extralinguistic comprehension of deceit, extralinguistic comprehension of standard communicative acts, and extralinguistic production of deceit.

To summarize, our analysis shows that the increasing difficulty between deceit and irony that we found in both comprehension and production seems better explained by our theoretical framework, resorting in the manipulation of mental representations of increasing complexity for both linguistic and extralinguistic phenomena. Indeed, the role played by Theory of Mind ability does not seem to explain *per se* the differences in patients' performance for deceit and irony comprehension and production tasks.

We do not want to deny the role of ToM in communicative interaction but, more generally, our results seem to support the general conclusion, regarding TBI patients'

communicative abilities, that various cognitive functions support communicative performance, but the impairment of none of them is unequivocally associated with the decay of a single pragmatic phenomenon.

The present study thus highlights the importance of considering all the contributing factors in order to explain the communicative deficits in patients that are affected by traumatic brain injury. In addition to ToM and executive function abilities, our results show the role that is played by the complexity of mental representations underlying the ability to comprehend and produce different communicative phenomena.

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