

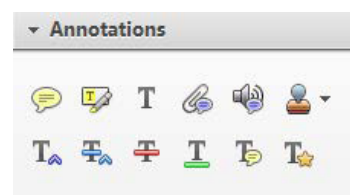
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Differential Impairments in Irony Comprehension in Brain-Damaged Individuals: Insight From Contextual Processing, Theory of Mind, and Executive Functions

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Objective: The comprehension of irony can be affected after brain injuries. The cognitive mechanisms accounting for such disorders remain yet unclear. The heterogeneity of cognitive profiles of brain-damaged individuals and the use of independent tests to measure the links between these mechanisms and the comprehension of irony might contribute to this lack of clarity. The present study aimed to further explore the underlying mechanisms of irony-understanding disorders (i.e., context processing, executive functions [EF], and theory of mind [ToM]) in patients with brain lesions. **Method:** We used a paradigm manipulating these mechanisms within an irony task to identify different patterns of pragmatic performance associated with cognitive profiles. We administered this task and standard neuropsychological tests assessing EF and ToM to 30 participants with acquired brain injury (ABI) and 30 healthy control (HC) participants. **Results:** A cluster analysis revealed that two thirds of the participants with ABI (3 subgroups out of 4) presented atypical pragmatic and neuropsychological patterns. The most severe disturbances in understanding irony, characterized by insensitivity to the context, were associated with a joint impairment of ToM and EF in 1 subgroup. In the 2 other context-sensitive subgroups, an isolated deficit in EF co-occurred with difficulties dealing with literal or ironic statements when the EF demand of the irony task was increased. However, the effect of this EF demand could be negated by the presence of markers helping the comprehension of irony. **Conclusion:** These results have important clinical implications for the evaluation and therapy of pragmatic disorders in individuals with ABI.

Key Points





Question: Explore the role of 3 cognitive mechanisms—context processing, EF, and ToM—in the comprehension of irony in patients with ABI. **Findings:** There are distinct subgroups of ABI, defined by different associations between these mechanisms and the understanding of irony. **Importance:** These cognitive mechanisms and the pathological profiles related to them should be considered in the development of assessment tools and therapies. **Next Steps:** The effectiveness of treatments targeting these cognitive mechanisms on the comprehension of irony should be further explored.

Keywords: irony, context processing, theory of mind, executive functions, right-brain injury

Supplemental materials: <http://dx.doi.org/10.1037/neu0000682.supp>

Irony is a form of nonliteral language in which the speaker says something but means something else, most commonly the opposite of what has been said (Gibbs, 1986). Let's imagine that Suzanne

and Alexander plan to picnic in the mountains, but the weather is just horrible: It's raining cats and dogs, and it's windy. Before they leave, Suzanne tells Alexander: "We are lucky with the weather."

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With the help of context, it's easy for Alexander to understand that the statement is ironic and that what Suzanne really means is that they are unlucky with the weather. Ironic utterances are relatively common in everyday life. They appear in 8% of conversational tours with friends (Gibbs, 2000) and approximately 5 times per episode of American comedies (Dews & Winner, 1997). Because poor comprehension of irony creates communication disorders, it can thus affect social and professional integration (Dahlberg et al., 2006; Hofgren, Esbjörnsson, & Sunnerhagen, 2010; Meulenbroek & Turkstra, 2016).

Many patients with acquired brain injury (ABI), following traumatic brain injury (TBI) or stroke in the right hemisphere (right hemisphere damage [RHD]), may experience difficulties understanding irony (see Lundgren & Brownell, 2016; Rowley, Rogish, Alexander, & Riggs, 2017 for reviews). Not all individuals with ABI, however, have such pragmatic deficits, and several studies have shown a significant heterogeneity of pragmatic disorders in populations with TBI or RHD (Blake, Duffy, Myers, & Tompkins, 2002; Champagne-Lavau, Cordonier, Bellmann, & Fossard, 2018; Champagne-Lavau & Joannette, 2009; Côté, Payer, Giroux, & Joannette, 2007; Dardier et al., 2011; McDonald & Pearce, 1996). Given the prevalence and heterogeneity of the disorders of non-literal language comprehension, one of the current challenges is to better understand the cognitive processes underlying these difficulties and to propose personalized and targeted therapies accordingly. The main goal of the present study was thus to investigate underlying mechanisms likely to account for difficulties in irony understanding in individuals with ABI. To take the heterogeneity into account, a cluster analysis was used in the present study, enabling us to identify different pragmatic profiles based on the performances of individuals with ABI on an irony task. Three mechanisms reported in the literature were considered in this study and are described herein: contextual processing, executive functions (EF), and theory of mind (ToM; see Martin & McDonald, 2003 for a review).

Understanding irony requires the integration of different types of contextual information. The perception of an incongruity between the context and the target statement is known to be an essential condition for understanding irony (Ivanko & Pexman, 2003; Kreuz & Glucksberg, 1989; Rivière, Klein, & Champagne-Lavau, 2018). Other markers, although not necessary, may also help (Attardo, 2000). This is the case for certain characteristics of the speakers, such as their professional occupation and the stereotypes attached to them: An ironic statement is judged more likely if produced by a comedian than by a priest (Pexman & Olineck, 2002). The presence of lexical markers, such as hyperbolic terms, within the utterance also facilitates the understanding of irony (e.g., "We are *extremely* lucky with this *amazing* weather!"; Kreuz & Roberts, 1995).

Several researchers have suggested that some patients with ABI may have difficulty detecting or using relevant contextual information to understand irony (Blake, 2010). Champagne-Lavau et al. (2018) demonstrated that a subgroup of patients with RHD showed a lack of sensitivity to contextual incongruity in the interpretation of ironic utterances. In the same way, Kaplan, Brownell, Jacobs, and Gardner (1990) highlighted that participants with RHD used only information about the actor's performance—not information about the relationship between characters—to judge whether the statement was ironic or truthful, as opposed to healthy subjects.

However, some studies tend to show that patients with ABI can make inferences when the context is sufficiently strong—strong contextual bias inducing the inference (Blake, 2009) or the presence of several contextual cues (McDonald & Flanagan, 2004). To our knowledge, no irony task has so far manipulated the strength of the context in terms of the absence or presence of markers inducing the comprehension of irony, such as speaker-occupation stereotypes and lexical markers, in patients with ABI. The present study sought to overcome this lack.

A second cognitive process, ToM, is critical to understanding irony. This ability to attribute mental states to others (Premack & Woodruff, 1978) allows us to bridge the gap between the literal meaning of a sentence and the intended meaning. It is thanks to inferences about the intention of the speaker that an interlocutor can perceive irony (Grice, 1957).

The links between ToM and comprehension of irony have been extensively highlighted through clinical and neuroimaging studies. Indeed, it is well established that deficits in ToM may result from a brain injury (for reviews, see Martin-Rodriguez & León-Carrión, 2010; McDonald, 2013; Weed, 2008). These deficits of ToM, and particularly second-order ToM, co-occurred with difficulties in understanding irony in many patients with ABI (Channon, Pelli-jeff, & Rule, 2005; McDonald & Flanagan, 2004; Shamay-Tsoory, Tomer, & Aharon-Peretz, 2005; Winner, Brownell, Happé, Blum, & Pincus, 1998; for a review see Rowley et al., 2017). Moreover, several studies using neuroimaging methods have shown the activation of a neural ToM network—left and right temporal-parietal junction, medial prefrontal cortex, and precuneus—when performing a task of irony understanding (Eviatar & Just, 2006; Shibata, Toyomura, Itoh, & Abe, 2010; Spotorno, Koun, Prado, Van Der Henst, & Noveck, 2012; Uchiyama et al., 2006; Wakusawa et al., 2007). Only one study (Martin & McDonald, 2005) found no association between measures of ToM and the comprehension of irony in patients with TBI. These authors suggested a role of general inferential reasoning rather than ToM to account for irony comprehension.

Finally, deficits in EF could also, at least in part, account for difficulties in understanding irony. The term *EF* refers to a set of cognitive control processes (e.g., inhibition, flexibility, working memory) that enable us to adapt our behavior in various goal-oriented situations (Miyake et al., 2000). EF would thus be strongly solicited in irony, insofar as the intentional meaning changes according to the context. Intact EF enable us to alternate rapidly between literal and nonliteral meanings and to inhibit salient but irrelevant literal meaning in a given context.

It is widely accepted that EF are mediated by networks, particularly involving the frontal lobes (Bettcher et al., 2016), and that they are frequently impaired after a brain injury (Channon & Watts, 2003; Honan, McDonald, Gowland, Fisher, & Randall, 2015; Zinn, Bosworth, Hoenig, & Swartzwelder, 2007; see McDonald, Flashman, & Saykin, 2002 for a review). The relationship between EF and the comprehension of nonliteral language is, however, more controversial. When EF are considered on the whole, hierarchical regression analysis suggests that working memory, cognitive flexibility, and planning contribute to the comprehension of irony (Bosco, Gabbatore, Angeleri, Zettin, & Parola, 2018; Bosco, Parola, Sacco, Zettin, & Angeleri, 2017). In a recent meta-analysis, Rowley and colleagues (2017) also demonstrated that the correlation between pragmatic understanding and EF was

from moderate to strong. On the other hand, the different EF, considered individually, do not seem to correlate to the understanding of irony in the same way. Indeed, flexibility skills are generally not related to measures of the comprehension of nonliteral language (Champagne, Desautels, & Joannette, 2004; Martin & McDonald, 2005; McDonald, 2000; McDonald et al., 2006; McDonald, Fisher, Flanagan, & Honan, 2017; Shamay-Tsoory et al., 2005), although an association between flexibility measures (the Trail Making Test [TMT; Reitan & Wolfson, 1993] and the Wisconsin Card Sorting Test [WCST; Heaton, 1981]) and nonliteral comprehension has been found in two studies (McDonald et al., 2006; Zimmermann, Gindri, de Oliveira, & Fonseca, 2011). Similarly, the links between working memory and the comprehension of nonliteral language are more contrasted; some studies have found links (Channon & Crawford, 2010; McDonald et al., 2006, 2017; Zimmermann et al., 2011), and others have not (Channon & Watts, 2003; Martin & McDonald, 2005). On the contrary, the role of inhibition in pragmatic understanding seems more obvious because all studies we know of have demonstrated a positive association between these two capacities (Champagne et al., 2004; Champagne-Lavau & Joannette, 2009; Channon & Crawford, 2010; Channon & Watts, 2003; McDonald et al., 2014). To explain the lack of consensus between EF and nonliteral language comprehension, many studies have put forward the hypothesis of a joint involvement of ToM and EF in the understanding of nonliteral language (Bosco et al., 2017; Byom & Turkstra, 2017; Champagne-Lavau & Joannette, 2009; Honan et al., 2015; McDonald et al., 2014). In addition, several studies (Byom & Turkstra, 2017; Honan et al., 2015; McDonald et al., 2014) have suggested that discourse and ToM disorders may be related to the cognitive demand of the task: Increasing demand in EF would reduce the ability of brain-injured patients to infer the mental states of others, such as ironic intent.

To summarize, many studies have focused on the relationship between ToM, EF, and irony comprehension. However, the tasks used vary significantly from one study to another, and the relationships are usually measured by independent measures (McDonald et al., 2014). Byom and Turkstra (2017) suggested that “a stronger method for examining the relationships between cognitive processes and social communication is to manipulate the theory of mind and executive function demands of the communication task itself” (p. 3). Nowadays, few authors have attempted to manipulate the cognitive processes involved in the comprehension of nonliteral language directly within the tasks created (Honan et al., 2015). Otherwise, the characteristic heterogeneity of brain-injured populations has rarely been considered in the analyses (Blake, 2017).

Therefore, the present study aimed to further explore the underlying mechanisms of irony-understanding disorders—context processing, ToM, and EF—in patients with ABI. To this end, we designed a written irony task that directly manipulated, within the task, (a) the context (presence or absence of contextual markers inducing irony) and (b) the EF demand (low or high). The presence of ironic and literal conditions allowed us to evaluate ToM through a question about the intention of the speaker (“What does X mean?”), which was asked at the end of each story. Standard ToM and EF tests were also administered. It was hypothesized that participants with ABI would be more sensitive to the presence of multiple markers of irony in the context and EF demand than the healthy subjects. In line with the current literature, we also aimed

to determine whether or not participants with ABI exhibited different pragmatic profiles associated with different neuropsychological performances. The following were hypothesized:

1. Deficits in ToM will manifest in difficulties in understanding irony in all conditions, regardless of the presence of markers of irony or EF demand. This lack of sensitivity to the context will manifest itself primarily as errors of literal interpretations in ironic conditions.
2. EF—especially inhibition—deficits will increase errors in the interpretation of literal and ironic statements in conditions with high EF demand. We expected erroneous literal and nonliteral interpretations related to uninhibited irrelevant information.
3. Concomitant deficits in ToM and EF will result in difficulties in all ironic conditions. These difficulties could be exacerbated in ironic conditions with high EF demand.
4. The absence of markers of irony in the stories will exacerbate the difficulties described in Hypotheses 2 and 3. The conditions with high EF demand and without markers of irony will be the ones in which participants with EF deficits will fail more frequently.
5. Participants with ABI will vary in the extent to which they manifest these difficulties.

Method

Participants

Thirty participants (18 males, 12 females) with chronic ABI were recruited from the outpatient records of a number of hospitals and clinical centers in the French part of Switzerland (Hôpital Fribourgeois [HFR], Hôpital Neuchâtelois [HNE], Clinique romande de réadaptation, and Foyer Valais de Coeur). All participants met the following inclusion criteria: They were between 18 and 65 years old and native French speakers; they received the medical diagnosis of stroke in the right hemisphere or moderate to severe TBI (Glasgow Coma Scale score of 13 or below or post-traumatic amnesia [PTA] of at least 24 hr; Maas, Stocchetti, & Bullock, 2008; Teasdale & Jennett, 1974); they were at least 6 months post-brain injury. Exclusion criteria included previous psychiatric or alcoholic history, reading difficulties, or aphasia according to neuropsychological reports and scores on the Détection des Troubles du Langage chez l'Adulte et la personne âgée (DTLA; Macoir et al., 2017) or a reading subtest of the Montreal-Toulouse Aphasia Battery (MT-86; Nespoulous et al., 1992). Thirteen of the participants had sustained a stroke in the right hemisphere, and 17 had a history of a moderate to severe TBI (9 in road traffic accidents and 8 in falls). The mean time since injury for all participants was 44.3 months (standard deviation [*SD*] ± 43.67), and the duration of PTA, taken from neuropsychological reports for 11 of the 17 participants with TBI, was 35.7 days (*SD* ± 44.51). Further clinical details, including clinical and radiological magnetic resonance imaging (MRI) or computed tomography (CT) reports, are available in Table 1.

Table 1
Demographic and Clinical Data for Participants With ABI

Participants	Gender	Age (years)	Education (years)	Etiology	Time post-onset (months)	Lesion site
ABI1	F	48	12	TBI	251	Right fronto-temporo-parietal
ABI2	M	36	12	TBI	12	Bilateral frontal, subcortical—diffuse injury
ABI3	F	57	13	TBI	60	Right frontotemporal, bilateral parietal—diffuse injury
ABI4	M	34	12	TBI	80	Right frontotemporal, subcortical—diffuse injury
ABI5	F	49	12	TBI	20	Right fronto-temporo-parieto-occipital, left temporal
ABI6	M	44	13	TBI	82	Right frontotemporal
ABI7	M	24	16	TBI	24	Right frontal
ABI8	M	42	13	TBI	246	Bilateral frontal, right temporal
ABI9	F	59	9	TBI	149	Bilateral frontal, right temporal, subcortical—diffuse injury
ABI10	M	49	13	TBI	45	Bilateral frontal, right temporal, white matter
ABI11	M	57	18	TBI	20	Right frontal
ABI12	M	59	16	TBI	44	Bilateral frontal, left temporal
ABI13	F	53	12	TBI	21	Right frontotemporal
ABI14	M	49	12	TBI	14	Bilateral fronto-parietal
ABI15	M	59	18	TBI	17	Right fronto-temporo-occipital—diffuse injury
ABI16	M	24	16	TBI	38	Bilateral fronto-parietal
ABI17	M	45	13	TBI	7	Bilateral frontotemporal, left parietal
ABI18	F	52	12	RHD	30	Right fronto-parieto-temporal
ABI19	M	58	13	RHD	30	Right anterior cerebral artery
ABI20	F	54	9	RHD	18	Right middle cerebral artery, right frontal
ABI21	F	54	12	RHD	16	Right frontal
ABI22	F	59	11	RHD	62	Right frontal
ABI23	M	64	9	RHD	83	Right middle cerebral artery
ABI24	M	64	13	RHD	108	Right fronto-occipital
ABI25	M	60	15	RHD	90	Right frontal
ABI26	F	63	9	RHD	31	Right frontal
ABI27	M	55	16	RHD	62	Right middle cerebral artery
ABI28	F	52	11	RHD	5	Right middle cerebral artery (M1, M2 segments)
ABI29	M	64	13	RHD	3	Right middle cerebral artery, subcortical
ABI30	F	45	12	RHD	6	Right fronto-temporo-parietal

Note. ABI = acquired brain injury; TBI = traumatic brain injury; RHD = right-hemisphere damage (following a stroke).

Thirty healthy control (HC) participants (12 males, 18 females) with similar demographic characteristics and no previous neurological history were also recruited in the local community. Exclusion criteria included psychiatric or alcoholic history, reading disabilities, and a score below 26 on the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005), a screening tool for neurocognitive impairment. They were matched with the participants with ABI for age (ABI mean [M] = 51.07, SD = 10.74; HC M = 51.2, SD = 10.59), $t(58) = 0.48$, $p > .05$, and level of education (ABI M = 12.83, SD = 2.42; HC M = 12.83, SD = 2.57), $t(58) = 0.01$, $p > .05$.

The study was approved by the local ethics committee (Commission cantonale d'éthique de la recherche sur l'être humain [CER-VD]), and all participants had given their written informed consent before inclusion in the study.

Materials and Procedure

All participants were tested individually, in a quiet room, for between 1 and 4 sessions depending on their level of fatigability. They were assessed with regard to their EF capabilities, ToM abilities, and irony understanding. The order of administration of the tests was counterbalanced between the participants.

Standard measures: Executive functions. Standardized neuropsychological tests were used to evaluate EF in all participants. Inhibition was assessed with the French version of the Hayling

Test (Rouleau, 1998), where participants had to complete sentences with the expected word (automatic condition) or an unexpected word (inhibition condition). Two scores (automatic and inhibition scores), based on response accuracy and response latencies in each condition, were calculated according to Burgess and Shallice (1997). Verbal fluency (letters *D* [DTLA; Macoir et al., 2017] and *F* [MoCA; Nasreddine et al., 2005]) was assessed, with the total number of words for the two letters as an index of mental flexibility. Finally, working memory was assessed with the Digit Span subtest (forward and backward) from the Wechsler Adult Intelligence Scale (3rd ed.; WAIS-III; Wechsler, 1981) and the French version of the Reading Span Test (RST; Desmette et al., 1995). For each test, the longest series of numbers and words recalled was used as a measure of working memory.

Standard measures: Theory of mind. A short version of the Faux Pas test of the Mini-Social Cognition and Emotional Assessment (Mini-SEA; Bertoux, 2014) was used to assess ToM abilities. The participants had to read 10 shorts stories, half of which contained a social faux pas. After each story, the participants had to determine if a character had said something that he or she should not have said. In the faux pas stories, the participants subsequently had to infer the unintentionality of the faux pas and the possible hurtfulness for the listener. In the control stories, no faux pas was committed. After all the stories, non-ToM-based memory questions were asked to assess the participants' story comprehension.

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Three scores were calculated: the faux pas stories (out of 30 total), control stories (out of 10 total), and total (out of 40 total) scores.

Experimental paradigm: Irony comprehension. An irony-comprehension task was purposely designed to explore the influence of context integration, EF, and ToM in the comprehension of irony. The irony-comprehension task consisted of 18 brief scenarios, inspired by Spotorno et al. (2012) and Champagne-Lavau et al. (2012). Each story depicted an interaction between two characters of different genders and ended with a statement that could be interpreted literally or ironically depending on the context preceding the statement. After each story, the participants had to answer two questions: a question on the speaker’s intent (“What does X [the speaker] mean?”) and a control question on contextual information (see Figure 1).

Each story was controlled in terms of structure and length. The first two sentences introduced the two characters. The third sentence introduced the contextual element, positive or negative, that induced the literal or ironic interpretation. A fourth neutral sentence was followed by the final utterance of the speaker. The stories were 70–80 words long and ended with a 5- to 8-word utterance, which was stated by a male speaker 50% of the time.

To evaluate to what extent the subjects were sensitive to the context and cognitive resources, six story conditions were created by manipulating three factors: (a) the context (inducing a literal or ironic meaning), (b) the EF demand of the stories (low or high), and (c) the markers of irony (with or without) cueing a speaker ironic intent (see Figure 1).

As previously mentioned, the context was manipulated in the third sentence of the story to induce a literal or an ironic meaning:

In the literal conditions, the target sentence (e.g., “The meal tonight will be hearty”) was always preceded by a positive context (e.g., fruitful fishing), whereas in the ironic conditions in the target sentence, it was preceded by a negative context (e.g., unsuccessful fishing).

The EF demand of half of the stories was manipulated by adding a four-sentence distractor paragraph, introducing a new character and irrelevant information for the interpretation of the target sentence. By bringing some noise and increasing the distance between the relevant contextual element (third sentence) and the target sentence, this supplementary paragraph increased the load on inhibition, flexibility, and working memory. It was absent in the (literal and ironic) conditions with low EF demand but was added to the (literal and ironic) conditions with high EF demand.

Finally, in the ironic conditions (with both low and high EF demand), the stories were manipulated in terms of the presence or absence of markers of irony. In the ironic conditions with markers (with low or high EF demand), an occupation stereotype cueing ironic intent was associated with the ironic character, whereas a lexical term of exaggeration was added to the target sentence. These markers were absent in the ironic conditions with no marker (with low or high EF demand).

In summary, each story was derived from six conditions:

- Literal with low EF demand
- Literal with high EF demand
- Ironic with low EF demand and no marker of irony
- Ironic with high EF demand and no marker of irony
- Ironic with low EF demand and markers of irony
- Ironic with high EF demand and markers of irony

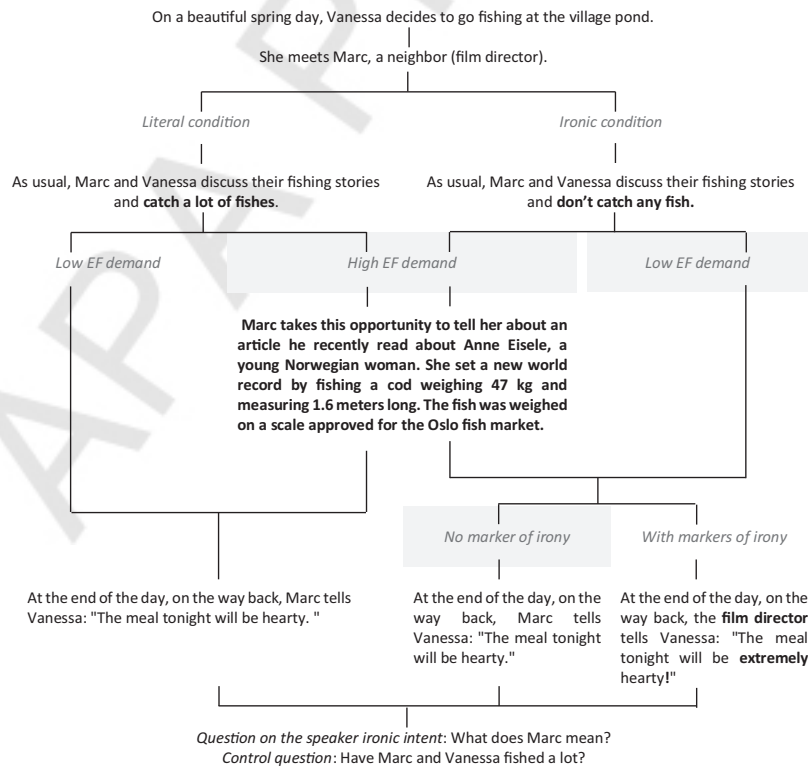


Figure 1. ●●●

Given the number of stories (18 stories \times 6 conditions), three groups of items, each comprising one third of the stories (6 of each condition), were created according to a Latin square design. Each ABI and HC participant was then randomly assigned to one of the three groups.¹ To control prosody and memory effect, stimuli were presented one at a time in a fixed randomized order on a single screen and were left on display during the answering of the questions.

Scoring. Verbal answers to questions on each speaker's intent were audio-recorded and transcribed. A binary scoring system was developed based on pilot data. In the literal conditions, 1 point was given for a correct paraphrase of the statement. In the ironic conditions, the participants were expected to mention an ironic intention, that is, a meaning that opposed or was different from the target utterance or a correct function of irony (e.g., "He is mocking the character") to score 1 point. Any other answer was rated 0. The errors were then classified according to five categories: incorrect ironic response (in literal conditions), incorrect literal response (in the ironic conditions), incorrect nonliteral response (e.g., "The character is flirting/is telling lies/doesn't want to hurt"), no response (e.g., "I do not know"), and other (off-topic answers).

Answers to each control question were also scored 1 if correct and 0 if incorrect. Half of the correct answers were "yes," and the other half were "no." All data were scored by the first author, and a random sample of the data (20% of the data, 792 responses) was scored by a research assistant who was blind to the type of participants tested. The interrater reliability was 96.59%, with a Cohen's kappa of .828 ($p < .0001$), showing strong interrater reliability. All differences were resolved by discussion.

Validation of the material. Two pilot studies were conducted to validate the material. The purpose of the first pilot study was to ensure a good understanding of the ironic or literal intention of the statements in the 20 stories. Forty-two undergraduate students (M age = 19.86, SD = 1.68) from the University of Neuchâtel and Geneva (Switzerland) were recruited. For each story, they were asked to judge if the final statement was sincere or sarcastic (with an "I don't know" answer available). The 18 stories with the highest success score were retained (M percentage of success = 97.55%, SD = 2.87).

The second pilot study, using the Pexman and Olineck (2002) procedure, was conducted to identify the occupation stereotypes cueing the speaker's ironic intent. This occupation stereotype then had to be incorporated into the stories in the ironic conditions with markers of irony. Fifty undergraduate students (M age = 22.48, SD = 3.01) from the University of Neuchâtel were recruited. They were asked to rate the likelihood that people with different occupations would make an ironic remark in a given situation (flat tire on the way to work) using a 5-point scale (1 = *low probability*, 5 = *high probability*). Of the 80 occupations tested in that pilot study, the following 10 occupations were judged as having the highest probability ($p > 3.3$) of ironic remarks ("sarcastic occupations"): radio host, TV show host, comedian, mechanic, film director, driving instructor, journalist, holiday club host, film critic, and lawyer (M = 3.65, SD = 0.31). The results of a paired t test showed that the average judgment of the 10 occupations selected differed significantly from the midpoint of the Likert scale (i.e., 3), $t(9) = 6.69$, $p < .0001$. Similarly, an independent t -test analysis revealed that the average judgment of the 10 occupations

selected was significantly higher than the average judgment of the 70 occupations not selected, $t(78) = 8.97$, $p < .0001$.

Data Analyses

Unpaired t tests were used to explore group differences in the neuropsychological data. To examine differences between groups in the irony task, two repeated-measure ANOVAs were performed. First, a 2 (Group: ABI, HC) \times 2 (Context: Literal, Ironic) \times 2 (EF Demand: Low, High) repeated-measures ANOVA was performed on the mean of correct responses to the question on the speaker's intent and the control question. Because the factor markers of irony were not manipulated in the literal conditions, only ironic conditions with no markers of irony were considered in this analysis. Second, a 2 (Group: ABI, HC) \times 2 (Markers of Irony: Without, With) \times 2 (EF Demand: Low, High) repeated-measures ANOVA was performed on the mean of correct responses to the question on the speaker's intent and the control question for the ironic conditions. These analyses were also performed with age as a covariable (analysis of covariance [ANCOVA]). The results showed no main effect of age or significant interaction with the age factor and thus are not reported here.

To account for the heterogeneity of patients regarding irony comprehension, a hierarchical cluster analysis using Ward's method (Ward, 1963) was then undertaken. This analysis was based on the responses of individuals with ABI to the speaker's intent questions in the six conditions. The Ward's method results were used to classify our participants with ABI into several subgroups according to their performance under the different conditions of the task. Participants with similar performances were thus grouped together in the same subgroup. Grouping clusters leads to the minimum increase in total within-cluster variance; thus, this agglomerative method has the advantage of minimizing the increase in the total within-cluster sum of the squared error, which is proportional to the euclidean distance squared between the centers of the clusters. Nonparametric analyses were then performed to characterize the different profiles obtained. Following these analyses, the different subgroups were named a posteriori according to the problematic condition(s) evidenced.

Measures of effect sizes were also calculated for each effect of interest by providing the partial eta squared for ANOVAs and the Cohen's d for t tests. The effect size was small if its value was between 0.01 and 0.05, moderate if between 0.06 and 0.13, and large if above 0.14 for the partial eta squared. For Cohen's d , the effect size was small if between 0.2 and 0.4, moderate if between 0.5 and 0.7, and large if above 0.8. Given multiple testing, the alpha level was adjusted with the false-discovery-rate (FDR) method using the Benjamini-Hochberg procedure. After this correction, the threshold of significance was set at $p < .019$ for all the analyses. Statistical analyses were conducted using Statistical Package for the Social Sciences (SPSS) Version 25.

¹ To control for the equivalence between the three lists of stimuli, a one-way analysis of variance (ANOVA) was performed on the total score calculated on questions on the speaker's intent of the task of irony. No significant difference between the three lists was found, $F(2,57) = 0.45$, $p > .05$.

Results

Group Comparison on Neuropsychological Measures

The neuropsychological characteristics of both groups are detailed in Table 2. The ABI group performed more poorly than the control group on the MoCA score and several EF measures, especially verbal inhibition (Hayling Test) and working memory (Digit Span, backward). They also had lower performance on ToM (Mini-SEA total score and Faux Pas score).

Group Comparison on Irony Comprehension: Irony With No Marker Versus Literal

Questions on the speaker’s intent. The ironic conditions (with low and high EF demand) were initially compared with the literal conditions (with low and high EF demand) for the two groups. The 2 (Group: ABI, HC) × 2 (Context: Literal, Ironic) × 2 (EF Demand: Low, High) repeated-measures ANOVA on the number of correct responses to the question on the speaker’s intent showed a main effect of group, $F(1, 58) = 7.99, p < .007; \eta_p^2 = .121$, with the participants with ABI having a significantly worse performance than the HC participants. There was also a main effect of context, $F(1, 58) = 10.98, p < .002; \eta_p^2 = .159$, with poorer performance in the ironic conditions with no marker of irony than in the literal conditions. A main effect of the EF demand was found, $F(1, 58) = 38.69, p < .0001; \eta_p^2 = .4$, with more errors in the high-EF-demand conditions than in the low-EF-demand conditions. The results also showed a significant Group × EF Demand interaction, $F(1, 58) = 16.66, p < .0002; \eta_p^2 = .223$. This interaction was broken down according to group. The ABI group made more errors in the high-EF-demand conditions than in the low-EF-demand conditions ($p < .0001$), whereas this difference did not exist in the HC group ($p > .05$). No further interactions were significant (see Table 3).

Control questions. the 2 × 2 × 2 repeated-measures ANOVA revealed a main effect of group, $F(1, 58) = 12.10, p < .001; \eta_p^2 = .173$, meaning that the participants with ABI made more errors than the HC participants. There was no main effect of context, $F(1, 58) = 0.15, p > .05$, and no main effect of EF

demand, $F(1, 58) = 2.59, p > .05$. No interactions were significant (see Table 3).

Group Comparison on Irony Comprehension: Irony With and Without Markers

Questions on the speaker’s intent. The ABI and HC groups were then compared with regard to the ironic conditions with and without markers of irony (with low and high EF demand). The 2 (Group: ABI, HC) × 2 (Markers of Irony: Without, With) × 2 (EF Demand: Low, High) repeated-measures ANOVA on the number of correct responses to the question on the speaker’s intent showed a main effect of EF demand, $F(1, 58) = 48.26, p < .0001; \eta_p^2 = .454$, with poorer performance in the high-EF-demand conditions than in the low-EF-demand conditions. There was no main effect of group, $F(1, 58) = 4.81, p < .033$, and no main effect of markers of irony, $F(1, 58) = 5.01, p < .03$. Group × Markers of Irony, $F(1, 58) = 0.97, p > .05$; Group × EF Demand, $F(1, 58) = 5.36, p < .025$; and Markers of Irony × EF Demand, $F(1, 58) = 3.71, p > .05$, interactions were not significant. The Group × Markers of Irony × EF Demand interaction was significant, $F(1, 58) = 7.63, p < .008; \eta_p^2 = .116$. This interaction was broken down according to group. In the high-EF-demand conditions, the ABI group made more errors in the ironic stories with no marker of irony than in the ironic stories with markers of irony ($p < .002$). In the low-EF-demand conditions, there was no difference between the ironic stories with or without markers of irony for that group ($p > .05$). In the HC group, there was no difference between the ironic stories with no marker of irony and the ironic stories with markers of irony, either in the high-EF-demand condition ($p > .05$) or in the low-EF-demand condition ($p > .05$; see Table 3).

Control questions. The 2 × 2 × 2 ANOVA revealed a main effect of EF demand, $F(1, 58) = 7.24, p < .01; \eta_p^2 = .111$, with a poorer performance in the high-EF-demand conditions than in the low-EF-demand conditions. There was no main effect of group, $F(1, 58) = 5.54, p > .05$, and no main effect of markers of irony, $F(1, 58) = 0.43, p > .05$. The Group × EF Demand interaction was significant, $F(1, 58) = 10.11, p < .003; \eta_p^2 = .148$. The participants with ABI made more errors in the high-EF-demand conditions than in the low-EF-demand conditions ($p < .0001$),

Table 2
Neuropsychological Data for Participants With ABI and HC Participants

Measure	ABI		HC		<i>t</i>	<i>p</i> value	Cohen’s <i>d</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>			
MoCA	25.67	3.21	27.43	1.41	2.76	.009*	0.76
Digit Span (forward)	8.20	2.25	9.83	2.44	2.70	.009*	0.67
Digit Span (backward)	6.90	1.88	8.63	2.03	3.43	.001*	0.82
RST	2.50	0.82	2.87	0.63	1.94	.057	—
Letter fluency (<i>D + F</i>)	21.43	7.84	27.53	7.40	3.10	.003*	0.77
Hayling (automatic)	6.03	0.72	6.47	0.51	2.70	.009*	0.69
Hayling (inhibition)	8.30	3.16	11.67	1.86	5.02	.0001*	1.10
Mini-SEA (total)	27.90	7.65	33.67	4.69	3.50	.001*	0.84
Mini-SEA (Faux Pas)	18.31	7.41	23.80	4.67	3.42	.001*	0.82
Mini-SEA (control)	9.59	0.98	9.87	0.51	1.38	.178	—

Note. ABI = acquired brain injury; HC = healthy control; MoCA = Montreal Cognitive Assessment; RST = Reading Span Test; Mini-SEA = Mini-Social Cognition and Emotional Assessment. The asterisk symbol (*) indicates significant differences between the groups.

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Table 3
Correct Responses to Questions on the Speaker’s Intent and the Control Questions in Each Condition in Participants With ABI and HC Participants

Questions	ABI		HC	
	<i>M</i> (/6)	<i>SD</i>	<i>M</i> (/6)	<i>SD</i>
Questions on the speaker’s intent				
Literal				
Low EF demand	5.77	0.57	5.87	0.35
High EF demand	5.17	0.95	5.77	0.50
Ironic				
Low EF demand				
No markers	5.57	0.94	5.67	0.48
With markers	5.40	1.16	5.87	0.35
High EF demand				
No markers	4.40	1.67	5.40	0.93
With markers	5.17	1.12	5.43	0.82
Control questions				
Literal				
Low EF demand	5.77	0.57	5.97	0.18
High EF demand	5.73	0.45	5.93	0.25
Ironic				
Low EF demand				
No markers	5.90	0.31	5.93	0.25
With markers	5.93	0.25	5.93	0.25
High EF demand				
No markers	5.67	0.55	5.97	0.25
With markers	5.77	0.50	5.93	0.25

Note. ABI = acquired brain injury; HC = healthy control; EF = executive functions.

whereas such a difference did not exist in the HC group ($p > .05$). No further interactions were significant (see Table 3).

Overall, these results suggest that the participants with ABI made more errors than the HC participants in answering questions on the speaker’s intent, especially in the conditions of high EF demand. Unlike the HC participants, they performed more poorly on ironic stories with no markers of irony than in ironic stories with markers of irony in high-EF-demand conditions. They also performed more poorly in answering control questions in the high-EF-demand conditions, although their scores remained high.

Different Patterns of ABI Performance

The hierarchical cluster analysis undertaken according to the performance of participants with ABI on the questions on the speaker’s intent in the six conditions revealed four clusters (see Figure 2) suggesting four patterns of performance. These four subgroups were named a posteriori according to the problematic condition(s) evidenced on the nonparametric analyses: unimpaired on ironic evaluation (ABI-U), impaired in the literal condition with high EF demand (ABI-LH), impaired in the ironic condition with no markers of irony and high EF demand (ABI-INH), and impaired in all the ironic conditions (ABI-I).

Because of the small number of participants in each subgroup, nonparametric tests (Kruskal–Wallis) were conducted to explore differences between the five groups (HC, ABI-U, ABI-LH, ABI-INH, and ABI-I) with regard to age, educational level, time since onset, neuropsychological data, and the irony task. A post hoc

Mann–Whitney test was performed when a difference was found in the Kruskal–Wallis analyses between the neuropsychological variables and the irony task. For the sake of clarity, only the significant results of the post hoc Mann–Whitney tests obtained in each subgroup are presented here.

Kruskal–Wallis analyses performed on sociodemographic and neuropsychological data revealed significant differences between groups on measures of working memory (Digit Span, backward), verbal inhibition (Hayling Test), and ToM (Mini-SEA total score and Faux Pas score). Means, standard deviations, and p values for sociodemographic variables and neuropsychological tests are available in Table 4.

The results of each subgroup in every condition of the irony task for the questions on the speaker’s intent and the control questions are shown in Table 5. The Kruskal–Wallis analysis performed on the correct responses to the questions on the speaker’s intent for each condition revealed significant group differences in all the conditions, except for the literal condition with low EF demand.

For the correct responses to the control questions, the Kruskal–Wallis analysis revealed significant differences between the subgroups only in the ironic condition with no markers of irony and high EF demand. The other differences were not significant.

Analyses of the results of the post hoc Mann–Whitney test revealed four profiles, characterized by distinct pragmatic and neuropsychological patterns.

Participants unimpaired on ironic evaluation (ABI-U profile; 7 TBI, 3 RHD). Thirty-three percent of the participants with ABI performed similarly to HC participants on the irony, executive, and ToM tasks. They made only 7 errors (out of 360 answers), mostly incorrect and nonliteral, when answering the questions on the speaker’s intent.

Participants impaired in the literal condition with high EF demand (ABI-LH profile; 4 TBI, 5 RHD). Thirty percent of the participants with ABI characterized by an inhibition deficit (Hayling Test, inhibition: $U = 57.50, p < .009$) showed difficulties in interpreting literal statements in the high-EF-demand condition ($U = 16, p < .0001$). Their 34 errors (out of 324 responses) were essentially incorrect ironic responses (30%) in the literal conditions and incorrect nonliteral responses (30%; e.g., “The character is flirting/is telling lies”) in the ironic conditions.

Participants impaired in the ironic condition with no markers of irony and high EF demand (ABI-INH profile; 3 TBI, 3 RHD). Twenty percent of our participants exhibited a co-occurrence of deficits in working memory (Digit Span, backward: $U = 34, p < .016$) and inhibition (Hayling Test, inhibition: $U = 18.50, p < .002$), with difficulties in answering the questions on the speaker’s intent ($U = 12.50, p < .0001$) and the control questions ($U = 33, p < .014$) in the ironic conditions with no marker of irony and a high EF demand. They made 28 errors (out of 216 answers) when answering the questions on the speaker’s intent: 43% of the errors were classified as incorrect nonliteral responses and 32% as incorrect literal responses.

Participants impaired in all the ironic conditions (ABI-I profile; 3 TBI, 2 RHD). Seventeen percent of our participants had poorer performance than the HC group when answering the questions on the speaker’s intent in all the ironic conditions: ironic

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F2

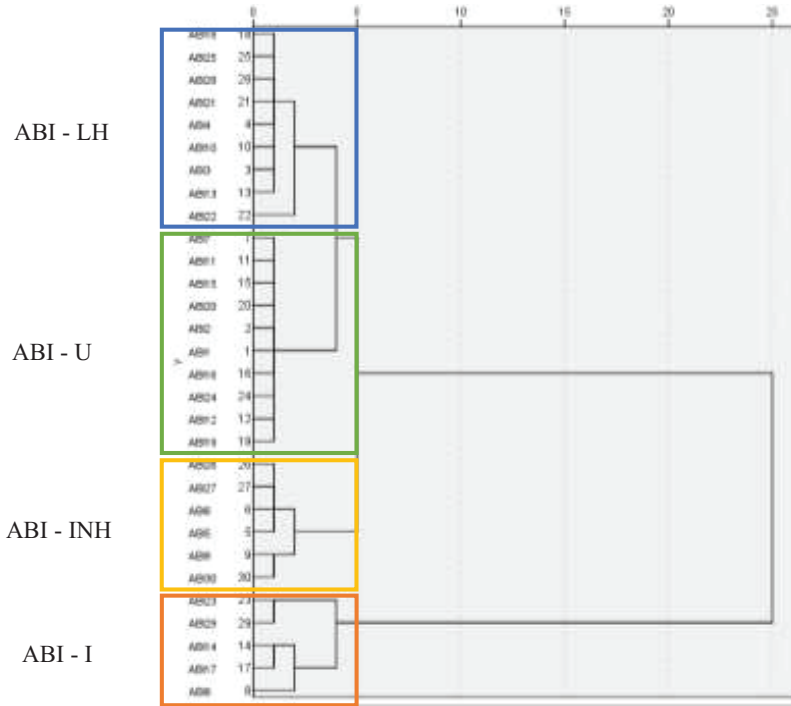


Figure 2. See the online article for the color version of this figure.

conditions with no markers of irony and low EF demand ($U = 25$, $p < .017$) or high EF demand ($U = 1$, $p < .0001$) and ironic conditions with markers of irony and low EF demand ($U = 0$, $p < .0001$) or high EF demand ($U = 6$, $p < .0001$). Out of the 71 errors (out of 180 answers), the majority of the errors (55%) were incorrect literal interpretations, whereas 33% of the errors were

incorrect nonliteral responses. This pattern of pragmatic performance co-occurred with worse performance on inhibition (Hayling Test, inhibition: $U = 2.50$, $p < .0001$; Hayling Test, automatic: $U = 24$, $p < .014$), working memory (Digit Span, backward: $U = 22$, $p < .01$), and ToM (Mini-SEA total: $U = 5.50$, $p < .001$; Mini-SEA Faux Pas: $U = 5$, $p < .001$).

Table 4

Sociodemographic and Neuropsychological Data for HC Group Compared With Participants With ABI (ABI-I, ABI-INH, ABI-LH, ABI-U)

	ABI-I		ABI-INH		ABI-LH		ABI-U		HC		<i>H</i>	<i>p</i> -value
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>		
Age	50.00	9.76	52.50	7.74	52.22	7.71	48.30	14.95	51.20	10.59	0.11	.998
Educational level (years)	12.75	0.50	11.83	2.64	12.33	1.23	14.30	2.95	12.83	2.57	4.63	.328
Time post-onset (month)	70.60	103.37	58.33	52.44	45.44	29.59	56.20	73.86	—	—	0.67	.879
MoCA	23.50	4.66	25.50	2.74	25.67	2.40	27.50	1.58	27.43	1.41	10.94	.027
Digit Span (forward)	7.25	1.26	8.17	3.43	8.00	1.41	9.10	2.23	9.83	2.44	9.50	.05
Digit Span (backward)	5.75	2.06	5.83	2.32	7.22	0.97	7.90	1.79	8.63	2.03	12.40	.015 £\$
RST	2.00	0.82	2.50	0.55	2.33	0.71	3.00	0.82	2.87	0.63	10.82	.029
Letter fluency (<i>D + F</i>)	20.25	8.73	21.17	6.21	22.44	8.38	22.50	8.10	27.53	7.40	8.44	.077
Hayling (automatic)	5.25	1.50	6.00	0.00	6.22	0.44	6.30	0.48	6.47	0.51	12.42	.015 \$
Hayling (inhibition)	5.50	2.52	7.00	3.16	9.00	2.83	9.90	2.89	11.67	1.86	23.25	.0001 !£\$
Mini-SEA (total)	17.75	8.06	30.33	2.25	28.44	6.56	30.00	8.03	33.67	4.69	14.69	.005 \$
Mini-SEA (Faux Pas)	8.75	6.95	20.67	1.51	19.11	6.77	20.00	8.03	23.80	4.67	14.00	.007 \$
Mini-SEA (control)	9.00	2.00	9.67	0.82	9.33	1.00	10.00	0.00	9.87	0.51	6.84	.144

Note. HC = healthy control; ABI = acquired brain injury; ABI-I = impaired comprehension in all ironic conditions; ABI-INH = impaired comprehension in ironic condition with no markers and high executive functions (EF) demand; ABI-LH = impaired comprehension in literal condition with high EF demand; ABI-U = unimpaired irony comprehension; MoCA = Montreal Cognitive Assessment; RST = Reading Span Test; Mini-SEA = Mini-Social Cognition and Emotional Assessment. The symbols !, £, and \$ indicate significant differences between the groups, with ! HC ≠ ABI-LH; £ HC ≠ ABI-INH; \$ HC ≠ ABI-I.

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Table 5

Correct Responses to Questions on the Speaker's Intent and Control Questions in Each Condition in HC Group Compared with Participants With ABI (ABI-I, ABI-INH, ABI-LH, ABI-U)

Questions	ABI-I		ABI-INH		ABI-LH		ABI-U		HC		H	p value
	M	SD	M	SD	M	SD	M	SD	M	SD		
Questions on the speaker's intent												
Literal												
Low EF demand	5.60	0.55	5.50	0.84	5.78	0.67	6.00	0.00	5.87	0.35	5.82	.213
High EF demand	4.80	1.30	5.33	0.52	4.33	0.71	6.00	0.00	5.77	0.50	30.25	.0001!
Ironic												
Low EF demand												
No markers	4.00	1.41	5.83	0.41	5.89	0.33	5.90	0.32	5.67	0.48	13.61	.009 \$
With markers	3.00	0.71	5.83	0.41	5.89	0.33	5.90	0.32	5.87	0.35	27.91	.0001\$
High EF demand												
No markers	1.60	1.14	3.33	0.82	5.33	0.50	5.60	0.52	5.40	0.93	28.33	.0001£\$
With markers	3.20	0.84	5.83	0.41	5.11	0.78	5.80	0.42	5.43	0.82	20.15	.0001\$
Control questions												
Literal												
Low EF demand												
No markers	5.60	0.55	5.50	0.84	5.78	0.67	6.00	0.00	5.97	0.18	10.84	.028
High EF demand												
With markers	5.60	0.55	5.83	0.41	5.56	0.53	5.90	0.32	5.93	0.25	9.28	.054
Ironic												
Low EF demand												
No markers	5.80	0.45	5.83	0.41	5.89	0.33	6.00	0.00	5.93	0.25	2.50	.644
With markers	5.80	0.45	5.83	0.41	6.00	0.00	6.00	0.00	5.93	0.25	3.69	.450
High EF demand												
No markers	5.20	0.84	5.33	0.52	5.89	0.33	5.90	0.32	5.97	0.18	21.82	.0002£
With markers	5.40	0.89	5.83	0.41	5.67	0.50	6.00	0.00	5.93	0.25	9.11	.059

Note. HC = healthy control; ABI = acquired brain injury; ABI-I = impaired comprehension in all ironic conditions; ABI-INH = impaired comprehension in ironic condition with no markers and high executive functions (EF) demand; ABI-LH = impaired comprehension in literal condition with high EF demand; ABI-U = unimpaired irony comprehension. The symbols !, £, and \$ indicate significant differences between the groups, with ! HC ≠ ABI-LH; £ HC ≠ ABI-INH; \$ HC ≠ ABI-I.

Discussion

The present study aimed to further explore the underlying mechanisms of ironic-understanding disorders (i.e., context processing, EF, and ToM) in patients with ABI. To this aim, we created the first irony task in which context, EF demand, and ToM were manipulated. The EF demand in the literal and ironic stories was manipulated by adding (high EF demand) or not adding (low EF demand) a distractor paragraph introducing irrelevant information for the interpretation of the target sentence. In the ironic conditions (with low and high EF demand), the stories were manipulated in terms of the presence or absence of markers inducing irony. Finally, the presence of ironic and literal conditions enabled us to evaluate ToM through a question about the intention of the speaker ("What does X [the speaker] mean?"), which was asked at the end of each story. We administered this task and classical neuropsychological tests assessing working memory, flexibility, inhibition, and ToM to 30 participants with ABI and 30 HC participants.

The main results showed that the ABI group made more errors than the HC group in answering questions about the literal or ironic intent of target statements, especially when the EF demand was high and in the absence of markers of irony. Given the heterogeneity of neuropathology and disorders following a brain injury, we conducted a cluster analysis to identify the interindividual differences possibly masked by the group analysis. This analysis pointed out that although one subgroup (ABI-U) did not differ from the HC group, the three other subgroups (ABI-LH,

ABI-INH, ABI-I) showed different neuropsychological and pragmatic patterns of performance. Such results confirmed the known heterogeneity and difficulties in understanding irony in individuals with ABI (Blake et al., 2002; Bosco et al., 2018; Champagne-Lavau et al., 2018; Champagne-Lavau & Joannette, 2009; Channon et al., 2005; Winner et al., 1998). These profiles did not differ in sociodemographic measures. On the contrary, the ability to process the context and the EF and ToM deficits seem to account for the different pragmatic profiles observed in the participants with ABI.

The ability to process the context differed according to our groups. Indeed, one subgroup (ABI-I, impaired in all the ironic conditions) exhibited a poor performance when answering the questions on the speaker's intent in all ironic conditions, regardless of the presence of markers of irony, with many incorrect literal interpretations of ironic utterances. This expected pattern of performance strengthens previous results showing that some individuals with ABI might be insensitive to context and would process the ironic statements locally (e.g., RHD-I subgroup in Champagne-Lavau et al., 2018; Cornejo et al., 2007; Kaplan et al., 1990). Two subgroups (ABI-U, unimpaired on ironic evaluation, and ABI-LH, impaired in the literal condition with high EF demand) succeeded in all the ironic conditions (with and without markers of irony). These findings confirm that such markers (occupation stereotype cueing ironic intent and lexical terms of exaggeration) are not necessary for the comprehension of irony (Attardo, 2000) because these participants with ABI performed well in ironic stories with

and without markers of irony. On the other hand, our results are in line with previous studies showing that patients with ABI are able to make inferences when the context is sufficiently strong (Blake, 2009; McDonald & Flanagan, 2004). Indeed, one subgroup (ABI-INH, impaired in the ironic condition with no markers of irony and high EF demand) made more errors than HC participants when answering the questions on the speaker's intent in ironic conditions with no markers of irony and high EF demand but performed well in conditions with markers of irony and either high or low EF demand. Our study is, however, the first to suggest that markers of irony, such as occupation stereotypes and lexical terms of exaggeration, could help some patients with ABI understand irony despite the impact of EF demand, as we will discuss further.

A second significant result suggests a potential role for certain EF in the comprehension of irony. As expected, the three subgroups with pragmatic impairments (ABI-LH, ABI-INH, and ABI-I) exhibited inhibition deficits measured by the Hayling Test. The preponderant role of inhibition in the comprehension of irony is consistent with prior literature (Champagne et al., 2004; Champagne-Lavau & Joannette, 2009; Channon & Crawford, 2010; Channon & Watts, 2003; McDonald et al., 2014). In the same way, the absence of flexibility disorders in our different subgroups supports the controversial role of flexibility in pragmatics abilities (Champagne et al., 2004; Martin & McDonald, 2005; McDonald, 2000; McDonald et al., 2006, 2017; Shamay-Tsoory et al., 2005).

A new finding concerns the influence of increased EF demand on the understanding of irony. Two subgroups (ABI-LH and ABI-INH) exhibited pragmatic impairments only in conditions with high EF demand. These results support earlier studies that found an impact of cognitive task demand on discourse (Byom & Turkstra, 2017; McDonald et al., 2014), understanding of metaphors (Prat, Mason, & Just, 2012), and ToM capacities (Honan et al., 2015) in individuals with TBI, individuals with RHD, and HCs. In our irony task, the addition of a distracting paragraph increased the gap between relevant information (e.g., the contextual incongruity) and the target statement. The resources in working memory were consequently more demanded. Just and Carpenter (1992) suggested that performance deterioration in language processing would be observed in tasks exceeding the limited resources in working memory. Tompkins, Bloise, Timko, and Baumgaertner (1994) thus demonstrated a significant correlation between measures of working memory and the ability to solve incongruous and congruent attitudinal inferences in individuals with RHD. Comprehension of irony is a complex process requiring the detection and repair of incongruity. Adding a distractor paragraph in ironic stories further increased the demand for working memory. We may presume that ironic conditions with a distractor paragraph required more working-memory resources than those available to our ABI-INH participants, as confirmed by their performance on the backward Digit Span. This insufficiency resulted in significant difficulties in answering questions on the speaker's intent in the ironic condition with high EF demand. The significant, albeit minimal, error rate in the factual control questions ($M = 5.3/6$) may also reflect the impact of the stories' length with high EF demand. These difficulties, however, were not apparent in the ironic condition with high EF demand when markers of irony were present. In this condition, an occupation stereotype was associated with the ironic character at the beginning of the story and before the target statement, and a lexical term of exaggeration was added to the

target statement. These markers of irony, being placed just before the target statement, could thus decrease the load in working memory by helping the participant to infer the ironic intention of the character at the end of the story. It would be interesting in future research to identify the nature and the number of indices contributing to the understanding of irony in participants with ABI because their influence has been suggested in several studies (Blake, 2010; Kaplan et al., 1990).

Similarly, we can assume that adding a distractor paragraph requiring a high level of working memory is likely to have exacerbated ToM impairments in the ABI-LH subgroup, as suggested by Honan et al. (2015). However, the novelty of this study lies in the analysis of errors in the questions on the speaker's intent, enabling a more detailed analysis of the ToM profiles of our participants. Abu-Akel (2003) suggested that ToM disorders could be represented as a continuum ranging from (a) an absence of understanding of the mental states of others to (b) a good understanding of mental states but a poor ability to apply them to (c) an intact understanding of the mind of others but a deterioration in the understanding of one's own mind. By their large proportion of incorrect ironic responses in the literal condition with high EF demand, the ABI-LH group appeared to present the second type of ToM disorder, characterized by an overattribution of intentions (Abu-Akel, 2003; Champagne-Lavau & Joannette, 2009). In contrast, the pattern of performance of the ABI-I subgroup seemed to correspond to the first type: They tended to respond literally to questions about the speaker's intent in the ironic conditions, regardless of the EF demand, and had a worse performance on the Faux Pas test. This latter subgroup also had significant EF deficits, confirming that a joint deficit of ToM and EF is generally associated with the most severe pragmatic disorders (Bosco et al., 2017; Byom & Turkstra, 2017; Champagne-Lavau & Joannette, 2009; Honan et al., 2015; McDonald et al., 2014).

These results have important clinical implications. They highlight the necessity of considering the cognitive demand of the tasks used to assess pragmatic disorders. This cognitive demand must be considered in both the structure of the stimuli and the format of the tasks used. The results of McDonald and Saunders (2005) suggest that audiovisual tasks, although more ecological, increase the amount of information to be processed and, therefore, the difficulties manifested by patients with ABI. The heterogeneity of the performances reported in this study must also be considered for therapies. Indeed, it is essential to identify the underlying deficit that may explain the difficulties to propose tailored and personalized treatments (Blake, 2007; Channon & Crawford, 2010; Tompkins, 2012). Several therapies based on the supposed underlying causes—suppression deficits, ToM, EF, and cognitive resources—have been advanced (Blake, 2007; Tompkins, 2012). The task developed in this study, by allowing the identification of distinct profiles, thus seems promising for the development of future therapies.

Several limitations of the present study need to be addressed. First, the sample size of 30 participants, although consistent with experimental studies involving brain-injured individuals, was relatively small. Once the cluster analysis was completed, subgroups contained a tiny number of individuals. If the generalization to other patients may prove to be limited, it is essential to note that these profiles confirm different results highlighted in the literature. Furthermore, it would be interesting to replicate the present study

with other EF tests to confirm our results. Finally, the lack of information on neuropathology did not enable us to identify the impact of brain damage on pragmatic performance.

To conclude, this study is the first to use a paradigm manipulating the mechanisms underlying irony-comprehension disorders (i.e., context integration, ToM, and EF) within an irony task. This paradigm allowed us to shed new light on these mechanisms, which proves to be of some importance. Our results confirmed the role of inhibition in the comprehension of irony and clarified the impact of working-memory impairment on understanding more cognitively complex ironic stories. The presence of markers of irony, such as speaker stereotypes and lexical markers, might help some patients with ABI bypass the cognitive-load effect. Our results also showed that the association of executive and ToM disorders might lead to the most severe pragmatic diseases, characterized by insensitivity to context and literal interpretations of ironic statements. The various impairments of these mechanisms might account, at least in part, for the heterogeneity of the irony-comprehension disorders observed in individuals with ABI.

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