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Research Article

Exploring Cognitive-Pragmatic Heterogeneity Following Acquired Brain Injury: A Cluster Analysis of Hint Comprehension

Natacha Cordonier,[a,b] Marion Fossard,[a] Yves Tillé,[c] and Maud Champagne-Lavau[b]

[a] Institut des sciences logopédiques, Faculté des lettres et sciences humaines, Université de Neuchâtel, Switzerland [b] Aix-Marseille Université, CNRS, LPL, Aix-en-Provence, France [c] Institut de statistique, Faculté des sciences, Université de Neuchâtel, Switzerland

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ABSTRACT

Purpose: Difficulties understanding nonliteral language (especially hints) are frequently reported following acquired brain injury (ABI). Several cognitive mechanisms, such as context processing, executive functions, and theory of mind (ToM), may underlie these disorders. However, their role remains controversial, mainly because of the characteristic heterogeneity of this population. Therefore, our study aimed to identify cognitive-pragmatic profiles in individuals with ABI.
Method: A new task of hint comprehension, manipulating executive demand, markers of hints, and ToM and neuropsychological tests were administered to 33 participants with frontal ABI and 33 control participants. Cluster analysis, a method sensitive to profile heterogeneity, was applied and coupled with error analysis.
Results: We highlighted two cognitive-pragmatic profiles. One subgroup of participants with ABI exhibited contextual insensitivity, leading them to infer the utterance meaning based on linguistic decoding alone—literal meaning. This difficulty in understanding hints was associated with deficits in working memory, inhibition, and ToM. The second subgroup of participants with ABI showed difficulty with literal statements, associated with impaired inhibition and ToM. In addition, the two subgroups differed only on the ToM task. This result suggests that various types of ToM deficit (misunderstanding vs. incorrect attribution of mental states) could contribute to the variability of the pragmatic profiles observed (difficulties in interpreting hints vs. literal statements).
Conclusion: The experimental design adopted in this study provides valuable insight into the explanatory hypotheses of nonliteral language comprehension disorders and has important clinical implications.
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A speaker wishing to obtain something (e.g., to have a coffee paid for) has a panoply of language strategies available to formulate their request (Blum-Kulka et al., 1989). They can thus resort to direct requests ("Buy me a coffee!") or indirect ones. Among the latter, they can opt for conventional indirect requests ("Will you buy me a coffee?") or unconventional indirect requests (also referred to as a hint: "I forgot my wallet."). By its opacity, the latter strategy has the advantage of leaving the speaker and the interlocutor the possibility of disengaging from the request (Weizman, 1989). However, understanding it is more complex. Indeed, hints are coded in the mental lexicon under their more frequent literal meaning (Giora, 2002). Therefore, a context-specific analysis and additional inferential processes are required for an adequate understanding of the request.

This complexity is a source of difficulty for individuals who have acquired brain injuries (ABIs) following traumatic brain injury (TBI) or stroke. Indeed, several studies have demonstrated that individuals with ABI may have difficulty understanding hints (Champagne-Lavau & Joanette, 2009; Dardier et al., 2011; Evans & Hux, 2011;

Correspondence to Natacha Cordonier: natacha.cordonier@gmail.com. *Disclosure: The authors have declared that no competing financial or nonfinancial interests existed at the time of publication.*

Hatta et al., 2004; Muller et al., 2010; Stemmer et al., 1994). Regarding error types, Evans and Hux (2011) analyzed the incorrect responses given by their participants with TBI to prediction probes (What will the speaker do next?) and interpretation probes (What does the speaker mean?) following hints in video vignettes. Their participants with TBI mostly produced incorrect nonliteral alternative interpretations (e.g., advising ordering more food rather than giving available food to a hungry character), followed by unrelated responses and a small proportion of literal interpretations. On the other hand, Foldi (1987), using a task designed to judge the appropriateness of short conversational exchanges between two characters, showed that participants with right hemisphere damage (RHD) judged literal responses to conventional indirect requests and hints as adequate, unlike control individuals.

However, these results are not unanimous: A few studies have reported a preserved hint comprehension in individuals with TBI and RHD (McDonald, 2000; McDonald et al., 2016). Two explanations could account for these discrepancies. First, the ecological dimension of the tasks used could influence performance: Individuals with RHD would perform better in natural or pseudonatural conversation situations than in nonnatural tasks (Vanhalle et al., 2000). Second, this lack of consensus might reflect the characteristic heterogeneity of these neurological populations: Not all individuals with ABI have pragmatic disorders, and among affected individuals, the altered pragmatic dimensions may diverge (Blake, 2017; Côté et al., 2007). This second explanation constitutes the starting point of our study. More precisely, our study aimed to analyze the variation in patients with ABI's pragmatic profiles in connection with the cognitive mechanisms and processes likely to underpin hint comprehension: context processing, executive functions (EF), and theory of mind (ToM).

Understanding hints is context dependent. It is based on the early and interactive integration of various contextual factors (Coulson & Lovett, 2010). Several sociocultural factors may thus influence the understanding of hints. Social distance and speaker status could be determining markers: A hint is more readily understood if formulated by an unfamiliar person and/or of higher hierarchical status (e.g., an employer to his employee; Blum-Kulka et al., 1989; Holtgraves, 1994; Stemmer et al., 1994).

The rapid integration of multiple contextual information can be problematic for individuals with ABI. Consequently, these individuals rely on a limited number of markers, or the most salient meaning of the statement, to interpret hints (Blake, 2010; Champagne-Lavau et al., 2018; Grindrod & Baum, 2003). Focusing on patients with RHD, Stemmer et al. (1994) manipulated the relationship between characters in a story (i.e., social power, familiarity, right to make a request, and obligation to comply with it) to induce direct requests (Type I stories) or hints (Type II stories). After each type of story, a request was formulated directly or as a hint. Participants with RHD and control participants were asked to judge the politeness, likelihood, and directness of these direct requests and hints following Type I and Type II contexts. Results showed that, on the one hand, the participants with RHD behaved similarly to control participants on direct requests in both story types. On the other hand, unlike the healthy participants (HC), they rated hints more likely after a Type I context (inducing direct requests) than after a Type II context (inducing a hint). The authors concluded that individuals with RHD would be sensitive to contextual variations but would rely primarily on linguistic and pragmalinguistic conventions (i.e., grammatical rules, lexical knowledge, and conventions linking linguistic items to specific pragmatic functions) to assess the hints. Therefore, they would treat and rate the hints similarly to the direct requests. According to these authors, this pattern reflects a deficit in integrating contextual information into an overall mental model of the situation. However, Champagne-Lavau et al. (2018) did not share this point of view. In their study on irony, a subgroup of individuals with RHD (RHD-I) showed insensitivity to the degree of contextual incongruity between the target utterance and the context. This insensitivity was evidenced by the absence of any difference in performance between a strong incongruity and a weak incongruity context condition. In other words, these individuals with RHD-I made more errors when interpreting ironic than literal target utterances (e.g., "How punctual!"), whether the incongruity was weak (a few minutes late) or strong (an hour late), with essentially literal errors. Conversely, control subjects and a second RHD subgroup performed slightly worse only in the weak incongruity, ambiguous condition. The authors concluded that the deficits of some individuals with RHD reflected an insensitivity or misperception of these markers, leading them to infer the utterance's meaning based on linguistic decoding (i.e., literal meaning), rather than difficulties in integrating contextual markers, which would have manifested themselves in a gradation of difficulty (low incongruity < high incongruity < no incongruity/literal). These two studies differ significantly in the form of nonliteral language considered and their methods (the type of task and contextual markers manipulated), which may explain their discrepancies. However, they agree that individuals with RHD make inadequate use of the contextual markers that are supposed to help them understand nonliteral language. More studies manipulating contextual factors are nevertheless needed to confirm whether their presence impacts the comprehension of indirect requests and, if so, to better characterize this influence.

ToM deficits constitute a second explanatory hypothesis for hint comprehension disorders. This ability to infer mental states (Premack & Woodruff, 1978) seems essential to bridge the gap between the literal meaning of a statement and the nonliteral meaning intended by the speaker. It is now well recognized that ToM is frequently impaired in individuals with RHD and TBI (see Lin et al., 2021; Martín-Rodríguez & León-Carrión, 2010, for reviews), thus raising the question of the links between such deficits and the understanding of nonliteral language.

This question has been addressed in several studies. Overall, the results tend to converge toward a link between hint comprehension and first-order, second-order ToM, and faux pas detection (Champagne-Lavau & Joanette, 2009; Muller et al., 2010). Furthermore, these results are corroborated by imaging studies, which have shown activation of the ToM network during hint processing (van Ackeren et al., 2012, 2016).

In addition to the nature of the tasks, the type of ToM deficit could also impact the pragmatic profile of individuals with ABI. Based on work with several psychiatric populations, Abu-Akel (2003) proposed a model of ToM disorders as a continuum comprising (a) an absence of understanding of others' mental states, manifested, for example, by egocentricity or difficulties in understanding false beliefs; (b) a good understanding of mental states but a certain inability to attribute them, with a possible tendency to overinference (this hyper-ToM, typically observed in schizophrenic individuals with positive symptoms, could be related to cognitive biases or difficulties in selecting the appropriate hypothesis among several [Abu-Akel & Bailey, 2000]); and (c) an intact understanding of others' minds but a deterioration in the understanding of one's own mind, typically characterized by low self-consciousness in patients with passivity. Although initially applied to the field of psychiatry, this model—and particularly the first two hypotheses—seems relevant to individuals with ABI. Indeed, several studies have reported an inability of individuals with ABI to represent the mental states of others through different ToM tasks (see Lin et al., 2021; Martín-Rodríguez & León-Carrión, 2010, for reviews). Moreover, negative attribution biases have been demonstrated in individuals with ABI (Neumann et al., 2015; Winegardner et al., 2016), suggesting that a hyper-ToM may operate in some individuals with ABI. This model was applied to hint comprehension in one study (Champagne-Lavau & Joanette, 2009). Based on the cognitive-pragmatic profiles of their participants with RHD, these researchers suggested that a lack of understanding of others' mental states (a) might be associated with a misunderstanding of communicative intentions, manifested by difficulties in inferring the nonliteral meaning of an utterance—typically a hint. On the other hand, an impaired ability to attribute them (b) might be characterized by a tendency to overinfer nonliteral intentions in literal conditions. However, more studies are needed to confirm these associations.

Finally, a third cognitive process that may underlie problems in understanding hints relates to EF. EF encompass a set of high-level cognitive processes that allow us to adapt our behavior in complex goal-directed situations, such as communication situations (Miyake et al., 2000). In the case of preferential but inappropriate activation of literal meaning, EF would allow the speaker to reject irrelevant literal meaning (inhibition) and generate an adequate alternative nonliteral meaning (flexibility) based on background and context-specific information manipulated jointly (working memory).

Two subhypotheses have thus been reported in the literature. The first, the hypothesis of a suppression deficit related to inhibitory capacities, suggests that difficulties in rejecting inappropriate meanings could be the cause of pragmatic disorders (Tompkins et al., 2000, 2002). The second hypothesis, cognitive resources, is linked to working memory capacities. Limited working memory resources impact individuals with ABI's ability to accomplish cognitively demanding tasks, such as hint comprehension tasks involving metalinguistic skills (Just & Carpenter, 1992; Monetta & Joanette, 2003).

Studies that have analyzed the links between the understanding of hints and EF (including inhibition, flexibility, and working memory) in individuals with ABI have led to inconclusive results (Champagne-Lavau & Joanette, 2009; McDonald et al., 2016; Zimmermann et al., 2011). Two studies that used co-occurrence analysis demonstrated pragmatic–executive dissociations, with executive impairment without disturbance in understanding hints in some individuals with RHD (Champagne-Lavau & Joanette, 2009; Zimmermann et al., 2011). These results led Champagne-Lavau and Joanette (2009) to postulate that a joint deficit of ToM and EF would be more likely to account for the pragmatic deficits observed.

Most of the studies mentioned above, having analyzed the links between ToM, EF, and hint comprehension, have used correlation or regression analyses. However, these methods are not sensitive to the well-documented heterogeneity of the ABI population. Cluster analysis is an interesting method for considering interindividual differences. This method makes it possible to obtain homogeneous subgroups of participants based on their performance in a given task. This method has been adopted in a single study on hint comprehension (Champagne-Lavau & Joanette, 2009). Their results showed three pragmatic performance profiles: one unimpaired in hint comprehension, one impaired in understanding hints, and one impaired in comprehending literal utterances. Each impaired group was associated with a distinct executive profile (e.g., reduced inhibition vs.

impaired flexibility). However, one limitation of this study lies in the task used (Montréal protocol for the Evaluation of Communication [MEC]; Joanette et al., 2004), which does not manipulate all contextual and executive variables of interest. For example, the social relationship between the characters is either equal (two friends) or hierarchical (a boss and his employee). Likewise, the length of the stories is similar throughout the task: The results, therefore, do not make it possible to determine whether the deficits observed constitute primary cognitive-pragmatic disorders or secondary to an overload of cognitive resources (Blake, 2017; Cummings, 2009). In addition, the executive and ToM measures used were independent of the hint comprehension task. Byom and Turkstra (2017) suggested that manipulating cognitive processes within pragmatic tasks themselves would be a better method to examine the links between pragmatics and these processes.

Thus, following the paradigm developed by Cordonier et al. (2022), we used a task of hint comprehension, which manipulates within it the context (inducing a literal or hint meaning), the markers of hints (absence vs. presence of a social power), cueing a hint interpretation, and executive demand of the stories (absence vs. presence of a distractor paragraph). Because of this paradigm and cluster analysis, we aimed to identify hint comprehension profiles in relation to the cognitive mechanisms and processes that likely underlie this understanding. Error analysis was also carried out to clarify these profiles.

Based on the literature (Champagne-Lavau & Joanette, 2009; Cordonier et al., 2020), the following specific hypotheses were formulated:

1. Difficulties in processing the context will result in poor hint comprehension in conditions with and without a marker of hints. Errors will be mostly literal.
2. Executive deficits will be associated with difficulty understanding hints and literal statements in stories with high executive demand. Errors will consist of erroneous literal and nonliteral interpretations relating to irrelevant, uninhibited information.
3. ToM deficits will manifest as difficulties interpreting hints or literal statements (Abu-Akel, 2003; Cordonier et al., 2020). Specifically, a lack of understanding of others' mental states (and therefore of the intent to request) will essentially induce errors in hint conditions. An erroneous attribution of mental states will lead to overinference of hints in literal conditions.
4. Joint involvement of executive deficits and ToM impairments should be associated with the most severe pragmatic disorders (i.e., impairments in hint understanding whatever the presence/absence of a marker of hint and the low/high executive demand).

Method

Participants

Thirty-three participants with ABI (13 women, 20 men) were recruited from hospitals and clinical centers in the French-speaking part of Switzerland. Thirty of these individuals also participated in a previous study on irony comprehension (Cordonier et al., 2020). In order to be included in the study, participants were required to be aged between 20 and 65 years old, right-handed, and native French speakers. They must have suffered, more than 6 months ago, a stroke in the right hemisphere (RHD) or a moderate-to-severe TBI (Glasgow Coma Scale score ≤ 13 or posttraumatic amnesia of at least 24 hr [Maas et al., 2008; Teasdale & Jennett, 1974] according to medical or neuropsychological reports). In addition, their brain lesions had to be localized in minima in the right frontal lobe, given its important implication in the understanding of nonliteral language (Reyes-Aguilar et al., 2018). The choice to include participants with two different etiologies (TBI and stroke) is based on a literature that has demonstrated similar pragmatic and cognitive profiles between these two populations (Channon & Crawford, 2010; Cordonier et al., 2020). This inclusion is also of interest for the representativeness of clinical practice and therapeutic needs (Blake, 2007). Nevertheless, analyses will be performed to examine possible neuropsychological and pragmatic differences between these two populations.

Participants were excluded from the study in case of psychiatric disorders, alcohol, or drug dependence history. Language difficulties (aphasia, reading disorders), objectified in neuropsychological reports or during the administration of the DTLA (Détection des troubles du langage chez l'adulte et la personne âgée; Macoir et al., 2017) and the Montréal-Toulouse 86 (MT-86) Reading Comprehension subtest (Nespoulous et al., 1992), were also grounds for exclusion. The sample thus included 19 individuals with TBI and 14 individuals with RHD, with an average time postonset of 55.36 months (SD = 61.00). Further clinical details are available in Table 1.

Thirty-three HC (19 women, 14 men) with no neurological or psychiatric history were also included in the study. Their overall cognitive functioning, assessed by the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005), had to have remained intact (score > 26/30). They were individually matched with the participants with ABI for age (ABI: M = 50.97, SD = 11.11; HC: M = 51.09, SD = 11.10), $t(64) = -0.44$, $p > .05$, and education level (according to the Swiss system: Level 1 = obligatory school; Level 2 = vocational training; Level 3 = university education). Gender matching was not strictly controlled, as a gender effect on pragmatic and ToM skills is not

Table 1. Demographic and clinical data for the participants with acquired brain injury (ABI).

Participants	Gender	Age (years)	Education (level)	Etiology	Time postonset (months)	Lesion site
ABI1	F	30	1	TBI	6	Right frontotemporal – diffuse injury
ABI2	F	48	2	TBI	251	Right frontotemporoparietal
ABI3	M	36	2	TBI	12	Bilateral frontal, subcortical – diffuse injury
ABI4	F	57	2	TBI	60	Right frontotemporal, bilateral parietal – diffuse injury
ABI5	M	34	2	TBI	80	Right frontotemporal, subcortical – diffuse injury
ABI6	F	49	2	TBI	20	Right frontotemporoparieto-occipital, left temporal
ABI7	M	44	2	TBI	82	Right frontotemporal
ABI8	M	24	3	TBI	24	Right frontal
ABI9	M	59	2	TBI	48	Bilateral frontotemporal, right parieto-occipital
ABI10	M	42	2	TBI	246	Bilateral frontal, right temporal
ABI11	F	59	1	TBI	149	Bilateral frontal, right temporal, subcortical – diffuse injury
ABI12	M	9	2	TBI	45	Bilateral frontal, right temporal, white matter
ABI13	M	57	3	TBI	20	Right frontal
ABI14	M	9	3	TBI	44	Bilateral frontal, left temporal
ABI15	F	53	2	TBI	21	Right frontotemporal
ABI16	M	49	2	TBI	14	Bilateral frontoparietal
ABI17	M	59	3	TBI	17	Right frontotempo-occipital – diffuse injury
ABI18	M	24	3	TBI	38	Bilateral frontoparietal
ABI19	M	45	3	TBI	7	Bilateral frontotemporal, left parietal
ABI20	F	52	2	CVA	30	Right frontoparietotemporal
ABI21	M	58	2	CVA	30	Right anterior cerebral artery
ABI22	F	54	1	CVA	18	Right middle cerebral artery, right frontal
ABI23	F	54	2	CVA	16	Right frontal
ABI24	F	59	2	CVA	62	Right frontal
ABI25	M	64	1	CVA	83	Right middle cerebral artery
ABI26	M	64	2	CVA	108	Right fronto-occipital
ABI27	M	60	2	CVA	90	Right frontal
ABI28	M	61	2	CVA	99	Right frontotemporal
ABI29	F	63	1	CA	31	Right frontal
ABI30	M	55	3	CVA	2	Right middle cerebral artery
ABI31	F	52	1	CVA	5	Right middle cerebral artery (M1, M2)
ABI32	M	64	2	CVA	3	Right middle cerebral artery, subcortical
ABI33	F	45	2	CVA	6	Right frontotemporoparietal

Note. Educational level, according to the Swiss system: Level 1 = obligatory school; Level 2 = vocational training; Level 3 = university education. F = female; TBI = traumatic brain injury; M = male; CVA = cerebrovascular accident.

generally reported in the literature (Neumann et al., 2022; Turkstra et al., 2020).

The local ethics committee (Commission cantonale d'éthique de la recherche sur l'être humain) approved the study. All participants gave written informed consent.

Materials and Procedure

Participants were tested individually in a quiet room, in one to four sessions, depending on their fatigue. The testing included standardized tests assessing ToM and EF and an experimental measure of hint comprehension. The order of administering the tests was counterbalanced among the participants.

Neuropsychological Assessment

ToM. The faux pas test (Social Cognition & Emotional Assessment [Mini-SEA]; Bertoux, 2014), consisting of detecting in written stories if a character had said something that they should not have said, was administered. The faux pas stories (/30), control stories (/10), and total (/40) scores were used as indexes of ToM.

EF. The Hayling Test (Rouleau, 1998) automatic and inhibition scores, calculated from response accuracy and response latencies in two conditions of sentence completion (expected and unexpected word), assessed inhibition ability. The total number of words for two letters of verbal fluency tasks, letters D (DTLA; Macoir et al., 2017) and F (MoCA; Nasreddine et al., 2005), was used as a measure of flexibility. Finally, the forward and backward digit spans (Wechsler Adult Intelligence Scale–Third Edition; Wechsler, 1997) and the reading span test (RST; Desmette et al., 1995) examined short-term and working memory.

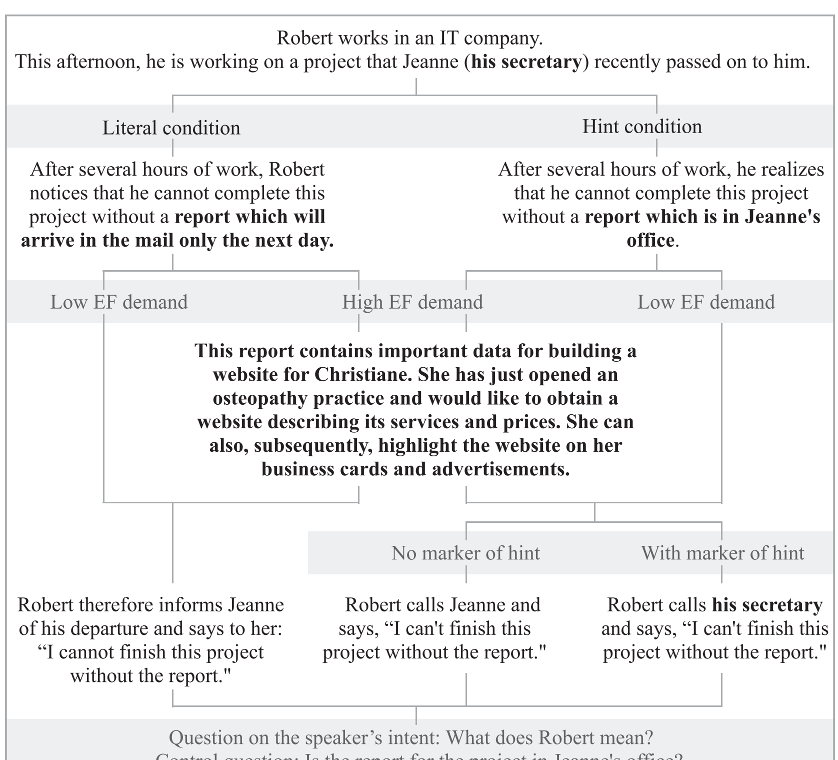
Experimental Task: Hint Comprehension

A hint comprehension task, including 18 written scenarios described in Cordonier et al. (2022), was used. Each scenario featured two characters of different gender and ended with either a literal statement or a hint from one of the characters. Two questions were asked at the end of each story: a question on the speaker's intent ("What does X [the speaker] mean?") and a control question relating to contextual information (see Figure 1). In order to control prosodic and memory parameters, the stories were presented in writing and remained visible to the participants when administering the written questions. The participant was asked to read each story silently and then orally answer the questions.

In order to explore the mechanisms possibly involved in hint comprehension, the scenarios were derived in six conditions through the manipulation of three factors. The first factor, the *context* preceding the target statement, was adjusted to induce a literal or indirect meaning. The second factor, *executive demand* (EF demand), was increased in half of the stories (high EF demand) by adding a distractor paragraph introducing a new character. This paragraph was absent in the conditions with low EF demand. Finally, a *marker* facilitating the understanding of hints—a power relationship between the characters—was introduced in half of the nonliteral stories (with a marker of hints). A low status (e.g., secretary) was associated with the character to whom the request was addressed in the story's second sentence and recalled just before the target statement. This marker was absent in the hint conditions with no marker (with low or high EF demand). These factors allowed us to assess the participants' ability to integrate various contextual information in inferring a literal or indirect meaning, the facilitating effect of the speaker status (Holtgraves, 1994), and the influence of cognitive overload on hint comprehension. The six conditions resulting from the manipulation of these factors were as follows:

1. literal with low EF demand,
2. literal with high EF demand,

Figure 1. Example and structure of the hint comprehension task. This task varied in terms of context (literal vs. hint), the executive functions (EF) demand (low vs. high), and, in the hint condition, the presence of a cue of hint (no vs. with). Reprinted from Cordonier et al. (2022) with permission of Oxford University Press.



3. hint with low EF demand and no marker of hints,
4. hint with high EF demand and no marker of hints,
5. hint with low EF demand and a marker of hints, and
6. hint with high EF demand and a marker of hints.

All stories were controlled for length and structure and were subjected to pilot studies described by Cordonier et al. (2022). Due to the many stimuli (18 stories × 6 conditions), the stories were divided into three equivalent versions of the test according to a Latin square plan. Each version included the 18 derivative scenarios in two different conditions, for a total of six stories per condition. Each participant with ABI and HC participant was then randomly assigned to one of the three groups.

Scoring. Verbal answers to questions on the speaker's intent were audio-recorded and transcribed. A binary scoring system was defined based on data from a pilot study and request strategy types reported by Stemmer et al. (1994). In the literal conditions, any clear paraphrase of the utterance was scored 1 point. In the indirect conditions, 1 point was awarded to responses mentioning a request with a mood derivable (e.g., linking to the example in Figure 1; "Bring me the report!"), a performative ("He is asking her to bring the report."), a locution derivable ("She should bring him the report."), a want statement ("He would like the report."), or a preparatory ("Could you bring the report?"). All other responses were scored 0 and classified according to the following error categories: "incorrect indirect request" (in the literal conditions; "He asks him for the report."), "incorrect literal response" (in the hint conditions; "He informs her that he cannot finish."), "erroneous mental inference" ("He is looking for an excuse not to work."), "nonmental logical inference" ("He cannot finish because the report is in Jeanne's office."), and "other" (off-topic responses, nonresponses). A maximum score of 6 was thus obtained for each of the six conditions. Twenty percent of the data (n = 792) were double scored by a research assistant who was blind to the condition of the participants tested (ABI or HC). Interrater reliability was strong, with an agreement rate of 92.43% and a Cohen's κ of .834 (p < .0001). Disagreements were resolved by discussion.

Responses to control questions were half affirmative and half negative. They were also scored binarily, depending on the accuracy of the response.

Data Analyses

As a first step, participants with RHD, participants with TBI, and HC participants were compared to have a general neuropsychological and pragmatic profile. For the sociodemographic and neuropsychological measures, one-way analyses of variance (ANOVAs) and post hoc unpaired t tests were used. For the hint comprehension task, two repeated-measures ANOVAs were performed. The first repeated-measures ANOVA, 3 (group: RHD, TBI, HC) × 2 (context: literal, hint) × 2 (EF demand: low, high), was performed on the mean of correct responses to the questions on the speaker's intent and the control questions. Because the factor marker was not manipulated in the literal conditions, only the hint conditions with no marker were considered in this analysis. The second repeated-measures ANOVA, 3 (group: RHD, TBI, HC) × 2 (marker of hints: without, with) × 2 (EF demand: low, high), was performed on the mean of correct responses to the questions on the speaker's intent and the control questions for the hint conditions only.

Then, to identify pragmatic profiles, the k-means clustering method was performed on the individuals with ABI's responses to the questions on the speaker's intent in the six conditions of the hint comprehension task. This partitioning method consists in analyzing, by successive iterations, the center of gravity of participant data (Jain, 2010). It thus allows to group individuals with the most similar characteristics within k groups to minimize the sum of within-cluster sum of the square over k clusters. To determine the optimal number of clusters, we used the elbow, silhouette, and gap statistic methods. The elbow method (Kodinariya & Makwana, 2013) is a visual method of gradually increasing the number of clusters to examine the percentage of variance explained by each number of clusters. At some point, the gain from adding a new cluster drops, forming an "elbow" in the graph. This elbow indicates the optimal number of clusters. The silhouette method (Rousseeuw, 1987) is another visual method that analyzes for each participant the difference between the average distance to participants in the same group (cohesion) and the average distance to participants in other neighboring groups (separation). A negative value will therefore indicate a misclassification of the participant. The gap statistic method (Tibshirani et al., 2001) finally measures the difference between the intracluster dispersion and that of a zero reference distribution for each cluster. The optimal number of clusters will be where the largest jump in intracluster distance has occurred based on a random uniform distribution of points.

In the end, the participants who had similar performances were grouped in the same subgroup, named a posteriori according to the conditions of interest highlighted during statistical analyses. Specifically, one-way ANOVAs and post hoc t tests were performed to explore differences between the ABI subgroups and the control group on neuropsychological data. For the hint comprehension data, two repeated-measures ANOVAs, 3 (group: ABI-L, ABI-H, and HC) × 2 (context: literal, hint) × 2 (EF demand: low, high) and 3 (group: RHD, TBI, HC) × 2 (marker of hints: without, with) × 2 (EF demand: low, high), were performed on the mean of correct responses to the questions on the speaker's intent and the control questions of the hint comprehension task.

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 .01 and .05, moderate if between .06 and .13, and large if above .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 the multiple testing, the alpha level was adjusted with the false discovery rate (FDR) method using the Benjamini–Hochberg procedure. Results were considered significant below an α level of .05 (after FDR correction). Statistical analyses were performed using IBM SPSS Version 25 and R Software Version 4.0.2.

Since the main question of this article is the identification of cognitive-pragmatic profiles, only the results of cluster analyses will be detailed in this article. Statistical tests for the RHD, TBI, and HC group differences are presented in Supplemental Material S1.

Results

Comparison of Participants With RHD, Participants With TBI, and HC Participants

These results are presented in detail in Supplemental Material S1. Comparisons of the individuals with RHD and TBI showed that the participants with TBI were significantly younger than the participants with RHD. No further measure (sociodemographic, neuropsychological, and hint comprehension) differentiated between the two subgroups.

Comparisons with the HC group showed that both participants with RHD and TBI performed worse than HC participants in answering the questions on the speaker's intent, but not in answering the control questions of the hint comprehension task. Regarding the sociodemographic and neuropsychological data, the individuals with RHD performed more poorly than the HC group on flexibility (letter fluency), verbal inhibition (Hayling inhibition), working memory (digit span, backward), and ToM (Mini-SEA total and faux pas) measures. For their part, the individuals with TBI had worse performance than the HC participants on inhibition (Hayling automatic and inhibition) and ToM (Mini-SEA total and faux pas) measures.

Cluster Analysis

The *k*-means method was performed with 1,000 sets of initial values for a number of clusters from 2 to 6. The various clustering were then evaluated using the elbow method, the silhouette method, and the gap statistic method (see Figure 2). The majority of these methods suggested that the optimal number of clusters would be two, which is the reason for our choice. Therefore, these two subgroups were named a posteriori according to the condition(s) of interest evidenced in the statistical analyses: ABI-L (impaired in the literal conditions) and ABI-H (impaired in the hint conditions).

Neuropsychological Assessment

Means, standard deviations, and *p* values for sociodemographic variables and neuropsychological tests are detailed in Table 2. One-way ANOVAs (or Kruskal–Wallis tests when appropriate) were performed to compare the sociodemographic and neuropsychological data of the various participant subgroups (ABI-L, ABI-H, and HC). Significant differences were observed in the performance of the digit span (forward and backward), Hayling (automatic and inhibition), and Mini-SEA (total, faux pas, and control) tests.

Post hoc unpaired *t* tests showed that the ABI-L subgroup performed significantly worse than the HC group on verbal inhibition (Hayling) and ToM (Mini-SEA total and faux pas) measures. Significant differences between the ABI-H and HC groups were found on the digit span (forward and backward), Hayling (automatic and inhibition), and Mini-SEA (total, faux pas, and control) tests. The two subgroups of participants with ABI differed only on one measure of the Mini-SEA (total score), with poorer performance in the ABI-H subgroup.

Experimental Task: Hint Comprehension

The three participant subgroups' performance in the hint comprehension task is shown in Figure 3.

Hint with no marker of hints versus literal: Questions on the speaker's intent. The 3 (group: ABI-L, ABI-H, HC) × 2 (context: literal, hint) × 2 (EF demand: low, high) repeated-measures ANOVA on the number of correct responses to the questions on the speaker's intent showed a main effect of group, $F(2, 63) = 25.528$, $p < .001$, $\eta_p^2 = .448$, with the participants with ABI-H having a significantly worse performance than the HC participants (FDR-corrected $p < .001$) and the participants with ABI-L (FDR-corrected $p < .001$). There was no significant difference between the participants with ABI-L and HC participants (FDR-corrected $p > .05$). There was no main effect of context, $F(1, 63) = 0.998$, $p > .05$, $\eta_p^2 = .016$, and no main effect of EF demand, $F(1, 63) = 2.137$, $p > .05$, $\eta_p^2 = .033$. The results also showed a significant Context × Group interaction, $F(1, 63) = 14.743$, $p < .001$, $\eta_p^2 = .319$.

Figure 2. Optimal number of clusters according to the elbow method (a), the silhouette method (b), and the gap statistic method (c). The elbow method is a heuristic method that consists of plotting the within-cluster sum of squares and picking the elbow of the curve as the number of clusters to use. In (a), a slight curvature is visible for a cluster number equal to 2. The optimal number of groups could also be the one that maximizes the overall average silhouette and is indicated in (b) by the dotted line (*N* = 2). Finally, the gap statistic method suggests that the optimal number of clusters could be the smallest one that is such that $Gap(k) \geq Gap(k) - s_{k+1}$, where *Gap(k)* is the Gap statistic computed for k clusters and s_{k+1} is the standard deviation of the Gap statistic. According to this methodology, the optimal number of clusters is indicated by the dotted line in (c).

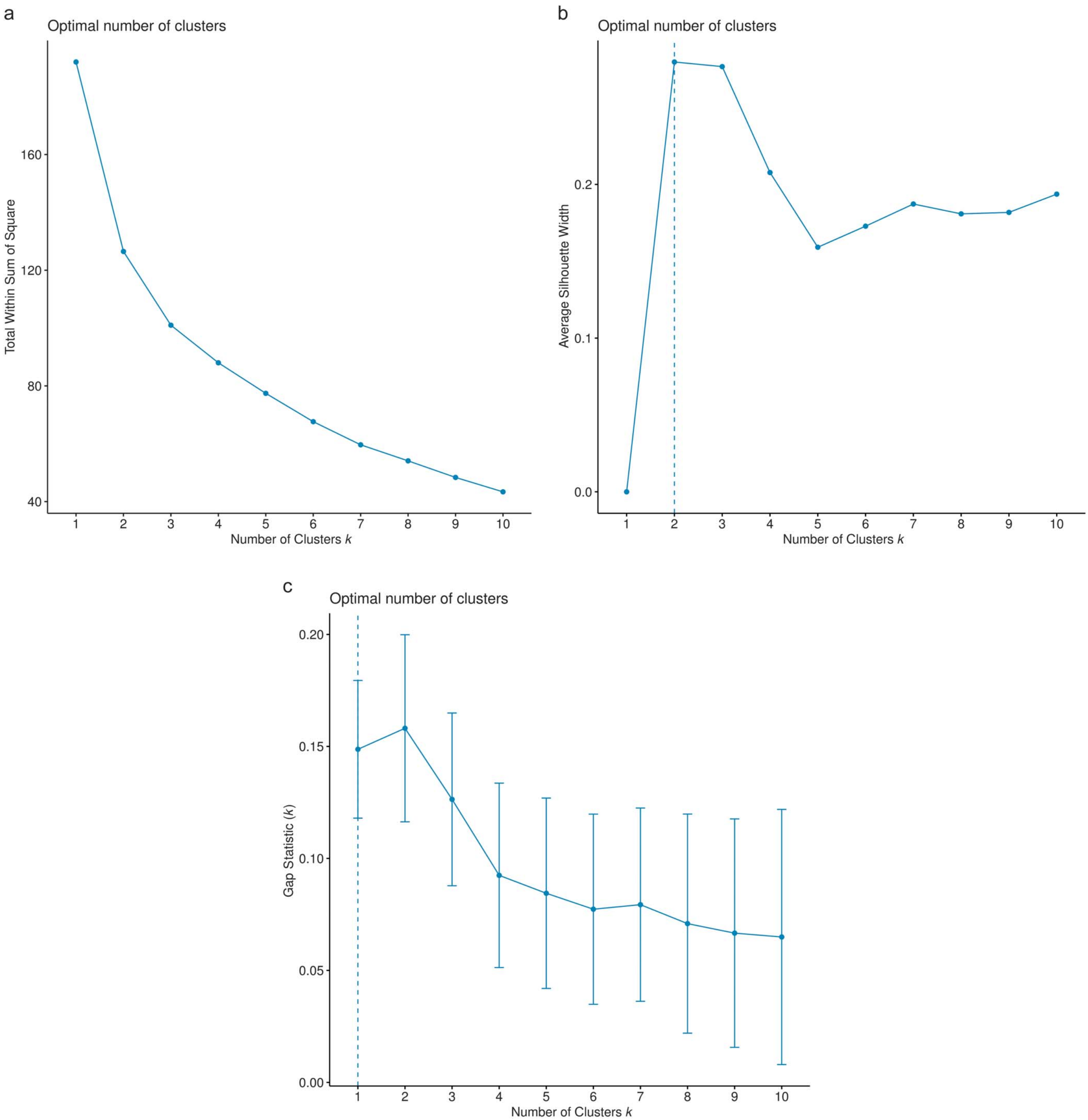


Table 2. Comparison of the sociodemographic and neuropsychological data between the healthy control (HC) group, the acquired brain injury (ABI) subgroup impaired in the literal conditions (ABI-L), and the ABI subgroup impaired in the hint conditions (ABI-H).

	ABI-L		ABI-H		HC		Test statistic		ABI-L vs. HC	ABI-H vs. HC	ABI-L vs. ABI-H
Variable	***M***	***SD***	***M***	***SD***	***M***	***SD***	***F/H***	***p*** **(η_p^2)**	**Post hoc *p* (Cohen's *d*)**	**Post hoc *p* (Cohen's *d*)**	**Post hoc *p* (Cohen's *d*)**
Age	50.18	12.20	51.81	10.15	51.09	11.10	0.09	.940	—	—	—
Educational level (1/2/3)	2/9/6		4/11/1		6/20/7		3.74	.154	—	—	—
Time postonset (month)	35.94	31.90	76.00	77.28	—	—	3.87	.111	—	—	—
Digit span (forward)	8.94	2.19	7.19	1.94	9.76	2.50	6.73	**.008** (.176)	.373	**.006** (1.100)	.053
Digit span (backward)	7.35	1.94	6.13	1.63	8.55	2.04	8.78	**.000** (.218)	.105	**.000** (1.258)	.111
RST span	2.59	0.80	2.31	0.79	2.85	0.62	3.17	.100	—	—	—
RST (total words)	18.00	9.54	14.19	6.99	20.03	6.73	3.19	.099	—	—	—
Letter fluency (D + F)	22.12	8.30	21.19	7.41	27.03	7.40	4.13	.053	—	—	—
Hayling (automatic)	6.24	0.437	5.81	0.83	6.48	0.51	7.08	**.008** (.183)	.139	**.006** (1.066)	.134
Hayling (inhibition)	9.06	3.42	7.25	2.35	11.55	1.89	17.52	**.000** (.357)	**.031** (0.993)	**.000** (2.097)	.153
Mini-SEA (total)	29.71	6.22	22.13	10.39	33.79	4.62	15.82	**.000** (.334)	**.034** (0.784)	**.000** (1.667)	**.049** (0.892)
Mini-SEA (faux-pas)	19.94	6.25	14.8	8.39	23.91	4.59	11.82	**.000** (.276)	**.037** (0.763)	**.006** (1.516)	.110
Mini-SEA (control)	9.76	0.66	8.80	1.97	9.88	0.49	5.68	**.017** (.155)	.611	**.017** (0.930)	.153

Note. *p* values adjusted with the false discovery rate method using the Benjamini–Hochberg procedure. The bold font indicates significant differences between the groups. Educational level, according to the Swiss system: Level 1 = obligatory school; Level 2 = vocational training; Level 3 = university education. RST = Reading Span Test; Mini-SEA = Social Cognition & Emotional Assessment.

This interaction was broken down according to group. The ABI-L subgroup made more errors in the literal conditions than in the hint conditions ($p < .03$), whereas the ABI-H subgroup made more errors in the hint conditions than in the literal conditions ($p < .001$). These differences did not exist in the HC group ($p > .05$). No further interactions were significant.

Hint with no marker of hints versus literal: Control questions. The 3 (group: ABI-L, ABI-H, HC) × 2 (context: literal, hint) × 2 (EF demand: low, high) repeated-measures ANOVA on the number of correct responses to the control questions showed a main effect of group, $F(2, 63) = 8.473$, $p < .01$, $\eta_p^2 = .212$, with the participants with ABI-H having a significantly worse performance than the HC participants (FDR-corrected $p < .001$) and the participants with ABI-L (FDR-corrected $p < .01$). There was no significant difference between the participants with ABI-L and the HC participants (FDR-corrected $p > .05$). There was no main effect of context, $F(1, 63) = 5.024$, $p > .05$, $\eta_p^2 = .074$, and no main effect of EF demand, $F(1, 63) = 0.510$, $p > .05$, $\eta_p^2 = .008$. No interactions were significant.

Hint with a marker of hints versus hint with no marker of hints: Questions on the speaker's intent. The 3 (group: ABI-L, ABI-H, HC) × 2 (marker of hints: without, with) × 2 (EF demand: low, high) repeated-measures ANOVA on the number of correct responses to the questions on the speaker's intent showed a main effect of group, $F(2, 63) = 68.395$, $p < .001$, $\eta_p^2 = .685$, with the participants with ABI-H having a significantly worse performance than the HC participants (FDR-corrected $p < .001$) and the participants with ABI-L (FDR-corrected $p < .001$). There was no significant difference between the participants with ABI-L and the HC participants (FDR-corrected $p > .05$). There was no main effect of the marker, $F(1, 63) = 4.142$, $p > .05$, $\eta_p^2 = .062$, and no main effect of EF demand, $F(1, 63) = 2.260$, $p > .05$, $\eta_p^2 = .035$. No interactions were significant.

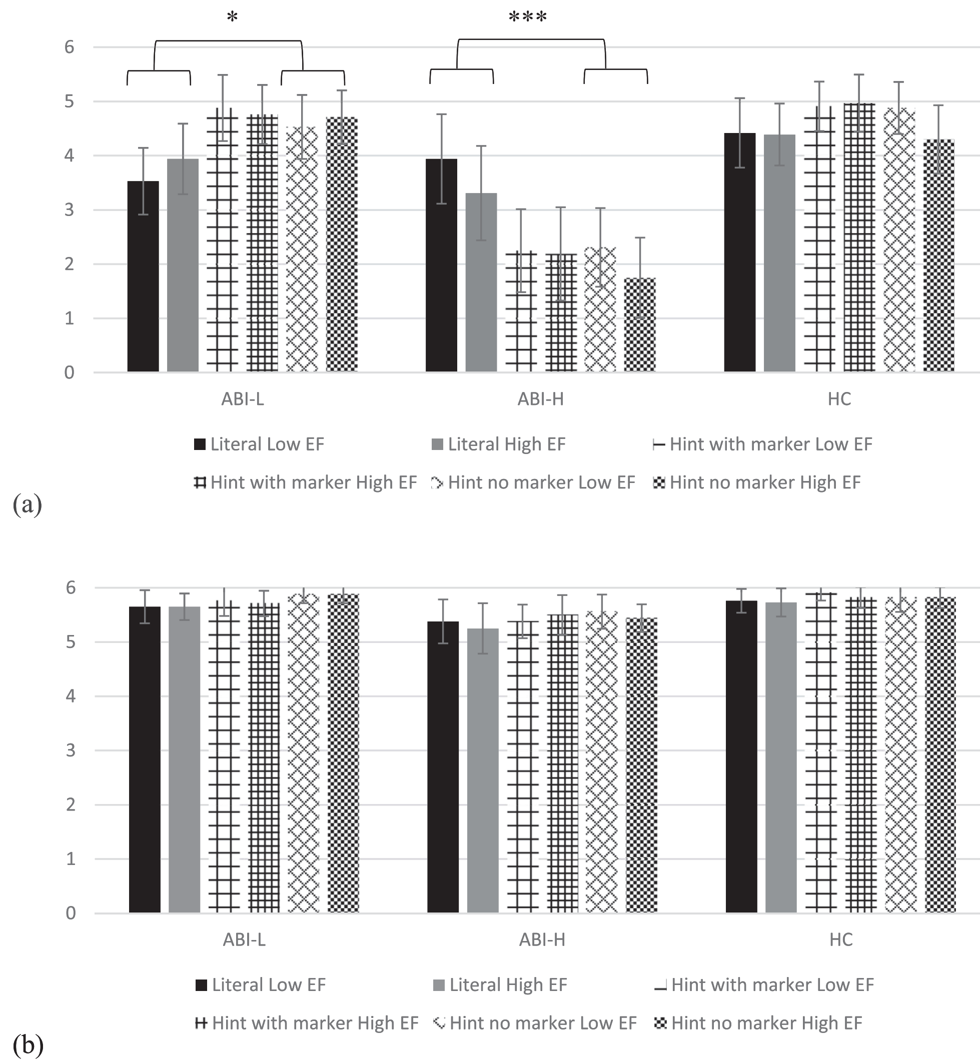
Hint with a marker of hints versus hint with no marker of hints: Control questions. The 3 (group: ABI-L, ABI-H, HC) × 2 (marker of hints: without, with) × 2 (EF demand: low, high) repeated-measures ANOVA on the number of correct responses to the control questions showed a main effect of group, $F(2, 63) = 8.503$, $p < .01$, $\eta_p^2 = .213$, with the participants with ABI-H having a significantly worse performance than the HC participants (FDR-corrected $p < .001$) and the participants with ABI-L (FDR-corrected $p < .01$). There was no significant difference between the participants with ABI-L and the HC participants (FDR-corrected $p > .05$). There was no main effect of the marker, $F(1, 63) = 1.398$, $p > .05$, $\eta_p^2 = .022$, and no main effect of EF demand, $F(1, 63) = 0.247$, $p > .05$, $\eta_p^2 = .004$. No interactions were significant.

Profile Summary

The ABI subgroup profiles can be summarized as follows:

Participants with ABI-L (nine TBI and eight RHD). These participants with ABI performed similarly to the HC participants in the hint comprehension task. Contrary to the latter, however, they had poorer performance in the

Figure 3. Correct responses to the questions on the speaker's intent (a) and to the control questions (b) in each condition for the acquired brain injury (ABI) subgroup impaired in the literal conditions (ABI-L), the ABI subgroup impaired in the hint conditions (ABI-H), and the healthy control (HC) group.



literal conditions, compared to the hint conditions. The analysis of errors (n = 162) showed a majority of incorrect indirect requests (in the literal conditions; "He asks him for the report."; 31%) and nonmental logical inferences ("He cannot finish because the report is in Jeanne's office."; 29%). On the neuropsychological measures, they performed worse than the HC participants on inhibition (Hayling) and ToM (Mini-SEA total and faux pas) measures.

Participants with ABI-H (10 TBI and six RHD). These participants with ABI demonstrated poorer performance than the HC group and the ABI-L subgroup in the hint comprehension task. Unlike the other two groups, they performed worse in the hint conditions, compared to the literal conditions. Out of the 323 errors, the majority (35%) was incorrect literal interpretations, whereas 28% of the errors were nonmental logical inferences. This pragmatic profile coexisted with worse performance in short-term memory, working memory, inhibition (Hayling automatic and inhibition), and ToM measures in comparison with the HC group. Only one ToM measure (Mini-SEA total) differentiated the two subgroups of participants with ABI, with poorer performance in the ABI-H participants.

Discussion

This study aimed to identify hint comprehension profiles in individuals with ABI in relation to the cognitive mechanisms and processes likely to underlie this understanding (i.e., context processing, ToM, and EF). To this end, we used the hint comprehension task developed by Cordonier et al. (2022), which manipulates these mechanisms. The executive demand in literal and hint stories was thus modulated by adding (high EF demand) or not (low EF demand) a distractor paragraph that introduced information irrelevant to the interpretation of the target utterance. In the hint conditions (with low or high EF demand), a marker of hints promoting the understanding of hints (a balance of power between the characters) was added in half of the stories to test participants' contextual integration abilities. Finally, the presence of hints and literal conditions allowed us to evaluate ToM by questioning the speaker's intent ("What does the speaker mean?"). We administered this task and neuropsychological tests assessing inhibition, flexibility, working memory, and ToM to 33 participants with ABI and 33 matched control participants.

The results revealed the presence of two profiles, which were sociodemographically similar but differed in pragmatic and neuropsychological terms. This variation in performance thus confirms the heterogeneity of the hint comprehension difficulties in ABI populations and consolidates the results of previous studies (Champagne-Lavau & Joanette, 2009; Côté et al., 2007; Dardier et al., 2011). Furthermore, the detailed analysis of the various profiles suggests that different cognitive impairments could account for this pragmatic heterogeneity.

Context processing deficit appeared to characterize one subgroup of participants with ABI (ABI-H). These participants demonstrated difficulty inferring hints in all conditions, regardless of the presence or absence of a marker of hints and the executive demand of the stories. This result thus confirms our first hypothesis and previous studies, which suggested that some individuals with ABI could be insensitive to the context (Champagne-Lavau et al., 2018; Cordonier et al., 2020). Consequently, they would interpret the statement based on its most common meaning (i.e., literal), as evidenced by the majority of literal errors. On the other hand, the lack of effect of the contextual marker could be explained by the marker used in the hint comprehension task (i.e., the power relationship between the characters). As demonstrated for irony comprehension in healthy individuals (Rivière & Champagne-Lavau, 2020), sociocultural markers might not be powerful enough to aid the understanding of indirect requests.

The role of ToM should be considered in both ABI participant subgroups. Indeed, the ABI-H subgroup, more altered in the hint conditions, demonstrated poorer performance than the HC group on all scores of the faux pas task (total, faux pas, and control). The ABI-L subgroup, which performed less well in the literal conditions, had more difficulties than the control group in understanding faux pas only.[1] The two ABI participant subgroups ultimately differed on the total score of the faux pas test. Overall, these results are in line with the study by Muller et al. (2010), which demonstrated a link between indirect speech act comprehension and faux pas comprehension. Regarding the various ToM pragmatic profiles, several hypotheses can be put forward. First, the severity or the type of ToM deficit could underlie these various pragmatic disorders. According to our third hypothesis, a lack of understanding of others' mental states could essentially induce errors in the hint conditions (ABI-H), whereas a good understanding of mental states but a certain inability to attribute them could lead to worse performance in the literal conditions (ABI-L; Abu-Akel, 2003; Cordonier et al., 2020). A second hypothesis, related to a general insufficiency of cognitive resources (Just & Carpenter, 1992; Monetta & Joanette, 2003), is explored below.

The role of EF was assessed in two ways in our study: by standardized executive tests and by manipulation of the EF demand within the stories of the hint comprehension task. Regarding the neuropsychological assessment, both ABI groups demonstrated executive difficulties in addition to ToM deficits, thus confirming our fourth hypothesis and the joint role of ToM and EF in pragmatic impairment reported in several studies (Bosco et al., 2017; Champagne-Lavau & Joanette, 2009). However, while the executive impairment was limited to inhibition in the ABI-L subgroup, it was more general in the ABI-H subgroup, with impairment in short-term memory, working memory, and inhibition. This profile raises the question of insufficient cognitive resources in this subgroup. This insufficiency would induce difficulties in cognitively demanding tasks, such as understanding hints and faux pas. It would also explain the slightly lower performance of the ABI-H subgroup in answering the control questions of the hint comprehension task and the faux pas task. However, this hypothesis should be viewed with caution in that cognitive resource availability is difficult to assess directly (Monetta et al., 2006) and is based on limited neuropsychological examination in our study.

In addition, our hypothesis of an association between executive deficits and difficulty in stories with high executive demand, based on the study by Cordonier et al. (2020), was not supported in this study. Indeed, the effect of the EF demand was not significant. This

[1]This association of difficulties in literal stories and faux pas stories only (and not control stories) may be explained by the fact that, although involving many common processes, these two tasks do not assess the same thing (Bosco et al., 2018). In addition, the different response modalities between these two tasks (i.e., elaboration of meanings in the hints task vs. detection for the false task) could induce various performances, as the detection of mental states is generally mastered before their comprehension (Wang & Su, 2006).

discrepancy between these two studies can be explained by the form of nonliteral language considered in these two studies—irony in the study by Cordonier et al. (2020) and hints in this study. Several studies have indeed suggested that irony is more complex to process than indirect requests (Angeleri et al., 2008; Champagne et al., 2003). Adding a distractor paragraph in ironic stories further increases the EF demand, which is already considerable. Difficulties may therefore arise under conditions of high EF demand in patients with milder or circumscribed executive difficulties (the ABI-LH and ABI-INH subgroups in the study by Cordonier et al., 2020). Patients with more limited cognitive resources (the ABI-I subgroup in the study by Cordonier et al., 2020), on the other hand, did not demonstrate an effect of EF demand insofar as low EF demand stories already proved problematic. In this study, since hint comprehension could be less cognitively demanding, adding a distractor paragraph might be insufficient to impact this comprehension in patients with circumscribed executive difficulties (i.e., ABI-L subgroup). However, the cognitive demand for hint comprehension, although less, is still present and could be sufficient to impact patients with minimal cognitive resources (i.e., ABI-H subgroup). This impact would be observed in all conditions, although visual analysis of the results suggests a slight pejoration in stories with high EF demand. However, more studies are needed to clarify the EF demand inherent in hint comprehension and its relation to standardized executive tests, with a possible even finer gradation of the task's difficulty.

This result has important clinical implications. It raises the question of the differential diagnosis of cognitive-pragmatic disorders in connection with the cognitive demand of the tasks (Blake, 2017). Some participants with ABI could indeed present "secondary" pragmatic disorders, reflecting mostly executive and general cognitive impairment. Thus, when assessing pragmatic disorders, attention should be paid to the cognitive demand or the ecological dimension of tasks. In addition, this differential diagnosis will promote the establishment of specific, more effective therapeutic objectives (Blake, 2007; Tompkins, 2012).

Another relevant result of our study relates to the etiology of the participants. Interestingly, our two subgroups of patients included a relatively equal number of participants with TBI and RHD. Group comparisons also showed no differences between participants with TBI and RHD—except for age. Therefore, although these two etiologies differ regarding the type of lesion (focal/diffuse, unilateral/bilateral damage) and demographical features (participants with TBI were younger than participants with RHD), similar cognitive-pragmatic profiles may result from it. This pragmatic and cognitive similarity has already been demonstrated for irony (Channon & Crawford, 2010; Cordonier et al., 2020). With respect to hints, Zimmermann et al. (2011) observed poorer performance in individuals with TBI than in individuals with RHD. The individuals with TBI, however, also differed in executive tasks. All of these observations have clinical implications. They suggest that faced with empirical deficiencies in the field of pragmatics, data from related pathologies (e.g., TBI and RHD) are relevant sources of inspiration for studying pragmatic disorders and developing assessing tools or treatments (Blake, 2007; Cassel et al., 2019).

Finally, several limitations of our study can be noted. First, patient subgroups included a modest number of individuals. However, this drawback is reduced due to the replicability of the profiles identified. Indeed, the two profiles of this study are quite similar, in both pragmatic and neuropsychological terms, to the profiles by Champagne-Lavau and Joanette (2009). This concordance strengthens the profiles' validity described, although more studies are needed. A second limitation concerns the lack of more precise data on lesion location. It would have been interesting to compare the lesion sites of the participants presenting the two cognitive-pragmatic profiles and to observe their possible overlap with the ToM neural network. A final limitation concerns the written format of the hint comprehension task. This format is justified by our decision to control for prosody, given the multiple other variables manipulated and the possible deficits in prosody comprehension in individuals with ABI (see Ferré et al., 2011; Ilie et al., 2017, for reviews). It also limits working memory load and partly reflects our everyday reality, as nonliteral language is frequently produced in written media such as e-mails (Whalen et al., 2009). However, a vast swath of spoken communication is obscured by this modality. Future studies using an oral format, as opposed to a written format, would therefore be relevant. These would promote broader generalization and enrich our knowledge about the effect of task modality on pragmatic performance.

In conclusion, this study contributes to a better understanding of the cognitive-pragmatic disorders of individuals with ABI, using the first task manipulating the underlying cognitive mechanisms and processes, and adopting an analysis method that took the heterogeneity of the ABI population into account. The hypothesis of contextual insensitivity in some individuals with ABI is thus reinforced by the absence of the marker effect and the executive demand in one subgroup (ABI-H). Moreover, various types of ToM deficits (lack of understanding (ABI-H) versus poor attribution of mental states (ABI-L) could explain, at least in part, the variability of the pragmatic profiles observed (difficulties in interpreting hints vs. literal statements). Limited cognitive resources could also lead to difficulties in pragmatic and ToM tasks, which are cognitively demanding. Finally, the similarity of the cognitive-pragmatic profiles observed in the individuals with TBI and RHD underlines the relevance of a transdiagnostic approach.

Data Availability Statement

The datasets generated using and/or analyzed during this study, as well as the hint comprehension task, are available from the corresponding author on reasonable request.

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