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PRE-PRINT VERSION

**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 functional magnetic resonance imaging (fMRI) to investigate whether common or different neural circuits underlie the comprehension of the same communicative speech act, uttered with the intention of being sincere, deceitful or ironic. We presented 23 healthy participants with 48 context stories each followed by a target sentence. For each story we designed different versions eliciting, respectively, four different pragmatic interpretations of the same target sentence, i.e. literal, deceitful, ironic or meaningless. We kept the semantic and syntactic complexity of the target sentence constant across the conditions. Our results showed that comprehension of ironic speech acts activated the left temporo-parietal junction (TPJ), the left inferior frontal gyrus (IFG), the left middle frontal gyrus (MFG), the left middle temporal gyrus (MTG), and the left dorsolateral frontal cortex (DLPFC). In particular, the left MTG was also found to be more active in the comprehension of irony vs. deceitful speech acts, suggesting its specific role in irony recognition. Comprehension of deceitful speech acts activated the left IFG, the left MFG, and the left DLPFC. fMRI analysis revealed that a left fronto-temporal network - including the IFG, the DLPFC and the MFG - is activated in both irony and deceit recognition. Our results showed that specific areas are involved in the recognition of a specific speech act, i.e. deceitful or

ironic; while common cerebral areas are recruited in the comprehension of both pragmatic phenomena.

*Keywords:* communicative intention, pragmatics, deceit, irony, fMRI, speech act, comprehension

## 1. Introduction

The aim of the paper is to investigate the neural correlate involved in the recognition of the same speech act uttered with the intention of being sincere, deceitful or ironic. 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 (Searle 1979, Grice 1989; Bara 2010). 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 (Bosco & Bucciarelli 2008; Bara, 2010).

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). 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 et al., 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 (Shany-Ur et al., 2012; Bosco et al., 2013; Colle et al. 2013; McDonald et al., 2014; Honan, McDonald, Gowland, Fisher, & Randall, 2015; Parola et al., 2016).

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; Enrici, Adenzato, Cappa, Bara, & Tettamanti, 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). 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, Toyomura, Itoh, & Abe (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. Uchiyama et al. (2012) reported specific neural activation in the left amygdala during the understanding of sarcasm, which the authors suggested was related to the detection of the speaker's emotional status during irony comprehension. 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 a recent meta-analysis (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 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 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 (Sullivan et al., 1994; Russel et al., 1995; 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). 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 (Wu, Loke, Xu, & Lee, 2011; Harada et al., 2009). 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 theory of mind 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 & 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 theory of mind 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 perform less well in the comprehension and production of ironic utterances than deceitful speech acts (Shany–Ur et al., 2012; McDonald et al., 2014; Angelieri et al. 2008; Gabbatore et al., 2014; Parola et al., 2016).

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. The novelty of the present study is that it investigates the neural circuits underlying the comprehension of the same speech act uttered in different contexts

with the intention of being sincere, deceitful or ironic. In particular, we were mainly interested in delineating whether common and different neural circuits are activated in the recognition of ironic and deceitful speech acts. 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 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 different pattern of activation in the comparison of ironic vs. deceitful speech acts, since understanding irony might entail more 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 expected that (some) of these areas might be strongly activated in the comprehension of irony as compared to deceit.

## **2. Method**

### **2.1 Participants**

Twenty-three students (12M, 11F; mean age = 22.52 (SD= 1.62), range 19-26) took part in the experiment. All participants gave their informed consent; none of them received any payment for taking part. The study was approved by the Bioethical Committee of the University of Turin. 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 Aphasia 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 Uchyama 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 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.

The number of words within each of the four scenarios associated with each target sentence was kept constant. The mean number of words for each of the four scenarios associated with each target sentence ranged from 39.5 +/- 3.41/ and 51 +/- 2.94 words. The mean number of words for the target sentences was 5.41 +/- 1.83.

## **2.3 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.

Insert Fig. 1 about here

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.

## **2.4 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<sup>2</sup>, 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<sup>3</sup>).

## 2.5 fMRI data analysis

Image preprocessing was performed using SPM8 (Wellcome Department of Cognitive Neurology, London, UK) implemented in Matlab (Mathworks, Chesham, 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 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., 2012) to detect brain regions involved during

ironic and deceitful conditions. In particular, we performed several 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.

### 3. Results

#### 3.1 Behavioral results

The mean rate and standard deviation of participants' responses during fMRI tasks was  $97.2 \pm 4.0$  for the literal condition,  $89.4 \pm 10.2$  for the ironic condition,  $91.7 \pm 7.0$  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.

### 3.2 fMRI results

Group analysis revealed significant brain activations in the following contrasts (see Table 1): i) in the *deceitful vs literal* condition, we observed the recruitment of the left inferior frontal gyrus (IIFG), left middle frontal gyrus (IMFG), left dorsolateral prefrontal cortex (IDLDFC), right Cerebellum (Fig. 2); ii) in the *ironic vs. literal* condition, we found significant increased activation in the left inferior frontal gyrus (IIFG), left middle frontal gyrus (IMFG), left middle temporal gyrus (IMTG), right cerebellum, left dorsolateral prefrontal cortex (IDLDFC), L supra./TPJp (Fig.3); iii) in the *ironic vs deceitful* condition, we observed the involvement of the left middle temporal gyrus (IMTG), (Fig.4).

Insert Fig. 2 about here

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

Insert Fig. 3 about here

Fig. 3 Brain activation maps in the *ironic* vs *literal* condition: left inferior frontal gyrus (IIFG), left middle frontal gyrus (IMFG), left middle temporal gyrus (IMTG), left dorsolateral prefrontal cortex (IDLDFC), L supra./TPJp.

Insert Fig. 4 about here

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

Finally, the conjunction analysis (*deceitful* > *literal*  $\cap$  *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).

Insert Fig. 5 about here

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

**Table 1. Significantly activated brain regions**

	MNI Coordinates			Z-score	Brodmann area
	X	Y	Z		
<b>Contrast of interest</b>					
<i>deceitful condition &gt; literal condition</i>					
Left inferior frontal gyrus (IIFG)	-54	20	14	4.37	45
Left middle frontal gyrus (IMFG)	-49	18	34	4.36	8
Left dorsolateral prefrontal cortex (IDLDFC)	-49	16	30	3.67	44
Right Cerebellum	9	-82	-26	4.17	
<i>ironic condition &gt; literal condition</i>					
Left inferior frontal gyrus (IIFG)	-53	25	6	4.42	45
Left middle frontal gyrus (IMFG)	-46	19	34	4.36	8
Left middle temporal gyrus (IMTG)	-51	-39	2	3.49	21
Left dorsolateral prefrontal cortex (IDLDFC)	-48	13	30	3.71	44
Right Cerebellum	14	-81	-26	4.62	
L supra /TPJp	-54	-56	38	3.02	39
<i>ironic condition &gt; deceitful condition</i>					
Left middle temporal gyrus (IMTG)	-49	-37	-2	3.01	21
<b>Conjunction analysis</b>					
<i>deceitful &gt; literal</i> $\cap$ <i>ironic &gt; literal</i>					
Left inferior frontal gyrus (IIFG)	-54	20	14	4.38	45
Left middle frontal gyrus (IMFG)	-49	18	34	3.63	8
Left dorsolateral prefrontal cortex (IDLDFC)	-49	16	30	3.67	44
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  $p < 0.05$  family-wise error corrected for multiple comparisons.

#### 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. 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 speech acts vs. sincere/literal ones activated: the left frontal gyrus (IFG, BA 45), the left middle frontal gyrus (MFG, BA 8), the dorsolateral

prefrontal cortex (DLPFC, BA 44) and the right cerebellum. The recognition of ironic speech acts, compared to recognition of sincere/literal ones, activated the left inferior frontal gyrus (IFG, BA 45), the MFG, the middle temporal gyrus (MTG, BA 21), the right cerebellum and left posterior supra temporo-parietal junction (supra/TPJp, BA 39).

Furthermore a conjunction analysis (*deceitful* > *literal*  $\cap$  *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.

We also performed a contrast between ironic and deceitful speech acts that revealed a specific area of activation, corresponding to the left MTG. The identification of a specific area of activation in the contrast between irony and deceit comprehension is again in line with the theoretical assumption of Bosco & Bucciarelli, (2008) and Bara, 2010. As already discussed, to produce a deceitful speech act, 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. Our study revealed that the left MTG is the brain area (as discussed in detail in paragraph 4.5 below) specifically involved in discriminating between an ironic and a deceitful speech act, 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, BA 45) and left middle frontal gyrus (MFG, BA8)*

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 and Bookheimer, 1999) and has a crucial role in the comprehension of the exact meaning of a word in a context utterance (Badre and 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 and 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 and 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. (2013) 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.

#### *4.3 Left Dorsolateral frontal cortex (DLPFC, BA 44)*

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, S. E., Petrides, M., & Strafella, 2010). In order to recognize a deceitful (Bara, 2010) and an ironic speech act (Azim, Mobbs, Jo, Menon, & Reiss, 2005; Shammi and 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 and Bucciarelli, 2008) and irony comprehension (Bosco and 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 irony perceived by the participants. Finally, in a recent study by Chan and Lavalley (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.

#### *4.5 Left Middle temporal gyrus (MTG, BA 21)*

The left MTG was activated in the present investigation by the contrast between the recognition of ironic vs. literal speech acts and 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; Vandenberghe et al. 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 and Dronkers 2011). Furthermore, Acheson & Hagoort (2013) found the left MTG to be active in accessing word meaning.

Our result showing the activation of the MTG 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. Irony requires the partner to understand that what is said does not correspond to what the speaker intends (Grice 1991), whereas in deceit comprehension what the speaker says corresponds to what he literally says (even if it contrasts with his/her private knowledge, Bosco & Bucciarelli 2008; Bara 2010). 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.

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 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.

#### *4.6 Left posterior Temporo Parietal Junction (TPJp, BA 39)*

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 Overwall, 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 and coll. (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 and Leekman 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 Enrici et al. (2011) indicating that the left TPJ, but not the right 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.

#### *4.7 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; Uchyama et a. 2006) was located in the left MTG/STG. Lastly, of the sixteen clusters identified by Rapp et al. (2012), thirteen were located in the left cerebral hemisphere (LH), thus showing, in line with the results of the present investigation, a dominance of the LH. The LH dominance in the comprehension of complex pragmatic phenomena such as deceit and irony highlighted by the present investigation, is also in line with the meta-analysis by Bohrne et al. (2012) on the comprehension of figurative language. 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.

#### *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. Further studies 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 vs. deceitful and ironic. 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. A comparison of the neural correlate involved in the recognition of speech acts proffered with different communicative intentions will help us to gain wider, more coherent and complete knowledge of human pragmatic-communicative ability.

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