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TITOLO DELLA TESI:

THE COGNITIVE AND NEURAL BASIS OF COMMUNICATIVE-PRAGMATIC ABILITY

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1. General Introduction[1]

1.1 Aim of the thesis

The primary aim of the present thesis was to investigate what are the cognitive and neural processes involved in communicative-pragmatic ability. Pragmatics can be defined as the ability to communicatively act in an appropriate way in a given context[2] (Levinson, 1983; Perkins, 2005), and it involves the appropriate use of a wide range of expressive means, such as language, gestures, proxemics, body movements, facial expressions. Communicative-pragmatic[3] ability is not limited to the use of linguistic elements (i.e., phonological, morphological and syntactical aspects), but it also requires contextual information and inferential ability, which allow people to fill the gap between the literal and the speaker's meaning of utterances.

In many communicative acts there is a discrepancy between what a speaker says and what he means. The ability to correctly infer the communicative intention that lies beyond a specific speech act is a key process in human communication, since it allows people to distinguish among the possible alternative interpretations of the same utterance, as in the following example:

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[1] Part of the data and the text reported in the introducion were published as: 1) "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" ; 2) "Bosco, F. M., Parola, A., Sacco, K., Zettin, M., & Angeleri, R. (2017). Communicative-pragmatic disorders in traumatic brain injury: The role of theory of mind and executive functions. *Brain and language*, *168*, 73-83)."; 3) "Bosco, F. M., Parola, A., Valentini, M. C., & Morese, R. (2017). Neural correlates underlying the comprehension of deceitful and ironic communicative intentions. *Cortex*, *94*, 73-86)."

[2] I will use here the term "context" in a broad sense, to refer to: 1) physical context, that is the spatio-temporal setting in which a conversation takes place 2) conversational context, that is what has been communicated before during a conversation 3) social context, that is the social relationship and the status of the persons involved in a conversation 4) epistemic context, that is the private beliefs and shared knowledge of the communicative partners 5) cultural context, that is the cultural background of the communicative partners. However, I adopt here a notion of context as a dynamic and evolving entity: definition of context can vary according to the specific study, and there is not a definitive and univocal definition of context.

[3] I will use here the term "pragmatic ability" and "communicative-pragmatic ability" as synonyms.

[1] A: *What a brilliant performance*!"

A person could say [1]: [a] sincerely to communicate to his partner that he performed brilliantly, or alternatively [b] ironically, to underline that his partner's performance was disastrous, or also in order to deceive, if he thinks the performance was a disaster but he has personal reasons for lying. Thus, the same statement could be sincere, ironic or deceitful according to the context in which it is proffered (Bosco & Bucciarelli, 2008; Bara, 2010). The comprehension of [1] requires the listener to fill the gap between the literal and the intended meaning of the utterance using inferential processes in order to reconstruct the communicative intention of the speaker.

Pragmatics is concerned with the study of inferential processes in communication. The aim of *pragmatics* is to disentangle the inferential steps necessary to fill the gap between the literal and the intended meaning of an utterance, as in [1]. As reported by Levinson, "*Pragmatics is essentially concerned with inference*" (Levinson, 1983, pag. 21). The notion of inference has assumed a central role in *pragmatics* literature since the seminal work of Searle (1975), which first introduced the notion of inferential chain in the study of indirect speech acts.

The ability to inferentially reconstruct the speaker's meaning is a high-level process that relies on the interaction of different cognitive functions. To give the reader an example of some of the processes involved in pragmatic interpretation, the comprehension of [1] requires the listener to pay attention and use long-term memory, in order to recall the relevant information that is needed to comprehend the utterance, as well as working memory to maintain such information active during the communicative exchange. It also involves processing the linguistic features of the sentence, i.e. syntactic, semantic and phonological elements. The listener must consider the speaker's mental state and represent the knowledge they share, in order to derive his communicative intention. In the last stage, all the previously processed information has to be integrated in order to build a coherent representation of the situation and to infer the meaning of the sentence (Cummings, 2014).

A similar chain of mental operations and inferential steps is required when a speaker produces a communicative act in response to her partner, and needs to adapt the content and the style of her response to the request set by the interlocutor and the specific communicative context.

How does this process unfold and lead to the comprehension and production of a communicative act? What cognitive systems are involved in the comprehension and production of a communicative act? What are the neural underpinnings of communicative-pragmatic ability?

In this thesis, I will investigate the cognitive and neural processes involved in pragmatic comprehension and production. I will focus in particular on two pragmatic phenomena that have been extensively investigated in pragmatics literature, namely irony and deceit.

Irony has traditionally been defined as a non-literal form of communication whereby the speaker implies the opposite of what he says (Grice, 1975; Searle, 1979), as in [2] - "*What a beautiful day*" - uttered while it's raining. Thus, a distinctive element characterizing irony is the presence of a contrast between what a speaker literally says and her private knowledge, and in order to understand irony a listener has to understand such contrast (Bara, 2010; Bosco & Bucciarelli, 2008; Cutica, 2007). Several studies have reported that irony is more difficult to comprehend and to produce than a literal statement, due to the high inferential load that processing irony requires (Shany-Ur et al., 2012; Bosco, Angeleri, Colle, Sacco, & Bara, 2013; Bosco, Angeleri, Sacco & Bara, 2015; Colle et al., 2013; McDonald et al., 2014; Honan, McDonald, Gowland, Fisher, & Randall, 2015).

Deceit has been defined as an intentional attempt to modify the listener's mental state in order to create a false belief (Perner, 1991). A deceitful speech act is an insincere form of communication, in which a speaker utters something that she privately thinks is untrue. To distinguish deceit, the listener has to recognize the contrast between the speaker's utterance and the real state of affairs (Bara, 2010; Bosco & Bucciarelli, 2008), and make inferences about the speaker's actual beliefs. For this reason, it has been associated with the ability to attribute mental states, i.e. a theory of mind (Winner et al., 1998). However, difficulties exhibited by typically developed children in recognizing deceit seem to be not only related to theory of mind (ToM) ability, but also to the cognitive load that comprehension of deceitful speech acts requires. Indeed, successful recognition[4] of deceit involves the ability to manage conflicting representations, due to the presence of a contrast between what the speaker says and her private knowledge, and inhibitory control (Sullivan, Zaitchik, & Tager-Flusberg, 1994; Russel, Jarrold, & Potel, 1994; Dennis, Purvis, Barnes, Wilkinson, & Winner, 2001; Bosco & Bucciarelli, 2008).

Several studies have shown that adults with brain damage and psychiatric disorders find deceitful speech acts more difficult to comprehend than sincere statements (Angeleri et al., 2008; Colle et al., 2013; Shany-Ur et al., 2012; Gabbatore et al., 2014). The study of the cognitive processes that are responsible for pragmatic impairment in the comprehension of deceitful and ironic communicative acts in different clinical populations provides the opportunity to investigate the relationship between cognitive functions and pragmatic ability, which is the aim of this thesis.

In the first chapter, I will present some of the most important pragmatic theoretical accounts present in the literature. I will focus specifically on theoretical models that have tried to explain the processes involved in the comprehension and production of irony and deceit. I will also introduce the Cognitive Pragmatic theory (CPT), the theoretical framework that we adopted in the three studies that are part of this thesis, and present the reasons for adopting this theoretical framework.

In the second chapter, I will present the first study of this thesis, "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 (RHD)". In this study, we investigated communicative-pragmatic performance in a sample of individuals with RHD. A few previous studies (Cutica et al., 2006; Cocks et al., 2007) have investigated pragmatic ability in individuals with RHD evaluating both the linguistic and extralinguistic modalities, and these reported that the extralinguistic modality may be impaired as a consequence of RHD. However, no studies have been performed to evaluate

[4] I will use here the terms "recognition" and "comprehension" (of a communicative act) as synonyms. In accordance with SPM, I argue that the active and fully comprehension of a communicative act corresponds to the recognition of the speaker's communicative intention beyond that specific communicative act.

in RHD the production and comprehension of different kinds of communicative phenomena (i.e., sincere (standard) communicative acts, deceit and irony) using both verbal (i.e. linguistic) and non-verbal (i.e. gestural) modalities. This study was realized to fill this gap. Thus, the aim of the present study is to evaluate comprehension and production of different communicative acts (i.e., sincere (standard) communicative acts, deceit and irony) expressed through linguistic and extralinguistic modalities (i.e., gestures and facial expressions), and to examine what are the cognitive factors that may responsible for difficulties exhibited by individuals with RHD in dealing with these different pragmatic tasks.

In the third chapter, I will present the second study that is part of this thesis, "Bosco, F. M., Parola, A., Sacco, K., Zettin, M., & Angeleri, R. (2017). Communicative-pragmatic disorders in traumatic brain injury: The role of theory of mind and executive functions". In this study, we investigated in a sample of individuals with TBI the relationship between cognitive functions, in particular theory of mind (ToM) and executive function (EF), and pragmatic ability. Most of the previous studies considered the relationship between only one of these cognitive functions, namely ToM or EF, and pragmatic ability. A few previous studies in literature examined cuncurrently the interplay between ToM, EF and pragmatic ability in TBI (Honan et al., 2015; McDonald et al., 2014). Moreover, few previous studies assessed the role that cognitive functions can have in explaining pragmatic impairment in both linguistic and extralinguistic modalities.

Thus, the aim of this study was to explore the role that cognitive functions, namely ToM and EF, can exert in explaining communicative-pragmatic disorders, and the comprehension and production of different communicative acts (i.e., sincere (standard) communicative acts, deceit and irony), in individuals with TBI.

In the fourth chapter, I will present the third study of this thesis, "Bosco, F. M., Parola, A., Valentini, M. C., & Morese, R. (2017). Neural correlates underlying the comprehension of deceitful and ironic communicative intentions". In this study, we focused on the neural underpinning of comprehension of different communicative acts, i.e. sincere (standard) communicative acts, deceit and irony. Previous studies have shown that the comprehension of speech acts is a high-level process that recruits an extended cerebral network. In particular, neuroimaging studies (Rapp et al., 2012; Harada et al. 2010) have explored the neural basis of irony and deceit comprehension, reporting the involvement of several fronto-temporal and temporo-parietal areas, such as the middle prefrontal cortex (mPFC), the inferior frontal gyrus (IFG) and the middle temporal gyrus (mTG). However, no studies have directly compared neural activation during the comprehension of these pragmatic phenomena. We used functional magnetic resonance imaging (fMRI) to investigate whether common or different neural circuits underlie the comprehension of the same speech act, uttered with the intention of being sincere, deceitful or ironic. Our aim was to show what are the specific cognitive and neural systems involved in the comprehension of these pragmatic phenomena. In the next chapter, I will present some of the most important pragmatic theoretical accounts present in the literature, namely Standard Pragmatic Model, Relevance theory and Cognitive Pragmatic theory.

1.2 Theoretical accounts

1.2.1 Standard Pragmatic model

The Standard Pragmatic Model (SPM) derives from the Gricean theory of conversation (1957, 1969). Grice was the first author to postulate that communication relies on the recognition of a specific set of mental states, i.e. communicative intentions:

*"Clearly we must at least add that, for x to have meant$_{NN}$ anything, not merely must it have been "uttered" with the intention of inducing a certain belief but also the utterer must have intended an "audience" to recognize the intention behind the utterance." (*Grice, 1957, pag 382*).*

When communicating, the speaker's intention is to produce an effect on the partner, by making the partner recognise that intention as such. Thus, according to Grice, communication is a form of intentional action. Grice proposed a distinction between "sentence meaning", which can be derived simply through analysis of the lexical and syntactic properties of a sentence, and "speaker's meaning", as defined by Schiffer (1972), that necessarily requires contextual disambiguation, and involves considering the intention that motivated the speaker's specific communicative act.

Another central point in Grice's account is the notion of conversational implicature. Conversational implicature refers to the fact that a speaker generally implicates something different from what is explicitly uttered. Consider the following example[5]:

[3] A: What's Claire's boyfriend like?

B: I can't understand why she is content with a man like that!

B's reply suggests more than the literal content of the actual words, that is "that the characteristics that appealed to Claire are unknown to him". In Grice's account, it is possible to drawn this implicature by virtue of a general principle, namely "Cooperative principle"(CP), that guides the process of inference-making in conversation.

Grice proposed that during communication people respect a general "Cooperative principle" , by assuming that their communicative partners will make a contribution that is in accordance with four conversation maxims: 1) maxim of quality: be truthful, do not provide information that you know is false or for which there is not adequate evidence; 2) maxim of quantity: make your contribution as informative as is required, but do not provide more information than is required; 3) maxim of relevance: make your contribution relevant and pertinent to the discussion; 4) maxim of manner: try to be clear, brief and orderly; avoid obscurity of expression and ambiguity. The key point of Grice's account is that he described the communicative process in terms of the inferential

[5] The example is taken from Bara (2010, pag 45).

processes that were drawn by the communicative partners, and he provided a set of criteria we generally use to derive inferences in conversation.

As far as irony comprehension is concerned, the SPM assumes that irony is a special case of conversational implicature, in which the speaker communicates something different from what he has uttered. In particular, in irony the speaker overtly violates the maxim of quality, uttering something that is not literally true. Grice called this mechanism a form of exploitation, in the sense that the speaker overtly intends to violate a maxim by communicating to the listener that he was flouting the maxims.

In the comprehension of irony, the SPM argues that the listener first recognises that the speaker has uttered something that is not literally true, but then, by virtue of the CP, assumes that the speaker has intentionally violated the maxim of quality to communicate something to him. So, in a first phase, the literal meaning is analysed and then rejected, and then it is replaced with a non-literal, i.e. ironic, meaning *via* implicatures. This model predicts that irony comprehension would take longer that the comprehension of a literal utterance, due to additional inferential steps required to replace the literal with the non-literal meaning.

Some of the limits of the SPM lie in the fact that Grice failed to explain how forms of irony other than antiphrasis, i.e. the simple inversion of the literal meaning, are understood.

Furthermore, Grice did not specify how a listener could distinguish between irony and lies. Both these phenomena are violations of the maxim of quality. For example, Grice's theory does not explain why the literal meaning *p* of an ironic utterance (for example "What a beautiful day" in [2], should be interpreted as *not p, i.e. "*It's not a beautiful day"). In addition, although Grice described irony as being generally associated with a special attitude or a feeling (such as scorn or criticism in sarcasm), he did not explain the role of attitude ascription in the comprehension of irony.

Some of these issues have been addressed by subsequent theories, such as Sperber and Wilson's Relevance theory and the Cognitive Pragmatic theory.

1.2.2 Relevance theory

In line with the Gricean view of communication, Sperber and Wilson (1986/1995) proposed a model of human communication, i.e. the Relevance theory (RT), which assigned a key role to inferential processes and contextual information. While Grice (1957, 1969) proposed that the way for drawing pragmatic inferences in conversation is mainly reflective, conscious and cognitively demanding, Sperber and Wilson proposed the existence of a specialised inferential mechanism, namely the Principle of Relevance (PR), which is more rapid, cognitively effortless and pre-reflective.

The PR guides the listener in understanding the speaker's communicative intention, and the speaker in producing a communicative act, which should be immediately and easily understood by the communicative partner. In this view, an input is relevant when it connects to previous knowledge and produces cognitive effects, i.e., interpretative possibilities, and at the same time is cognitively effortless. The authors proposed that the PR is embedded in human cognition and that the search for relevance is a property of human cognition, that has emerged under evolutive pressure:

"*We claim that in hominid evolution there has been a continuous pressure towards greater cognitive efficiency, so that human cognition is geared to the maximization of relevance (we call this claim First, or Cognitive, Principle of Relevance)*" (Sperber & Wilson, 2002, pag 14).

In addition, the authors sustained that this mechanism is embedded in a ToM module aimed at recognising the speaker's communicative intention (Sperber & Wilson, 2002).

To explain the comprehension of irony, the authors proposed the Echoic theory of irony:

"*We define echoic use as a subtype of attributive use in which the speaker's primary intention is not to provide information about the content of an attributed thought, but to convey her own attitude or reaction to that thought. Thus, to claim that verbal irony is a subtype of echoic use is to claim, on the one hand, that it is necessarily attributive, and, on the other, that it necessarily involves the expression of a certain type of attitude to the attributed thought*." (Wilson & Sperber, 2012, pag 11).

The authors considered irony as an attributive use of language. In attributive use of language, a speaker uses a given expression not to refer directly to a state of affairs or to a thought that he wants to communicate, but to refer to a second thought that is similar to the first in content, and that the speaker attributes to an external source other than himself. Echoic use is a subtype of attributive use, in which the speaker expresses an attitude (for example mockery or scornfulness in sarcasm) towards the thought attributed to a second external source. This is an example provided by the authors (Wilson & Sperber, 2012, pag 12):

[4] Jack: I've finally finished my paper.

Sue (happily): (a) You've finished your paper! (b) *Let's celebrate*!

It is clear from Sue's answer in (a) that she is not communicating to Jack a concept or thought that Jack has just expressed ("*You've finished your paper")*; instead, she is communicating her attitude toward this thought, namely surprise and joy. Thus, a key process in irony comprehension is recognising the speaker's attitude.

In this model, irony recognition does not involve different sequential steps (compared to literal language) as postulated by the SPM; similar processes, in terms of quantity of necessary inferences, are involved in the comprehension of literal and non-literal expressions. These processes are guided by a non-specialised modular mechanism, i.e., PR. The prediction of this model is thus that irony is not necessarily more difficult to understand than literal statements, and that it can be accessed directly without replacing the literal meaning with a non-literal one.

The RT helped to overcome some of the limitations of the SPM, such as for example by providing a reason why a speaker should use irony instead of literal speech (to express an attitude towards an utterance), and specifying more clearly which inferential mechanisms could be involved in pragmatic comprehension and production. It also extended and clarified the notion of pragmatic inference beyond language, as the authors proposed that the comprehension and production of every utterance or other ostensive stimulus (e.g. gesture) is guided by the presupposition of relevance, i.e. by the PR.

The limit of this approach is that it does not permit the formulation of specific predictions about the different levels of difficulty involved in understanding different pragmatic phenomena (such as irony and deceit) observed in individuals with neurologic and psychiatric disorders (e.g., Angeleri et al., 2008; Colle et al., 2013; Shany-Ur et al., 2012; Gabbatore et al., 2014). In addition, it would hardly seem plausible that a single principle, namely the PR, could explain the whole variety of communicative phenomena characterising human communication. Lastly, not all cases of irony are echoic, and the RT does not account for comprehension of other forms of irony. Some of these issues have been addressed by the Cognitive Pragmatic theory.

1.2.3 Cognitive Pragmatic theory

Cognitive Pragmatics (CPT; Airenti, Bara & Colombetti, 1993a, b; Bara, 2010) is a theory of human communication that focuses on the inferential processes underlying communicative interactions. Communicative intentions can be expressed not only through the linguistic modality (i.e., language) but also through extralinguistic or non-verbal (i.e., the use of gestures and facial expressions, etc.) and paralinguistic modalities (i.e., intonation, rhythm, tone of voice, pitch, intensity and quality). In line with CPT, I use the terms ‘linguistic’/’extralinguistic’ instead of the classical ‘verbal’/’non-verbal’ (for further details, please see Bara and Tirassa (2000)). According to the CPT (Bara, 2010) pragmatics is grounded on a person’s cognitive processes as the basis for communicative interaction, regardless of the expressive means used, linguistic, as speech acts, or extralinguistic, as gestures or facial expressions.

The basis of communication begins and ends with the expression and comprehension of communicative intention: the mental and inferential processes that are involved in undersanding the communcative intention of a speaker are similar independently from the gestural or lingusitic input used to convey meaning. According to this view, linguistic and extralinguistic communicative acts share the most relevant mental processes in each specific pragmatic phenomenon (as in case of sincere (standard) communicative acts, irony and deceits). Thus, information acquired by different expressive modalities, such as linguistic or extralinguistic ones, is equivalent by the standpoint of the mental processes necessary to reconstruct the speaker’s communicative itntention. Empirical evidence provided support to this model showing that communicative acts expressed by language or gestures share the same cognitive and neural processes (Xu et al., 2009; MacSweeney et al., 2008; Bara et al., 2011, Enrici et al., 2011; Tettamanti et al., 2017).

CPT distinguishes between standard and non-standard communication: while in standard communication (i.e., sincere communicative acts) there is a correspondence between what an actor (literally) says and his private knowledge, non-standard communication (i.e., irony and deceit) is characterized by the presence of a conflict between what an actor overtly and literally says and his private knowledge. Non-standard communicative acts are more difficult to handle than standard communicative acts since they require more inferential ability in order to be understood or produced (see Bucciarelli, Colle & Bara, 2003; Angeleri et al., 2008). Inferential ability is the cognitive process allowing speakers to go beyond the literal meaning of an utterance in order to understand or to reach a specific communicative meaning. The more conflicts there are underlying a given pragmatic phenomenon, the more difficult it is to understand it (see Bosco & Bucciarelli, 2008; Angeleri et al., 2008). In particular, the comprehension (and production) of deceit requires the speaker (and the listener) to produce (and recognize) the presence of such conflicts. With irony, instead, the speaker (and the listener) must also keep in consideration that the speaker (and the listener) wants him to recognize this conflict on the basis of the knowledge they share with each other: irony is therefore more difficult to understand than deceit. Consider the following example (Bosco, 2006) to clarify this concept: *Angela and Bob share that the lesson they have just attended was really boring. Angela is annoyed with Carl because Carl had not come to the lesson and she wishes not to let him know that she lost the whole morning for nothing. After the lesson Angela and Bob meet Carl who asks them: "How was the lesson?" Ann answers: [3] "It was wonderful!".* Bob is able to comprehend that Angela is deceiving Carl because he recognizes the difference between the knowledge she is expressing and the knowledge she actually - though privately - entertains.

Furthermore, a statement becomes ironic when, along with this difference, the partner also recognizes (or produces) the contrast between what is expressed and the scenario provided by the knowledge that the actor shares with the partner. In our example, Bob might also interpret [3] as ironic because he shares with Angela the knowledge that the lecture was not interesting at all. For an observer, the simultaneous activation of the representation of the actor's utterance ("It was wonderful") and of the contrasting shared belief ("The lesson was boring") makes an ironic communicative act more difficult to comprehend (or to produce) than a deceitful one.

According to the theory, the number of conflicts involved in every communicative act, and thus the complexity of the inferential processes necessary to handle it, is able to explain the increasing trend[6] of difficulty shown by typically developing children (Bosco et al., 2009; 2012b; 2013) and

[6] I will use here the term "trend" to refer to the presence of a linear trend into the data, i.e. the mean performance of individuals decrease or increase in a linear way. A linear trend indicates that the dependent variable (scores of participants in each pragmatic tasks) tends to decrease in a linear way across the ordered categories of the independent variable (the different type of pragmatic task, i.e. sincere (standard) communicative acts, deceit and irony). Since linear contrast is the most basic form of polynomial contrast commonly used in Analysis of Variance (ANOVA) to test the presence of a trend within the data, we used it in the studies described in chapter 2 and 3 to test the hypothesis that individual performance in the pragmatic tasks tends to decrease in an approximately linear way as well as the inferential complexity of the task involved tend to increase.

adults with neurological disease, i.e. traumatic brain injury (Angeleri et al., 2008), aphasia (Gabbatore et al., 2014) and psychiatric disorders, i.e. schizophrenia (Colle et al., 2013) in the comprehension and production of different kinds of pragmatic phenomena, i.e. sincere (standard) communicative acts, deceit and irony.

Even Sperber & Wilson (1986/1995) claimed that shared knowledge is important in determining the interpretation of au utterance, but they have not specified the way by which shared knowledge is used by communicative partners in the comprehension and production of speech acts. The CPT stressed the importance of shared knowledge between communicative partners, and described the ways by which this knowledge is used as a background scenario to derive communicative intentions.

In the following chapters, I will describe the studies that are part of this thesis. We explored how communicative-pragmatic ability, a highly sophisticated process that encompasses different cognitive skills, may be disrupted by brain injury, in particular after RHD and TBI. We also investigated how deficits in cognitive functions, especially EF and ToM, can contribute to generate pragmatic disorders in these clinical populations, with the aim of providing more information on the relationship between cognitive functions and pragmatic ability. Lastly, we investigated the neural correlates of pragmatic ability during the comprehension of deceitful and ironic communicative acts. In these studies, we adopted the CPT as the theoretical framework.

The adoption of the CPT as the background theoretical framework was motivated by several reasons. As reported by Cummings, a theoretical framework is necessary to identify the cognitive mechanisms that are responsible for the pragmatic impairment. Without a theoretical framework, it is impossible to make testable predictions about the cognitive processes involved in the comprehension and production of communicative acts. Instead, adopting a pragmatic theoretical framework can make it possible to go beyond the simple description of pragmatic disorders and to provide a coherent explanation of these. Moreover, as Blake (2006) suggested, a theoretical framework can help to identify at which level of cognitive processing the pragmatic deficits originated, and this is crucial in order to plan effective rehabilitation programs focused on a specific patient's difficulties. However, only few studies have adopted a theoretical framework in explaining pragmatic disorders, and only a small number of the assessment batteries used to detect pragmatic disorders are grounded on a theoretical framework of communicative processes (e.g Zaidel et al., 2002):

"*However, at the same time as there has been a proliferation of empirical findings, many of these findings can appear poorly interconnected and of limited significance. They can also often lack proper explanatory value. It is important to interrogate why this is the case. As I will argue in this chapter, the answer lies in the lack of theoretical models in clinical pragmatic research. In the absence of these models, clinical pragmatic studies have produced copious findings. However, only some of these findings have the type of theoretical significance that can advance our understanding of pragmatic disorders*". (Cummings, 2014, pag 95).

Previous studies have shown the CPT to be particularly suitable for explaining pragmatic disorders (Angeleri et al., 2008; Gabbatore et al., 2014; Colle et al., 2013). The CPT provides a model of human communication that can be used to make testable predictions to explain the communicative performance of individuals with pragmatic disorders. In addition, the Assessment Battery for Communication (ABaCo; Sacco et al., 2008; Angeleri et al., 2012; Bosco et al., 2012) has been developed within the framework of CPT. The ABaCo's structure and its reference to a precise theoretical framework make this clinical tool particularly suitable for diagnosing communicative-pragmatic disorders in individuals with brain damage, and for investigating the cognitive and neural factors that may be responsible for such impairments. I will present the hypothesis made on the basis of the CPT separately for each of the three studies that are part of this thesis in the following chapters.

1.3 Right hemisphere damage and pragmatic ability

1.3.1 Pragmatic deficits following RHD

Individuals with RHD rarely exhibit deficits that affect the microlinguistic aspects of language, such as phonological, morphological and syntactical aspects (e.g., Brownell et al., 1992; Tompkins et al., 2002; Marini et al., 2005; Marini, 2012), which are generally associated with lesion at the left hemisphere (LHD). By contrast, one of communicative aspects that is most seriously impaired after RHD is the pragmatic one. Patients with right hemisphere damage (RHD) frequently report a wide range of communicative disorders that can seriously undermine their ability to effectively communicate in everyday contexts (Mackenzie et al., 2001). For these reasons, the processing of pragmatic aspects of communication has been historically associated to the right hemisphere (RH) of the brain (e.g., Blake, 2017; Kaplan, Brownell, Jacobs, & Gardner, 1990) .

It is now established that RHD can compromise the pragmatic domain, undermining patients' ability to understand indirect speech acts (Weylman et al., 1989), non-literal and figurative expressions such as idioms and proverbs (Papagno et al., 2006; Brundage, 1996), humour (Cheang & Pell, 2006), lies and jokes (Winner et al., 1998), and irony and sarcasm (McDonald, 2000). These studies showed that RHD patients are able to comprehend the meaning of literal sentences whereas they fail to grasp the meaning of non-literal and figurative expressions such as metaphor and irony. The characterization of communicative deficits in RHD patients suggests that the origin of these difficulties can be referred to high-level of language processing: what is compromised is the ability to correctly draw contextual inferences, in order to appreciate the speaker's intention and accomplish the demands of the surrounding communicative context (Sabbagh, 1999; Kaplan et al., 1990; Gardner et al., 1983).

Furthermore, impairment in terms of conversational and discursive skills was often detectable in RHD patients, resulting in egocentric and irrelevant responses, tangential comments, digressions from the topic, lack of coherence in discourse and difficulties respecting turn-taking (Myers, 1999; Bartels-Tobin & Hinckley, 2005; Chantraine et al., 1998; Marini et al., 2005; Hird & Kirsner, 2003; Blake, 2006; Sherratt & Bryan, 2012). Moreover, RHD can also lead to a reduction in the ability to understand and produce those paralinguistic elements, such as tone, intonation, rhythm and prosody, which contribute to generate the pragmatic meaning of a communication act (Krauss, 1998; Krauss, Morrel-Samuels & Colasante, 1991; Vaissière, 2005). Indeed, RHD patients exhibit difficulties in recognizing both linguistic and emotional prosody: difficulties in recognizing emotions from tone of voice and facial expressions (Kucharska-Pietura et al., 2003; Shamay-Tsoory et al., 2005), in using prosody to distinguish between different basic speech acts, such as to distinguish between declarative and interrogative sentences (Pell, 1998, 2006), and in recognizing paralinguistic contradictions, namely the inconsistency between the semantic message and the intonational meaning conveyed through an utterance (Tompkins & Mater, 1985). They also do not adequately modulate prosodic elements to comply with the requests set by the communicative context, producing monotonous or atypical prosodic contours (Pell, 1999; Blake, 2007).

Another significant area of impairment in RHD communicative competence seems to be represented by difficulties in the use of non-verbal communicative modality. Most of the studies in the relevant literature evaluated communicative abilities in RHD patients focusing on the linguistic aspects of the pragmatic ability (e.g. McDonald, 2000; Cheang & Pell, 2006; Joanette et al., 1990), while few researchers have attempted to analyse the role of non-verbal modality, i.e. gesture and facial expressions, in generating communication disorders in RHD patients. Cocks et al. (2007) observed a reduction in gesture production during spontaneous conversation in RHD patients, compared to healthy controls, especially when the examiner elicited discourses with an emotional content. Cutica et al. (2006) analysed the comprehension of gesture during communicative interaction comparing the performance of LHD and RHD patients. The RHD patients exhibited greater impairment in gestural modality compared to the LHD patients: the RHD patients also failed to appreciate the simplest communicative acts (i.e., sincere communicative acts) when expressed through gesture. Overall, these studies seem to suggest that RHD can undermine the ability to comprehend and produce the pragmatic aspects of communication when also expressed through non-verbal modality. However, the limited number of studies evaluating non-verbal expressive meaning given RHD do not allow us to draw firm conclusions on the relationship between gestures and language, and further investigations into this aspect are required.

The researches described above highlight that communicative-pragmatic impairments represent a typical outcome following RHD; this supports the hypothesis that communicative competence can be ascribed to the conjoint activity of both hemispheres and overcoming the traditional view which associates it with the linguistic areas of the left hemisphere (e.g. Goodglass & Kaplan, 1983; Tompkins, 1995; Zaidel et al., 2002). Several recent neuroimaging studies have confirmed that processes are distributed across several brain areas, involving an extended bilateral cerebral network (e.g. Mason & Just, 2006; Bambini et al., 2011).

1.3.2 Communicative assessment of RHD patients

Some theoretical and methodological issues affect the assessment procedures of communicative-pragmatic abilities in RHD patients. As previously reported, few pragmatic approaches for assessing acquired communicative deficits have combined the assessment of linguistic abilities with a systematic evaluation of both the comprehension and production of communicative gestures and facial expressions: the assessment tools developed to diagnose communication impairments following RHD, such as the “Right Hemisphere Communication Battery” (RHCB, Gardner & Brownell, 1986), the “Right Hemisphere Language Battery” (RHLB;

Bryan, 1995) and the “Batteria sul Linguaggio dell’Emisfero Destro” (Rinaldi, Marangolo & Lauriola, 2004) have focused on some aspects of communication (i.e., the linguistic and prosodic components) without providing a detailed description of the ability to communicate through other expressive means, such as gestures and facial expressions. The lack of instruments able to evaluate the ability to communicate using non-verbal modality could be problematic. Previous studies reported that RHD individuals can use their preserved ability to manage syntactical aspects during discourse comprehension (Brownell et al., 1992) to compensate for their pragmatic difficulties; thus, RHD patients can be facilitated when a message is expressed through linguistic modality. Indeed, the study of Cutica et al. (2006) confirmed that RHD patients (compared to LHD patients) found communicative acts expressed through language easier to comprehend than those expressed through gesture. These data suggest that communicative assessment tools developed for RHD should concomitantly evaluate all the expressive modalities of pragmatic competence in order to avoid the risk of underrating patients’ difficulties.

In addition, previous studies revealed that communicative deficits can vary widely across participants, generating highly variable clinical profiles. Studies that have examined the problem directly (Cote et al., 2007; Champagne-Lavau & Joanette, 2009) have identified clusters of RHD patients characterized by different patterns of performance. This heterogeneity represents a critical problem for clinicians working with RHD patients, as it makes it fairly difficult to characterize the disorder and define the neurological condition. Communicative deficits after RHD can be: 1) subtle, and emerge only when the communicative tasks administered require a high cognitive load 2) evident only evaluating certain expressive modalities (e.g. linguistic, extralinguistic or paralinguistic), making it difficult to ascertain their presence 3) limited to the comprehension or production of specific pragmatic phenomena, such as irony or figurative expressions. As a result, in most of the previous experimental studies the authors reported the presence of different subgroups of individuals with very different patterns of communicative-pragmatic performance: some individuals performed similarly to healthy controls, while others exhibited a severe impairment in pragmatic ability. In addition, in the subgroup of individuals who exhibited pragmatic disorders, it was often possible to find diffent profiles of communicative impairment, for example with some patients showing only (or prevalently) deficits in conversational skills, and others showing only (or prevalently) deficits in comprehending figurative or non-literal expressions (e.g. Cote et al., 2007; Champagne-Lavau et al., 2009). This variability has prevented the definition of a univocal clinical label to identify communicative disorders following RHD, with negative effects for assessment approaches (Myers, 2001). Considering the variability of impairment after RHD, it is important to provide a comprehensive evaluation of communicative-pragmatic ability to avoid the risk of underrating patients' difficulties.

Finally, a limited number of clinical batteries devised for assessing pragmatic abilities in individuals with RHD are based on precise theoretical frameworks of communicative processes. The use of a theoretical framework that allows for the identification of the specific level at which the impairment is placed is important, and represents a necessary step to plan effective rehabilitative programmes focused on patients' difficulties (Blake, 2006). In order to overcome the above-mentioned limitation, in recent years the Assessment Battery for Communication (ABaCo; Sacco et al., 2008; Angeleri et al., 2012; Bosco et al., 2012) has been developed within the framework of CPT (Airenti, Bara & Colombetti, 1993; Bara, 2010). The ABaCo consists of different pragmatic tasks aimed at investigating a broad range of communicative phenomena expressed through different communicative modalities, such as sincere (standard) communicative act, deceit and irony (see section 2.2.2.1 for a detailed description of the clinical tool, and a detailed list of all the communicative phenomena investigated in the battery). The ABaCo has already been used to efficiently assess pragmatic abilities in psychiatric and neuropsychological disorders (Gabbatore et al., 2014; Colle et al., 2013; Bosco et al., 2014). Moreover, the normative data of the ABaCo (Angeleri et al., 2012) enable us to determine more precisely the specific levels of communicative impairment of each patient.

1.3.3 Summary

Compelling evidence supports the hypothesis that cerebral areas pertaining to the RH underlie the mechanisms involved in communicative-pragmatic competence. For example, the RH has been associated with inferential ability (Beeman et al., 2000), discourse production (ŁOjek-Usiejuk, 1996), processing of prosodic (Pell, 1999) and emotional aspects (Kucharska-Pietura et al. 2005), and comprehension of figurative language (Champagne-Lavau, 2015).

Individuals with RHD have generally been reported as having spared core language skills (such as syntax and semantics), while they frequently show communicative-pragmatic disorders. Pragmatic impairment in RHD is generally related to the comprehension and production of the more complex aspects of communication, such as deceit, irony and metaphor, that are very inferentially demanding. Pragmatic impairment after RHD can compromise not only the linguistic modality, but also the paralinguistic and extralinguistic ones. However, assessment procedure aimed at evaluating pragmatic disorders following RHD focused on linguistic modality, while few attention has been paid to extralinguistic one. Only one study assessed pragmatic abilty evaluating (and comparing) both linguistic and extalinguistic modality (Cutica et al., 2006).

Moreover, some theoretical and methodological issues with the assessment procedure of pragmatic impairment in RHD still remain, in particular: 1) the heterogeneity of communicative deficits after RHD 2) the lacking of a background theoretical framework in most of the clinical batteries devised for assessing pragmatic abilities in RHD, that makes it possible to identify the cognitive factors responsible for such impairment.

In the first study of this thesis, “Assessment of pragmatic impairment in Right Hemisphere Damage”, we provided a multifocal assessment of pragmatic abilities in patients with RHD. Given the association between the RH and pragmatic aspects of communication, RHD represents an ideal condition for studying the cognitive mechanisms underlying communicative-pragmatic impairment. In this study, we tried to address some of the issues and to overcome some of the limitations reported above.

In particular, we used the ABaCo to evaluate comprehension and production of sincere (standard) communicative acts, deceit and irony, in both linguistic and extralinguistic modality. Our aim was to evaluate what are the cognitive processes that may be responsible for pragmatic impairment in individuals with RHD in dealing with these communicative phenomena. We focused on the role that a deficit in inferential processes can play in generating communicative-pragmatic disorder in RHD, adopting as background theoretical framework the CPT. I will detail the aim, experimental hypothesis, methodology and results of this study in chapter 2.

In the second study of this thesis, we moved on to investigate the cognitive factors, in particular theory of mind and executive functions, that might be responsible for pragmatic impairment following acquired brain damage. In this study, we focused on individuals with traumatic brain injury (TBI): TBI is often associated with lesions to the frontal lobe, that can result in deficits in two cognitive functions, i.e. ToM and EFs, in addition to communicative-pragmatic deficits. This clinical profile offered the opportunity to explore the relationship between cognitive deficits and pragmatic disorders. We used the ABaCo to evaluate comprehension and production of sincere (standard) communicative act, deceit and irony, in both linguistic and extralinguistic modality, and we explored the role that two cognitive functions, namely ToM and EF, may play in explaing the communicative performance of individuals with TBI using the CPT as theoretical framework. In the next chapter, I will present the relevant literature on the relationship between cognitive functions and pragmatic ability in TBI.

1.4 Cognitive functions and pragmatic ability

Pragmatic comprehension (and production) is a high-level process that involves the interplay of several cognitive processes, such as working memory, attention, inferential ability, reasoning, emotional processing, to cite just a few. Among these processes, ToM and EFs have been proposed as having a key role in communication. Studies in developmental pragmatics have confirmed that the emergence and the development of pragmatic ability are associated with ToM and EFs, and studies in clinical pragmatics have frequently revealed a pattern of correlation between pragmatic disorders and ToM and EF deficits in clinical populations (Wimmer & Perner, 1983; Baron-Cohen et al., 1985; Happè, 1993; Bloom, 2000; Martin & McDonald, 2003).

In the next chapter, I will examine the cognitive functions underlying pragmatic-communicative ability, focusing in particular on ToM and EFs, and the different ways in which a deficit in these cognitive skills could impair pragmatic comprehension and production. The interest in the study of the cognitive underpinning of pragmatic disorders has grown considerably in the last decades (Bambini et al., 2016a, b; Honan et al., 2015; Cummings, 2014; 2017; Stemmer, 1999; Langdon et al., 2002).

The importance of studying the relationship between pragmatic disorder and the underlying cognitive deficits is twofold. First of all, identifying the cognitive deficits that are actually responsible for pragmatic impairment could help us to gain a better understanding of how pragmatic interpretation unfolds, which is the main aim of this thesis. As the study of aphasia has allowed us to gain more knowledge about the organisation of linguistic and semantic processes, the study of pragmatic and cognitive disorders in clinical populations provides the opportunity to disentangle the relationship between cognitive functions and pragmatic ability. Secondly, communicative-pragmatic ability relies on the interplay between different cognitive systems, so it is possible that similar pragmatic deficits may have originated from different deficits in the pragmatic system; from a clinical perspective, the study of the cognitive deficits responsible for pragmatic disorders could help to define a specific treatment focused on the patient's difficulties.

In the next chapter, I will focus on communicative impairment in traumatic brain injury (TBI). TBI can severely undermine the ability to communicate, resulting in a serious reduction in the capacity to draw the relevant inferences during a communicative exchange, even in the absence of deficits in core linguistic aspects (i.e., syntactic and semantic elements). TBI often results in multifocal as well as diffuse cerebral damage: however, irrespective of the site of impact, the areas most at risk from focal damage are localised in the cortical areas of the frontal and temporal lobes (Mennel, 1997). The multi-focal injury to the frontal and temporal lobes does not only produce deficits in pragmatic ability, but can lead to severe deficits in other cognitive functions that are associated with the frontal lobe, namely ToM and EF. Thus, TBI offers an opportunity to evaluate the relationship between pragmatic impairment on one side, and ToM and executive deficits on the other.

Conversely, RHD after stroke are more commonly associated with focal damage often localized in the basal ganglia, due to the different mechanisms responsible for the accident (vascular in RHD, and traumatic in TBI)[7]. For these reasons, while the presence of ToM and EF deficits is well known in TBI, the evidence reporting such deficits after RHD is less robust and more sparse (Weed, McGregor, Feldbæk Nielsen, Roepstorff, & Frith, 2010; McDonald, 2000). The association between communicative-pragmatic impairment, and EFs and ToM, has received less empirical support in RHD populations, compared to TBI, perhaps due to differences in the clinical features and lesional profiles in the two disorders (Rao & Lyketsos, 2000), To sum up, the clinical features characterising TBI make this condition particularly suitable for investigating the relationship between ToM, EF, and pragmatic ability.

In the next chapter, I will review the literature investigating the cognitive underpinning of communicative-pragmatic disorders in individuals with TBI, focusing on ToM and EFs. Even though other cognitive and affective processes may be involved in communicative-pragmatic processing, such as general intelligence (IQ), reasoning ability, emotional processing, we decided to focus on ToM and EFs for several reasons. Different pragmatic theoretical accounts have hypothesised a role for these cognitive functions in pragmatic processes (see chapter 1.2): studying

[7] To give the reader an idea of the different localization of brain injury in TBI and stroke, Zhang et al. (2016) reported the different lesional profiles of a sample of 230 patients (103 with TBI and 127 with stroke). In patients with stroke the affected areas were, respectively: 1) basal ganglion (74.02%), 2) temporal lobe (16.54%), 3) parietal lobe (14.96%), 4) frontal lobe (14.17%); in patients with TBI: 1) temporal lobe (34.95%), 2) frontal lobe (30.10%), 3)parietal lobe (19.42%), 4) basal ganglion (16.50%).

the relationship between ToM, EF and pragmatic ability in experimental research could help to validate (or falsify) hypotheses made on the basis of the different pragmatic theoretical accounts. The role of other cognitive functions, such as emotion and IQ, is not so systematically specified in pragmatic theory, and it is thus more difficult to investigate their specific role in pragmatic ability. In addition, developmental and clinical studies have suggested that the development of ToM and EFs plays a specific role in pragmatic comprehension, and the development of the cognitive systems supporting these different functions (ToM, EF and pragmatic ability) may be related (Wimmer & Perner, 1983; Baron-Cohen et al., 1985; Happè, 1993; Bloom, 2000; Happé, 1993).

1.4.1 Pragmatic disorder in TBI

A number of studies have confirmed that traumatic brain injury (TBI) is associated with communicative-pragmatic impairments (Bara, Tirassa & Zettin, 1997; Angeleri et al. 2008; Johnson & Turkstra, 2012; Bosco, Angeleri, Sacco & Bara, 2015). 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 (McDonald, 1992; McDonald & Pearce, 1996; Channon et al., 2007), 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 through gestures, facial expressions, and body posture (Bara, Cutica, & Tirassa, 2001; Rousseaux, Vérigneaux, & Kozlowsky, 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 et al., 2011; Marini, Zettin & Galetto, 2014).

1.4.2 Executive function explanation

Several definitions of executive function (EF) have been proposed in literature, and they generally refers to: "*those capacities that enable a person to engage successfully in independent, purposive, self-serving behavior*" (Lezak, Howieson, Loring, Hannay, & Fischer, 2004, pag 35). The EF system encompasses a set of high-level cognitive processes that allow people to plan and perform goal-directed behaviour in a flexible manner, monitoring and adjusting performance during task execution, and adapting it to the constraints set by a specific task.

EFs are not a unified construct, and different models have been proposed in the last years to explain their functioning (Lezak, 1995; Miller & Cohen, 2001; Smith & Jonides, 1999; Sullivan, Riccio, & Castillo, 2009; Thomas, Snyder, Pietrzak, & Maruff, 2014; Dikmen et al. 2009). For example, Smith & Jonides (1999, pag 1659) proposed a model including the following EFs: "*i) focusing attention on relevant information and processes and inhibiting irrelevant ones ("attention and inhibition"); (ii) scheduling processes in complex tasks, which requires the switching of focused attention between tasks ("task management"); (iii) planning a sequence of subtasks to accomplish some goal ("planning"); (iv) updating and checking the contents of working memory to determine the next step in a sequential task ("monitoring"); and (v) coding representations in working memory for time and place of appearance ("coding")*". Miyake et al. (2000) found three main executive components, namely *updating*, i.e. the ability to manipulate information in working memory, *shifting* (i.e. the ability to shift attention between multiple tasks), and *inhibition* (i.e. the ability to suppress automatic responses).

EF deficits could reflect on the ability to communicate in everyday situations in various ways: problems in planning ability could diminish the ability to construct a coherent discourse by organising the sequence of topics in a hierarchical and flexible order; inhibitory control deficits could lead to difficulty in suppressing irrelevant or interfering information during language comprehension, impairing the ability to recognise and produce indirect, figurative and non-literal forms of language; problems in inhibition may also generate inappropriate comments and difficulties in respecting turn taking; deficits in cognitive flexibility and shifting may impair inferential skills, reducing the ability to manage complex mental representations and to consider alternative interpretations of an utterance; deficits in the awareness and monitoring of communicative errors reduce the possibility of recognising and recovering communicative failures (McDonald & Pearce, 1996; McDonald & van Sommers, 1993; Bosco et al., 2015; Cummings, 2012).

EFs are frequently impaired as a consequence of TBI (e.g Ashman, Gordon, Cantor, & Hibbard, 2006), and some authors have proposed that EF deficits are the primary impairment responsible for the communicative difficulties observed in different clinical populations such as TBI, RHD and schizophrenia (see Martin & McDonald, 2003; Thoma, & Daum, 2006). In individuals with TBI, several studies have reported an association between EF and pragmatic impairment.

McDonald & Pearce (1998) evaluated pragmatic ability in 15 individuals with acquired brain damage and 15 matched controls. The authors used a production task in which the participants were required to make a request to a second person, after reading a social scenario describing their partner and an obstacle that could prevent them from making the request. The authors reported that individuals with TBI found it more difficult to make requests that had to take into account the speaker's needs; moreover, this performance was related to executive dysfunction, i.e. inhibitory control deficits. Channon & Watts (2003) evaluated comprehension of indirect speech acts, and they assessed a set of EF, i.e. inhibition, working memory, and multitasking. The results showed as the only factor that provided a significant contribution in explaining patients' pragmatic difficulties was inhibitory control, while no influence of working memory and multitasking was found. Youse & Coelho (2005) investigated communicative-pragmatic ability in patients with closed head injury (CHI). The study evaluated pragmatic ability using a narrative discourse production task, and assessed working memory (WM). The results showed significant, though modest, correlations between some measures of discourse production and the WM test. Douglas (2010) evaluated EF (verbal fluency, the speed of verbal processing, and the ability to maintain and manipulating information) and pragmatic abilities in patients with TBI using LA Trobe Questionarie (LCQ, Douglas, O'Flaherty, & Snow, 2000). The results showed that executive skills predicted 32% of the variability of the pragmatic performance of people with TBI in LA Trobe Questionarie.

However, it is worth pointing out that not all previous studies have found a relationship between EF and pragmatic ability (Dardier et al., 2011; Schmitter-Edgecombe & Bales, 2005). For example, Dardier et al. (2011) evaluated EF and pragmatic performance in eleven participants with TBI. The authors evaluated three aspects of pragmatic ability, namely production (topic maintenance, digression and speaking turns) during an interview, comprehension of direct requests, conventional indirect requests, and hints, and metapragmatic knowledge. They also assessed EFs, i.e. mental flexibility, self-regulation, inhibition ability and conceptual capacities. The results revealed that individuals with TBI showed weak pragmatic performance in some of the tasks (topic maintenance in production and metapragmatic knowledge), but normal performance in other tasks (turn-taking in production, and request comprehension, including hints). More interestingly, the authors did not find any evidence of an association between measures of EF and pragmatic performance: among the four patients who exhibited the best pragmatic performance, three had executive deficits; on the contrary, among the four patients with no executive impairments only one exhibited good pragmatic performance. Altogether, previous studies partially support the role that

EF plays in pragmatic comprehension and production. However, the experimental results are mixed: some studies have not found any significant association between executive impairments and pragmatic deficits (Schmitter-Edgecombe & Bales, 2005; Dardier et al., 2011), and it is difficult to delineate a stable pattern of association between the impairment of specific executive processes and the impairment of specific pragmatic phenomena.

An alternative explanation for the relationship between communicative-pragmatic disorders and executive dysfunction is that both may be related to a more basic general cognitive impairment associated with the severity of brain injury; however, most studies have not found any association between injury severity and pragmatic performance (Channon & Watts, 2003; Douglas, 2010). Additionally, executive functions are a multidimensional construct referring to different cognitive functions; each study measured only a limited set of these cognitive functions, adhering to different EF models each time, and using different neuropsychological tests. Thus, most of the results have not been replicated, and more evidence is needed to confirm the generalisability of these findings. Finally, EF deficits could be reflected in impaired performance in ToM tasks; thus, some of the associations found between pragmatic ability and EF could in fact reflect an underlying association between ToM and pragmatic disorder. These issues, and the relationship between pragmatic ability and ToM, will be analysed in the next chapter.

1.4.3 Theory of mind explanation

Theory of Mind (ToM) refers to the ability to attribute mental states such as beliefs, desires and emotions to one's own mind and to the minds of others in order to predict behaviour (Premack and Woodruff, 1978)[8].

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[8] Several studies in the fields of *pragmatics* conflated the concept of mental inference with those of inference in communication. In line with CPT, in this thesis I will adopt a view that points to a specificity of communicative-pragmatic competence, that is distinct and thus cannot be reduced to other cognitve functions, such as ToM. Even if theory of mind can require inferential reasoning

The idea that human communication is strictly interwoven with the attribution of mental states was initially proposed by Grice (1957, 1969), who first underlined how the appreciation of communicative intentions is a prerequisite of human communication. Grice and the SPM (Grice, 1957), identified the success of communicative processes with the listener's recognition of a set of mental states, which are the speaker's intention to affect the listener's mental states plus a second-order intention that this first intention would be recognised as such.

Other pragmatic theories such as the RT (e.g. Sperber & Wilson, 2002), or CPT (Bara, 2010), advocated a key role of ToM in pragmatic ability. The Relevance theory points out that a necessary step in the recognition of a sarcastic remark consists in the recognition of a particular mental state, namely the speaker's attitude. Moreover, Sperber and Wilson (2002) argued that the Relevance mechanism is a specialisation of, and operates within, a more general ToM module.

The CPT also underlines that identifying the communicative effect that the speaker wants to achieve is crucial in order to derive the speaker's communicative intention. For example, when we listen to something that we know to be false, we only become able to differentiate between a mistake and a lie when we identify the speaker's intention to deceive, i.e. the intention to voluntarily modify our mental states in order to make us believe something that is not true (see Adenzato & Bucciaelli, 2008).

In sum, most of the theories in the field of pragmatics argue for the role of ToM in communication, even though the extent and the specificity of ToM involvement in the comprehension of different communicative acts remains under debate (see Martin & McDonald, 2003). In the fields of cognitive psychology and clinical pragmatics, several lines of research have confirmed the association between ToM and pragmatic disorders. For example, studies on neurodevelopmental disorders have shown that impairments in communication in individuals with autism are related to a deficit in ToM ability (Wimmer & Perner, 1983; Baron-Cohen et al., 1985;

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about other persons' mental states, the inferential processes necessary to recognize communicative intentions may be different to those involved in a theory of mind task.

Happè, 1993). Other studies have addressed the role of ToM in verbal interaction in both children and adults (see Bloom, 2000). As far as acquired pragmatic disorders in adults with neurological or psychiatric illness are concerned, there is a wide body of research evidence supporting the association between ToM deficits and disorders of pragmatics (e.g. Champagne-Lavau, Stip, & Joanette, 2006; Corcoran, Cahill, & Frith, 1997; Langdon, Davies, & Coltheart, 2002; Mazza, Di Michele, Pollice, Roncone, & Casacchia, 2008; Winner, Brownell, Happé, Blum, & Pincus, 1998).

In individuals with TBI, several authors proposed theoretically and verified empirically that poor comprehension on ToM tasks could be a crucial factor in explaining pragmatic disorders (see Martin & McDonald, 2003; McDonald, 2013). 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 speaker's intention, 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 & Rule (2005) reported that 19 individuals with closed head injury performed poorly in a task evalutating understanding of two different types of sarcasm , that is sarcastic utterance that could be understood only by reversing the literal meaning and sarcastic remarks that were not directly related to (not simple the opposite of) the literal meaning. The authors evaluated also ToM using a task that evaluated the comprehension of a sequence of human actions vs. physical events, whereby the former (human action) may be solved only considering the mental state of the protagonists of the story. Results showed as individuals' with TBI difficulties were related to their ToM abilities, in particular to the incorrect appreciation of the mental states of the characters involved in their tasks. Muller (2010) evaluated in patients with TBI the comprehension of direct and indirect speech acts, and ToM using a faux pas test.

Performance on the indirect speech acts comprehension task significantly correlated with scores on the faux pas test as well as on second-order false belief stories. The authors proposed that impairment in pragmatic skills exhibithed by patients with TBI may be partially explained by their difficulties in the ability to attribute mental states. More recently, Byom & 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.

However, not all the studies confirmed the role of ToM in explaining pragmatic disorders (Bara, Tirassa & Zettin, 1997; Martin & McDonald, 2005). A shortcoming of the studies reported above is that they did not control for the role of EFs as a moderator variable in the relationship between ToM and pragmatic ability. Several authors have claimed that most ToM tasks require EFs in order to be solved, and results published in the developmental literature provide evidence to support this association, showing that EF performance could be predictive of later performance on ToM tests (Carlson, Moses, & Breton, 2002; Marcovitch et al., 2015). In particular, the EFs involved the most in ToM tasks are working memory, necessary to keep the relevant information of the story in mind so that it can be updated during mentalistic inference making, cognitive flexibility or shifting, necessary to step into the other's person perspective, and inhibitory control, in order to inhibit one's own perspective and consider the other's perspective (McGilloway, Cooper, & Douglas-Cowie, 2003).

Some authors found that EFs could partially explain ToM impairment observed in individuals with TBI (Bibby and McDonald, 2005; Honan et al., 2015). For example, Henry et al. (2006) found that participants with TBI showed a deficitary performance in ToM tasks and emotional tasks compared to healthy controls. The authors also found that partcipants' with TBI performance in ToM tasks strongly correlated with scores on a phonemic fluency test, measuring cognitive flexibility and self-regulation. Also Channon & Crawford (2010) found a significant correlation between executive tasks, measuring working memory and inhibition, and a mentalistic interpretation task.

Since there is much evidence to show that EFs may be crucial in solving ToM tasks, a few studies have started to evaluate the possible role of both EFs and ToM in explaining pragmatic disorders in the same experimental sample. 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.

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. Honan et al. (2015) compared performance of individuals with TBI in a conversational task with that of healthy controls, and investigated the role of EF and ToM in predicts pragmatics deficits. The conversational tasks comprised four different experimental conditions, i.e. (i) high working memory (WM) (ii) high flexibility (iii) high inhibition and (vi) low cognitive load; in addition, the task requires respectively low or high ToM loadings. Individuals with TBI performed worse than the healthy controls in high-ToM tasks in the high WM condition, while no difference have been observed in the other conditions. The authors proposed that the role of ToM in predicts deficits of individuals' with TBI in everyday conversation can be in fact due to working memory demands.

Globally, these findings indicate that ToM does play a role in communication, but also that this role tends to decrease or disappear when the contribution of EF 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 addition, not all the studies found an association between ToM and pragmatic ability (Martin & McDonald, 2005; Bara, Tirassa & Zettin, 1997), and a stable association between specific ToM components and pragmatic phenomena has not yet been found.

1.4.4 Summary

The results of previous studies investigating the relationship between ToM, EF and pragmatic ability, have shown that these cognitive factors contribute to pragmatic deficits in individuals with TBI. Studies that examined the relationship between EF and pragmatic ability found that different EFs, in particular working memory and inhibitory control, were associated with pragmatic impairment in TBI. As far as ToM is concerned, the findings indicate, on the whole, that ToM does play a role in communication, but also that this role tends to decrease or disappear when the contribution of EFs is controlled; the idea of a domain-specific contribution of ToM in predicting pragmatic deficits in individuals with TBI is thus not well supported.

On the whole, a clear picture of the relationship between comprehension and production of specific pragmatic phenomena (such as irony and deceit) and specific cognitive functions has not emerged. The experimental evidence is sometimes inconsistent, with some studies confirming a relationship between EF or ToM and pragmatic ability (Channon & Watts, 2003; Channon, Pellijeff & Rule, 2005; Douglas, 2010; Muller et al., 2010), while others do not (Bara, Tirassa, Zettin, 1997; Martin & McDonald, 2005), and some critical issues still remain (see Cummings, 2014, 2017).

The heterogeneity observed in the experimental results may be due to different reasons. Several pragmatic tasks were used in different studies. Pragmatic tasks can have very different requirements in terms of EF and ToM ability, making it difficult to compare results across studies. In this respect, it might be useful to assess pragmatic ability using a comprehensive assessment device that evaluates different aspects of communicative ability in the same patients, to establish the different ways in which pragmatic tasks could involve different cognitive functions. Moreover, as suggested by Martin & McDonald (2003), many studies used only comprehension or production tasks to assess pragmatic ability, and this could, in part, be the reason for such mixed experimental results. Considering the high level of heterogeneity that characterises communicative impairment profiles due to brain damage (see also chapter 1.3.2), it is important to evaluate both production and comprehension, because different tasks can involve different cognitive functions.

It is also crucial to consider not only the linguistic modality, but also the extralinguistic modality. Most of the studies presented above investigated pragmatic ability focusing only on linguistic means of expression, neglecting the importance of extralinguistic modalities. Previous studies have shown that the extralinguistic modality may be impaired in TBI, and that this impairment is associated with poor social functioning (Angeleri et al., 2008; Bornhofen & McDonald, 2008; Rousseaux, Vérigneaux, & Kozlowski, 2010); however, no previous studies have investigated in TBI the relationship between extralinguistic impairment and cognitive functions. The analysis of the relationship between cognitive functions and pragmatic impairment in non-verbal skills can help us to gain a better understanding of the cognitive mechanisms involved in communicative processes.

As a final point, very few studies have concurrently examined the relationship between ToM, EFs and pragmatics in individuals with TBI in an attempt to disentangle the unique contribution of ToM or EFs to their communicative-pragmatic performance. Among these studies, Honan et al. (2015) and McDonald et al. (2014) found a relationship between ToM and pragmatic ability; however, Honan et al. (2015) reported that the contribution of ToM was mediated by WM demands, and McDonald et al. (2014) found that the ToM contributed to explain pragmatic performance only in the experimental condition where executive demands were higher. On the contrary, Martin & McDonald (2005), did not find any association between ToM and pragmatic disorder. These studies show that it is crucial to evaluate all three of these functions together in order to establish the exact relationship between cognitive deficits and pragmatic impairment in TBI.

In the <u>second study</u> of this thesis, “Communicative-pragmatic disorders in traumatic brain injury: The role of ToM and EF**”,** we investigated the ability of patients with TBI to understand and produce linguistic and extralinguistic communicative-pragmatic tasks. This study examined the relationship between the ability to comprehend and produce different communicative phenomena - sincere (standard), deceitful and ironic communicative acts - and cognitive and ToM abilities in individuals with TBI, evaluated using the Assessment Battery of Communication (ABaCo), and a battery of EF and ToM tasks. I will detail the aim, experimental hypothesis, methods and results of this study in chapter 3.

In the third study of this thesis, we performed an fMRI study to investigate the neural correlates involved in the comprehension of sincere (standard) communicative acts, deceit and irony. Studying the cerebral areas activated during the on-line execution of a pragmatic task may enable us to shed light on which cerebral and cognitive systems have a key role in the comprehension of different kinds of communicative acts, such as sincere (standard) communicative acts, deceit and irony. The relevant literature on the neural correlates associated with the comprehension of communicative intention during communicative exchange will be presented in the next chapter.

1.5 Neuropragmatics: neural correlates underlying the comprehension of communicative intentions

Neuropragmatics is an interdisciplinary field of research with the primary aim of studying the neural underpinnings of pragmatic ability (Bara & Tirassa, 2000; Bambini; 2010; Bambini & Bara, 2012; Stemmer, 1999, 2008, 2017). Neuropragmatics adopts an approach focused on the study of the brain architecture that underlies the construction of meaning during communicative interaction. The term neuropragmatics was coined relatively recently (Bara & Tirassa, 2000; Stemmer & Schonle, 2000), but a systematic investigation of the neural underpinnings of communicative ability started in the 1970s, when clinical practitioners documented the presence of communicative impairments in individuals with brain damage that were not due to impairment of the cerebral structures involved in linguistic encoding. (e.g., semantic and syntactic processes; see Winner & Gardner, 1977; Wapner et al., 1981). More recently, neuroimaging techniques have allowed important progress to be made in identifying the neural mechanisms involved in pragmatic processing. In this chapter, I will focus on studies that have used functional magnetic resonance (fMRI) to investigate the neural correlates of pragmatic processing. With the fMRI technique it is possible to visualise the pattern of neural activation during real time execution of pragmatic tasks with a good spatial resolution, so it may provide valuable information about the involvement of different brain and cognitive networks in the recognition of communicative intention[9].

Recent neuroimaging studies have shown that the recognition of communicative intention during the comprehension of a speech act is a high-level process that recruits extended cerebral networks (e.g. Bara, Ciaramidaro, Walter, & Adenzato, 2011; Jang et al., 2013; Rapp, Mutschler, & Erb, 2012; Shibata, Toyomura, Itoh, & Abe, 2010; Spotorno, Koun, Prado, Van Der Henst, & Noveck, 2012; Uchiyama et al., 2012; Schnell et al., 2016). In a series of studies, Bara & colleagues (Ciaramidaro et al., 2007; Bara et al., 2011) identified the Intention Processing Network (IPN), an extended cerebral network that is recruited in the recognition of different intentions, and that overlaps with some of the areas generally associated with ToM. The authors found that within this network, some cerebral areas are dedicated to the recognition of communicative intention, as compared to recognition of individual intention (i.e. the intention of an actor to achieve a private goal, e.g., grasp an object) and prospective social intention (i.e. the intention to achieve a social goal by interacting with someone else, and with the social interaction postponed to the future (e.g., buy a birthday present for a friend)).

[9] In the field of experimental pragmatics, other neuroimaging or behavioural techniques, such as EEG or eye-tracking, have been used to investigate the neural and cognitive mechanisms involved in pragmatic processing (see for example Spotorno et al., 2013; Filik et al., 2014; Masia et al., 2017). These techniques have a good temporal resolution, that may allow to delineate precisely the time course of pragmatic processing; however, compared to fMRI, these techniques have a lower spatial resolution, and thus they do not allow to identify precisely (or as precisely as the fMRI allows) the cerebral areas, and the cognitive systems, involved in the recognition of communicative intentions during pragmatic tasks. For these reasons, in this work I decided to focus (and report) only on neuroimaging studies that investigated pragmatic comprehension and production using fMRI.

This network includes the temporo-parietal junction bilaterally, the precuneus and the prefrontal cortex (MPFC) and bilateral posterior temporal sulcus (pSTS). The whole network was activated only by the recognition of communicative intention; differently, the recognition of the private intention recruited only the right TPJ and the precuneusm, while the recognition of prospective social intention activated also the MPFC. The authors also found that individuals with schizophrenia or autism exhibited an atypical pattern of activation in the areas pertaining to the IPN during the recognition of communicative intention (Bara et al., 2011). Another important finding of these studies is that some cerebral areas pertaining to this network were activated by the recognition of communicative intention regardless of the communicative modality used, i.e. linguistic or extralinguistic (Enrici et al., 2011; Tettamanti et al., 2017): this in line with the assumption of the CPT (see Chapter 1.2.3) that communicative acts expressed through the linguistic or extralinguistic modality share similar cognitive and neural processes, and with the results of the studies that we will present in chapter 2 and chapter 3.

Basnakova et al. (2013) investigated the ability to identify the speaker’s meaning using a task in which participants had to listen to a dialogue between two individuals in two different conditions. In the *direct* condition, the second person provided a direct answer (the speaker’s meaning corresponded to the literal one) to the question uttered by the first; in the *indirect* condition, the second character replied to the first with an indirect reply (the speaker’s meaning did not correspond to the literal one and had to be derived *via* inferential processes). The results showed that the comprehension of the speaker’s communicative intention activated several brain regions including the MFC, the right TPJ, the anterior insula, right temporal regions and the bilateral prefrontal cortex. The comparisons between the *indirect* vs. *direct* conditions engaged the MFC extending into the right anterior part of the SMA, and the right TPJ.

Also Jang et al. (2013) investigated the neural processes involved in infererring indirect meaning during a conversational exchange. The task required participants to comprehend implicit answers (Question: "Is today a holiday?”, Answer: "The street is empty!", proffered to mean

“Yes”). The experimental design comprised three conditions: explicit answers, moderately implicit answers, and highly implicit answers. The resutls showed that several areas were associated to the comprehension of indirect answers, compared to direct ones, such as the left anterior temporal lobe, left angular gyrus, and left posterior middle temporal gyrus. The understanding of highly implicit answers recruited additional cerebral areas, corresponding to the left inferior frontal gyrus, left medial prefrontal cortex, left posterior cingulate cortex and right anterior temporal lobe.

To sum up, neuroimaging data have shown that the neural processes involved in recognising and producing communicative intentions only partially overlap with the cerebral areas involved in linguistic decoding (syntactic and semantic) (Willems & Varley, 2010), also extending to non-linguistic areas in the frontal and parietal cortex. The study of the neural activations during the execution of pragmatic tasks could provide important information about the involvement of cognitive functions, such as ToM and EFs, in the comprehension of different communicative acts, such as irony and deceit.

1.5.1 Neuroimaging studies on Irony and deceit

In the last decades, an increasing number of studies have explored the neural basis of irony and deceit comprehension. As reported in chapter 1.4, some authors have proposed that ToM and EFs may play an important role in the comprehension of ironic and deceitful communicative acts. Neuroimaging studies on irony and deceit have investigated how cognitive systems interact in order to derive the speaker’s communicative intention during pragmatic tasks, in an attempt to unveil the cognitive functions underlying pragmatic ability.

Eviatar & Just (2006) measured neural activation using fMRI on 16 healthy participants during a story comprehension task that ended with one of the protagonists uttering a literal, metaphoric, or ironic sentence. The comprehension of metaphorical utterance, compared to both the literal and ironic ones, activated the left inferior frontal gyrus and bilateral inferior temporal cortex, while irony (compared to literal statement) activated the right superior and middle temporal Gyri.

Uchiyama et al. (2006) evaluated neural underpinnings of sarcasm recogniton using a scenario-reading tasks, that described a social situtation followed by a sarcastic (or literal) comments uttered by one of the protagonists. The authors found prominent activation in the inferior frontal gyrus (IFG), in the middle temporal gyrus (MTG) and in the medial prefrontal cortex (mPFC) during sarcasm recognition. The authors interpreted activation in the mPFC as being related to ToM, and activation in the inferior frontal regions and MTG as being related to activity in the semantic-executive system engaged in semantic retrieval, selection and evaluation during sentence comprehension. Shibata et al. (2010) also observed activations in the mPFC and MTG/superior temporal sulcus (STS) during irony comprehension tasks, confirming the role of these regions in high-order linguistic processing. Spotorno et al. (2012) found irony recognition to be associated with activity in several areas pertaining to the mentalizing network (Frith & Frith, 2006; Mar, 2011), i.e. MPFC, temporal-parietal junction (TPJ) and the precuneus. The authors also found that irony activated the IFG, MTG and dorsolateral prefrontal cortex (DLPFC), which they suggested was related to the high executive demands and integrative processes involved in the comprehension of complex forms of language. As a whole, these studies have shown that understanding irony is a demanding process involving a cerebral network that includes several fronto-temporal and fronto-parietal areas, as confirmed by recent meta-analyses (Bohrn, Altmann, & Jacobs, 2012; Rapp et al., 2012).

Recenlty, Rapp et al. (2012) performed a coordinate-based activation-likelihood estimation meta-analysis of fMRI studies that investigated non-literal forms of language (metaphors, metonymy, idioms, proverbs, and ironic expressions). The results showed as the comprehension of non-literal forms of language activated a network prevalently localized in the left hemisphere, with activation foci in the left and right inferior frontal gyrus; the left, middle, and superior temporal gyrus; and medial prefrontal, superior frontal, cerebellar, parahippocampal, precentral, and inferior parietal regions. However, the authors did not perform any specific contrast to compare activations of ironic vs. literal, or ironic vs. metaphoric, communicative acts, thus it was not possible to identify any neural areas specifically associated with irony comprehension. In the same year, Bohrn et al. (2012) performed a similar meta-analysis of fMRI studies that investigated figurative and non-literal language processing. The processing of figurative language (compared to literal one) activated the left and right IFG, the left temporal lobe, the bilateral medial frontal gyri (medFG) and an area close to the left amygdala. The authors also performed a sub-analysis of studies that investigated only neural activations of irony (compared to literal statements); this analysis revealed activations related to irony comprehension in the MPFC, the anterior cingulate cortex/medial frontal gyrus region and the right anterior STG. However, only four studies on irony were included in this meta-analysis compared to the six studies of Rapp et al. (2012), due to different (and more restrictive) inclusion criteria.

The majority of studies investigating the neural basis underlying the recognition of verbal deceit have focused on moral reasoning (Wu, Loke, Xu, & Lee, 2011; Harada et al., 2009). Deceit recognition may also involve deontic reasoning, i.e. an evaluation of the transgression of social rules and their consequences (e.g. Spence et al., 2004), since deceit violates the social norm of conversation that requires the speaker to make a truthful contribution (Grice, 1991). Wu et al. (2011) for example found that moral judgments about lying activated a cerebral network comprising the right lingual gyrus (LG), the postcentral gyrus (PoCG), the precuneus and the bilateral IPL. The authors also observed that the detection of bad lying (i.e. lying to conceal one's wrongdoing) compared to good lying (i.e. lying about one's own good action) activated the left superior frontal gyrus (SFG), the left IPL and bilateral cuneus. To our knowledge, only one study has examined neural activation during the recognition of the intention to deceive using a verbal story comprehension task. Harada et al. (2009) evaluated neural activation with fMRI using a task in which participants had to decide whether or not the protagonist of a story uttered a speech act with the intention to deceive, or whether or not the protagonist's behavior was morally bad. Detection of the intention to deceive, as compared to the control task, activated the bilateral TPJ, IPL, the right MTG, and DFLPFC. The authors interpreted TPJ activation as being related to ToM processes in deceit recognition, while DLPFC activation was related to the executive demands set by the task. The authors also found that the IFG and the rmPFC were activated by both the moral judgment and the intention recognition tasks, while they did not observe any specific areas of activation during the moral judgment task only.

Irony and deceit present some common features, given that both speech acts involve a contrast between what a speaker affirms and his private knowledge (Bosco & Bucciarelli, 2008). In line with CPT, and as shown by Winner et al. (1998), and Bosco & Bucciarelli (2008) and Bara (2010), the comprehension of both kinds of pragmatic phenomena requires an understanding of the knowledge shared between the interlocutors. Winner & colleagues (1998) reported that the ability to distinguish between lies and irony may be associated with ToM ability, in particular the ability to attribute second-order mental states, i.e. to recognize one person's mental state about another person's mental state. However, deceit and irony also have some differences. A speaker utters a deceitful speech act with the intention that the listener will not recognize the conflict between what she said and her private knowledge; on the other hand, a speaker making an ironical utterance produces this contrast on purpose and expects the listener to recognize it to derive the ironic meaning (Bucciarelli, Colle, & Bara, 2003; Bosco & Bucciarelli, 2008; Bara, 2010). Several studies have pointed out that different populations of subjects, such as typically and atypically developed children, perform less well on comprehension and production of irony than on deceit tasks (Bosco et al., 2013; Winner et al., 1998; Peskin, 1996), and that adults with psychiatric disorders (Colle et al., 2013) and with brain lesions (Angeleri et al., 2008; Gabbatore t al., 2014) perform less well in the comprehension and production of ironic utterances than deceitful speech acts (Shany–Ur et al., 2012; McDonald et al., 2014; Angeleri et al., 2008; Gabbatore et al., 2014; Parola et al., 2016). Recently, neuroimaging studies have shown that several fronto-temporal and temporo-parietal areas in both hemispheres are recruited in the recognition of both ironic (Eviatar & Just, 2006; Wakusawa et al., 2007; Shibata et al., 2010; Spotorno et al., 2012; Rapp et al., 2012; Bohrn et al., 2012; Uchiyama et al., 2012; Akimoto et al., 2014) and deceitful speech acts (Harada et al., 2009). However, to the best of our knowledge no authors have to date directly compared the neural activation associated with the recognition of the communicative intention underlying deceitful and ironic speech acts.

1.5.2 Summary

Neuroimaging studies have shown that the comprehension of communicative intentions activates a cerebral network that extends well beyond the cerebral areas involved in the core linguistic processes localised in the left hemisphere. The comprehension and production of communicative intentions activated an extended fronto-temporo–parietal network, with some of key areas localized in the middle prefrontal cortex (mPFC), in the inferior frontal gyrus (IFG), in the middle temporal gyrus (MTG), and in the superior temporal gyrus (STG) (Tettamanti et al., 2017; Jang et al., 2013; Rapp et al., 2012; Bohrn et al., 2012; Spotorno et al. ,2012; Shibata et al., 2010; Uchiyama et al., 2006). These studies have shown that pragmatic comprehension recruits cerebral areas located in both the right and left hemispheres, and that different cognitive systems are recruited during the recognition of a communicative act.

As regards irony comprehension, neuroimaging studies have revealed the recruitment of cerebral areas related to cognitive systems that have generally been associated with pragmatic comprehension, such as EF and ToM, as well as specific areas related to linguistic and inferential processes (e.g. Harada et al., 2010; Spotorno et al., 2012; Uchiyama et al., 2012; Jang et al, 2013). However, these studies have also shown that activation of different brain areas may be modulated by task characteristics and by the specific linguistic features of the experimental materials used to evaluate pragmatic ability. These could be responsible for the variability in the experimental results. In particular, the role of ToM in irony comprehension has yet to be clarified. Most of the studies reported activation of the MPFC, an area activated by the ToM network; however, only a few revealed the involvement of other areas pertaining to the ToM network, such as the precuneus and TPJ, in irony recognition (see Spotorno et al., 2012). In addition, only one study (Harada et al. 2009) investigated deceit comprehension adopting a pragmatic standpoint, while none of them directly compared neural activation during the recognition of deceitful and ironic communicative intentions.

In the third study of this thesis, “Neural correlates underlying the comprehension of deceitful and ironic communicative acts”, we used fMRI to investigate the existence of common and specific neural circuits underlying the comprehension of the same speech act, uttered with different communicative intentions, i.e. of being sincere, deceitful or ironic. I will describe the aim, the experimental hypothesis, methods and results of this study in chapter 4.

2. Assessment of pragmatic impairment in Right Hemisphere Damage[10]

2.1 The present study

The main aim of the present study was to provide a multifocal assessment of pragmatic abilities in patients with right hemisphere damage (RHD), and to evaluate what cognitive processes may be responsible for pragmatic impairment following RHD. We used the ABaCo to evaluate the pragmatic comprehension and production of different communicative acts, i.e., sincere (standard) communicative acts, deceit and irony, expressed through linguistic and extralinguistic modalities (i.e., gestures and facial expressions). Moreover, we evaluated patients' ability to comprehend and produce paralinguistic elements of communication (tone, intonation, rhythm and prosody). The novelty of the present study is that we evaluated both the comprehension and production of communicative phenomena of increasing inferential complexity in the linguistic and extralinguistic modality (i.e gestural one). To our knowledge, only one study evaluated and compared comprehension of different communicative acts expressed through linguistic and gestural modalities in RHD (Cutica et al., 2006); however, no studies evaluated in RHD both the comprehension and the production of different kinds of communicative phenomena (i.e., sincere (standard) communicative acts, deceit and irony) using both verbal, i.e. linguistic, and non-verbal, i.e. gestural, modalities. In line with the assumption of CPT (see chapter 1.2.3) we hypothesised that:

1) Individuals with RHD, compared to controls, would only be impaired in the comprehension and production of non-standard versus standard communicative acts. Indeed,

[10] Part of the text and the data of this chapter were published as: "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"

RHD is generally associated with impairment in comprehension and production of the more subtle aspects of language, which require a higher inferential load.

2) A deficit in inferential ability, frequently reported after RHD, could be one of the cognitive factors responsible for patients' difficulties in dealing with the pragmatic tasks of the ABaCo.

3) Individuals with RHD would be more impaired in extralinguistic versus linguistic ability, due to the specialisation of the RH in extralinguistic competence.

The secondary aim of the present study was to examine the presence of a sub-cluster of performance in the group of RHD individuals. We expected patients with RHD to show different patterns of impairment in communicative performance, confirming the heterogeneity of communicative profiles following RHD. As reported in chapter 1.3.2, some theoretical and methodological issues affect the the assessment procedure in RHD. In addition, heterogeneity represents a critical problem for clinicians working with RHD patients, as it makes it fairly difficult to characterize the disorder and define the neurological condition. Deficits can be subtle (e.g only evident in dealing with complex phenomena such as irony) or limited to certain expressive modalitiy (linguistic, extralinguistic or paralinguistic) making it difficult to ascertain the presence of impairment. Considering the variability of impairment after RHD, it is important to evaluate comprehension and production of a wide range of communicative phenomena of different complexity, presented in different modalities. To overcome some of these limitations, we used the ABaCo to evaluate the pragmatic comprehension and production of different communicative acts (sincere (standard) communicative acts, deceit and irony; basic speech acts, basic emotions, paralinguistic contradiction, see chapter 2.2.2.1) expressed through linguistic, extralinguistic (i.e., gestures and facial expressions), and paralinguistic (i.e. prosodic) modalities.

The heterogeneity in the profiles of communicative disorders following RHD may limit the generalisability of experimental results. However, it is possible to address the factors that may be responsible for this heterogeneity. In the present study, we wanted to verify whether the ABaCo would be sensitive enough to detect the variability that characterises communicative deficits following RHD, making it possible to identify different patterns of communicative impairment; we also wanted to test whether the CPT would allow us to identify the cognitive factors underlying these different profiles of communicative deficits (see also chapter 1.2.3).

2.2 Material and Methods

2.2.1 Participants

Seventeen patients (10 males, 7 females) with unilateral right hemisphere damage due to a single vascular accident (ischemic or haemorrhagic) participated in the study (lesion site and demographic data are reported in Table 1). Their age ranged from 43 to 72 years (M = 60.0; SD = 8.68), their years of education ranged from 5 to 18 years (M = 11.58; SD = 4.44). See Table 1 for a detailed description of the sample. Participants with brain lesion were recruited at rehabilitation centres in Turin and Milan. The study was approved by the local ethics committee, University of Turin.

We recruited post-stroke patients, with an onset time ranging from one to five months (M = 2.47; SD = 1.45) in order to provide a detailed characterization of their communicative profiles immediately after being admitted to the rehabilitation centre[11].

The inclusion criteria for participation in the study were: (1) at least 18 years of age, (2) native Italian speakers, and (3) right-handedness (minimum of 90% on the Edinburgh Handedness Inventory; Oldfield, 1971). Moreover, neuropsychological tests were administered in order to

[11] According to the local system, patients are usually transferred from the hospital to a specialized functional rehabilitative centre when they get out of the acute phase and they arrive at stable clinical conditions. Patients are, then, included in specific rehabilitative programmes according to their needs and the identification of the most impaired abilities. It is therefore important to provide an early overview of pragmatic competence at the time of the entrance of patients into rehabilitative units (nearly one month post-onset) in order to plan an effective rehabilitation programme.

exclude those patients for whom basic cognitive or linguistic impairments prevented them from correctly understanding the video material presented during the tasks. Thus, we adopted as an inclusion criterion: (4) the achievement of a cut-off score in the following neuropsychological tests:

1. Mini Mental State Examination (MMSE, Folstein et al., 1975); cut-off score ≥ 24/30. MMSE was administered to get a general overview of the cognitive profile of each patient. The cut-off score was set so to exclude severe cognitive impairments.

2. Token Test (De Renzi & Vignolo, 1962, Spinnler & Tognoni, 1987); cut-off score ≥ 29/36. The Token Test was administered to ensure that patients were able to comprehend simple linguistic commands and instructions, excluding the presence of aphasic symptoms. Our aim was to evaluate pragmatic ability, and so we needed to rule out the possibility that basic linguistic impairments (i.e., phonological, morphological and syntactical) were responsible for the observed pragmatic deficits.

3. Ideomotor Apraxia Test (Spinnler & Tognoni, 1987); cut-off score ≥ 19/20. The Ideomotor Apraxia Test was used to ensure patients were able to correctly produce symbolic gestures, converting the "idea" of a gesture into a correct execution. Indeed, we did not evaluate the ability to produce gestures at all but rather the pragmatic ability to produce the correct gesture on the basis of contextual information provided by the pragmatic task.

4. The Simple Test of Visual Neglect (Albert, 1973); cut-off score > 34/36. The Simple Test of Visual Neglect was used to exclude the presence of visual neglect, ensuring that patients were able to properly watch the video material that made up the pragmatic tasks.

The cut-off figures represent the normal limit of performance based on the Italian standardization of the tests (Spinnler & Tognoni, 1987). All the participants scored within normal limits.

Exclusion criteria were: (1) presence of significant cortical atrophy, (2) presence of a concomitant diagnosis of dementia or psychiatric disorder, (3) a prior history of neurological or psychiatric disorders and (4) a prior history of drug or alcohol addiction. All patients were informed about the aims and the procedures of the study and they provided their informed consent to participate in the research.

A control group of seventeen healthy controls was recruited, comparable with the clinical group in terms of age (*T-Test*; t = .66; p = .93) and years of education (t = .54; p = .58).

Table 1. Demographic and neurological details of RHD patients

Subject	Sex	Age	Education	Time post-onset (months)	Brain lesion	Cluster
RHD1	F	49	13	3	Fronto-temporal	2-LEI
RHD2	M	61	5	1.5	Parietal	3-PLEI
RHD3	F	65	8	4	Temporal	2-LEI
RHD4	F	59	5	1	Temporal	3-PLEI
RHD5	M	49	13	1.5	Fronto-temporal	1-PI
RHD6	M	71	8	1	Fronto-parietal	2-LEI
RHD7	M	43	13	2	Temporal	1-PI
RHD8	F	52	13	1	Temporal	1-PI
RHD9	F	72	8	1	Parietal	2-LEI
RHD10	M	66	13	2	Parietal	1-PI
RHD11	M	55	13	1	Temporal	1-PI
RHD12	F	71	5	4	Fronto-temporal	1-PI
RHD13	M	69	18	2	Temporal-parietal	1-PI
RHD14	M	59	18	5	Fronto-parietal	2-LEI
RHD15	M	62	11	5	Fronto-parietal	2-LEI
RHD16	F	62	15	3	Occipito-temporal	1-PI
RHD17	M	53	18	4	Fronto-temporo-parietal	2-LEI

Note. 1-PI: Paralinguistic impaired; 2-LEI: Linguistic and Extralinguistic impaired; 3-PLEI: Paralinguistic, Linguistic and Extralinguistic impaired.

2.2.2 Materials and Procedures

2.2.2.1 Assessment Battery for Communication

All participants were administered the Linguistic, Extralinguistic and Paralinguistic scales of the Assessment Battery of Communication (ABaCo; Angeleri et al., 2015; Sacco et al., 2008). The tasks consisted of a series of videos, each lasting 20-25 seconds; all the tasks comprised a controlled number of words (range: 7 ± 2) and they were characterized by the same lexical and syntactical complexity. In each task, the actors were to play out a communicative exchange using, respectively, language (the linguistic scale), gestures and facial expressions (the extralinguistic scale) or prosody only (the paralinguistic scale). At the end of every scene, the examiner would investigate the correct comprehension of the protagonist's conclusive communicative act or else elicit the production of a communicative act in response to the protagonist's sentence or gesture. The linguistic and extralinguistic scales in the ABaCo assess the comprehension and production of pragmatic phenomena of differing complexity according to the different knowledge of the speaker and the listener and the inferential complexity underlying every phenomenon: *sincere (standard) communicative acts, deceit and irony*, expressed verbally on the linguistic scale and through gestures and facial expressions on the extralinguistic scale.

In the comprehension tasks, the subjects were shown short videos where two actors are engaged in a communicative interaction: the actor asks his partner a question and the partner replies. The subject has to understand the communicative act he has just observed.

In the production tasks, subjects are shown short videos where two actors are engaged in a communicative interaction: the actor says something to the partner, the video stops and the subject is requested to assume the partner's perspective in answering the actor.

In both the comprehension and the production tasks, on the linguistic scale the actors communicate verbally, whereas on the extralinguistic scale they communicate through gestures and facial expressions, without language-support. In the production tasks belonging to the extralinguistic scale, the actor performs communicative gestures and the subject has to reply using gestures alone. Examples of the items are provided in Table 2.

Table 2.
Examples of tasks in the comprehension and production of the linguistic and extralinguistic scales of the ABaCo.

Comprehension task **Deceit, extralinguistic scale**	**Production task** **Irony, linguistic scale**
Nadia and Sergio are arguing - having a pillow fight - in their bedroom. In all the confusion, Nadia hits the lamp on the bedside table, and it falls onto the floor. Having heard the noise, their father comes to their room, puts his hands on his hips and, with a questioning air, at the same time assuming a cross expression as if to say "What's going on?" he points with his finger to the lamp on the floor. Nadia immediately picks up a book and shows it to her father, as if to say "I was reading". The subject is then asked: - *What did the boy want to say to the girl?* - *Was he speaking seriously?* - *Why did the boy answer the girl with that gesture?*	*Fabio and Claudia are having their breakfast. Fabio is enchanted in front of the TV and he doesn't realize he has involuntarily placed his elbow on the jam. Claudia is amused and looks at him smiling. Fabio, still looking at the TV screen, asks: "Could you please pass me the jam?"* The subject is then asked: - *What could Claudia answer, in order to be ironic?* - If the answer is not clear: *What does it mean?*

The Paralinguistic scale investigates the comprehension and production of prosodic elements using different communicative phenomena:

(1) *Basic speech acts* (questions, statements, requests or commands): the examiner shows the subjects a video in which an actor, speaking an invented language, makes a statement, asks a question, makes a request or gives a command. According to Kasher (1991), basic speech acts are the simplest form of utterance. In the present investigation, the subject has to comprehend the type of act conveyed by the paralinguistic components only. To measure production abilities, the examiner asks the subjects to produce questions, statements, requests or commands using exclusively the adequate paralinguistic indicators.

(2) *Basic emotions* (anger, happiness, fear and sadness): the examiner evaluates comprehension by showing the subjects short videos in which an actor, speaking an invented language, conveys one of the basic emotions. The subject has to recognize the correct emotion using paralinguistic

indicators only. The examiner investigates production by asking the subjects to pronounce a sentence conveying a specific emotional tone.

(3) *Paralinguistic contradiction*: the examiner evaluates comprehension by showing the subjects short videos in which an actor verbally communicates a message that is in overt contradiction with the paralinguistic indicators. The subject has to recognize this discrepancy. Examples of items of the paralinguistic scale are provided in Table 3.

All the participants performed the ABaCo individually in a quiet room; the entire administration lasted approximately one hour and 30 minutes. Their performance was video-recorded and transcribed by the examiner. For a detailed explanation of the organization and administration of the ABaCo, see Sacco et al., (2008), Angeleri et al., (2012) and Bosco et al. (2012a).

Table 3.
Examples of tasks in comprehension and production of the paralinguistic scale of the ABaCo.

	Comprehension	**Production**
Basic speech acts	The actor asks a question. The subject is asked to choose among the following options: *1. Ask a question (Target)* *2. Give an order* *3. Say something he thought* *4. Make a request*	Request *Ask me to give you the pen.* Order *Order me to give you the pen.*
Basic emotions	The actor laughs while he speaks. The subject is asked to choose among the following options: *1. Amused (Target)* *2. Surprise (Liable to be confused)* *3. Angry (Opposite)* *4. Disgusted*	*Ask me what time it is.* Ask me as if you were bored.
Paralinguistic contradiction	It's Robert's birthday. Monica gives him a gift. Monica: "Happy Birthday!" Robert opens the package and finds a tie with terrible colours. With a bored face and voice, he says: "Thanks. Really, I really needed it… beautiful!" Test question*: In your opinion, what did the boy want to say to the girl?* If the participant repeats the actor's reply: *What does it mean?* In-depth question: *In your opinion, did the boy like the tie? Why?*	--

2.2.2.2 Scoring procedure

Data were coded by an independent judge, blind to the composition of the experimental groups and to the experimental hypothesis. He was trained in the coding procedure reported in the ABaCo instruction manual, and coded the data individually watching the video recordings. Possible scores for each task were 0 or 1: A score of 1 was awarded for correct answers, and a score of 0 for incorrect answers. The reliability of the ABaCo has already been measured in several studies which have shown it to have high inter-rater agreement and suggested that it can be administered and scored by any trained judge (Sacco et al., 2008).

2.3 Results

In order to have a general overview of the results, we compared performance obtained by patients and healthy controls in each scale using a series of *T-test* (the scores are summarized in Table 4). Taken as a whole, patients performed worse than healthy participants on all of the scales investigated, i.e. linguistic, extralinguistic and paralinguistic tasks, in both comprehension and production (*T test*: $2.48 < t < 3.64$; $.001 < p < .03$). The results for each single scale are reported in the next section. We set the threshold of significance to $p < .05$. For multiple comparison we adopted Bonferroni correction, which provided the corrected threshold of significance.

Table 4.
Mean and standard deviation of Linguistic, Extralinguistic and Paralinguistic Scales in both comprehension and production

	Comprehension			
	Patients	Controls	t	p
Linguistic scale	.79 (.14)	.92 (.12)	2.89	.007
Extralinguistic scale	.65 (.16)	.84 (.19)	3.08	.004
Paralinguistic scale	.76 (.09)	.84 (.07)	2.92	.006
	Production			
	Patients	Controls	t	p
Linguistic scale	.83 (.10)	.92 (.11)	2.36	.025
Extralinguistic scale	.67 (.23)	.90 (.12)	3.71	.001
Paralinguistic scale	.89 (.10)	.97 (.06)	2.91	.007

2.3.1 Linguistic scale

To analyse subjects' performance on the Linguistic scale we conducted a repeated measures ANOVA, with one between-subjects factor (type of subject, with two levels: patients and controls) and one within-subjects factor (type of task, with three levels: sincere (standard) communication acts, deceit and irony). The same analyses were conducted for both comprehension and production tasks. We then introduced a linear contrast for each scale in order to verify the presence of a linear trend into the data (i.e., that the mean performance of individuals decreased or increased in a linear way). The scores obtained by patients in the different pragmatic phenomena are reported in Table 5.

Table 5.
Linguistic scale: mean and standard deviation of the scores obtained for sincere (standard) communication acts, deceit and irony in both comprehension and production.

	Comprehension			
	Patients	Controls	t	p
Sincere communication acts	.95 (.08)	.96 (.12)	.40	.69
Deceit	.76 (.30)	.90 (.13)	1.85	.074
Irony	.66 (.21)	.88 (.27)	2.72	.011
	Production			
	Patients	Controls	t	p
Sincere communication acts	.95 (.11)	.99 (.04)	1.19	.244
Deceit	.82 (.25)	.94 (.14)	1.71	.097
Irony	.71 (.29)	.82 (.29)	1.14	.265

In comprehension, the results revealed a main effect of the type of subject ($F_{(1,32)}$ = 8.34; p = .007; η^2 = .20): patients performed worse than control subjects. Moreover, there was a main effect of the type of task ($F_{(2,64)}$ = 8.10; p = .001; η^2 = .20). We introduced a linear contrast and observed the presence of a linear decrease in scores due to the complexity of the communicative act analysed ($F_{(1,32)}$ = 9.48 ; p = .004; η^2 = .229): sincere (standard) communication acts were the easiest to understand, followed by deceit and irony (Figure 1). We then analysed the differences in performance between patients and controls for each individual communicative phenomenon. Pairwise comparisons revealed that the patients and the controls did not differ in their comprehension of sincere (standard) communicative acts (p = .69), while the differences in performance tended to increase in terms of the comprehension of deceit (although not statistically significant) (p = .074) and irony (p = .011) (see also Table 5). In order to verify whether the effect of the type of task was significant both in patients and controls, we performed an ANOVA for each sub-sample. The results showed that effect of the type of task is observable only in the patients ($F_{(2,32)}$ = 8.40; p = .001; η^2 = .345), while in the controls it is not significant ($F_{(2,32)}$ = .91; p = .410; η^2 = .054). The difficulty of the patients in this task seems to be mainly due to their performance of irony comprehension; conversely, the controls did not find irony more difficult to comprehend than sincere (standard) communicative acts or deceit.

As regards production abilities, the results revealed a main effect of the type of subject ($F_{(1,32)}$ = 5.55; p = .025; η^2 = .14): patients performed worse than control subjects. Moreover, there was a main effect of the type of task ($F_{(2,64)}$ = 7.41; p = .003; η^2 = .18). We introduced a linear contrast and observed the presence of a linear decrease in scores due to the complexity of the communicative act analysed ($F_{(1,32)}$ = 14.27; p < .001; η^2 = .30): sincere (standard) communication acts were the easiest to produce, followed by deceit and irony (Figure 2). We then analysed the difference in performance between the patients and the controls for each communicative phenomenon. Pairwise comparison revealed that no statistically significant difference was detectable for the communicative phenomena investigated (.24 > p > .097) (Table 3). To control whether the effect of the type of task was significant both in the patients and the controls, we performed an ANOVA for each sub-sample. The results showed that the effect of the type of task was observable both in the patients ($F_{(2,32)}$ = 4.03; p = .027; η^2 = .201) and in the controls ($F_{(2,32)}$ = .3.64; p = .037; η^2 = 186).

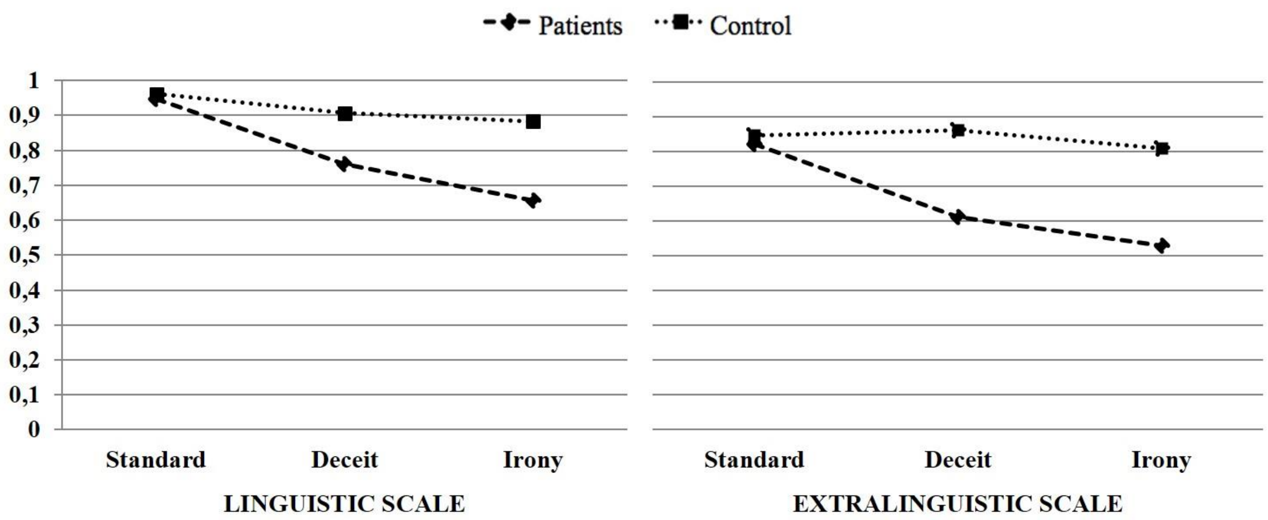


Figure 1. Performance by patients and controls in linguistic and extralinguistic tasks in the comprehension of standard communication acts, deceit and irony

2.3.2 Extralinguistic scale

Group differences on the extralinguistic scale were examined using a repeated measures ANOVA, with one between-subjects factor (type of subject, with two levels: patients and controls) and one within-subjects factor (type of task, with three levels: sincere (standard) communication acts, deceit and irony). The same analyses were conducted for both comprehension and production tasks. The scores obtained by patients in the different pragmatic phenomena are reported in Table 6.

In comprehension, the results revealed a main effect of the type of subject ($F_{(1,32)} = 9.48$; $p = .004$; $\eta^2 = .22$): patients performed worse than control subjects. There was also a main effect of the type of task ($F_{(2,64)} = 4.60$; $p =.014$; $\eta^2 = .12$). We introduced a linear contrast and observed the presence of a linear decrease due to the complexity of the communicative act analysed ($F_{(1,32)} = 7.64$; $p = .009$; $\eta^2 = .193$): sincere (standard) communication acts were the easiest to understand, followed by deceit and irony (Figure 1).

We then analysed the difference in performance between the patients and the controls for each individual communicative phenomenon. A pairwise comparison showed that the patients found deceit and irony more difficult to comprehend than the controls ($.012 > p > .005$), whereas no significant difference was observed in the comprehension of sincere (standard) communicative acts ($p = .72$) (Table 4). In order to verify whether the effect of the type of task was significant in both the patients and the controls, we performed an ANOVA for each sub-sample. The results showed that the effect of the type of task was present only in the patients ($F_{(2,32)} = 6.03$; $p = .006$; $\eta^2 = .274$), while it was not significant in the controls ($F_{(2,32)} = .35$; $p = .708$; $\eta^2 = .021$). The patients' difficulty in this scale seems to be due to their performance in relation to non-standard communication acts (i.e., deceit and irony); conversely, the controls did not find non-standard communicative acts more difficult to comprehend than sincere (standard) communicative acts.

As regards production, the results revealed a main effect of the type of subject ($F_{(1,31)} = 17.22$; $p < .0001$; $\eta^2 = .46$): patients performed worse than control subjects. There was also a main effect of the type of task ($F_{(2,64)} = 27.37$; $p < .0001$; $\eta^2 = .46$). We introduced a linear contrast that revealed the presence of a linear decrease in scores due to the complexity of the communicative act analysed ($F_{(1,31)} = 50.77$; $p < .0001$; $\eta^2 = .62$): sincere (standard) communication acts were the easiest to produce, followed by deceit and irony (Figure 2). We then analysed the differences in performance between the patients and the controls for each individual communicative phenomenon. A pairwise comparison revealed that the patients produced deceit and irony significantly worse than the controls ($.002 > p > .001$), while no significant difference was observed in the production of sincere (standard) communicative acts ($p = .117$) (Table 4). The effect of the type of task was present both in the patients ($F_{(2,32)} = 22.12$; $p < .001$; $\eta^2 = .596$) and in the controls ($F_{(2,32)} = 6.35$; $p = .005$; $\eta^2 = .286$).

Table 6.
Extralinguistic scale: mean and standard deviation of standard communication acts (direct and indirect), deceit and irony in both comprehension and production

	Comprehension			
	Patients	Controls	t	p
Sincere communication acts	.82 (.20)	.85 (.22)	.62	.720
Deceit	.61 (.32)	.86 (.22)	2.65	.012
Irony	.53 (.26)	.81 (.29)	3.00	.005
	Production			
	Patients	Controls	t	p
Sincere communication acts	.89 (.22)	.99 (.06)	1.61	.117
Deceit	.70 (.27)	.96 (.13)	3.46	.002
Irony	.36 (.35)	.76 (.31)	3.50	.001

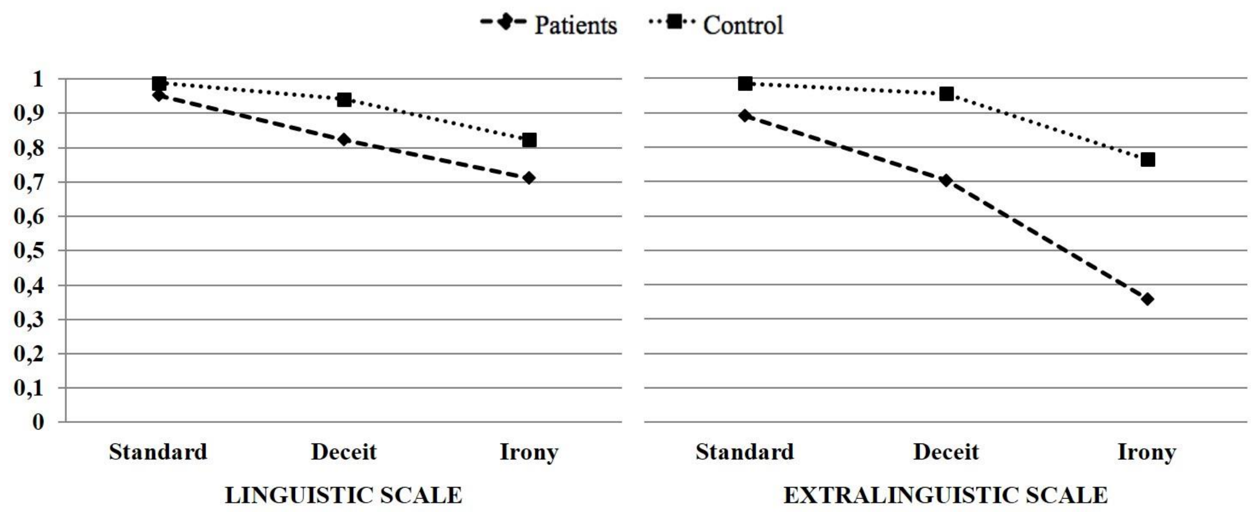


Figure 2. Performance by patients and controls in linguistic and extralinguistic tasks in the production of standard communication acts, deceit and irony

2.3.3 Paralinguistic scale

We investigated subjects' performance on the paralinguistic scale in both comprehension and production. The scores obtained by patients in the different pragmatic phenomena are reported in Table 7.

To analyse comprehension abilities, we conducted a repeated measures ANOVA, with one between-subjects factor (type of subject, with two levels: patients and controls) and one within-subjects factor (type of task, with three levels: basic communication acts, basic emotion, paralinguistic contradiction). The results revealed a main effect of the type of subject ($F_{(1,32)} = 8.54$; $p = .006$; $\eta^2 = .21$): patients performed worse than control subjects. There was also a main effect of the type of task ($F_{(2,64)} = 19.23$; $p < .0001$; $\eta^2 = .37$). We introduced a linear contrast that revealed the presence of a linear decrease ($F_{(1,32)} = 26.5$; $p < .001$; $\eta^2 = .45$): paralinguistic contradictions were the easiest to understand, followed by basic emotions and basic communication acts (Figure 3). We then analysed the differences in performance between the patients and the controls for each individual communicative phenomenon: the results revealed that the patients performed worse than the controls in relation to paralinguistic contradictions ($p < .046$), while no significant differences were observable in terms of basic emotions and basic communication acts ($.10 < p < .35$).

Similar analyses were conducted for production abilities, using a repeated measures ANOVA, with one between-subjects factor (type of subject, with two levels: patients and controls) and one within-subjects factor (type of task, with two levels: basic communication acts and basic emotion). The results revealed a main effect of the type of subject ($F_{(1,32)} = 8.46$; $p = .007$; $\eta^2 = .20$): patients performed worse than control subjects. There was also a main effect of the type of tasks ($F_{(2,32)} = 25.96$; $p < .0001$; $\eta^2 = .44$): basic communication acts are easier to produce than basic emotions (Figure 3). We investigated the differences in performance between the patients and the controls for each individual communicative phenomenon: the results revealed that the patients performed worse than the controls in terms of basic emotion ($p = .002$), while no significant differences were observable for basic communication acts ($p = .32$).

Table 7.
Paralinguistic scale: mean and standard deviation of the obtained scores, in both comprehension and production

	Comprehension			
	Patients	Controls	t	p
Basic communication acts	.63 (.20)	.69 (.15)	.94	.353
Basic emotion	.81 (.14)	.89 (.14)	1.69	.101
Paralinguistic contradiction	.84 (.20)	.96 (.10)	2.07	.046
	Production			
	Patients	Controls	t	p
Basic communication acts	.96 (.06)	.98 (.07)	1.01	.321
Basic emotion	.82 (.14)	.96 (.06)	3.59	.002

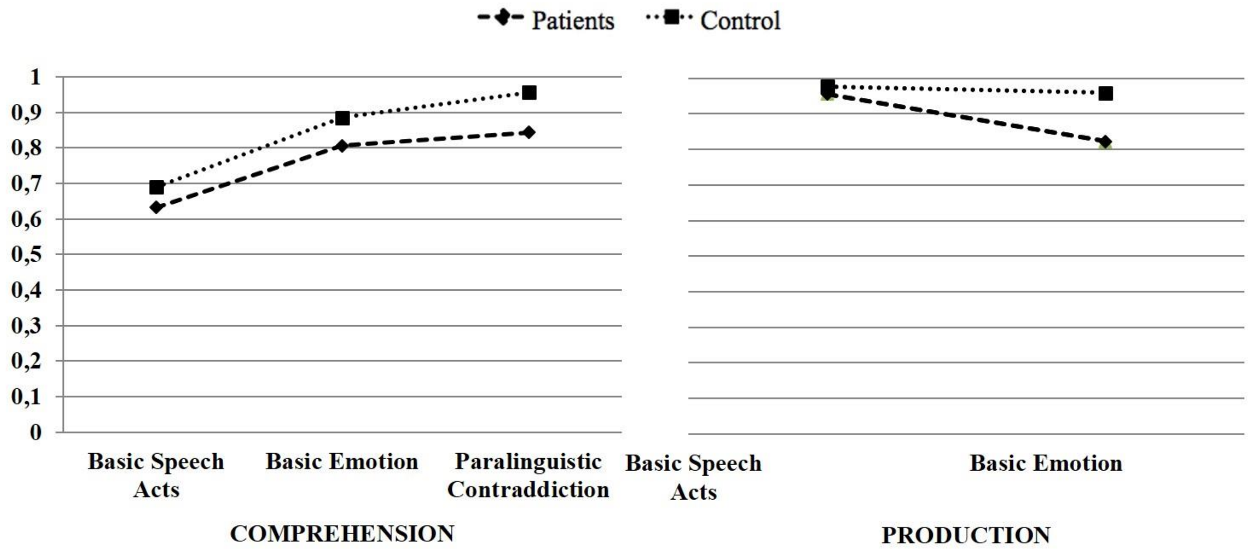


Figure 3. Performance by patients and controls in paralinguistic tasks, both in comprehension and production

2.3.4 Comparison between linguistic and extralinguistic tasks

To compare participants' performance on linguistic and extralinguistic tasks, we conducted a repeated measures ANOVA with one between-subjects factor (type of subject, with two levels: patients and controls) and one within-subjects factor (type of task, with two levels: linguistic and extralinguistic tasks). The analysis revealed a main effect of the type of subject ($F_{(1,32)} = 22.21$; $p < .0001$; $\eta^2 = .41$): patients performed worse than controls. Moreover there was a main effect of type of task ($F_{(1,32)} = 28.63$; $p < .0001$; $\eta^2 = .47$): performance in extralinguistic tasks was significantly worse than performance in linguistic tasks. We also found an interaction effect between the two main factors, type of subject and type of task ($F_{(1,32)} = 7.48$; $p = .010$; $\eta^2 = .19$). The interaction between subject and task factors revealed that only patients, and not healthy controls, performed significantly worse on the extralinguistic scale than on the linguistic scale. Patients therefore exhibited poorer performance in both extralinguistic and linguistic tasks compared to healthy controls, but were more severely impaired in extralinguistic tasks.

2.3.5 Hierarchical cluster analysis

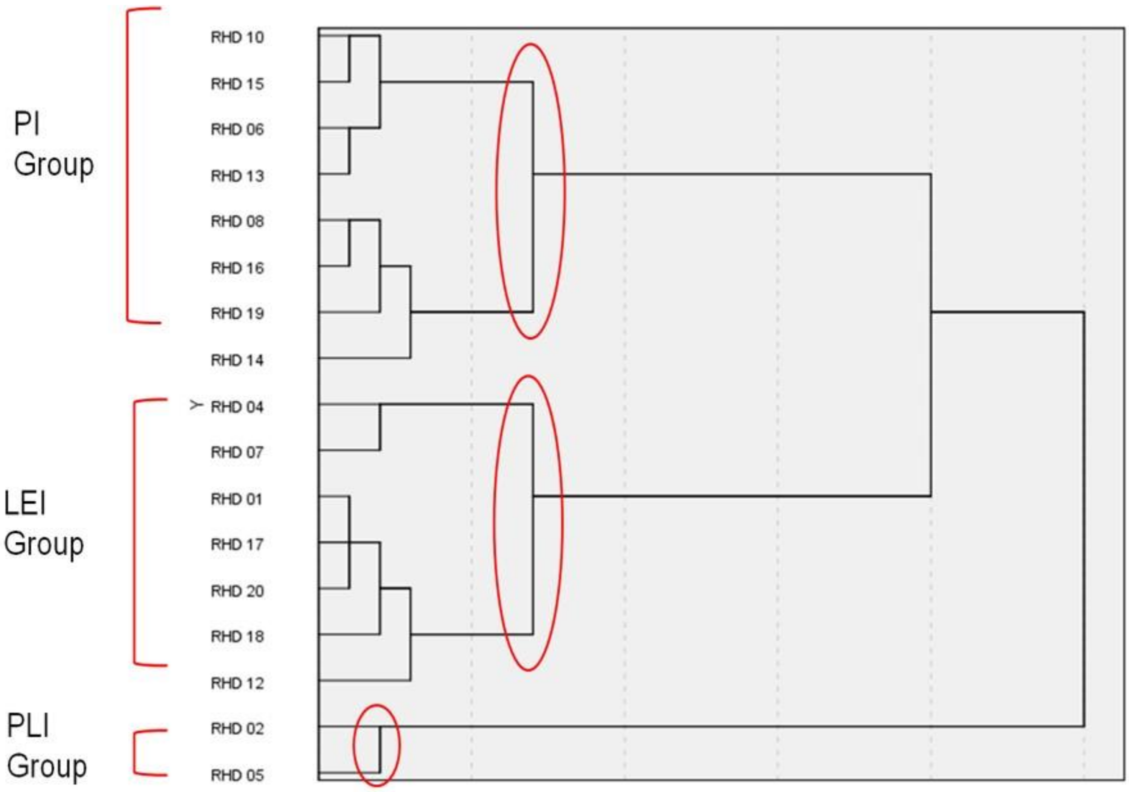
Patients' performance in the various tasks revealed a great deal of variability across subjects. We therefore performed hierarchical cluster analysis to explore whether our experimental sample could comprise different sub-groups of patients. We conducted a cluster analysis using Ward's Method, which minimizes the total within-cluster distance, using patients' level of performance in both comprehension and production in linguistic, extralinguistic and paralinguistic tasks, as classifying variables. The analysis revealed the presence of three different sub-groups (Figure 4), characterized by three main patterns of performance. In order to control which variables are responsible for the difference between clusters, we conducted a MANOVA using six dependent variables (linguistic comprehension, linguistic production, extralinguistic comprehension, extralinguistic production, paralinguistic comprehension, paralinguistic production) with a between-subjects main factor (type of cluster, with three levels: Cluster 1, Cluster 2 and Cluster 3). To explore genuine differences between clusters we conducted a series of *post hoc* pairwise comparisons using Bonferroni correction that revealed the following: Cluster 1 and Cluster 2 were significantly different on the linguistic comprehension ($p < .001$), extralinguistic comprehension ($p = .002$) and paralinguistic production ($p = .003$) variables. Cluster 1 and Cluster 3 were significantly different on the extralinguistic production ($p < .001$) and paralinguistic production ($p = .018$) variables. Cluster 2 and Cluster 3 were significantly different on the linguistic comprehension ($p = .026$), extralinguistic comprehension ($p = .045$), extralinguistic production ($p < 0.001$) and paralinguistic production ($p < .001$) variables. On the basis of these differences we were able to identify three main patterns of performance characterizing the three clusters (Table 8):

Table 8.
Demographic data and pragmatic abilities of RHD patient sub-groups (PI, LEI and PLEI groups) and healthy controls (HC)

	HC (n = 17)	PI (n = 8)	LEI (n = 7)	PLEI (n = 2)
Age	58.2 (8.9)	58.4 (10.1)	61.6 (8.6)	60.0 (1.4)
Education	11.7 (4.0)	12.9 (3.6)	12.0 (4.5)	5.0 (0.0)
Post-onset time	--	2.1 (1.0)	3.3 (1.7)	1.3 (0.4)
Pragmatic abilities				
Linguistic comprehension	.92 (.12)	.89 (.10)	.66 (.72)	.79 (.14)
Linguistic production	.92 (.11)	.83 (.13)	.84 (.06)	.79 (.18)
Extralinguistic comprehension	.84 (.19)	.77 (.11)	.49 (.07)	.76 (.01)
Extralinguistic production	.90 (.12)	.74 (.09)	.74 (.18)	.18 (.14)
Paralinguistic comprehension	.84 (.09)	.79 (.07)	.75 (.11)	.66 (.02)
Paralinguistic production	.97 (.06)	.87 (.06)	.96 (.06)	.72 (.04)

- Cluster 1 (*PI group*, Paralinguistic Impaired group): this cluster (n = 8) was composed of individuals who performed better in linguistic and extralinguistic comprehension tasks, and less well in paralinguistic production tasks compared to Cluster 2.
- Cluster 2 (*LEI group*, Linguistic and Extralinguistic Impaired group): this cluster (n = 7) comprised individuals who performed better in paralinguistic comprehension tasks, and performed significantly worse than the *PI group* in linguistic and extralinguistic comprehension tasks.
- Cluster 3 (*PLEI group*, Paralinguistic, Linguistic and Extralinguistic Impaired group): these patients were clustered together due to their poor performance on extralinguistic production and paralinguistic production tasks, which was significantly worse than that of the two other groups.

In order to control that the differences between the three clusters cannot be explained by factors other than RHD-related deficits, and given the small number of participants composing the three clusters, we performed a Kruskall-Wallis non-parametric test, that revealed no significant differences between the three clusters on age ($p = .79$), educational level ($p = .08$) and time of onset (p = .21). Thus deficits resulting from right hemisphere damage appear to be responsible for cluster composition.



2.4. Discussion

The present study aimed to provide a multifocal assessment of communicative abilities in a sample of RHD patients, evaluating different aspects of pragmatic competence, i.e. linguistic, extralinguistic and paralinguistic abilities. Our main expectation was to observe an overall impairment in all the abilities considered, in both comprehension and production, and in particular we expected to find a substantial impairment in the extralinguistic modality (i.e. gestures and facial expressions), in line with the results reported by Cutica and colleagues (2006).

2.4.1 Linguistic and extralinguistic tasks

Considering performance on the linguistic scale, our results confirmed that RHD patients have difficulties in both comprehending and producing communicative acts expressed verbally. The patients were found to be capable of comprehending and producing sincere (standard) communicative acts as well as the controls, but their performance decreased in comprehending and producing deceit and irony. However, the difference between the patients and the controls was significant for the comprehension of irony but not for its production; furthermore, even though patients' scores were lower than controls' score in terms of the comprehension and production of deceit, these differences are only close to be statistically significant. This datum is quite surprising in light of the presence of the main effect of the type of subject revealed by the ANOVA. A possible explanation could be that the difference between the patients and the controls did not raise a significant statistical threshold because of the high variability characterizing the patients' performances. Moreover, these results might be due at least in part to the presence of different sub-clusters of patients considering that only RHD patients in Cluster 2 (LEIG) performed worse than the controls in linguistic tasks. At the same time, this result confirms - in line with previous studies - that the linguistic-pragmatic difficulties of RHD patients are limited to the comprehension of most complex pragmatic phenomena, such as irony, while RHD patients do not encounter significant difficulties in the comprehension of literal expressions (e.g., Winner et al., 1998; McDonald et al., 2000).

Considering the extralinguistic scale, we observed a similar pattern of results, with patients exhibiting difficulties in comprehending and producing communicative acts expressed through the use of gesture and facial expressions. This data are in line with Cocks and colleagues (2007), who reported a significant reduction in gesture production during spontaneous conversation. Moreover, our results confirmed those obtained by Cutica et al. (2006), who observed a greater impairment in the comprehension of extralinguistic aspects during a communicative exchange in RHD patients, compared to LHD; results of the present study allow us to extend the presence of deficits also to the production of communicative gesture. Patients in our study understood and produced the easiest communicative acts (i.e. direct and indirect communicative acts) as well as healthy controls, but they performed significantly worse than controls in comprehending and producing deceit and irony.

In both the linguistic and extralinguistic scales, a linear trend of difficulty in terms of the comprehension and production of communicative acts was detected. In line with previous studies (Angeleri et al., 2008; Colle et al., 2013; Gabbatore et al., 2014), the patients found sincere (standard) communicative acts easier than deceit; in turn, they found deceit easier than irony, which was the most difficult pragmatic phenomenon. The presence of a linear trend of increasing difficulty in the comprehension and production of communicative acts follows the main assumption of Cognitive Pragmatics theory: non-standard communicative acts (deceit and irony) are more difficult to handle than sincere (standard) communicative acts since they involved the presence of conflicts between what the speaker says and his private knowledge and thus require more inferential ability in order to be understood or produced. In particular, the use of a deceit requires to keep into consideration the presence of a conflict between shared and private knowledge; irony, moreover, requires to keep into consideration the recognition of this conflict and its mutual sharing (Bara, 2010; see also Bosco & Bucciarelli, 2008).

The trend of increasing difficulty detected both in linguistic and extralinguistic tasks confirmed that the communicative deficits of RHD individuals could refer to a high-level of linguistic processing: when communicative acts become more complex in terms of inferential complexity, such as in the case of deceit and irony, RHD patients' difficulties increase significantly. Our results are not surprising considering that deficits in non-literal and figurative language comprehension and production in RHD patients have been widely reported in the literature (e.g., Papagno et al., 2006; Brundage, 1996; McDonald, 2000). Deficits mainly occur when a specific task requires patients to select, update and adapt contextual information in order to infer the intention of a conversational partner or to produce an adequate response to the specific communicative context. The more complex communicative acts, such as deceit and irony, require additional inferential demands, and consequently contribute to highlight patients' pragmatic impairments. A reduction in inferential ability, frequently reported after RHD (e.g., Tompkins et al., 1999; Beeman, 2000), can be considered as one of the cognitive factors responsible for patients' difficulties in dealing with such tasks.

2.4.2 Comparison between the linguistic and extralinguistic scales

The results obtained in the linguistic and extralinguistic scales confirmed that pragmatic impairment in RHD individuals is not limited to linguistic modality, but that it extends to the use of communicative gestures and facial expressions in both comprehension and production: extralinguistic as well as linguistic abilities per se require an actor to make context-relevant inferences in order to produce or comprehend the meaning beyond a specific communicative act.

Comparing performance on the linguistic and extralinguistic scales, our data revealed that even though patients showed deficits in pragmatic ability expressed through both linguistic and extralinguistic modalities, their impairment was more evident at the extralinguistic level: impairment in in the linguistic abilities assessed through ABaCo was more subtle, probably due to the fact that RHD patients seem to be able to partially compensate for pragmatic deficits by using preserved syntactic ability. On the contrary, pragmatic-extralinguistic deficits are difficult to compensate in an accurate manner, becoming more evident and critical. Deficits that affected the extralinguistic modality in our sample cannot be referred to more basic motor or visual impairments, given that patients with such disabilities were initially excluded from the study. Their extralinguistic deficits therefore appear to be referable to specific damage of the right hemisphere, thus supporting the hypothesis that the RH is primarily involved in these aspects of communication (e.g. Tompkins, 1995; Zaidel et al., 2002).

2.4.3 The paralinguistic scale

Another communication disorder that is typically associated with RHD is a reduced ability to manage the paralinguistic aspects of communication, such as tone, intonation, rhythm and prosody. Consistent with previous studies (Kucharska-Pietura et al., 2003; Shamay-Tsoory et al., 2005; Tomkins & Mater, 1985; Pell, 1998, 1999, 2006; Blake, 2007), we found the RHD patients to be severely impaired in terms of both the linguistic and emotional aspects of prosody, and such deficits are detectable in both comprehension and production tasks. In particular, the patients performed as well as the controls in the comprehension of basic speech acts (assertions, commands, requests and orders) and basic emotions (anger, happiness, fear and sadness), displaying a preserved ability to recognize paralinguistic cues (e.g., to distinguish a question from an assertion) and emotional cues such as tone of voice and intonation. By contrast, their ability to recognize when semantic content does not cohere with the paralinguistic elements accompanying it (i.e., paralinguistic contradictions) was impaired. They also exhibited difficulties in conveying emotional states through the use of appropriate paralinguistic cues.

2.4.4 Heterogeneity of performance

Overall, the present study provided a comprehensive description of the clinical outcome resulting as a consequence of RHD. However, as we have shown in the introduction, RHD patients are often heterogeneous in their clinical pictures. Thus, in order to identify possible subgroups within our sample, we conducted a hierarchical cluster analysis: it revealed the presence of three main clusters corresponding to three main patterns of performance. The first group (*PI group,* n = 8) comprised patients reporting a partial preservation of linguistic and extralinguistic abilities with severely impaired performance on the paralinguistic scale. Conversely, the second group (*LEI group*, n = 7) consisted of patients characterized by a substantial impairment in the linguistic and extralinguistic scales who showed less severe deficits in terms of the paralinguistic aspects. Two subjects (PLEI group, n = 2) exhibited severe impairments in both the extralinguistic and paralinguistic scales, showing overall defective performance. These dissociations could not be explained by other factors such as age, educational level or post-onset time, reflecting genuine differences between profiles of impairment. It should be noted that the communicative-pragmatic performances exhibited by the patients belonging to the three clusters were not comparable to those exhibited by healthy controls; this datum confirms that the incidence of communication disorders following RHD is high and invalidating.

2.4.5 Limitations

The study has some limitations. Further investigations need to be carried out to provide a precise neuropsychological assessment in order to identify cognitive functions potentially responsible for the deficits we observed. Studies in the literature suggest that some pragmatic deficits may refer to the cognitive disability generally associated with RHD in terms of attentional and executive functions and theory of mind deficits (e.g., Rainville et al., 2003; Griffin et al., 2006). McDonald (2000) explored the biases of RHD pragmatic disorders, finding that pragmatic performance was closely related to visuo-perceptual ability. Champagne-Lavau and Joanette (2009) found that the association - with high degree of variability among patients - of ToM deficits with executive dysfunction might be a predictor of different patterns of pragmatic deficits. Inferential deficits could also contribute to communicative difficulties following RHD (Tompkins, 1999; Beeman, 2000; Blake, 2009). For these reasons, more research is needed to clarify the relation between pragmatic impairment and cognitive abilities.

Moreover, a detailed anatomical description of the patients’ lesion sites would allow us to make more precise considerations concerning the relation between the pattern of pragmatic performance and the neural profile of impairment of each patient. Finally, the sample of the present study is relatively small: performing an assessment with a larger number of patients would confirm and strengthen the present results.

2.5 Conclusions

Despite the aforesaid limitation, our assessment allows us to draw some relevant considerations from a clinical perspective. Firstly, it represents an attempt to systematically describe the pattern of pragmatic-communicative impairments following RHD, considering different expressive modalities, i.e. linguistic, extralinguistic and paralinguistic. The relevance of a systematic description of communicative deficits after RHD could be crucial in clinical settings: as suggested by Blake (2006), the use of a theoretical framework is necessary in order to identify the level at which a specific deficit is located and successfully plan and implement a rehabilitative program focused on the patient’s difficulties (Gabbatore et al., 2015). Another feature of our work was the evaluation of extralinguistic pragmatic abilities, an aspect that has generally been neglected in previous studies, apart from some rare exceptions (Cutica et al., 2006; Cocks et al., 2007): we found patients to be severely impaired in communication using the extralinguistic modality, in both comprehension and production. Considering that the microlinguistic abilities of patients with RHD are generally not impaired (e.g. Brownell et al., 1992; Tompkins et al., 2002; Marini et al., 2005; Marini, 2012), so that they can sometimes partially compensate for pragmatic deficits using preserved, e.g. syntactic, linguistic abilities, the evaluation of the extralinguistic modality could help to avoid the risk of underrating their difficulties (see Cutica et al., 2006). Finally, our results totally confirmed the heterogeneity of communication disorders following RHD, as reported in previous studies (Cote et al., 2007; Champagne-Lavau & Joanette, 2009). Myers (2001) stated that the lack of a univocal label to identify communicative impairments following RHD has a negative impact on the possibility of diagnosing such disorders in these patients: the ABaCo has proved sensitive to the variability that characterizes communicative deficits following RHD, making it possible to identify different patterns of impairment and contributing to clarify the nature of pragmatic disorders following RHD.

3. Communicative-pragmatic disorders in traumatic brain injury: The role of theory of mind and executive functions.[12]

3.1 The present study

The purposes of this study were to investigate the pragmatic ability of patients with TBI, and to examine the role of cognitive components, in particular EF and ToM, in explaining their pragmatic performance. We used the linguistic and extralinguistic scales of the ABaCo to evaluate the pragmatic comprehension and production of different communicative acts, i.e., sincere (standard) communicative acts, deceit and irony. To evaluate cognitive functions we administered a set of cognitive cognitive tasks (see chapter 3.2.2) evaluating basic neuropsychological functions - attention and long-term memory-, EF - planning, cognitive flexibility and working memory-, and ToM. We hypothesised that:

1) Individuals with TBI would perform worse than healthy controls in the 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; Bosco, Angeleri, Zuffranieri, Bara, & Sacco, 2012; Angeleri et al., 2008).

2) In line with CPT, we expected to observe an increasing trend in difficulty in the comprehension and production of communicative acts of differing complexity (sincere (standard) communicative acts, deceit and irony) in both the linguistic and extralinguistic expressive modalities.

[12] Part of the data and the text reported in this chapter were published as: "Bosco, F. M., Parola, A., Sacco, K., Zettin, M., & Angeleri, R. (2017). Communicative-pragmatic disorders in traumatic brain injury: The role of theory of mind and executive functions. *Brain and language*, *168*, 73-83)."

3) We expected that patients with TBI would 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.

As reported in previous chapters, few studies evaluated concurrently the relation between ToM, EF and pragmatic disdorder in TBI, and results are still inconclusive. In addition, these studies only evaluated comphrehension or production, without comparing them directly in the same subjects, and no previous studies evaluated the role of cognitive functions, i.e. ToM and Ed in explaining pragmatic performance expressed using linguistic and extralinguistic modalities.

The main aim of this study was to examine the role of EF and ToM ability in explaining the performance of individuals with TBI in linguistic and extralingiuistic scales of the ABaCo; we also explored the role of these cognitive functions in explaining the capacity of individuals wih TBI to comprehend and produce communicative acts requiring an increasing inferential ability, i.e.sincere (standard), deceitful and ironic communicative acts.

3.2 Method

3.2.1 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 = .034, p = . 97) and years of education (T-test; t = .83, p = . 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).

Table 1 - Demographic and neurological details of individuals with TBI

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

3.2.2 Materials

In order to examine the participants' pragmatic abilities we used the linguistic and extralinguistic evaluation scales derived from the ABaCo (Assessment Battery for Communication; Angeleri, et al., 2015; Angeleri, et al., 2012; 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 (Colle et al. 2013; Angeleri et al., 2016). 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.

3.2.2.1 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.

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 sincere (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 sincere (standard; direct or 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.

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 sincere (standard) communicative acts, 4 deceitful communicative acts, and 4 ironic communicative acts) and 12 tasks for the production subscales (4 sincere (standard) 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.

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 et al. (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.

3.2.2.2 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.

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).

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, 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 (Kortte, Horner & Windham, 2002; Arbuthnott & Frank, 2000; Johnco, Wuthrich & Rapee, 2013). 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).

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).

3.2.3 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.

3.2.4 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 x 2 x 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 (McDonald et al., 2014; Honan et al., 2015) that executive functions may play a role in solving ToM tasks.

The same analysis have been performed to investigate the role of cognitive and theory of mind functions in the comprehension and production of different communicative acts; in this case we used as dependent variables the respective scores on the comprehension and production of the different communicative acts investigated, i.e., sincere (standard) communicative acts, deceit and irony, separately for the linguistic and extralinguistic scales.

3.3 Results

3.3.1 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 ($F_{(1,58)} = 65.12$; $p < .0001$; $\eta^2_p = .53$), 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 ($F_{(1,58)} = 26.22$; $p < .001$; $\eta^2_p = .31$), indicating poorer performance on the extralinguistic than on the linguistic scales. These main effects were qualified by a significant Factor 1 x Factor 2 interaction effect ($F_{(1,58)} = 5.33$; $p < .05$; $\eta^2_p = .08$). The planned comparisons revealed that the effect of Factor 2 (linguistic vs. extralinguistic) was only significant in the group of TBI individuals ($F_{(1,58)} = 27.59$; $p < .001$; $\eta^2_p = .32$), 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 ($F_{(1,58)} = .091$; $p = .76$; $\eta^2_p = .002$), 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 ($.234 < r_s < .284$, $.129 < p < .214$).

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

	TBI	Controls
Linguistic Comprehension	.72 (.17)	.91(.09)
Extralinguistic Comprehension	.62 (.22)	.83 (.12)
Linguistic Production	.68 (.20)	.92 (.11)
Extralinguistic Production	.57 (.21)	.92 (.07)

3.3.2 Cognitive performance

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 ($2.47 < t < 9.07$; $.0001 < p < .016$).

Table 3 – Mean and standard deviation of neuropsychological tests: Attention (Attentional Matrices), Working Memory (Disyllabic Word Repetition Test, Corsi's Block-Tapping Test, Immediate recall test), Long term memory (Differed 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	.39 (.27)	.87 (.13)	9.07	.0001
Long term memory	.26 (.22)	.67 (.13)	8.72	.0001
Working memory	.47 (.27)	.63 (.23)	2.47	.016
Cognitive flexibility	.52 (.39)	.96(.10)	5.91	.001
Planning	.54 (.28)	.89 (.10)	6.35	.0001
overall ToM	.80 (.24)	.97 (.08)	3.65	.001

3.3.3 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 – Hierarchical regression analysis for variables predicting performance of individuals with TBI 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					
	Model 1	-.035	.037	.51	.603
Comprehension	**Model 2**	.156	.265	3.03	**.049**
	Model 3	.359	.190	8.61	**.007**
	Model 1	-.052	.021	.289	.751
Production	**Model 2**	.151	.276	3.14	**.044**
	Model 3	.294	.143	5.85	**.024**
Extralinguistic Scale					
	Model 1	-.018	.52	.74	.487
Comprehension	**Model 2**	.206	.291	3.54	**.030**
	Model 3	.292	.095	3.91	.060
	Model 1	.03	.072	1.05	.365
Production	Model 2	.161	.234	2.69	.069
	Model 3	.395	.215	10.31	**.004**

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 patients' 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 ($F_{(1,21)} = 5.92$; $p = .009$), linguistic production ($F_{(1,21)} = 3.97$; $p = .034$) and extralinguistic comprehension ($F_{(1,21)} = 4.80$; $p = .038$). 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^2in linguistic comprehension ($F_{(1,20)} = 8.15$; $p = .010$), linguistic production ($F_{(1,20)} = 4.97$; $p = .037$) and extralinguistic production ($F_{(1,20)} = 10.6$; $p = .003$).

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}: $.015 < F < 3.84$; $.063 < p < .98$).

To explore the role of cognitive deficit in explaining the ability of patients with TBI to comprehend and produce different pragmatic phenomena, i.e. sincere (standard) communicative acts, deceit and irony, we conducted a series of multiple regression analyses using respectively as dependent variable TBI participants' scores on the comprehension and production of the different communicative acts investigated, i.e., sincere (standard) communicative acts, deceit and irony, separately for the linguistic and extralinguistic scales of the ABaCo.

Pragmatic performance on each single pragmatic phenomenon appears to have been affected by the different cognitive functions. The inclusion of the Model 1 – basic cognitive functions (attention and long term memory) - have not increased significantly the quote of explained variance of patients' pragmatic performance. Including Model 2 - executive functions (cognitive flexibility, working memory and planning) – there was an increase of the quote of explained variance for the comprehension of linguistic irony ($F(3,24) = 4.07$; $p = .019$). The inclusion of Model 3 - theory of mind abilities – increased the quote of explained variance for the linguistic understanding of deceit ($F(1,23) = 14.18$; $p = .001$), for the extralinguistic understanding of deceit ($F(1,23) = 6.85$; $p = .015$), for the extralinguistic production of sincere communication acts ($F(2,27) = 7.66$; $p = .011$) and deceit ($F(1,23) = 10.86$; $p = .003$) (see Table 5).

***Table 5** – Hierarchical regression analysis for variables predicting TBI performance on comprehension and production of standard, deceitful and ironic communicative acts in both linguistic and extralinguistic scales: Model 1 (Attention, Long term memory), Model 2 (Working memory, Planning, Cognitive flexibility), Model 3 (overall Theory of Mind. The table show* **regression coefficients (R^2) 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 ($Sig\ F_{Change}$).**

DVs	IVs	R^2	R^2_{Change}	F_{Change}	Sig. F_{Change}
Linguistic Comprehension					
	Model 1	.10	.10	1.42	.26
Standard	Model 2	.13	.04	.35	.79
	Model 3	.22	.08	2.43	.13
	Model 1	.02	.02	.34	.72
Deceit	Model 2	.27	.24	.24	.07
	Model 3	.55	.28	14.18	**.001**
	Model 1	.20	.20	3.32	.051
Irony	**Model 2**	.47	.27	4.07	**.018**
	Model 3	.48	.01	.36	.55
Linguistic Production					
	Model 1	.01	.06	.06	.94
Standard	Model 2	.23	.26	2.33	.10
	Model 3	.26	.3	.87	.36
	Model 1	.05	.05	.64	.54
Deceit	Model 2	.26	.22	2.39	.09
	Model 3	.31	.04	1.38	.25
	Model 1	.03	.03	.38	.69
Irony	Model 2	.17	.15	1.40	.27
	Model 3	.30	.12	4.00	.06
Extralinguistic Comprehension					
	Model 1	.06	.06	.81	.46
Standard	Model 2	.43	.13	1.25	.31
	Model 3	.22	.04	1.03	.32
	Model 1	.00	.00	.03	.97
Deceit	Model 2	.20	.20	1.99	.14
	Model 3	.38	.18	6.85	**.015**
	Model 1	.31	.01	1.49	.24
Irony	Model 2	.57	.23	2.68	.07
	Model 3	.68	.01	.30	.59
Extralinguistic Production					
	Model 1	.04	.04	.52	.60
Standard	Model 2	.18	.15	1.43	.26
	Model 3	.39	.20	7.66	**.011**
	Model 1	.01	.01	.15	.86
Deceit	Model 2	.13	.12	1.11	.37
	Model 3	.41	.28	10.86	**.003**
	Model 1	.12	.12	1.82	.18
Irony	Model 2	.26	.14	1.48	.25
	Model 3	.27	.01	.35	.56

3.4 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 (Rousseaux, Vérigneaux, & Kozlowsky, 2010; Dardier et al., 2011; Murphy, Huang, Montgomery & Turkstra, 2015) 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; Angeleri et al 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 (Happe', Brownell & Winner, 1999; Martin & McDonald, 2003; Bibby & McDonald, 2005; Havet-Thomassin et al., 2006) 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 in line 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 scale, 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 .060 to .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 atic 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, 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-.

We also analyzed the possible causal role of cognitive functions, i.e. EF and ToM, on patients' with TBI performance in comprehension and production each single pragmatic phenomena, i.e. sincere (standard) communicative acts, deceit and irony, both in linguistic and extralinguistic scales of ABaCo.

We found that basic cognitive functions - attention and LTM – have a marginally (and not significant) role in explaining pragmatic performance of individuals with TBI. The inclusion of EF - cognitive flexibility, working memory and planning- increased significantly the percentage of explained variance only in the comprehension of linguistic irony. The insertion of theory of mind in the regression model increased significantly the quote of explained variance in the extralinguistic production of sincere (standard) and deceitful communicative acts, and the linguistic and extralinguistic comprehension of deceit. This result is in line with those studies that hypothesized a role of ToM in the ability to understand and produce deceit (Peskin, 1996). Moreover, we have not found evidence supporting the role of ToM in explaining the difficulties of individuals with TBI in comprehending and producing irony.

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 Gabbatore et al., 2015; Bosco, Gabbatore, Gastaldo & Sacco, 2016; Sacco et al., 2016) in order to remediate such difficulties.

4. Neural correlates underlying the comprehension of deceitful and ironic communicative intentions[13]

4.1 The present study

The aim of the present study is to investigate the neural circuits underlying the comprehension of the same speech act uttered with different communicative intentions, that is, of being sincere, deceitful or ironic. In particular, we were interested in investigating the existence of a specific neural mechanism devoted to the comprehension of ironic communicative intention compared with the comprehension of a deceitful one. In line with previous neuroimaging studies and pragmatic theorization, we expected the recognition of both phenomena to be associated with the activation of common cerebral areas due to the detection of a conflict between the literal aspects of a sentence and the speaker's private mental states. To derive the speaker's communicative intention when such a contrast is present, the listener must make a cognitive effort related to the use of theory of mind, executive controls and high-level inferential processes in order to establish coherence between the target sentence and the related context. Previous studies have reported that theory of mind can be localized within a neural network comprising the MPFC, the TPJ and the PC (Van Overwalle & Baetens, 2009; Schurz, Radua, Aichhorn, Richlan, & Perner, 2014) while executive controls generally activate the DLPFC (e.g. (Minzenberg, Laird, Thelen, Carter, & Glahn, 2009). In addition, high-level linguistic processing during comprehension of complex pragmatic phenomena may activate a cerebral network extending to the fronto-temporal and fronto-parietal areas, such as the temporal pole, the IFG and the middle frontal gyrus (MFG), the MTG and superior temporal

[13] Part of the data and the text reported in this chapter were published as: "Bosco, F. M., Parola, A., Valentini, M. C., & Morese, R. (2017). Neural correlates underlying the comprehension of deceitful and ironic communicative intentions. *Cortex*, *94*, 73-86)."

gyrus (STG) (Jang et al., 2013; Rapp et al., 2012). We expected that those cerebral areas might be activated together in the comprehension of both deceitful and ironic speech acts. At the same time, we also expected to observe a specific pattern of activation in the comparison of the same speech act proffered with an ironic vs. deceitful intention, since understanding irony entails more complex inferential processes than deceit, as underlined in previous studies (Bosco & Bucciarelli, 2008; Angeleri et al., 2008). Earlier studies have reported that cerebral areas activated by the comprehension of non-literal speech acts, i.e. metaphors and irony, which require a high inferential load, recruit the temporal pole, the IFG and the MFG, the MTG and STG (Rapp et al., 2012). Thus, we explored whether one specific area, among those mentioned above, is strongly activated in the comprehension of irony as compared to deceit.

4.2 Method

4.2.1 Participants

Twenty-three students (14M, 9F; mean age = 22.70 (SD= 1.89), range 19-27; years of education = 17.13 (SD= 1.18), range 14-18) took part in the experiment. Participants were undergraduate and graduate students from the University of Turin and they took part on a free voluntary basis. All participants gave their informed consent. The study was approved by the Bioethical Committee of the University of Turin (protocol number: 27221). All participants had to meet the following inclusion criteria to take part in the experiment: (1) be right-handers (Oldfield, 1971) (2) have no previous history of neurological or psychiatric illness (3) demonstrate basic cognitive and linguistic abilities by achieving a cut-off score in the following neuropsychological tests: Mini-Mental State Examination (MMSE, Folstein, Folstein, & McHugh, 1975; cut-off score 29/30) and two sub-scales (Comprehension of written words and comprehension of written sentences) of the Aachener Aphasie Test (AAT, Huber, Poeck, & Willmes, 1983); cut-off 112/120) (4) have a normal visual acuity (5) be Italian native speakers. Five participants were excluded from the fMRI analysis for several reasons: excessive movement artifacts (>2 mm) or technical problems during fMRI acquisition.

4.2.2 Materials

The experimental material consisted of 48 short stories followed by a target sentence to evaluate comprehension of different communicative acts, i.e. literal, deceitful, ironic and meaningless. Each story was made up of two different parts. The first part represented the context (C) of the story and described the scenario in which the events of the story would unfold. Each story had two protagonists, one of whom spoke to the other at the end of the story. The second protagonist replied to the first with a statement that represented the target sentence (T).

We created four different context-scenarios in order to suggest four different communicative intentions for the speaker: literal (L, control condition), deceitful (D), ironic (I) or meaningless (M, used as a further control condition in line with Uchiyama et a al. (2012) and Shibata et al. (2010).

This in an example:

[LITERAL] (L) Tom and Mary decided to go to the mountains the next day. Next morning they wake up and go to the kitchen to have breakfast. Mary asks Tom what the weather is like, he looks out of the window and sees that the sun is shining. Tom replies:

[DECEITFUL] (D) Mark knows that the weather forecast is for rain tomorrow, but he wants to persuade Ann to come with him to the seaside despite the bad weather. Ann tells him that she will only come if it is a sunny day, and she asks Mark what the weather is like. Mark replies:

[IRONIC] (I) Frank and Alice are going on a picnic. They take the picnic basket and get in the car to drive to the countryside. They have just arrived when they hear a loud clap of thunder and feel a few drops of rain. Alice shoots Frank a questioning glance. Frank exclaims:

[MEANINGLESS] (M) Danny and Sally are painting the walls of their new apartment white. Danny has almost finished painting the living room when he realizes that there is almost no paint left. He asks Sally whether she remembers where they put the spare tin of paint. Sally says:

[TARGET SENTENCE] (T) “It’s a beautiful day!”

We carried out a preliminary study in order to verify that the interpretation of the experimental material was in line with our expectations. Twenty-five students read the context story followed by the target sentence in written form, and chose the speaker's communicative intention from among the four alternatives proposed (sincere, deceitful, ironic and meaningless). The participants demonstrated good comprehension of the materials, recognizing each condition with at least 90% of accuracy.

During the experimental tasks the subjects read one of the four story contexts followed by the target sentence. Then the target sentence disappeared and the experimental subjects had to recognize the speaker's communicative intention by choosing from among four alternative response options on the screen, i.e. (1) sincere (2) deceitful (3) ironic and (4) meaningless. We created four different context-scenarios for each of the 12 target sentences, for a total of 48 trials, 12 for each condition (literal, deceitful, ironic and meaningless). The order of trial presentation was pseudorandomized and counterbalanced across participants.

4.2.3 Measures on materials

To ensure that the four context-scenarios associated with each (identical) target sentence and eliciting the four different communicative intentions, i.e. sincere, deceitful and ironic, were comparable in terms of reading difficulty, we controlled for different measures, i.e. the length of each story in words and syllables and the Gulpease readability index. The Gulpease readability index is a measure of how difficult a written text is to read (see Bambini, Resta, & Grimaldi, 2014; Masia, Canal, Ricci, Vallauri, & Bambini, 2017), and it is based on the length of words (measured in letters) and length of sentences within a written text. The value obtained can range between 0 and 100, with a value of 0 indicating the lowest readability and a value of 100 indicating the highest readability. The average Gulpease values for all the context-scenarios and target sentences were in the range 60-100 (see Table 1), values equal or over 60 indicates cases of ease of readability for subjects with a high school diploma. (Piemontese, 1996). The number of words and syllables for the target sentences ranged between 3 and 7 words and between 7 and 13 syllables. The mean number of words (SD) and syllables (SD) for target sentences was 5.41 (1.8) and 10.91 (2.2). The mean Gulpease index for target sentences was 100 (see Table 1). Lastly, we measured the mean number of words and syllables within each of the four context-scenarios associated with each target sentence. The mean number of words (SD) and syllables (SD) for the four context-scenarios associated with each (identical) target sentence eliciting the four different communicative intentions ranged respectively between 39.5 (3.41) and 51 (2.94) words, and 77.25 (5.3) and 102.75 (2.5) syllables. The mean number of words, syllables and the Gulpease index for the four different context-scenarios (sincere, deceitful and ironic, meaningless) associated with each target sentence are reported in Table 1.

We performed a series of repeated-measures ANOVAs with one within-subjects factor (sincere, deceitful and ironic, meaningless) to evaluate whether the mean number of words, the mean number of syllables and the Gulpease readability index differed across the four scenarios (sincere, deceitful and ironic, meaningless) associated with each target sentence. We found no differences in the mean number of words ($F_{(1,3)} = 1.23$; $p = .312$; $\eta^2_p = .07$), the mean number of syllables ($F_{(1,3)} = 0.22$; $p = .883$; $\eta^2_p = .01$) or the mean Gulpease index ($F_{(1,3)} = 1.90$; $p = .143$; $\eta^2_p = .11$), indicating that the different scenarios associated with each target sentence did not differ in terms of length and reading complexity.

Condition	Mean Length (SD) - number of words	Mean Length (SD) – number of syllabes	Mean Gulpease (SI
Sincere Context	44.1 (4.3)	91.5 (7.8)	67.8 (5.1)
Deceitful Context	46.3 (4.0)	89.7 (8.4)	71.7 (4.5)
Ironic Context	44.5 (5.5)	91.0 (9.6)	72.2 (.5.9)
Meaningless Context	42.8 (4.2)	88.9 (9.3)	69.0 (5.5)
Target Sentence	5.4 (1.8)	10.9 (2.2)	94.5 (6.6)

Table 1. The mean number of words, syllables and the Gulpease index for target sentence and the four different context-scenarios (sincere, deceitful, ironic and meaningless) associated with each target sentence

4.2.4 Procedure

Before the fMRI scan we explained the experimental task in detail to the subjects, and they performed a computerized tutorial with a set of sentences different from those utilized in the experimental task.

We presented the visual stimuli using E-Prime software (Psychology Software Tools, Inc., Pittsburgh, PA) via a head coil-mounted display system (Resonance Technology, Inc.).

Each trial started with the presentation on the screen of the context story for 15s, followed by a fixation cross (“+”) for 5-7s; then the target sentence was displayed on the screen for 6s followed by a fixation mark (“+”) for 5-7s (see Fig.1). The response screen was then presented for 4s followed by a 10/12s fixation cross (“+”). During the presentation of the response screen on the display, the participants had to identify the speaker's communicative intention expressed by means of the (same) utterance. Four alternative choices (literal, deceitful, ironic and meaningless) were provided and the subjects were able to respond by pressing a button on the response box.

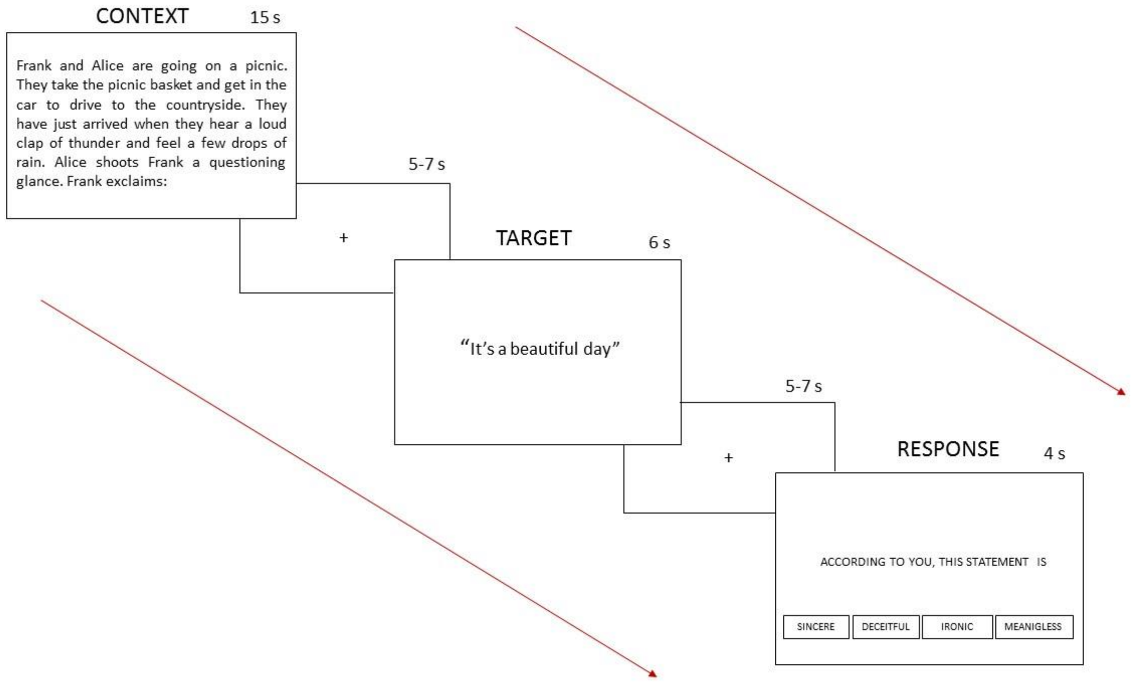


Fig 1. Structure of experimental task used in our study. Each trial started with the presentation on the screen of the context story for 15s, followed by a fixation cross ("+") for 5-7s; target sentence for 6s, a fixation mark ("+") for 5-7s and response screen for 4s.

4.2.5 fMRI data acquisition

The fMRI data were collected using a 3.0 T MRI Scanner (Philips Ingenia) with a 32 channel array head coil at the Città della Salute e della Scienza Hospital in Turin. Functional images were acquired using an Echo-Planar Image sequence (EPI) (TR/TE= 3000 / 30 ms, 32 slices, matrix size=92×96, slice gap=0.5 mm, field of view (FOV)=224x224 mm^2, flip angle = 90°, slices aligned on the AC-PC line) during two functional runs, each consisting of 380 volumes. In between the fMRI runs, structural images of the whole brain were acquired using a T1-weighted sequence (TR 8.1 ms, TI 900 ms, TE 3.7 ms, voxel size 1×1×1 mm^3).

4.2.6 fMRI data analysis

Image preprocessing was performed using SPM8 (Wellcome Department of Cognitive Neurology, London, UK) implemented in Matlab (Mathworks, Cherborn, MA, USA). All functional images of each participant were spatially realigned to the first volume and anatomical images were coregistered to their mean. The functional images were then normalized to the MNI (Montreal Neurological Institute) space and smoothed with an 8 mm Gaussian Kernel. After preprocessing, in order to investigate the comprehension of the speaker's communicative intention, for each participant we applied a General Linear Model (GLM) (Friston et al., 1995) to convolve the onset times, corresponding to the presentation of the *target sentences*, with the canonical hemodynamic response function (HRF) to form regressors. We only used onset times corresponding to target sentences for which each participant provided the correct responses. In each GLM, four separate regressors were used to model the hemodynamic responses during presentation of *target sentences*: literal, deceitful, ironic and meaningless conditions. At the second level, in order to investigate the neural correlates involved during deceitful and ironic communicative intention, we used SPM8 software to perform a one-way ANOVA with one factor (communicative intention) at four levels (literal, deceitful, ironic and meaningless control conditions) within-subjects. Based on our hypothesis about the role of brain networks in these processes, we defined multiple a priori ROIs, and used small volume corrections in these predefined regions. ROIs were defined a priori in line with the accepted procedure defined by Poldrack et al. (2008) in which we first looked at ROIs, and then at whole-brain data in order to reduce type-I error rates. In particular, we used small volume correction with a sphere of 10 mm radius centered on coordinates from previous neuroimaging studies and meta-analyses (Schurz et al., 2014; Rapp et al., 2012; Harada et al., 2009) to detect brain regions involved during ironic and deceitful conditions.

The present investigation is the first study directly investigating the neural circuits underlying the comprehension of irony and deceit at the same time. Thus, in order to investigate the existence of a specific neural correlate involved in the comprehension of the same speech act, uttered with the communicative intention of being ironic or deceitful, we used in all contrasts the meta-analysis of Rapp et al. (2012), the most recent meta-analysis investigating neural circuits underlying non-literal forms of language, such as irony, metaphors, idioms, and the coordinates of Harada et al. (2009) for the recognition of verbal deceit. To our knowledge, this is the only study to date to have investigated neural activation during recognition of verbal deceit. Finally, considering that previous studies showed the involvement of Theory of Mind related areas in the comprehension of irony and deceit (e.g. Spotorno et al., 2012; Bohrn et al., 2012; Harada et al., 2009; Rapp et al., 2012; Uchiyama et al., 2012), we used, in addition to the above mentioned ones, and again in all contrasts, the coordinates that the meta-analysis of Schurz et al. (2014) showed to be active during theory of mind tasks. In particular, from among these different group tasks, considering our experimental design, we chose the experimental tasks most similar to ours.

In detail, we performed the following contrasts: *deceitful vs literal condition* and *ironic vs literal condition* to investigate neural correlates respectively recruited in these different cognitive processes, *ironic vs deceitful condition* to discriminate between the brain regions activated. The *meaningless condition* was only included in the design as a further control condition, for a comparison between the *literal condition* and *meaningless condition* see the fMRI results in Supplementary Material. Finally, we used conjunction analysis to determine areas commonly activated by both deceitful and ironic conditions.

Specifically for the *deceitful vs. literal condition*, we focused on the Left inferior frontal gyrus (lIFG, (x=-52 y=18 z=14) (Harada et al., 2009), Left middle frontal gyrus (lMFG, x= -54 y= 20 z=28), (Rapp et al., 2012), Left dorsolateral prefrontal cortex (lDLPFC, x=-48 y=18 z=38), (Harada et al., 2009), and Right Cerebellum (x=12 y=-78 z= -34) (Rapp et al., 2012); for the *ironic vs. literal condition* we focused on the Left middle temporal gyrus (lMTG, x=-56 y=-32 z=-2), (Rapp et al., 2012), Left inferior frontal gyrus (lIFG, x=-50 y=24 z=14) (Rapp et al., 2012), Left middle frontal gyrus (lMFG, x=-54 y=20 z=28), (Rapp et al., 2012), Left dorsolateral prefrontal cortex (lDLPFC, x=-48 y=18 z=38), (Harada et al., 2009), L supra /TPJp (x=-55 y=-39 z=-35) (Schurz et al., 2014), and Right Cerebellum (x=12 y=-78 z=-34), (Rapp et al., 2012). For the *ironic vs. deceitful condition*, we focused on the Left middle temporal gyrus (lMTG, x=-56 y=-32 z=-2) (Rapp et al., 2012). Lastly, for the conjunction analysis we focused on the Left inferior frontal gyrus (lIFG, x=-52 y=18 z=14) (Harada et al., 2009), Left middle frontal gyrus (lMFG, x=-54 y=20 z=28) (Rapp et al., 2012), Left dorsolateral prefrontal cortex (lDLPFC, x=-48 y=18 z=38), (Harada et al., 2009), and Right Cerebellum (x=12 y=-78 z= -34), (Rapp et al., 2012).

4.3 Results

4.3.1 Behavioral results

The mean rate (SD, 95% confidence interval) of participants' responses during fMRI tasks was 97.2 (4.0, 95.21 – 99.23) for the literal condition, 89.4 (10.2, 84.26 - 94.43) for the ironic condition, 91.7 (7.0, 88.18 - 95.14) for the deceitful condition. Participants demonstrated good comprehension of all the experimental conditions (>89% accuracy).

We performed a one-way repeated measures ANOVA with one within-subjects factor (sincere, deceitful and ironic) to evaluate whether participants' accuracy differed between different experimental conditions. We found a main effect of type of pragmatic phenomenon ($F_{(1,34)} = 5.12$; $p = .011$; $\eta^2_p = .23$), indicating a difference in accuracy of comprehension in each experimental condition (sincere, deceitful and ironic). In particular, post-hoc comparison using Bonferroni correction indicated that deceitful ($t_{(17)} = 2.74$; $p = .043$) and ironic ($t_{(17)} = 3.31$; $p = .012$) speech acts were more difficult to comprehend compared to sincere/literal speech acts.

4.3.2 fMRI results

Group analysis revealed significant brain activations in the following contrasts (see Table 2): i) in the *deceitful* vs *literal* condition, we observed the recruitment of the left inferior frontal gyrus (lIFG), left middle frontal gyrus (lMFG), left dorsolateral prefrontal cortex (lDLPFC), right Cerebellum (Fig. 2); ii) in the *ironic* vs. *literal* condition, we found significant increased activation in the left inferior frontal gyrus (lIFG), left middle frontal gyrus (lMFG), left middle temporal gyrus (lMTG), right cerebellum, left dorsolateral prefrontal cortex (lDLPFC), L supra./TPJp (Fig.3); iii) in the *ironic* vs *deceitful* condition, we observed the involvement of the left middle temporal gyrus (lMTG), (Fig.4). Finally, the conjunction analysis (*deceitful* > *literal* ∩ *ironic* > *literal***)** detected the involvement of common brain regions in the left IFG, left MFG, left DLPFC and right cerebellum during the deceitful and ironic conditions (Fig. 5).

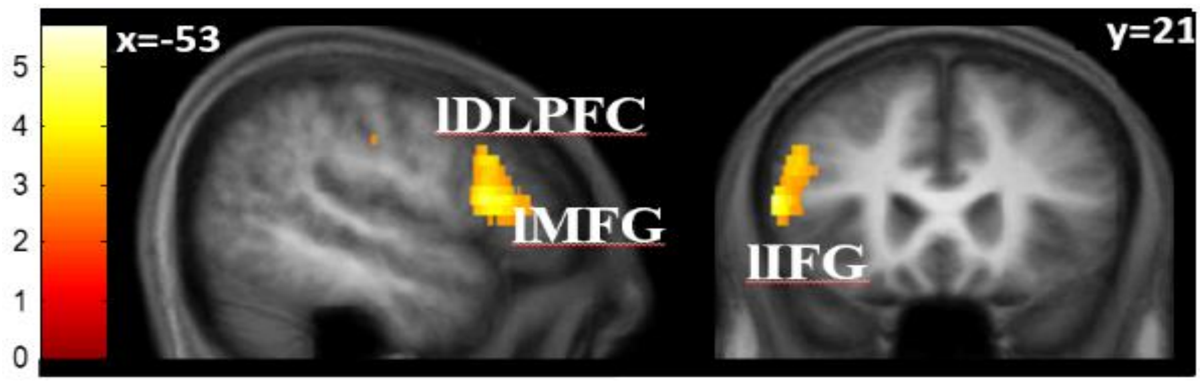


Fig. 2 Brain activation maps in the *deceitful* vs *literal* condition: left inferior frontal gyrus (lIFG), left middle frontal gyrus (lMFG), left dorsolateral prefrontal cortex (lDLPFC).

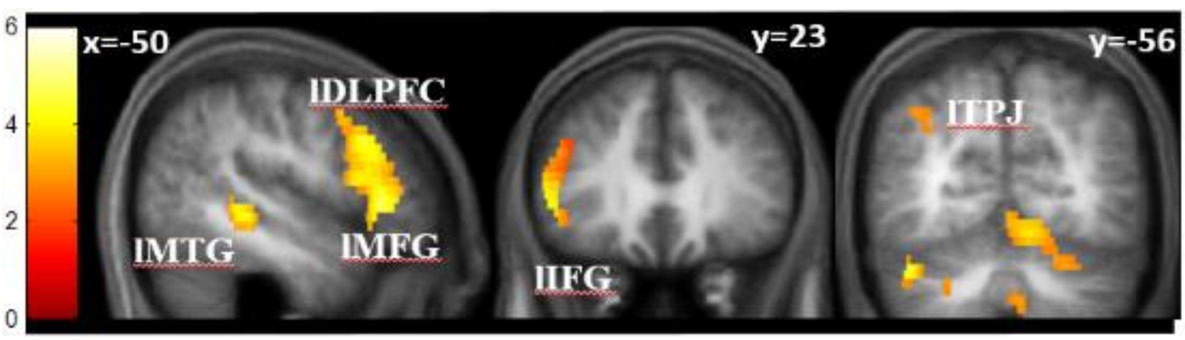


Fig. 3 Brain activation maps in the *ironic* vs *literal* condition: left inferior frontal gyrus (lIFG), left middle frontal gyrus (lMFG), left middle temporal gyrus (lMTG), left dorsolateral prefrontal cortex (lDLPFC), L supra./TPJp.

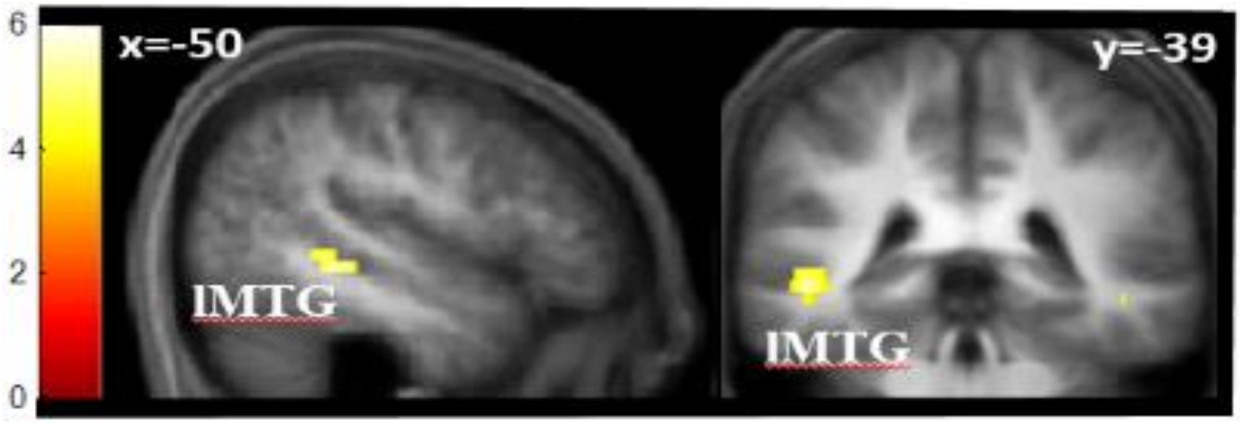


Fig. 4 Brain activation maps in the *ironic* vs *deceitful* condition show the involvement of the left middle temporal gyrus (lMTG).

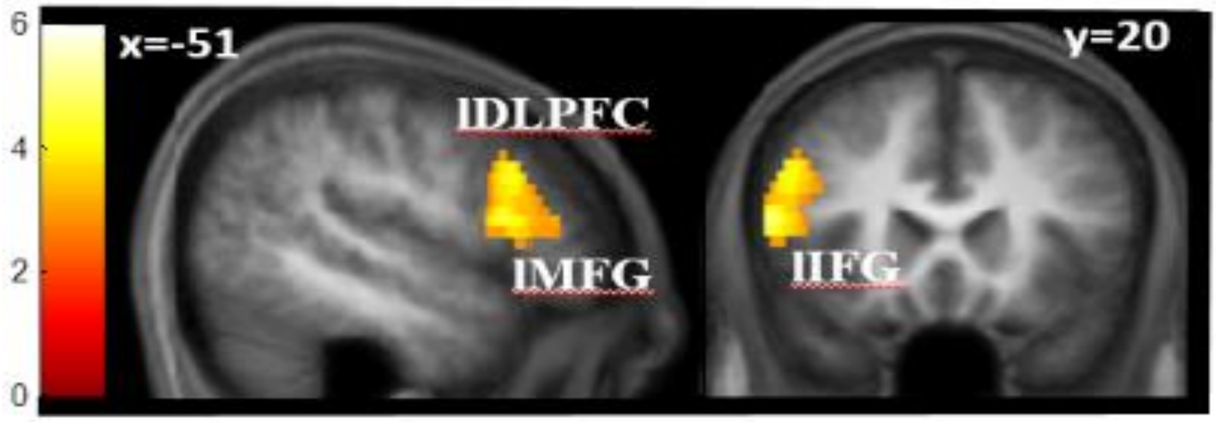


Fig. 5 Conjunction analysis, ***deceitful* > *literal*** ∩ ***ironic* > *literal***, show the involvement of common neural substrates (the left IFG, left MFG, left DLPFC) during the deceitful and ironic conditions.

Table 2. Significantly activated brain regions				
	MNI Coordinates			**Z-score**
	X	*Y*	*Z*	
Contrast of interest				
deceitful condition > literal condition				
Left inferior frontal gyrus (lIFG)	-54	20	14	4.37
Left middle frontal gyrus (lMFG)	-49	18	34	4.36
Left dorsolateral prefrontal cortex (lDLPFC)	-49	16	30	3.67
Right Cerebellum	9	-82	-26	4.17
ironic condition > literal condition				
Left inferior frontal gyrus (lIFG)	-53	25	6	4.42
Left middle frontal gyrus (lMFG)	-46	19	34	4.36
Left middle temporal gyrus (lMTG)	-51	-39	2	3.49
Left dorsolateral prefrontal cortex (lDLPFC)	-48	13	30	3.71
Right Cerebellum	14	-81	-26	4.62
L supra /TPJp	-54	-56	38	3.02
ironic condition > deceitful condition				
Left middle temporal gyrus (lMTG)	-49	-37	-2	3.01
Conjuction analysis				
deceitful > literal ∩ ironic > literal				
Left inferior frontal gyrus (lIFG)	-54	20	14	4.38
Left middle frontal gyrus (lMFG)	-49	18	34	3.63
Left dorsolateral prefrontal cortex (lDLPFC)	-49	16	30	3.67
Right Cerebellum	9	-83	-26	4.17

Table 2. Peak activity coordinates are given in MNI space.

All contrasts were analyzed using a small volume correction (SVC) with a sphere of 10 mm radius centered on the reported coordinates with a statistical threshold of $p<0.05$ family-wise error corrected for multiple comparisons.

4.4 Discussion

In this study we investigated the neural correlate involved in the recognition of the same speech act uttered with the intention of being sincere (i.e. literal, the control condition), deceitful or ironic. The analysis of behavioral performance confirmed that participants correctly understood the sincere, deceitful or ironic communicative intention of the protagonists of short written stories - our experimental stimuli - based on the previous context. The participants recognized all the experimental conditions with a good level of accuracy (>89%), and found comprehension of deceitful and ironic speech acts more complex than comprehension of literal speech acts. This result is in line with previous studies that reported comprehension of deceitful and ironic speech acts as being more difficult than comprehension of literal statements (Shany–Ur et al., 2012; McDonald et al., 2014; Angeleri et al., 2008; Gabbatore et al., 2014; Parola et al., 2016).

The novelty of the present study is that it directly compared two pragmatic phenomena, irony and deceit, usually investigated separately in the fMRI literature. In order to ensure that the activations shown by the different contrasts cannot be due to semantical, lexical and syntactical differences of the stimuli, we measured the neural activation precisely during the presentation of the target sentence, that was kept constant across the conditions, i.e. sincere, deceitful and ironic communicative intentions. However, to rule out any possibility that other confounding factors in the experimental material could have played a role in determining our results, we measured readability and length in words and syllables for each of the four scenarios preceding each target sentence and we did not find any differences for the various scenarios preceding the target utterance.

Overall, the analysis on single contrasts - deceitful vs. literal and ironic vs. literal - revealed, in line with our expectations, the existence of both common and specific areas of activation. Focusing in detail on each single phenomenon, we found that recognition of deceitful vs. sincere/literal communicative intention activated: the left frontal gyrus (IFG), the left middle frontal gyrus (MFG), the dorsolateral prefrontal cortex (DLPFC) and the right cerebellum. The recognition of ironic intention, compared to recognition of sincere/literal one, activated the left inferior frontal gyrus (IFG), the MFG, the middle temporal gyrus (MTG), the right cerebellum and left posterior supra temporo-parietal junction (supra/TPJp).

Furthermore, a conjunction analysis (*deceitful* > *literal* ∩ *ironic* > *literal)* allowed us to reveal an activation of common brain regions concerning the left IFG, the MFG, the DLPFC and the right cerebellum. The existence of common cognitive processes underlying the comprehension of both deceit and irony is in line with the theoretical assumption of Bosco & Bucciarelli (2008) and Bara (2010). According to the authors, in the case of both deceit and irony, what the speaker says does not correspond to his/her private knowledge and in order to understand them a partner has to recognize such a conflict.

In order to investigate the existence of a specific cerebral area involved in the recognition of the same speech act proffered with the intention of being ironic vs. deceitful, we performed a contrast between these two conditions that revealed a specific area of activation, corresponding to the left MTG. The identification of this specific area of activation supports the theoretical assumption of Bosco & Bucciarelli (2008) and Bara (2010) and provides a stronger and more complete explanation of the mechanism underlying the comprehension of these two complex pragmatic phenomena. In proffering a deceitful utterance, the speaker says something that conflicts with her/his private knowledge. To recognize the deception, the partner has to detect the difference between what the speaker expresses and what s/he privately knows. Also with irony, the speaker says something that (as in the case of deceit) conflicts with her/his private knowledge. However in this case, unlike with deceit, the content of the utterance also contrasts with the knowledge the speaker shares with the partner. Thus, in the absence of paralinguistic and non-verbal cues - as in our experiment-, what is, or is not, shared between the speaker and the partner allows the latter to distinguish between an ironic and deceitful speech act. The original result of the present study is that it revealed that the left MTG (as discussed in detail in paragraph 4.4 below), specifically makes it possible to discriminate between an ironic and a deceitful communicative intention, on the basis of the knowledge that is, or is not, shared between the interlocutors. We will now analyze each specific area of activation in detail.

4.4.1 Left inferior frontal gyrus (IFG) and left middle frontal gyrus (MFG)

Reviews and meta-analyses of text and discourse have reported the involvement of the IFG in discourse comprehension (Ferstl, Neumann, Bogler, & Von Cramon, 2008; Jung-Beeman, 2005; Mason & Just, 2006). In particular the IFG is involved in semantic processes during utterance comprehension (Dapretto & Bookheimer, 1999) and has a crucial role in the comprehension of the exact meaning of a word in a context utterance (Badre & Wagner, 2007; Menenti, Petersson, Scheeringa, & Hagoort, 2009; Rapp et al., 2012). The IFG thus has a key role in semantic processes since it selects the plausible pragmatic inference from among the various possible alternatives (see Jang et al., 2013). To recognize irony, the partner must understand that what the speaker says is the opposite of (Grice, 1975; 1991) or in contrast with (Bosco & Bucciarelli, 2008; Bara, 2010) what s/he means. Thus what the speaker means (speaker's meaning) by being ironic does not correspond to what s/he literally expresses (literal meaning, see Grice 1975; 1991). The role of the IFG seems thus to be to correctly infer the (correct) intended meaning starting from the (wrong) literal meaning of the utterance. Furthermore, recognition of an ironic speech act requires a more complex inferential process with respect to the comprehension of a literal one, since the partner has to recognize the contrast between what the speaker says and the knowledge s/he shares with the partner, while in the comprehension of a sincere speech act such a contrast does not exist, since what the speaker says is in line with her private belief and with the knowledge s/he shares with the interlocutors (Bosco & Bucciarelli, 2008; Bara, 2010).

The activation of the left IFG is in line with the current fMRI literature investigating irony. For example Uchiyama et al. (2006), observed left IFG activation during the presentation of sarcastic utterances. Our result is also consistent with Spotorno et al. (2012) investigating irony through the recognition of a target sentence that could be either literal or ironic according to the context of presentation. More in general, our findings are in line with the two available meta-analyses on the comprehension of figurative language, i.e. idioms, metaphors and irony, (Bohrn et al., 2012; Rapp et al., 2012). Bohrn et al. (2012) indicated, among others, a stronger activation of the left IFG and left MFG associated with the processing of figurative as opposed to literal language. Furthermore, Rapp et al. (2012) identified the largest cluster of activation involved in the recognition of non-literal language in the left IFG with extension into the left MFG. The result of our investigation thus supports the fundamental role of these two brain regions in the identification of the pragmatic meaning of non-literal, i.e. ironic, sentences. Again in line with Rapp et al. (2012), we suggest that activation of the IFG seems to be related to a higher cognitive demand (see also Bambini et al., 2011; Rapp, Leube, Erb, Grodd, & Kircher, 2004), required in irony comprehension with respect to the comprehension of a literal speech act.

4.4.2 Left Dorsolateral frontal cortex (DLPFC*)*

The result of the present investigation revealed the involvement of the DLPFC in the recognition of both deceitful and ironic speech acts. The DLPFC is an important brain region for executive functioning (see Leh, Petrides, & Strafella, 2010). In order to recognize a deceitful (Bara, 2010) and an ironic speech act (Azim, Mobbs, Jo, Menon, & Reiss, 2005; Shammi & Stuss, 1999; Bara, 2010) a partner has to resolve the conflict/inconsistency between the speaker's literal utterance and what s/he privately knows (deceit) or shares with the interlocutors (irony). From this perspective, both deceit (Bosco & Bucciarelli, 2008) and irony comprehension (Bosco & Bucciarelli, 2008; Strick, Holland, van Baaren, & van Knippenberg, 2009) require more cognitive resources than comprehension of a literal/sincere speech act. The recruitment of the dorsolateral cortex could thus sustain the resolution of such conflict/contrast.

As far as the recognition of deceitful statements is concerned, our findings are in line with

Harada et al. (2009). This study is, to our knowledge, the only one apart from ours that focuses on deceit recognition per se rather than specifically investigating the moral aspect involved. The authors carried out an experiment similar to ours in which the participants read brief stories and had to perform a lie judgment task. The authors suggested that the DLPFC might be activated by the executive functions recruited to combine the inferences necessary to understand the speaker's intention to deceive with the comprehension that social norms are violated (see Grice, 1991).

Regarding the recognition of an ironic speech act, the result of the present investigation is again consistent with Spotorno et al. (2012) investigating irony through the recognition of a target sentence that could be either literal or ironic according to the context of presentation. Our result concerning the activation of the left DLPFC is also in line with Akimoto et al. (2014), who reported that the activation of this area, during an utterance comprehension task, was modulated by the degree of humor perceived by the participants. Finally, in a recent study by Chan & Lavallee (2015) the DLPFC was found to be active in all three different tasks - bridging-inference jokes, exaggeration-jokes, and ambiguity jokes - created in order to investigate humor comprehension and thus testifying the role of this brain area in irony/humor comprehension, independently of the kind of task used to empirically investigate it.

4.4.3 Left posterior Temporo Parietal Junction (TPJp)

In the present investigation we found the left TPJp to be activated by the contrast between irony vs. literal speech act comprehension. A large body of evidence has shown that TPJ is classically activated by a third person theory of mind or mentalizing task (for a review see Van Overwalle, 2009; for a meta-analysis see Marr, 2011 and Schurz et al., 2014). Its function seems to be to facilitate reasoning and social event interpretation in connection with the content of mental states (Saxe, 2006). In particular in a recent meta-analysis Schurz et al. (2014) performed a conjunction analysis and found that, regardless of the experimental stimuli used, all analyzed tasks activated the posterior part of the TPJ (TPJp). Furthermore Gobbini et al. (2007) reported that the posterior TPJ plays a role in processing covert mental states, i.e. mental states not explicitly associated with visible action. A number of authors (Happé, 1993; Winner & Leekam, 1991; Sperber & Wilson, 2002) have proposed that ToM plays a role in irony comprehension. In particular ToM could have a role in the comprehension of the speaker's actual and real mental state that does not correspond to what s/he is actually saying. However, to our knowledge, the study by Spotorno et al. (2012) is the only one to have observed the involvement of the TPJ in the contrast between irony vs. literal comprehension. The exact role of the TPJ in the comprehension of irony thus needs further studies in order to be clarified.

Our results seem to be in line with those of Ciaramidaro et al. (2007) and Walter et al. (2009) indicating that the TPJ is specifically involved in the understanding of communicative intentions in respect of other kinds of non communicative-social intentions. The results of the present study thus seem to support the involvement of the left TPJ in the comprehension of communicative intentions. Unlike Harada et al. (2009), we did not observe the activation of the TPJ during the recognition of deceitful speech acts. However, it should be considered that as a control condition Harada and colleagues used a gender judgment task (participants had to decide whether the protagonist of the story was a girl or a boy) that required no theory of mind involvement at all. We used the comprehension of sincere/literal speech acts as the control condition in our experiment, since previous studies have shown that the recognition of a speaker's communicative intention might involve theory of mind reasoning (Walter et al., 2004). The role of the TPJ in the comprehension of linguistic deceit should therefore be clarified in further studies.

4.4.4 Left Middle temporal gyrus (MTG)

The most interesting finding of the present study is the activation of the left MTG that emerged from the contrast between the recognition of ironic vs. sincere/literal communicative intention and the novel results revealed by the contrast between the recognition of an ironic vs. deceitful one.

The left MTG plays a role in the semantic integration of word meaning in the sentence context (Noppeney & Price, 2004; Vandeberghe, Nobre, & Price, 2002). A meta-analysis by Ferstl et al. (2008) suggested that the left MTG has a key role for coherence analysis and for the comprehension of texts. In their meta-analysis of brain area activation underlying the comprehension of non-literal language, Rapp et al. (2012) highlighted that the MTG is a multimodal association area and that it has a crucial position within language networks given its large number of connections with other cortical association areas (see Turken & Drokers, 2011). Furthermore, Acheson & Hagoort (2013) found the left MTG to be active in accessing word meaning.

Our result showing the activation of the lMTG by the contrast between ironic and literal speech acts is in line with that reported by Eviatar & Just (2006), who found an increased activation of this area in the recognition of ironic statements as compared to literal ones. Our result is also in line with the work by Uchiyama et al. (2006), who observed the involvement of this brain region in a sarcasm scenario-reading task.

However, in our study this area was also specifically activated by the contrast between the recognition of an ironic communicative intention minus the recognition of a deceitful one. Differently from deceit, irony requires the partner to understand that what is said does not correspond to what the speaker intends (Grice, 1991). It is thus possible that the MTG may have a specific role in determining when, given a specific context, the meaning of a word does not correspond to its usual semantic meaning, i.e. in the utterance "What a beautiful day!" proffered ironically on a rainy day, the word "beautiful" means the exact opposite, i.e. “horrible".

Furthermore, Jang et al. (2013) observed the activation of the MTG in an fMRI study on pragmatic inferential ability. The authors investigated participants’ ability to comprehend implicit answers such as: Question: "Is today a holiday?”, Answer: "The street is empty!" (Proffered to mean “Yes”). In line with Bosco & Bucciarelli (2008) and Bara (2010) the comprehension of irony requires a greater cognitive demand and more inferential processes than deceit. According to the authors, to be ironic the speaker says something that (as in the case of deceit) conflicts with her/his private knowledge. However in this case, unlike with deceit, what the speaker says also contrasts with the knowledge s/he shares with the partner. The recognition of such a contrast makes recognizing an ironic communicative act more difficult and thus more demanding than recognizing a deceitful one, in view of the inferential ability required. From this perspective the recruitment of the left MTG could sustain the additional inferences necessary to comprehend irony with respect to deceit.

However, since the MTG is a rather large cerebral area, some authors have proposed a functional specialization within this area along an anterior-posterior axis. In particular, Jung-Beeman (2005) proposed that during text comprehension the posterior part of the MTG may be responsible for "semantic activation", i.e. the initial access to semantic features and primary associations of the target word, and the anterior part of the MTG may be involved in "semantic integration", i.e. the recognition and computing of high-order semantic relations to support the interpretation of the whole message. In the present investigation the activation of the lMTG for the contrast between ironic vs. deceitful is localized more posteriorly, in line with the results of the meta-analysis by Rapp et al. (2012) and with the study by Jang et al. (2013), that found the lMTG to be active in the contrast between moderate and highly implicit speech acts, compared to explicit ones. A recent study by Davey et al. (2016), showed that the left posterior middle temporal gyrus (lMTG) plays a pivotal role in controlling the retrieval of semantic information. In particular, the authors proposed that the posterior part of the MTG was able to integrate information from different semantic systems, i.e. the automatic retrieval of dominant information between concepts that are highly related, with the controlled retrieval of goal-oriented information requested by a specific task's instruction. In this view, the pMTG may allow specific semantic features to be retrieved and maintained active, and thus contribute to shaping a specific thematic context from which to select and retrieve relevant features, as in the case when having to retrieve concepts with relatively weak associations between them. The stronger involvement of this area in comprehension of irony, compared to deceit, could be necessary in order to retrieve and maintain active a supporting linking context necessary to grasp the discrepancy between the literal aspects of an expression ("What a beautiful day!") and the communicative intention beyond it (i.e. of being ironic, to communicate "What a horrible day!"). The retrieval and retention of the relevant contextual semantic features may allow a listener to perform the more demanding inferential step, compared to deceit, necessary to recognize the speaker's ironic communicative intention.

The recruitment of additional cognitive inferential resources in order to comprehend an ironic speech act as opposed to a deceitful one is also in line with other studies in the developmental or clinical literature, showing that children of school age (Bosco et al., 2013), and different kinds of patients, i.e. traumatic brain injured patients (Angeleri et al., 2008), with right hemisphere lesion (Parola et al., 2016) or patients with schizophrenia (Colle et al., 2013), find the comprehension of the former more difficult than comprehension of the latter. The functional differentiation between the anterior and posterior part of the MTG in the comprehension of non-literal expressions is however not still completely clarified, and future studies could help to shed further light on this point.

4.4.5 Right cerebellum

In all our analyses, with the only exception of the specific contrast between the ironic vs. deceitful condition, the activation of the right cerebellum emerged. Anatomically, the right cerebellum has a connection with the left hemisphere (Middleton & Strick, 1994) and it is devoted not only to the control of fine grained motor actions but also to high level cognitive functions (Strick, Dum, & Fiez, 2009), including language processes (Mariën, Engelborghs, Fabbro, & De Deyn, 2001; De Smet, Paquier, Verhoeven, & Mariën, 2013). In line with the results of the present investigation, it has been found to be involved in the comprehension of non-literal forms of language (Rapp et al., 2012).

In the last decade, lesions to the cerebellum have been found to affect patients' performance in spoken (Mariën et al., 2014) and written (De Smet, Engelborghs, Paquier, De Deyn, & Mariën, 2011) language tasks and some authors have suggested that the right cerebellum has a key role in language processing (Stoodley & Schmahmann, 2009, see Murdoch, 2010 for a review). The result of the present investigation is in line with previous findings supporting the key role of the right cerebellum in the comprehension of non-literal speech acts, more in general, supporting its key role in language comprehension.

4.4.6 Overall discussion

Overall, the results of the present investigation concerning irony are in line with the meta-analysis by Rapp et al. (2012) which identified the brain regions involved in the comprehension of non-literal language, i.e. metaphors, idioms, and irony, and revealed the existence of a fronto-temporal network. The largest and more active cluster identified by the authors was located in the left IFG with extension into the MFG. The second strongest cluster, identified by the authors with the specific contribution of irony comprehension (Shibata et al., 2010; Uchiyama et al., 2006) was located in the left MTG/STG. As far as deceit is concerned, this is the first study to observe a complex brain network including the IFG, the MFG, the DLPFC and the right cerebellum, that is recruited in order to recognize a deceitful communicative intention conveyed through a speech act.

Lastly, we found that all the activated clusters that emerged as key areas in irony and deceit comprehension are located in the left hemisphere (LH), with the exclusion of the right cerebellum, that is however anatomically connected to the left hemisphere (Middleton & Strik, 1994), and play a role in the language processes (see Murdoch, 2010). In line with the results of the present investigation, of the sixteen clusters identified by Rapp et al. (2012), thirteen were located in the left cerebral hemisphere (LH), thus showing a dominance of the LH. The LH dominance in the comprehension of complex pragmatic phenomena such as deceit and irony is also in line with the meta-analysis by Bohrn et al. (2012) on the comprehension of figurative language. Linguistic theories investigating the cognitive underpinning of non-literal or figurative forms of language proposed that the right hemisphere might be crucial in the interpretation of these figurative expressions (Jung-Beeman, 2005; Giora, 1997), and some authors found that right hemisphere damage can impair the ability to recognize irony and to distinguish between lies and jokes (Winner et al., 1998; Shamay-Tsoory, Tomer, & Aharon-Peretz, 2005). Our data did not confirm the RH dominance hypothesis for non-literal language, pointing instead towards a left-lateralized network with a modest contribution of the right hemisphere, limited to the right cerebellum. However, some limitations should be considered in claiming that the right hemisphere did not play a role in the recognition of communicative intention in the present study. First, the experimental materials consisted of linguistic stimuli only, and this could partially explain the left lateralized activations. It is possible that the involvement of the right hemisphere would be observable if we had used linguistic speech acts accompanied by non-verbal (i.e. gestural) and paralingusitic (i.e. prosodic) cues. Secondly, previous studies showed that the involvement of the right hemisphere in irony and deceit recognition is located especially in cerebral areas related to theory of mind processes, such as the TPJ and MPFC. As highlighted previously (see paragraph 4.3), the recognition of the speaker's communicative intention might involve theory of mind reasoning (Walter et al., 2004). Since we used the comprehension of sincere speech acts as the control condition, the activation in the right hemisphere associated with ToM areas could be subtracted during contrast. Finally, fMRI studies that highlighted a greater involvement of the RH focused mainly on the comprehension of metaphoric and idiomatic expressions (see Rapp et al., 2012), especially novel and non-salient ones, that have not been investigated in the present study.

4.4.7 Limitation

A limit of the present investigation is the fact that we did not directly investigate the possible role of the Theory of Mind (Premack & Woodruff, 1978) or mentalizing ability in the understanding of a deceitful or ironic intention. Since the Theory of Mind continues to develop after the childhood through the adolescence and adulthood (Blakemore; 2008; Bosco, Gabbatore & Tirassa 2014) further studies, focusing on the cognitive processes and the relation between ToM and the ability to comprehend deceit and irony in young adults and adults, should investigate such issue.

4.5 Conclusions

Despite its limits, this study is important because it is the first to compare the same statement proffered with the intention of being literal/sincere or deceitful or ironic.

More in detail, it is the first work to have investigated and shown the existence of a precise brain area, the lMTG, specifically activated by the contrast between the recognition of an ironic vs. deceitful communicative intention. Furthermore, unlike the majority of studies in the literature (e.g. Wu et al., 2011; Hayashy et al., 2014), that focused on the moral aspects involved in recognizing deceit, our study concentrates on the communicative aspects of deceit recognition (but for an exception see Harada et al., 2009). Specifically, the present investigation revealed that certain brain areas, i.e. the left IFG, the MFG, the DLPFC and the right cerebellum, are involved in the recognition of both ironic and deceitful communicative intentions. At the same time the recognition of an ironic vs. a deceitful speech act also specifically activates the left MTG, that thus seems to have a specific role in discriminating between the speaker's two different communicative intentions (deceitful or ironic) based on what is, or is not, shared by the participants in the communicative interaction. The investigation of the neural correlate involved in the recognition of speech acts proffered with different communicative intentions allows to give a deeper and more complete explanation of the cognitive processes involved in human pragmatic-communicative ability.

5. General discussion and conclusions

The present work aimed to investigate the role that cognitive and neural processes play in sustaining communicative-pragmatic ability. Communicative-pragmatic ability can be impaired as a consequence of acquired brain damage, such as RHD or TBI. Moreover, individuals with brain damage often exhibit deficits in cognitive functioning. As a result, studying the relationship between communicative-pragmatic disorder and cognitive function deficits in individuals with brain damage provided an opportunity to shed further light on the cognitive mechanisms involved in the comprehension and production of different communicative acts. Two cognitive functions, i.e. theory of mind (ToM) and executive functions (EFs), have been proposed as having a crucial role specifically in the encoding of communicative intention. In the present work, we investigated the role of inferential processes, necessary to fill the gap between the literal and the speaker's intended meaning of an utterance, and ToM and EFs, in explaining pragmatic disorders in individuals with TBI and RHD. Lastly, we investigated the neural correlates of pragmatic processing in healthy subjects.

In the first study, we assessed communicative-pragmatic ability in a sample of individuals with RHD using behavioural measures. We used the Assesment Battery of Communication (ABaCo, Angeleri et al., 2015; Bosco et al., 2012) to evaluate the comprehension and production of different communicative acts - as for example sincere (standard) comunicative acts, deceit and irony - expressed through linguistic and extralinguistic modalities, and the comprehension and production of paralinguistic elements.

The results showed as patients with RHD performed significantly worse than healthy controls in all the subscales of the ABaCo, i.e. linguistic, extralinguistic and paralinguistic, both in comprehension and production. Individuals with RHD showed a similar decreasing trend in their performance on the linguistic and extralinguistic scales of the ABaCo. More in detail, they produced and comprehended sincere (standard) communicative acts as well as healthy controls;

however, they performed significantly less well than healthy controls when faced with the most difficult communicative phenomena: they failed in the communicative tasks that required a high inferential load, namely comprehension and production of deceit and irony. We proposed, in line with the CPT, that a deficit in inferential ability, frequently reported after RHD (e.g., Beeman, Bowden, & Gernsbacher, 2000; Tompkins, Lehman, & Baumgaertner,1999), could be considered as one of the cognitive factors responsible for patients' difficulties in dealing with such tasks.

The similar pattern of performance in linguistic and extralinguistic tasks of the ABaCo provided evidence to support another hypothesis of the CPT: understanding the speaker’s communicative intention involves similar inferential processes regardless of the gestural or linguistic input used to convey the meaning. According to this view, the comprehension and production of linguistic and extralinguistic communicative acts (as in the case of sincere (standard), irony and deceit) share the most relevant cognitive processes. Recent neuroimaging studies also support the hypothesis that common processes are involved in the recognition of communicative intentions regardless of the specific expressive modality used to convey the meaning (Tettamanti et al., 2017), but further investigation is needed.

The results of cluster analyses confirmed that a deficit in inferential ability may be responsible for pragmatic impairment in RHD: we found a subgroup of patients (LEI group) with a substantial impairment on the extralinguistic and linguistic scales of the ABaCo. On the other hand, another subgroup (PI group) only exhibited severe impairment on the paralinguistic scale of the ABaCo. Thus, we proposed that the two different communicative performance profiles may be due to two distinct types of impairment, namely impaired inferential ability in the LEI group, and impaired emotional and prosodic processing in the PI group.

The ABaCo proved to be sensitive enough to detect the variability that characterises communicative deficits following RHD. As in most of the previous studies (Cote et al., 2007; Champagne-Lavau et al., 2009; see also Blake, 2017), a limit of our study is that the experimental sample was highly heterogeneous with respect to the patients’ clinical features, lesional profile and communicative performance; however, we have shown that a comprehensive evaluation of pragmatic ability, as provided using the ABaCo (comprehension and production; linguistic, extralinguistic and paralinguistic modalities; a wide range of pragmatic phenomena: sincere (standard) communicative acts, deceit and irony; basic speech acts, basic emotions, paralinguistic contradiction; see chapter 2.2.2.1), and the use of a background pragmatic theoretical framework, as provided by the CPT, could make it possible to detect different patterns of communicative difficulties and to clarify, at least in part, the nature of such pragmatic disorders following RHD.

A limit of the present study is that we have not provided a neuropsychological evaluation in order to identify the cognitive functions, such as theory of mind and EFs, that may have contributed to generating the communicative-pragmatic impairment observed in individuals with RHD. Previous studies suggested that the presence of pragmatic deficits in RHD may be related to cognitive deficits (e.g., Rainville et al., 2003; Griffin et al., 2006). Thus, more research is needed to clarify the relation between pragmatic impairment and cognitive deficits in RHD.

We considered the role of cognitive ToM and EFs in inferential pragmatic ability in the second study of this thesis. Individuals with TBI have often been reported to show deficits in communicative-pragmatic ability. In addition, TBI is frequently associated with damage to the frontal lobe, and as a result it may impair cognitive functions generally associated with the frontal areas of the brain, such as ToM and EFs. Thus, in individuals with TBI it is possible to evaluate whether the presence of pragmatic impairment is associated with concurrent ToM and EF deficits.

In the second study, we investigated the role of cognitive functions, i.e. theory of mind and executive functions, in explaining pragmatic disorders in individuals with TBI. We used the linguistic and extralinguistic scales of the ABaCo in order to evaluate the possible role of EFs and ToM in originating the trend of increasing difficulty in comprehension and production of sincere (standard) communicative acts, deceit and irony that we found in the first study of this thesis in individuals with RHD, and we hypothesised to be present also in individuals with TBI. In addition, we administered a battery of neuropsychological and theory mind tasks to evaluate cognitive performance – i.e. basic neuropsychological functions - attention and long-term memory-, EF - planning, cognitive flexibility and working memory-, and ToM.

Results showed that individuals with TBI performed worse than controls in all the pragmatic tasks administered, i.e. linguistic and extralinguistic tasks, both in comprehension and production. The analysis of communicative performance once again showed an increasing trend of difficulty, regardless of the gestural or linguistic input used to convey meaning, in line with the assumptions of the CPT and with the results of the first study. We then examined the relationship between cognitive deficits and pragmatic impairment. The results showed that EFs and ToM provided a unique contribution (that is, not mediated by other cognitive functions) in explaining pragmatic performance of patients with TBI on the linguistic and extralinguistic scales of the ABaCo, even after controlling for the role of more basic cognitive functions, i.e. long-term memory and attention. We also examined the role of ToM and EF in comprehension and production of different communicative phenomena, i.e. sincere (standard) communicative acts, deceit and irony. For EFs, we only observed a significant effect for the comprehension of linguistic irony. ToM contributed to increase significantly the percentage of explained variance of TBI patients' performance in the extralinguistic production of sincere (standard) and deceitful communicative acts, and the linguistic and extralinguistic comprehension of deceit.

Our results confirmed that ToM plays a role in the ability to comprehend and produce deceit, in line with other authors who claimed the importance of such cognitive function in dealing with deceit (Peskin, 1996). On the contrary, differently from Winner et al. (1998), we found no evidence to support the hypothesis that a deficit in ToM is the main factor able to explain the difficulties of individuals with TBI in understanding and producing ironic communicative acts. In line with the CPT, we proposed that another cognitive factor, the inferential load necessary to infer the speaker's communicative intention, may be responsible for the fact that individuals with TBI performed less well in dealing with irony. A limit of the present investigation is that it only considered a limited number of EFs, 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).

In the third study, we focused on sincere (standard) communicative acts, deceit and irony, in order to investigate the neural underpinning of the comprehension of such pragmatic phenomena. No previous studies in the literature have compared neural activation during the comprehension of irony and deceit: we conducted this study to fill this gap. We used fMRI to investigate in healthy participants whether common or different neural circuits underlie the comprehension of the same speech act, uttered with the intention of being sincere, deceitful or ironic. We wanted to test the theoretical assumption of the CPT which hypothesised that the comprehension of deceitful and ironic (non-standard) communicative acts is more difficult that the comprehension of sincere (standard) ones because it involves recognising the presence of a conflict between the speaker's utterance and what he privately thinks. The CPT also predicted that irony would be more difficult to understand than deceit, because it depends on the recognition of this conflict on the basis of the knowledge shared by the communicative partners.

The results of the study showed as a left fronto-temporal network is involved in irony comprehension. The clusters were located in the left inferior frontal gyrus (IFG) with extension into the middle frontal gyrus (MFG) and dorsolateral prefrontal cortex (DLPFC), in the left middle/superior temporal gyrus (MTG), and in the temporo parietal-junction (TPJ). As far as deceit is concerned, we observed a brain network including the IFG, the MFG, the DLPFC. These results showed that the TPJ, an area generally related to theory of mind tasks, was activated by irony recognition, and the DLPFC, an area associated with executive processes, was found to be active during the recognition of both ironic and deceitful speech acts, confirming the role of these cognitive functions in pragmatic processing.

However, the results also revealed that the key areas activated by the recognition of both ironic and deceitful speech acts were the left IFG, the MFG, the DLPFC. These areas are generally involved in the comprehension of non-literal forms of language that require high-order linguistic processing, which are necessary to integrate contextual information and to infer the speaker's communicative intention (e.g. Rapp et al., 2012; Jang et al., 2013; Basnakova et al., 2013). We suggested that these areas may be important in detecting a contrast between the literal aspects of a sentence and the speaker's private knowledge. This result is also in line with a recent study by Prado et al. (2015), who suggested that pragmatic processing interacts with logical inference-making when understanding arguments in narrative discourse. The authors found that two areas, i.e. the MFG and IPL, are specifically involved in pragmatic inference. They proposed that the right dMFG might detect a conflict between background information and a stated conclusion.

The recognition of an ironic vs. a deceitful speech act activated the left MTG, that, in line with the theoretical assumption of the CPT (Bara, 2010), we suggest is specifically involved in discriminating between a deceitful and an ironic communicative intention, based on what is, or is not, shared by the participants in the communicative interaction. Previous studies suggested that the MTG plays a role in integration of word in the sentence context (Jung-Beeman, 2005), in control the retrieval of semantic information (Davey et al., 2016), and in non-mental inferential processes (Jang et al., 2013).

In conclusion, the results of the studies reported in this thesis shed further light on the cognitive and neural mechanisms involved in the pragmatic processing of communicative intention within a communicative exchange; we also showed the different ways in which deficits in cognitive functions and inferential ability may impair communicative-pragmatic ability following brain damage.

5.1 Future perspective

The studies presented in this thesis provided new insights into the relationship between cognitive functions and pragmatic ability. However, further investigations are needed to clarify the effects we found.

The results of the present studies confirmed the importance of addressing the interplay between cognitive functions and pragmatic ability when we evaluate the nature and the extent of pragmatic disorders. However, the experimental results showed the size of the effect of the relationship between cognitive functions and pragmatic ability to be modest, with a large percentage of variance of pragmatic performance that often remained unexplained (see Rowley, Rogish, Alexander, & Riggs, 2017).

Inferential processing has been considered as one of the defining elements of *pragmatics* since the term was first defined (Levinson, 1983). Several studies in the fields of *pragmatics* have conflated the concept of inference in the social domain with that of inference in communication. Even though theory of mind may require inferential reasoning about other people's mental states, the inferential processes necessary in order to recognise communicative intentions may not be identical to those required in theory of mind tasks (Cummings, 2015). Inferential ability has its own specificity, that is the object of study of *pragmatics*. For these reasons, it would be a challenge for future studies to investigate the differences between the social and non-social inferential processes involved during pragmatic comprehension and production of communicative acts. Neuroimaging studies can provide an important contribution in order to disentangle the similarities and differences between social and non-social inferential reasoning, in order to directly compare the neural activations during the execution of tasks requiring these two different types of inferential processes.

Lastly, it will be interesting to study the pattern of brain connectivity associated with pragmatic processing. As shown by our third study, and in line with previous literature (e.g. Rapp et al., 2012; Bohrn et al., 2010), several brain areas are involved in the comprehension of complex pragmatic phenomena such as irony and deceit. These activations may reflect the activity of different cerebral networks that support specific processes involved in pragmatic ability. In recent years, some studies have started to investigate functional and effective brain connectivity between the different networks involved in the recognition of communicative intentions (Spotorno et al., 2012; Prado et al., 2015; Tettamanti et al., 2017). The investigation of brain connectivity during the execution of pragmatic tasks could help to provide an insight into how different cognitive systems, such as the theory of mind network, localised in the MPFC, TPJ and precuneus, non-mental inferential mechanisms, generally related to the activity of fronto-parietal regions, and executive functions, related to the DLPFC and frontal regions, interact in order to allow a listener to derive the speaker's communicative intentions; more importantly, it could help to discover whether an altered pattern of brain connectivity among these systems might be responsible for the communicative difficulties observed in individuals with pragmatic disorders.

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