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Research report

Neural correlates underlying the comprehension of deceitful and ironic communicative intentions

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ABSTRACT

Neuroimaging studies have shown that a left fronto-temporo-parietal cerebral network is recruited in the comprehension of both deceitful and ironic speech acts. However, no studies to date have directly compared neural activation during the comprehension of these pragmatic phenomena. 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. In particular, the novelty of the present study is that it explores the existence of a specific cerebral area involved in the recognition of irony versus deceit. We presented 23 healthy participants with 48 context stories each followed by a target sentence. For each story we designed different versions eliciting, respectively, different pragmatic interpretations of the same target sentence – literal, deceitful or ironic–. We kept the semantic and syntactic complexity of the target sentence constant across the conditions. Our results showed that the recognition of ironic communicative intention activated the left temporo-parietal junction (lTPJ), the left inferior frontal gyrus (lIFG), the left middle frontal gyrus (lMFG), the left middle temporal gyrus (lMTG), and the left dorsolateral prefrontal cortex (lDLPFC). Comprehension of deceitful communicative intention activated the lIFG, the lMFG, and the lDLPFC. fMRI analysis revealed that a left fronto-temporal network–including the inferior frontal gyrus (IFG), the dorsolateral prefrontal cortex (DLPFC) and the middle frontal gyrus (MFG)–is activated in both irony and deceit recognition. The original result of the present investigation is that the lMTG was found to be more active in the comprehension of ironic versus deceitful communicative intention, thus suggesting its specific role in irony recognition. To conclude, our results showed that common cerebral areas are recruited in the comprehension of both pragmatic phenomena, while the lMTG has a key role in the recognition of ironic versus deceitful communicative intention.

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1. Introduction

The aim of the paper was to investigate the neural correlates involved in the recognition of the same speech act uttered with different communicative intentions, that is, of being sincere, deceitful or ironic. More in detail, we wanted 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 versus deceitful.

Pragmatic ability, i.e., the use of language in a specific context (Levinson, 1983) requires the listener to do more than merely decode the literal sense, and involves inferential processes in order to fill the gap that often exists between the literal meaning and the speaker's communicative intention (Bara, 2010; Bosco, Bono & Bara 2017; Grice, 1991; Searle, 1979). 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. A classical example is irony: a person could say [1] "*What a brilliant performance!*", [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 (Bara, 2010; Bosco & Bucciarelli, 2008).

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). The notion of irony is close to that of sarcasm, even though the latter is considered to be more bitter and caustic, and is usually directed against an individual (Gibbs, 1986). Sarcasm is thus generally considered a stronger form of verbal irony used to indirectly convey the speaker's criticism of a victim, which is able to provoke in the listener a negative attitude such as scorn or contempt (McDonald, 1999; McDonald & Pearce, 1996).

In the present investigation we considered all forms of irony and did not specifically focus on sarcasm. However, given the relationship between the two pragmatic phenomena we also took studies focusing on sarcasm into consideration.

Some authors have argued that the ability to infer the speaker's mental states, i.e., the theory of mind (ToM, Premack & Woodruff, 1978), is necessary to identify the ironical attitude expressed by a speaker (Sperber & Wilson, 2002). The relationship between ToM and irony is still not completely clear in the current literature: some studies have found this association (Happé, 1993), whereas others have not or have observed that it can be partially mediated by other cognitive functions, such as executive functions (Martin & McDonald, 2005; Mo, Su, Chan, & Liu, 2008). Furthermore, 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 (Bosco, Angeleri, Colle, Sacco, & Bara, 2013; Bosco, Angeleri, Sacco, & Bara, 2015; Colle et al., 2013; Honan, McDonald, Gowland, Fisher, & Randall, 2015; McDonald et al., 2014; Parola et al., 2016; Shany-Ur et al., 2012).

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; Schnell et al., 2016; Shibata, Toyomura, Itoh, & Abe, 2010; Spotorno, Koun, Prado, Van Der Henst, & Noveck, 2012; Uchiyama et al., 2012). In particular, in the last decade an increasing number of studies have explored the neural basis of irony comprehension. Uchiyama et al. (2006) found prominent activation in the inferior frontal gyrus (IFG), in the middle temporal gyrus (MTG) and in the medial prefrontal cortex (mPFC) during irony recognition. The authors interpreted activation in the mPFC as being related to mentalizing activity, 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), 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).

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 ToM (Winner, Brownell, Happé, Blum, & Pincus, 1998).

However, difficulties exhibited by typically developed children in recognizing deceit seem to be not only related to ToM ability, but also to the cognitive load that comprehension of deceitful speech acts requires. Indeed, successful recognition 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 (Bosco & Bucciarelli, 2008; Dennis, Purvis, Barnes, Wilkinson, & Winner, 2001; Russell, Jarrold, & Potel, 1994; Sullivan, Zaitchik, & Tager-Flusberg, 1994). 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; Gabbatore et al., 2014; Shany-Ur et al., 2012). 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).

The majority of studies investigating the neural basis underlying the recognition of verbal deceit have focused on moral reasoning (Harada et al., 2009; Wu, Loke, Xu, & Lee, 2011). 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). As shown by Winner et al. (1998), and Bosco and 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 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 (Bara, 2010; Bosco & Bucciarelli, 2008; Bucciarelli, Colle, & Bara, 2003). 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; Peskin, 1996; Winner et al., 1998), and that adults with psychiatric disorders (Colle et al., 2013) and with brain lesions perform less well in the comprehension and production of ironic utterances than deceitful speech acts (Angeleri et al., 2008; Gabbatore et al., 2014; McDonald et al., 2014; Parola et al., 2016; Shany-Ur et al., 2012). Recently, Bosco and Gabbatore (2017) showed that children's ability to solve ToM tasks was not able to explain their increasing capacity to comprehend ironic versus deceitful intention.

Neuroimaging studies have shown that several fronto-temporal and temporo-parietal areas in both hemispheres are recruited in the recognition of both ironic (Akimoto et al., 2014; Bohrn et al., 2012; Eviatar & Just, 2006; Rapp et al., 2012; Shibata et al., 2010; Spotorno et al., 2012; Uchiyama et al., 2012; Wakusawa et al., 2007) 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. The novelty of the present study is that it investigates 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 ToM, 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 ToM can be localized within a neural network comprising the MPFC, the TPJ and the PC (Schurz, Radua, Aichhorn, Richlan, & Perner, 2014; Van Overwalle & Baetens, 2009) 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 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 versus deceitful intention, since understanding irony entails more complex inferential processes than deceit, as underlined in previous studies (Angeleri et al., 2008; Bosco & Bucciarelli, 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.

2. Method

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.

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 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.

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

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.

Condition	Mean Length (SD) – number of words	Mean Length (SD) – number of syllabes	Mean Gulpease (SD)
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)

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 ($F_{(1,3)} = .22$, $p = .883$, $\eta^2_p = .01$) 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.

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 15 sec, followed by a fixation cross ("+") for 5–7 sec; then the target sentence was displayed on the screen for 6 sec followed by a fixation mark ("+") for 5–7 sec (see Fig. 1). The response screen was then presented for 4 sec followed by a 10/12 sec 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.

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 msec, 32 slices, matrix size = 92 × 96, slice gap = .5 mm, field of view (FOV) = 224 × 224 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 msec, TI 900 msec, TE 3.7 msec, voxel size 1 × 1 × 1 mm^3).

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 (Harada et al., 2009; Rapp et al., 2012; Schurz et al., 2014) 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

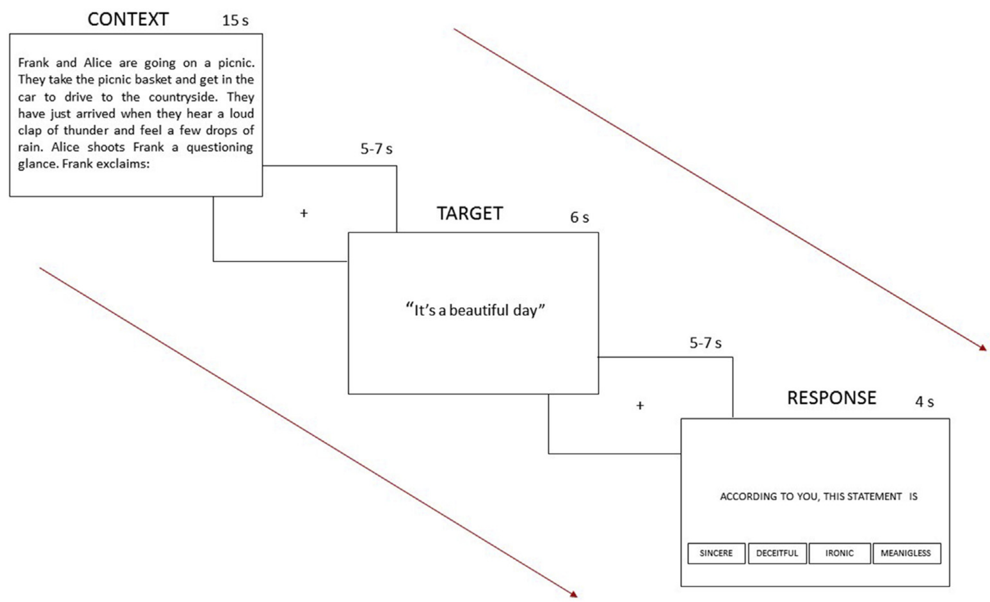

Fig. 1 – Structure of experimental task used in our study. Each trial started with the presentation on the screen of the context story for 15sec, followed by a fixation cross ("+") for 5–7sec; target sentence for 6sec, a fixation mark ("+") for 5–7sec and response screen for 4sec.

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 ToM related areas in the comprehension of irony and deceit (e.g., Bohrn et al., 2012; Harada et al., 2009; Rapp et al., 2012; Spotorno 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 ToM 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* versus *literal condition* and *ironic* versus *literal condition* to investigate neural correlates respectively recruited in these different cognitive processes, *ironic* versus *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* versus *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* versus *literal condition* we focused on the Left middle temporal gyrus (lMTG, $x = -56$, $y = -32$, $z = -2$), (Rapp et al., 2012), lIFG($x = -50$, $y = 24$, $z = 14$) (Rapp et al., 2012), lMFG($x = -54$, $y = 20$, $z = 28$), (Rapp et al., 2012), 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* versus *deceitful condition*, we focused on the lMTG($x = -56$, $y = -32$, $z = -2$) (Rapp et al., 2012). Lastly, for the conjunction analysis we focused on the lIFG($x = -52$, $y = 18$, $z = 14$) (Harada et al., 2009), lMFG($x = -54$, $y = 20$, $z = 28$) (Rapp et al., 2012), lDLPFC($x = -48$, $y = 18$, $z = 38$), (Harada et al., 2009), and Right Cerebellum ($x = 12$, $y = -78$, $z = -34$), (Rapp et al., 2012).

3. Results

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

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

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 $p < .05$ family-wise error corrected for multiple comparisons.

main effect of type of pragmatic phenomenon ($F_{(1,34)} = 5.12$, $p = .011$, $\eta_p^2 = .23$), 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.

3.2. *fMRI results*

Group analysis revealed significant brain activations in the following contrasts (see Table 2): i) in the *deceitful* versus *literal* condition, we observed the recruitment of the lIFG, lMFG, lDLPFC, right Cerebellum (Fig. 2); ii) in the *ironic* versus *literal* condition, we found significant increased activation in the lIFG, lMFG, lMTG, right cerebellum, lDLPFC, L supra./TPJp (Fig. 3); iii) in the *ironic* versus *deceitful* condition, we observed the involvement of the 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).

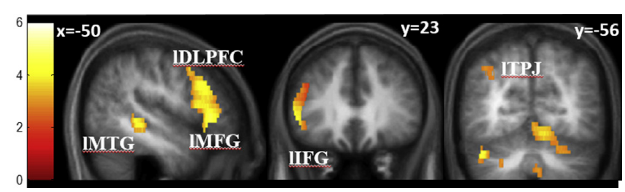

Fig. 3 – Brain activation maps in the *ironic* versus *literal* condition: left inferior frontal gyrus (lIFG), left middle frontal gyrus (lMFG), left middle temporal gyrus (lMTG), left dorsolateral prefrontal cortex (lDLPFC), L supra./TPJp.

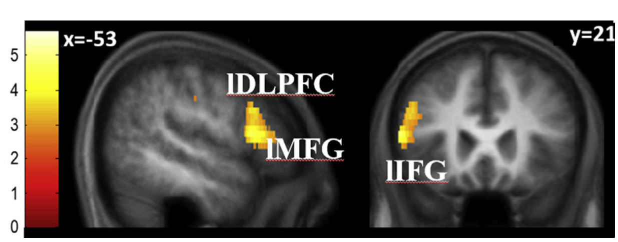

Fig. 2 – Brain activation maps in the *deceitful* versus *literal* condition: left inferior frontal gyrus (lIFG), left middle frontal gyrus (lMFG), left dorsolateral prefrontal cortex (lDLPFC).

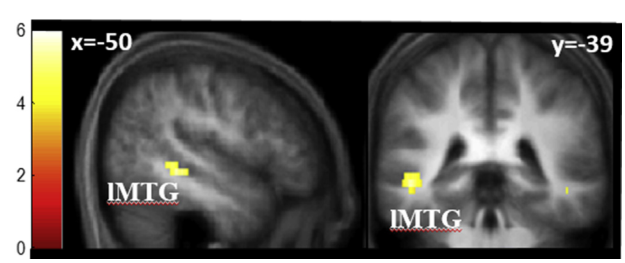

Fig. 4 – Brain activation maps in the *ironic* versus *deceitful* condition show the involvement of the left middle temporal gyrus (lMTG).

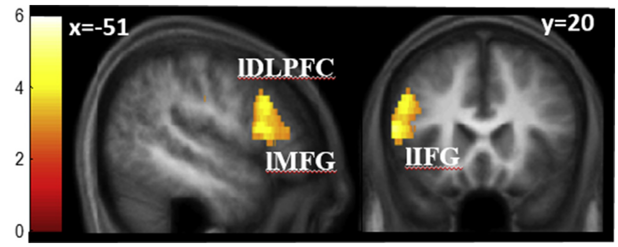

Fig. 5 – Conjunction analysis, *deceitful* > *literal* ∩ *ironic* > *literal*, show the involvement of common neural substrates (the left IFG, left MFG, left DLPFC) during the deceitful and ironic conditions.

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 (Angeleri et al., 2008; Gabbatore et al., 2014; McDonald et al., 2014; Parola et al., 2016; Shany-Ur et al., 2012).

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 versus literal and ironic versus 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 versus sincere/literal communicative intention activated: the lIFG, the lMFG, the DLPFC and the right cerebellum. The recognition of ironic intention, compared to recognition of sincere/literal one, activated the lIFG, the MFG, the 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 and 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 versus deceitful, we performed a contrast between these two conditions that revealed a specific area of activation, corresponding to the lMTG. The identification of this specific area of activation supports the theoretical assumption of Bosco and 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 lMTG (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.

4.1. *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 (Bara, 2010; Bosco & Bucciarelli, 2008) 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 (Bara, 2010; Bosco & Bucciarelli, 2008).

The activation of the lIFG is in line with the current fMRI literature investigating irony. For example Uchiyama et al. (2006), observed lIFG 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 lIFG and lMFG 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 lIFG with extension into the lMFG. 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, Gentili, Ricciardi, Bertinetto, & Pietrini, 2011; Rapp, Leube, Erb, Grodd, & Kircher, 2004), required in irony comprehension with respect to the comprehension of a literal speech act.

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; Bara, 2010; Shammi & Stuss, 1999) 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 lDLPFC 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 and 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.

4.3. Left posterior temporo parietal junction (TPJp)

In the present investigation we found the left TPJp to be activated by the contrast between irony versus literal speech act comprehension. A large body of evidence has shown that TPJ is classically activated by a third person ToM or mentalizing task (for a review see Van Overwalle, 2009; for a meta-analysis see Mar, 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, Koralek, Bryan, Montgomery, and Haxby (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; Sperber & Wilson, 2002; Winner & Leekam, 1991) 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 versus 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 ToM 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 ToM 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. *Left middle temporal gyrus (MTG)*

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

The lMTG plays a role in the semantic integration of word meaning in the sentence context (Noppeney & Price, 2004; Vandenberghe, Nobre, & Price, 2002). A meta-analysis by Ferstl et al. (2008) suggested that the lMTG 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 & Dronkers, 2011). Furthermore, Acheson and Hagoort (2013) found the lMTG 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 and 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 and 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 lMTG 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 versus 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 (lpMTG) 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.

4.5. *Right cerebellum*

In all our analyses, with the only exception of the specific contrast between the ironic versus 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 (De Smet, Paquier, Verhoeven, & Mariën, 2013; Mariën, Engelborghs, Fabbro, & De Deyn, 2001). 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.

4.6. *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 lIFG 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.

4.7. *Limitation*

A limit of the present investigation is the fact that we did not directly investigate the possible role of the ToM (Premack & Woodruff, 1978) or mentalizing ability in the understanding of a deceitful or ironic intention. Since the ToM 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.

5. Conclusion

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 versus deceitful communicative intention. Furthermore, unlike the majority of studies in the literature (e.g., Wu et al., 2011; Hayashi 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 lIFG, 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 versus a deceitful speech act also specifically activates the lMTG, 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.

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Supplementary data

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