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Cognitive correlates of pragmatic language comprehension in adult traumatic brain injury: A systematic review and meta-analyses

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ABSTRACT

Effective pragmatic comprehension of language is critical for successful communication and interaction, but this ability is routinely impaired following Traumatic Brain Injury (TBI) (1,2). Individual studies have investigated the cognitive domains associated with impaired pragmatic comprehension, but there remains little understanding of the relative importance of these domains in contributing to pragmatic comprehension impairment following TBI. This paper presents a systematic meta-analytic review of the observed correlations between pragmatic comprehension and cognitive processes following TBI. Five meta-analyses were computed, which quantified the relationship between pragmatic comprehension and five key cognitive constructs (declarative memory; working memory; attention; executive functions; social cognition). Significant moderate-to-strong correlations were found between all cognitive measures and pragmatic comprehension, where declarative memory was the strongest correlate. Thus, our findings indicate that pragmatic comprehension in TBI is associated with an array of domain general cognitive processes, and as such deficits in these cognitive domains may underlie pragmatic comprehension difficulties following TBI. The clinical implications of these findings are discussed.

KEYWORDS

Cognition; communication; language; pragmatics; traumatic brain injury

In human communication, listeners are able to derive far more meaning from language than is contained in its linguistic propositions alone. Any given spoken discourse is interpreted by a listener in the context of their prior knowledge, belief, competency and values (3). As a result the meaning of the same set of linguistic propositions can have entirely unrelated, or indeed conflictual meanings, dependent upon the context of the communication. The ability to comprehend these contextual aspects of communication is then profoundly important in enabling humans to develop effective communicative relationships with others. The ability to comprehend the implied and contextually dependent meanings within communication has been termed 'pragmatics'.

Levinson (4) states: 'pragmatics is the study of the relations between language and context that are basic to an account of language understanding'. To exemplify, consider the use of sarcasm in the phrase 'that was such a fantastic movie!', the use of figurative language in 'I was late and so flew to work', and the requirement for a listener to infer a request in the indirect question 'are you able to close the window?'. These illustrations make clear that the meaning of an utterance can differ substantially from its content; it might mean more, less or indeed something substantially different to its linguistic proposition. This principle of linguistic underdeterminacy means that semantics alone cannot determine the proposition of a speaker when they utter a sentence. Instead, context must be drawn upon to come to an appropriate interpretation (4,5).

One view (3) is that pragmatic comprehension is itself one module of a broader system which enables us to draw inferences about the beliefs, desires and intentions of conspecifics (Theory of Mind; ToM). Wilson (p. 1132) writes:

> *'Understanding an utterance involves constructing a hypothesis about the speakers meaning [. . .]. Recognising a speaker's meaning amounts to recognising the intention behind the speaker's communicative behaviour, and this is a special case of the more general problem of explaining an individual's behaviour in terms of attributed mental states'.*

Clearly then, there are theoretical links between the capacity for comprehension of the implied meaning of conversational remarks and social cognition, particularly mental state reasoning. Nonetheless, more basic cognitive processes may be more parsimoniously related to comprehension of language implicature. Executive resources may be deployed in order to support pragmatic comprehension, for example by inhibition of inappropriate interpretations (6,7) and for general inferential reasoning (8). In addition, due to the theoretically limitless amount of contextual information that can be drawn upon in order to inform pragmatic interpretation of any given remark (3), declarative and working memory, as well as attentional and processing resources, are likely to play some kind of supportive role in pragmatics. Indeed, neuroimaging studies have provided emerging evidence that inferential language comprehension relies on a distributed frontal-parietal network typically associated with multiple cognitive functions, including the lateral frontopolar, anterior prefrontal, dorsolateral prefrontal and anterior cingulate cortices, as well as the inferior and superior parietal cortices (9). In short, there is a good case that pragmatics is a demanding executive ability.

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TBI

Traumatic brain injury (TBI) has been characterized as 'alteration in brain function, or other evidence of brain pathology, caused by an external force' (10; p1637). Neuropathological consequences of non-penetrating TBI typically include traumatic axonal injury, which is the acute functional impairment of neural axons, which can lead to cell necrosis, particularly in white matter and transcallosal tracts. In non-penetrating TBI, the frontal cortex is affected in the majority of cases, as part of a diffuse pattern of cortical lesion and degradation to the structure and integrity of axons (11–13).

TBI frequently causes disruption of communicative ability, even in the absence of core language faculty disturbances (14–16). As such many of the communication difficulties experienced by those with TBI relate not to syntactical and lexical aspects of language but to the *pragmatics* of language comprehension and production.

In language production, persons with TBI produce shorter sentences, provide less elaboration (17) and are less time efficient in conveying information than controls (18). They commit more errors of cohesion and coherence due to frequent derailments, interruptions and extraneous utterances (19). They find it more difficult to plan sentences (20), and tell stories in a way that makes clear the causal and temporal relationships between events (21). Participants with TBI have difficulty then in the production of *meaningful* language, which requires microlinguistic aspects, such as grammar and syntax to be combined with macrolinguistic skills. According to Marini and colleagues (19), macrolinguistic aspects are those processes which are 'recruited in establishing cohesive and conceptual links among contiguous [...] or long-distance sentences/utterances [...] and in formulating a mental model or gist of a story or procedure' (p. 2904). Unsurprisingly then, the discourse of patients with TBI has been described as 'incoherent and impoverished' (22; p282). Partners of persons with TBI in marital dyads give similar summaries (23), and these communicative difficulties appear to remain stagnant even over the very long-term (24).

In terms of pragmatic comprehension, when given novel metaphors, participants with TBI take longer to interpret their meaning, and make more errors in doing so than controls (16). Similarly, sarcastic remarks are often misunderstood; those with TBI often accept the literal meaning of the statement or interpret it in a non-literal but nevertheless inappropriate way (25). The ability to detect humour is also attenuated (26), and although participants with TBI perform similarly to controls without neurological injury when making basic and automatic inferences in real-world conversation, they are poorer than controls when required to employ conscious reasoning to analyse the context of a statement in order to arrive at an inference (27). Finally, participants with TBI are less able to comprehend indirect requests than non-injured controls (28), and demonstrate an impaired ability to comprehend the 'gist' of story narratives, despite intact ability to follow the microstructural aspects of a story (29).

In communicative exchanges, persons with TBI have difficulty with turn taking and topic management (30,31), more readily violate cooperation norms (32,33), and have difficulty producing communication that is appropriate to the social context (34). That those persons with TBI additionally have difficulties in recognizing such norm violations when committed (34) is likely to compound the social and communicative difficulties presented by these impairments.

In addition, chronic cognitive impairments in the domains of declarative memory (encoding, storage and retrieval (35,36), working memory (37), executive functions (35,36,38,39), attention (40,41) and processing speed (42) have been documented after TBI, reflecting the diffuse nature of TBI pathophysiology. Diffuse axonal injury in TBI is associated, particularly, with processing speed (43,44) and executive functioning impairments (45,46), and even mild TBI causes acute cognitive impairments (47–49) which extend to the chronic stage in a proportion of patients (50).

Finally, TBI also results in significant difficulties in social cognition. Specifically, impairments have been documented in the low-level processes enabling recognition of emotion in faces and vocal prosody (38,51), as well as in the reflexive mimicry of facial emotion (52). Higher order processes of social cognition, including the representation of the intentions and emotional state of others (53), and second order belief reasoning (54) are also impaired.

Need for this review

Over a decade ago, Youse and Coelho (55) commented that despite an array of research into pragmatic communication deficits following TBI, a clear understanding of the relationship between cognition and communication disorder had not been established for this patient population. It is arguable that this remains the case. Studies have implicated a core group of cognitive processes in pragmatic comprehension; declarative and working memory, attention, executive functions and social cognition have all been investigated (9,56).

Several mechanisms have been proposed which attempt to account for difficulties in pragmatic comprehension following TBI. Schmitter-Edgecombe and Bales (57) found that following TBI, impairment in declarative memory correlated with a reduced ability to infer meaning from textual language. Working memory impairment also correlates with increasing difficulties in pragmatic comprehension (56), and as such it has been suggested that pragmatic interpretation may be compromised following TBI because these patients have poorer access to prior linguistic and contextual information during communication. Thus, persons with TBI may focus to a larger extent on individual propositions, failing to fully appreciate the integrated story and hold this information in working memory to generate appropriate inferences.

Another study investigated the involvement of social cognition in pragmatics following TBI and found that social cognition was uniquely associated with pragmatics even after accounting for the influence of general cognitive abilities, emotion perception abilities, age, injury severity and mood (58). The authors interpret this finding as indicating that pragmatics are supported by the ability of a listener to infer the speaker's communicative intention, and thus that social

cognition is an important cognitive aspect of impaired pragmatics following TBI.

Another study (8) bolsters claims of the importance of inference, reporting that *general* inferential reasoning abilities, but not Theory of Mind, predict pragmatic comprehension deficit in people with TBI. As such, domain general inference supported by executive processes might be of primary importance, rather than a domain specific mental state reasoning faculty (i.e. Theory of Mind).

Unfortunately, the possible role of attention and speeded processing resources in TBI have been somewhat neglected in the literature. Although measures of these cognitive constructs have been correlated with pragmatic comprehension in several TBI studies with positive findings, very little attention has been directed towards interpreting these results and developing a theoretical account of the role of these ubiquitous cognitive processes within pragmatics. Nonetheless, attentional impairment is common in TBI (40,42) and there are many routes by which attention impairment might conceivably lead to impaired pragmatics during real world communication. This might include difficulties in processing linguistic and paralinguistic information with sufficient speed during conversation or becoming distracted by irrelevant mental or environmental stimuli, which are common clinical observations in brain injury rehabilitation settings (59).

However, rarely has any individual study taken a comprehensive measure of all of these cognitive functions, and as a result, it is difficult to draw conclusions about the *relative* importance of each in pragmatic comprehension. An estimate of this relative importance is a crucial step towards the development of a model of dysfunction in pragmatic comprehension following TBI. This will allow future research to further investigate those cognitive constructs which are not only of theoretical relevance, but also empirically implicated. There is then a need to synthesize and integrate the work done in this area.

Finally, findings from the literature in this area may not filter easily into clinical knowledge and practice, despite clear relevance to neurorehabilitative settings. The literature sits on the academic and professional boundary between Neuropsychology and Linguistics, and as a result may not be readily accessible to professionals from each discipline. However, the relationship between cognition and communication has implications clinically and may allow clinicians to understand risk factors for pragmatic difficulties based on particular cognitive impairments, and vice versa.

The present study attempts to address these issues by systematically drawing together published studies which report data on the cognitive correlates of pragmatic comprehension following TBI, and by quantifying the extent of each of these relationships.

Method

Search strategy

The EBSCOhost search engine was used to conduct an extensive literature search of the Medline, PsycInfo and CINAHL databases. This search was undertaken in January 2016 and yielded no systematic or meta-analytic reviews of the relationship between cognition and pragmatics.

Search terms

Search terms were as follows:

('communicati* OR conversation* OR (language N2 comprehension) OR (expressi* N2 language) OR (language N2 producti*) OR (recepti* N2 language) OR discourse OR figurative OR humo#r OR idiom OR irony OR linguistic* OR metaphor* OR narrative OR (persua* N3 discourse) OR pragmatic* OR proverb OR sarcasm OR psycholinguistic* OR sociolinguistic*) AND (Amnesi* OR attention* OR "belief reason*" OR cogniti* OR "desire reason*" OR "executive function*" OR "executive dysfunction" OR "dysexecutive syndrome" OR "false belief" OR fMRI OR frontal OR prefrontal OR "functional magnetic resonance imaging" OR (intention N3 reason*) OR memory OR mentali* OR mindread* OR neuroimag* OR "sally-ann*" OR "social cognition" OR "theory of mind" OR (intention N3 infer*) OR (processing N2 speed)) AND ("Traumatic brain injur*" OR "head injur*" OR "head trauma"')

Search limits

These search terms were applied to article titles, abstracts and key words. Limiters were employed in EBSCOhost specifying that all peer reviewed papers published between January 1975 and December 2015 and written in the English language be returned. None of the included papers predated 1991.

Criteria for inclusion

The following criteria were applied to the returned articles in order to determine eligibility.

Inclusion criteria

a. The study includes a measure of the comprehension of pragmatics, either by:
   (1) Formal standardized measure
   (2) Novel experimental tasks
   (3) The study includes a measure of any of the following cognitive processes:
   (i) Declarative memory
   (ii) Working memory
   (iii) Attention/processing speed
   (iv) Executive functioning
   (v) Social cognition
   (vi) Vi. The study includes a defined group of participants who have sustained a TBI of at least mild severity in adulthood
   (vii) The study reports correlation of the relationship between I) and II) in the TBI group

OR

b. The authors make these data available via personal correspondence

Results of the systematic search strategy

Figure 1 outlines the search procedure in diagrammatic form. A total of 1544 papers were returned using the search procedure outlined. Further investigation revealed 476 of these records were duplicates, leaving 1068 papers for screening.

In the first instance, abstracts were compared against the inclusion criteria. A total of 1009 papers were excluded at this stage, leaving 59 for full-text review. Of these, 10 papers

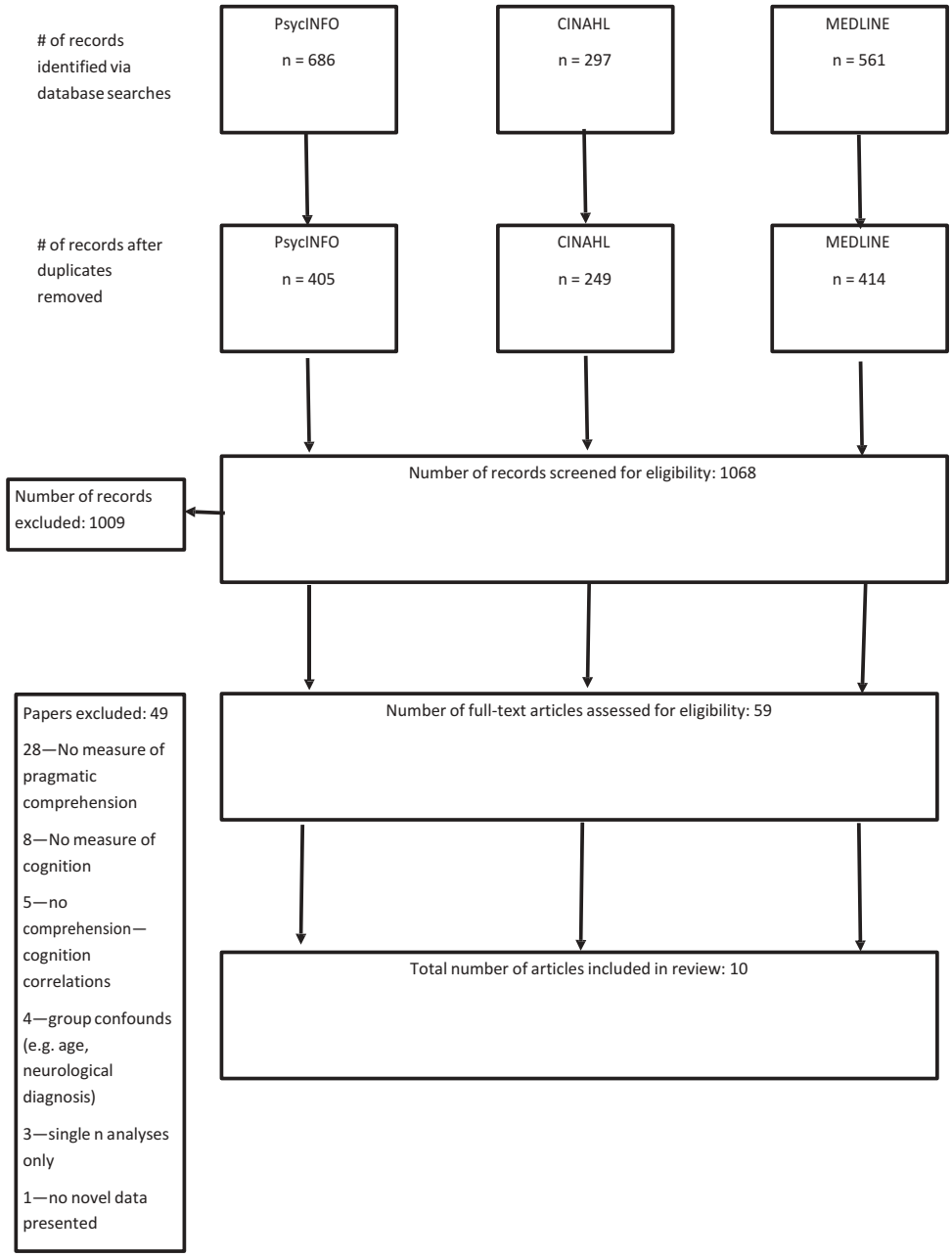


Figure 1. Flow diagram of the systematic review process.

were ultimately identified as eligible for inclusion. Appropriate correlation data were not reported in four of these papers but the authors provided this via personal communication (8,56,60,61). The reference lists of all included papers were scrutinized for additional relevant papers. None were found using this method.

Data extraction

Correlative data were extracted from the selected papers in order to populate meta-analyses. In preparation for these analyses, each pertinent correlation reported was extracted individually. Correlation coefficients were standardized by inverting where necessary, in order to ensure that a positive r-value indicated a relationship in which improvement in cognitive variable indicated an improvement of the corresponding language variable. Where multiple correlations were reported on the same construct (e.g. three different measures of executive functions were employed), these coefficients were averaged to create a single r-value for input into the appropriate meta-analysis.

Variable categorization

Neuropsychological measures employed in each study (see Table 1) were categorized in the first instance by the first author with reference to an authoritative compendium of neuropsychological tests (74). These categorizations were then reviewed by an experienced clinical neuropsychologist (author MR). Table 2 displays all measures used in the included studies and their categorization.

Table 1. Characteristics of studies included in the meta-analyses.

Study	N (TBI)	Severity	Type (CHI /PHI)	Age (mean)	Years post-injury	Language measures	Cognition Measures
Barbey Colom and Grafman(9)	145	Not reported	PHI	58	Not reported	DCT	(1) WAIS; (a) working memory index; (b) processing speed index; (2) Emotional IQ test
Channon, Pellijeff and Rule (25)	19	Severe	CHI	46	10	Sarcasm comprehension (Exp.)	Mentalizing ToM task (Exp.)
Hinchliffe, Murdoch and Chenery(62)	25	Severe	CHI	26	< 1	comprehension of humour, inference and figurative language (RHLB)	(1) WAIS; (a) digit-symbol (2) D-KEFS; (a) trails A and B; (b) colour-word inference 1 and 3; (3) WMS verbal paired associates; (4) RAVLT; (5) verbal fluency
LeBlanc et al. (56)	179	Mild - Severe	CHI	55	Acute	D-MEC comprehension indices	(1) WMS; (a) digits forwards; (b) digits backwards; (2) D-KEFS; (a) trails A and B; (b) verbal fluency
Martin and McDonald (8)	16	Severe	CHI	39	9	Pragmatic interpretation (Exp.)	(1) second order belief reasoning (Exp.), (2) complex non-mental state inference (Exp.) (3) CANTAB (a) circles task; (b) IED task; (4) Verbal Fluency
McDonald, Fisher, Flanagan and Honan (58)	31	Severe	CHI	47	>1	Interpretation of sincerity (Exp.)	(1) TASIT; (2) Balanced emotional empathy scale; (3) WAIS; (a) Digit Span; (b) Digit symbol; (4) Trails
McDonald and Flanagan (60)	34	Severe	CHI	41	9	Interpretation of sincerity/sarcasm (TASIT)	(1) TASIT; (a) emotion recognition; (b) belief inference; (c) intention inference; (d) emotion inference
McDonald et al.(61)	25	Moderate - Severe	CHI	48	14	Interpretation of sincerity/sarcasm (TASIT)	(1) Hayling test; (2) WMS; (a) logical memory index; (2) WAIS; (a) digit span; (3) D-KEFS; (a) Trails A and B (b) letter fluency; (4) TASIT; (a) emotion recognition; (5) RME; (6) IRI Perspective
Muller et al., 2010 (54)	15	Severe	CHI	37	8	Indirect speech comprehension (D-MEC)	(1) Faux Pas Test, (2) first and second order false belief tasks (Exp.); (3) character intention task (Exp.); (4) RME
Schmitter- Edgecombe and Bales, 2005 (57)	20	Severe	CHI	31	5	Pragmatic inference comprehension (Exp.)	(1) WMS letter-number sequencing; (2) symbol-digit modalities test; (3) CVLT; (4) WCST; (5) D-KEFS colour-word inference

Exp., experimental measure. Language measure abbreviations; DCT, Discourse Comprehension Test (63); RHLB, Right Hemisphere Language Battery (64); D-MEC, Protocole Montreal d'evaluation de la communication (65); TASIT, The Awareness of Social Inference Test (66); WAIS, Wechsler Adult Intelligence Scale (67); WCST, Wisconsin Card Sort Task (68); RAVLT, Rey-Osterrieth Auditory-Verbal Learning Test; WMS, Wechsler Memory Scale (69); D-KEFS, Delis-Kaplan Executive Functioning System (70); CANTAB, Cambridge Neuropsychological Test Automated Battery (IED, Intra/extradimensional shift); RME, Reading the Mind in the Eyes (71); IRI, Interpersonal Reactivity Index (72); CVLT, California Verbal Learning Test (73)

Table 2. Neuropsychological instruments used in the included studies by cognitive construct.

Declarative memory	Working memory	Attention/processing speed	Executive functions	Social cognition
RAVLT	WAIS working memory index	WAIS processing speed index	WCST	Emotional IQ Test
Rey 15 wordimmediate/delayed recall	WAIS digit spans	SCOLP silly sentences	Verbal Fluency	Mentalizing ToM task (Exp.)
WMS logical memory	WMS working memory index	WAIS digit symbol	D-KEFS	Second order belief reasoning
WMS verbal paired associates	WMS digit spans	symbol-digit modalities test	complex non-mental state inferences	TASIT (selected indices)
WMS immediate memory index	WMS letter-number sequencing	SCOLP comprehension speed	CANTAB	Balanced emotional empathy scale
CVLT			BADS	RME
WMS associate learning			Hayling Test	IRI perspective taking index
			Script analysis test	Faux Pas Test
first and second order false belief tasks				
Character intention task				
facial affect recognition				
prosody recognition				

Data analysis

Data extracted from the included papers was clustered according to the categorization of variables and used to populate meta-analyses, which were computed using the 'R' statistical package (75). A total of five meta-analyses were performed, in which pragmatic comprehension was compared individually with each cognitive construct. Many of the 10 studies reported data on more than one cognitive construct, and as such data from these papers appear in more than one meta-analysis.

Results

Study characteristics

Table 1 displays the characteristics of the studies included in the review. In total, the papers comprising the review included 509 participants. The average number of participants in each study was 51 and 9 of 10 studies reported data on participants who had sustained closed head injury (CHI). Participants were aged on average 42.8 (SD = 10.0) years of age at the time of testing, and were on average 97.8 months post injury (SD = 4.4).

Pragmatic comprehension variables

Table 1 outlines the instruments which were taken as measures of pragmatic comprehension in the meta-analyses. Of the 10 studies, 6 used validated measures and 4 used novel tasks. The measures were homogeneous in that they all assessed participant ability to make inferences about the implied meanings in ambiguous speech – whether this be related to sarcasm, humour or otherwise figurative language. Nine of the papers employed direct behavioural measures of pragmatic comprehension – requiring participants to make inferences in response to a stimulus set of ambiguous linguistic material. One study (56) employed a questionnaire measure in which clinicians rated the ability of their patients to generate accurate pragmatic inference.

Meta-analyses

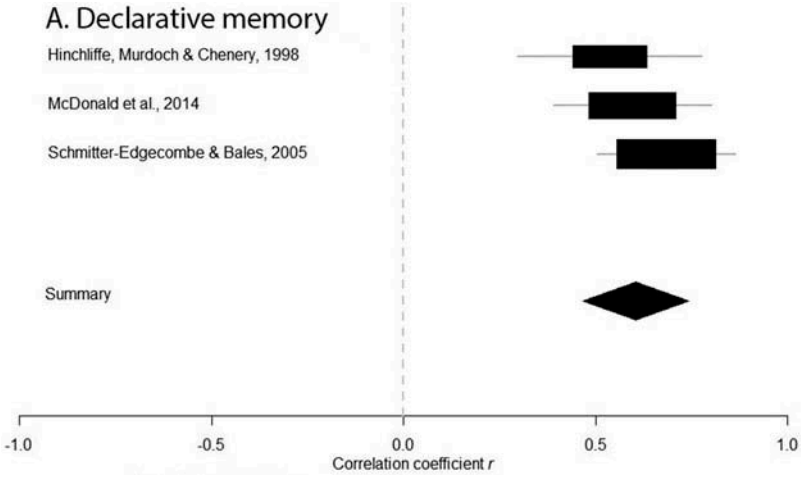
Table 3 displays all of the meta-analytic results and Figure 2 displays forest plots for all analyses. All cognitive variables showed significant correlations with pragmatic comprehension. Declarative memory was the strongest correlate (r = .605, p < 0.001), followed by executive functions (r = 0.473, p < 0.001) and social cognition (r = .421, p < 0.001). Working memory (r = 0.320, p < 0.001) and attention (r = 0.291, p < 0.001) correlated less strongly.

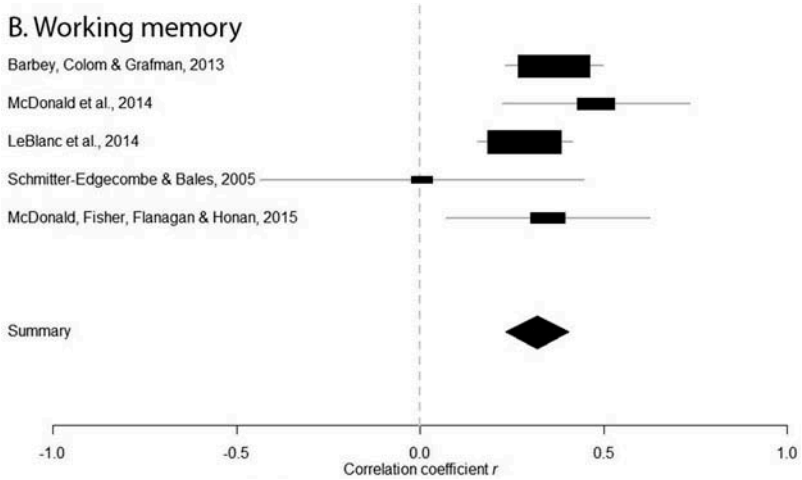
Discussion

Humans are capable of decoding the implied meanings within linguistically ambiguous speech, and do so flexibly according to the idiosyncratic context of any particular utterance. However, this ability is impaired following TBI (1,2), and there was a need to systematically examine the literature with a view to identifying the extent to which this phenomenon is related to cognitive dysfunction, and which cognitive processes are most closely involved. Thus, the present paper systematically collated data from the published literature which reported correlations between neuropsychological domains and pragmatic comprehension following TBI, and used the data extracted to populate meta-analyses. We found that pragmatic comprehension correlated strongly with declarative memory, and moderate-to-strongly with executive functions. In addition, pragmatic comprehension showed moderate correlations with working memory, attention and social cognition, indicating that a broad range of domain general cognitive processes are associated with pragmatic comprehension following TBI.

Table 3. Results of meta-analyses of pragmatic comprehension-cognition relationships in samples of patients with TBI.

Studies (n)		Participants(n)	R	95% CI	Z	P
Declarative memory	3	68	0.605	0.43 to 0.74	0.701	0.00000
Working memory	5	400	0.320	0.23 to 0.41	0.331	0.00000
Attention/ processing speed	6	355	0.291	0.19 to 0.38	0.299	0.00000
Executive functions	5	239	0.473	0.37 to 0.57	0.514	0.00000
Social cognition	7	289	0.421	0.32 to 0.51	0.449	0.00000





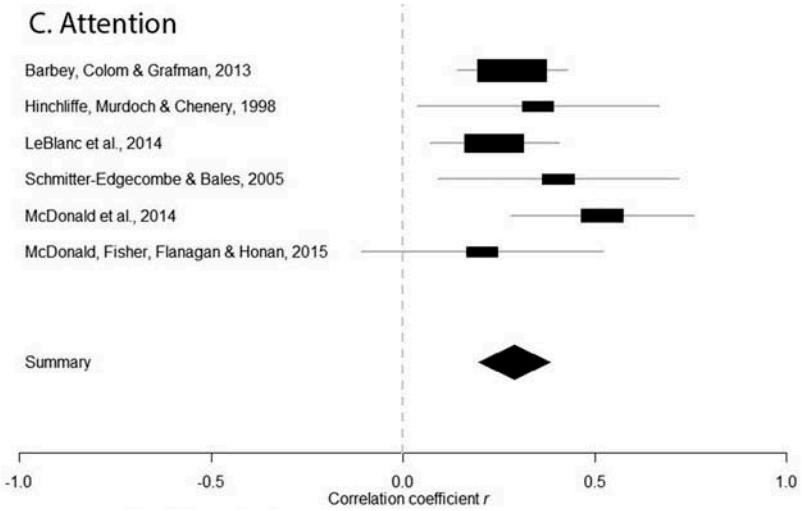


Figure 2 A-E : Forest Plots of studies included in the metaanalyses of Pragmatic Comprehension and cognitive variables. (A) Pragmatic Comprehension – Declarative Memory. (B) Pragmatic Comprehension – Working Memory. (C) Pragmatic Comprehension – Attention. (D) Pragmatic Comprehension – Executive functions. (E) Pragmatic Comprehension – Social Cognition.

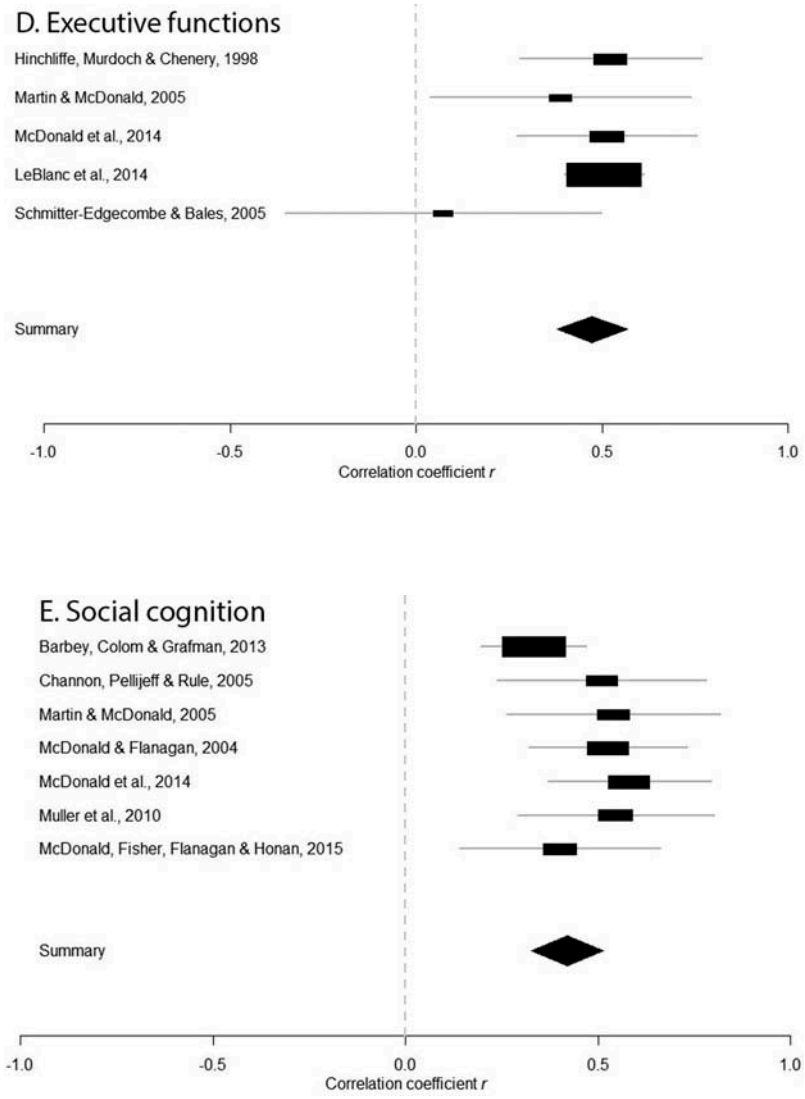


Figure 2 A-E (Continued).

The finding that declarative memory correlates strongly with pragmatic comprehension following TBI is in accordance with theoretical accounts that describe contextual and semantic knowledge as crucial in pragmatic interpretation (3), and suggests that declarative memory processes may play a substantial role in pragmatic interpretation. However, given that our review only identified three studies with modest participant numbers that spoke to this relationship, conclusions must necessarily be tentative. Nonetheless, we suggest that the impact of declarative memory impairment on pragmatic comprehension after TBI may have been overlooked in the literature, and that this area warrants further study.

A debate has arisen over recent years regarding the relative contributions of executive functions and social cognition to pragmatic comprehension (61), which has taken place in the context of a more entrenched dispute regarding the extent of independence of these cognitive constructs (76). Our review indicates that these functions have a relationship with pragmatic comprehension which is relatively similar in strength, indicating that both may play a role in pragmatic interpretation. However, the data do not offer resolute support to theoretical accounts which ascribe primacy to the role of ToM in pragmatic comprehension (3), as social cognition did not show a particularly strong correlation with pragmatic comprehension in our analyses. Additionally, given the difficulties in developing experimental tasks which precisely isolate executive components from social cognitive components in tests of the latter, many of the tasks which measured social cognition in this review contained an executive component. This issue is longstanding in the literature (77).

As such, competing theoretical positions which posit central roles for domain-specific mental state inferences (ToM) (3), versus more domain-general inferential reasoning (8) and executive inhibition (6,7), cannot be convincingly discriminated between on the basis of the current findings. At the very least, it is logically clear that pragmatic interpretation requires an inference to draw conclusions based on underdetermined data; access to contextual information alone is not sufficient

for understanding (5). Whether such a task is carried out by a specialized mentalizing module or supported by a domain general executive system remains to be seen.

That working memory and attention correlated less strongly than the other cognitive constructs indicates that these may have a more peripheral role in pragmatic interpretation following TBI. Indeed, theoretical accounts (2) have not ascribed a central role for attentional processes, but attention is nonetheless likely to have a general influence on communicative ability to the extent that lapses in attention may make pragmatic misunderstandings more likely.

Additionally, the finding that working memory correlates moderately with pragmatic interpretation provides support for the view that the two concepts are related. As suggested by Wilson (3), this role might be to hold contextual information 'online' in working memory in order to draw upon it when making inferences during the interpretations of ambiguous speech. One difficulty in attempting to test this possibility using correlative designs is that working memory tasks are heavily reliant on executive resources. As such, the observed correlation between working memory and pragmatic interpretation may reflect the general importance of executive processes, rather than a specific computational role for working memory. Experimental paradigms which manipulate working memory load whilst gauging pragmatic comprehension performance would be beneficial in evaluating this putative relationship in future research.

Clinical and research implications

The primary clinical finding of this review is that difficulties in pragmatics following TBI is associated with an array of cognitive impairments. Clinicians may wish to pay particular attention to the extent to which patients demonstrate pragmatic comprehension impairments during assessment when cognitive impairment is present, as it is tentatively possible to conclude that for patients with cognitive impairment following TBI, there is a risk of associated pragmatic interpretation difficulties.

Having established an empirical link between cognition and pragmatics, it becomes important to consider how impairment in pragmatics might present clinically in the context of cognitive impairment, and also to consider overlaps in the presentation of cognitive versus pragmatic comprehension impairments. One syndrome, classic after TBI, has been termed 'acquired sociopathy' (78,79) and involves impaired social cognition. These typically include reduced empathy, apathy and blunted emotions, inappropriate affect, poor frustration tolerance, emotional lability, indecisiveness, poor social judgment and a tendency to act in socially inappropriate ways. Given that language is an intensely social phenomenon, and that this particular group of patients show characteristically social impairments following TBI, it might be difficult (or even undesirable) to attempt to dissociate difficulties in pragmatics from social and behavioural disturbances. It is certainly feasible that an acquired difficulty in pragmatics might contribute to the appearance of 'acquired sociopathy'; inappropriate affect could involve a misinterpretation of a speaker's prosody, poor frustration tolerance could betray confusion in communication, and indecisiveness might relate in part to difficulties in organizing verbal information into a 'gist'. These links demonstrate the potentially close inter-relatedness of these clinical presentations in TBI, and the possibility that 'acquired sociopathy' might be reconceptualized as arising from communication difficulty.

Assessment of pragmatics in TBI

One clinical assessment tool which makes explicit this close association is The Awareness of Social Inference Test (TASIT) (66). This assessment was developed for use in populations with TBI and assesses recognition of basic emotions as well as social inference. In the latter, videos are shown to participants depicting actors in sincere, sarcastic and deceptive exchanges. Probe questions are asked to assess whether the examinee is able to use contextual and paralinguistic cues to decode the thoughts and feelings of the speaker, as well as the message they intended to portray in their speech act (i.e. sincere, sarcastic or deceptive).

In addition, the Right Hemisphere Language Battery (RHLB) (64) is a comprehensive pragmatics assessment battery. It enables assessment of a broad range of abilities, most notably an examinee's ability to comprehend language implicature, appreciate verbal humour, comprehend verbal and visual metaphors and decode prosody. A discourse analysis can also be completed in order to assess for any impairments in pragmatics during real social interaction with the examiner.

On the basis of the present findings then, pragmatic language disorder appears to have neuropsychological relevance in addition to speech and language aspects for patients with TBI, and should be considered during neuropsychological assessment. Future research in this area might attempt to develop a model of the precise mechanisms by which these cognitive domains contribute to this uniquely human trait.

Conclusion

The literature investigating the real-world functional use of language and its interface with cognition is beginning to provide some insights into the extent of their relationships. This review indicates that the pragmatic interpretation of language is likely to rely substantially on a distributed, domain general cognitive architecture, and may also recruit more domain-specific social cognitive processes.

Declaration of Interest

The authors report no declarations of interest.

Acknowledgments

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References

1. Douglas JM. Relation of executive functioning to pragmatic outcome following severe traumatic brain injury. J Speech, Lang Hearing Res. 2010;53(2):365–82. doi:10.1044/1092-4388(2009/08-0205).
2. Martin I, McDonald S. Weak coherence, no theory of mind, or executive dysfunction? Solving the puzzle of pragmatic language disorders. Brain Lang. 2003;85(3):451–66. doi:10.1016/S0093-934X(03)00070-1.
3. Wilson D. New directions for research on pragmatics and modularity. Lingua. 2005;15(8):1129–46.
4. Sc L. Pragmatics (Cambridge Textbooks in Linguistics). Cambridge: Cambridge University Press; 1983.
5. Huang Y. Pragmatics (Oxford Textbooks in Linguistics). Oxford: Oxford University Press; 2007.
6. Faust ME, Gernsbacher MA. Cerebral mechanisms for suppression of inappropriate information during sentence comprehension. Brain Lang. 1996;53(2):234–59.
7. Gernsbacher MA, Keysar B, Robertson RR, Werner NK. The role of suppression and enhancement in understanding metaphors. J Mem Lang. 2001;45(3):433–50.
8. Martin I, McDonald S. Evaluating the causes of impaired irony comprehension following traumatic brain injury. Aphasiology. 2005;19(8):712–30.
9. Barbey AK, Colom R, Grafman J. Neural mechanisms of discourse comprehension: A human lesion study. Brain. 2013;137(1):277–87.
10. Menon DK, Schwab K, Wright DW, Maas AI. Position statement: definition of traumatic brain injury. Arch Phys Med Rehabil. 2010;91(11):1637–40. doi:10.1016/j.apmr.2010.05.017.
11. Adams JH, Graham DI, Scott G, Parker LS, Doyle D. Brain damage in fatal non-missile head injury. J Clin Pathol. 1980;33(12):1132–45. doi:10.1136/jcp.33.12.1132.
12. Lezak MD, Howieson DB, Bigler ED, Tranel D. Neuropsychological assessment. Oxford: Oxford University Press; 2012.
13. Smith DH, Meaney DF, Shull WH. Diffuse axonal injury in head trauma. J Head Trauma Rehabil. 2003;18(4):307–16. doi:10.1097/00001199-200307000-00003.
14. Hagen C. Language disorders in head trauma. In: Holland A, editor. *Language disorders in adults*. San Diego: College Hill; 1984. p. 245–81.
15. Holland AL. When is aphasia aphasia? The problem of closed head injury. In: Brookshire RH editor. Clinical Aphasiology: conference proceedings. Minneapolis: BRK Publishers; 1982. p. 345–49.
16. Yang FG, Fuller J, Khodaparast N, Krawczyk DC. Figurative language processing after traumatic brain injury in adults: A preliminary study. Neuropsychologia. 2010;48(7):1923–29. doi:10.1016/j.neuropsychologia.2010.03.011.
17. Coelho CA. Story narratives of adults with closed head injury and non-brain injured adults: influence of socioeconomic status, elicitation task, and executive functioning. J Speech, Lang Hearing Res. 2002;45(6):1232–48. doi:10.1044/1092-4388(2002/099).
18. Matsuoka K, Kotani I, Yamasato M. Correct information unit analysis for determining the characteristics of narrative discourse in individuals with chronic traumatic brain injury. Brain Inj. 2012;26(13–14):1723–30. doi:10.3109/02699052.2012.698789.
19. Marini A, Galetto V, Zampieri E, Vorano L, Zettin M, Carlomagno S. Narrative language in traumatic brain injury. Neuropsychologia. 2011;49(10):2904–10. doi:10.1016/j.neuropsychologia.2011.06.017.
20. Peach RK. The cognitive basis for sentence planning difficulties in discourse after traumatic brain injury. Am J Speech-Language Pathol. 2013;22(2):S285–S297. doi:10.1044/1058-0360(2013/12-0081).
21. Mozeiko J, Le K, Coelho C, Krueger F, Grafman J. The relationship of story grammar and executive function following TBI. Aphasiology. 2011;25(6–7):826–35. doi:10.1080/02687038.2010.543983.
22. Marini A, Zettin M, Galetto V. Cognitive correlates of narrative impairment in moderate traumatic brain injury. Neuropsychologia. 2014;64:282–88. doi:10.1016/j.neuropsychologia.2014.09.042.
23. Bracy CA, Douglas JM. Marital dyad perceptions of injured partners' communication following severe traumatic brain injury. Brain Impairment. 2005;6(1):1–12.
24. Ponsford JL, Downing MG, Olver J, Ponsford M, Acher R, Carty M, Spitz G. Longitudinal follow-up of patients with traumatic brain injury: outcome at two, five, and ten years post-injury. Journal of Neurotrauma. 2014;31(1):64–77.
25. Channon S, Pellijeff A, Rule A. Social cognition after head injury: sarcasm and theory of mind. Brain Lang. 2005;93(2):123–34.
26. Braun CM, Lussier F, Baribeau JM, Ethier M. Does severe traumatic closed head injury impair sense of humour? Brain Inj. 1989;3(4):345–54.
27. Johnson JE, Turkstra LS. Inference in conversation of adults with traumatic brain injury. Brain Inj. 2012;26(9):1118–26.
28. Evans K, Hux K. Comprehension of indirect requests by adults with severe traumatic brain injury: contributions of gestural and verbal information. Brain Inj. 2011;25(7–8):767–76.
29. Holliday R, Hamilton S, Luthra A, Oddy M, Weekes BS. Text comprehension after traumatic brain injury: missing the gist? Brain Lang. 2005;95(1):74–75.
30. Coelho CA, Youse KM, Le KN. Conversational discourse in closed-head-injured and non-brain-injured adults. Aphasiology. 2002;16(4–6):659–72.
31. Mentis M, Prutting CA. Analysis of topic as illustrated in a head-injured and a normal adult. J Speech, Lang, Hearing Res. 1991;34(3):583–95.
32. Grice HP. Logic and conversation. The William James lectures, II. In: Cole P, Jl M, editors. Syntax and semantics 3: speech acts. New York: Academic Press; 1975.
33. Glosser G. Discourse production patterns in neurologically impaired and aged populations. In: Brownell HH, Joannette Y, editors. Narrative discourse in neurologically impaired and normal aging adults. San Diego, CA: Singular; 1993. p. 191–211.
34. Angeleri R, Bosco FM, Zettin M, Sacco K, Colle L, Bara BG. Communicative impairment in traumatic brain injury: A complete pragmatic assessment. Brain Lang. 2008;107(3):229–45.
35. Fork M, Bartels C, Ebert AD, Grubich C, Synowitz H, Wallesch CW. Neuropsychological sequelae of diffuse traumatic brain injury. Brain Inj. 2005;9(2):101–08.
36. Scheid R, Walther K, Guthke T, Preul C, Von Cramon DY. Cognitive sequelae of diffuse axonal injury. Arch Neurol. 2006;63(3):418–24.
37. McDowell S, Whyte J, D'Esposito M. Working memory impairments in traumatic brain injury: evidence from a dual-task paradigm. Neuropsychologia. 1997;35(10):1341–53.
38. Milders M, Fuchs S, Crawford JR. Neuropsychological impairments and changes in emotional and social behaviour following severe traumatic brain injury. J Clin Exp Neuropsychol. 2003;25(2):157–72.
39. Stuss DT. Traumatic brain injury: relation to executive dysfunction and the frontal lobes. Curr Opin Neurol. 2011;24(6):584–89.
40. Mathias JL, Wheaton P. Changes in attention and information-processing speed following severe traumatic brain injury: a meta-analytic review. Neuropsychology. 2007;21(2):212–23.
41. Rios M, Perianez JA, Munoz-Cespedes JM. Attentional control and slowness of information processing after severe traumatic brain injury. Brain Inj. 2004;18:257–72.
42. Madigan NK, DeLuca J, Diamond BJ, Tramontano G, Averill A. Speed of information processing in traumatic brain injury: modality-specific factors. J Head Trauma Rehabil. 2000;15:943–56.
43. Felmingham KL, Baguley IJ, Green AM. Effects of diffuse axonal injury on speed of information processing following severe traumatic brain injury. Neuropsychology. 2004;18(3):564–71.
44. Niogi SN, Mukherjee P, Ghajar J, Johnson C, Kolster RA, Sarkar R, Lee H, Meeker M, Zimmerman RD, Manley GT, et al. Extent of microstructural white matter injury in postconcussive syndrome correlates with impaired cognitive reaction time: a 3T diffusion

tensor imaging study of mild traumatic brain injury. Am J Neuroradiology. 2008;29(5):967–73.
45. Lipton ML, Gulko E, Zimmerman ME, Friedman BW, Kim M, Gellella E, Gold T, Shifteh K, Ardekani BA, Branch CA. Diffusion-tensor imaging implicates prefrontal axonal injury in executive function impairment following very mild traumatic brain injury. Radiology. 2009;252(3):816–24.
46. Wallesch CW, Curio N, Kutz S, Jost S, Bartels C, Synowitz H. Outcome after mild-to-moderate blunt head injury: effects of focal lesions and diffuse axonal injury. Brain Inj. 2001;15(5):401–12.
47. Binder LM. A review of mild head trauma. Part II: Clinical implications. J Clin Exp Neuropsychol. 1997;19(3):432–57.
48. Binder LM, Rohling ML, Larrabee GJ. A review of mild head trauma. Part I: Meta-analytic review of neuropsychological studies. J Clin Exp Neuropsychol. 1997;19(3):421–31.
49. Erez ABH, Rothschild E, Katz N, Tuchner M, Hartman-Maeir A. Executive functioning, awareness, and participation in daily life after mild traumatic brain injury: A preliminary study. Am J Occup Ther. 2009;63(5):634–40.
50. Carroll L, Cassidy JD, Peloso P, Borg J, Von Holst H, Holm L, Paniak C, Pépin M. Prognosis for mild traumatic brain injury: results of the WHO collaborating centre task force on mild traumatic brain injury. J Rehabil Med. 2004;36:84–105.
51. Spikman JM, Timmerman ME, Milders MV, Veenstra WS. van der Naalt J. Social cognition impairments in relation to general cognitive deficits, injury severity, and prefrontal lesions in traumatic brain injury patients. J Neurotrauma. 2012;29(1):101–11.
52. McDonald S, Li S, De Sousa A, Rushby J, Dimoska A, James C, Tate RL. Impaired mimicry response to angry faces following severe traumatic brain injury. J Clin Exp Neuropsychol. 2011;33 (1):17–29.
53. Havet-Thomassin V, Allain P, Etcharry-Bouyx F, Le Gall D. What about theory of mind after severe brain injury? Brain Inj. 2006;20 (1):83–91.
54. Muller F, Simion A, Reviriego E, Galera C, Mazaux JM, Barat M, Joseph PA. Exploring theory of mind after severe traumatic brain injury. Cortex. 2010;46(9):1088–99.
55. Youse KM, Coelho CA. Working memory and discourse production abilities following closed-head injury. Brain Inj. 2005;19 (12):1001–09.
56. LeBlanc J, De Guise E, Champoux M, Couturier C, Lamoureux J, Marcoux J, Maleki M, Feyz M. Acute evaluation of conversational discourse skills in traumatic brain injury. Int J Speech Lang Pathol. 2014;16(6):582–93.
57. Schmitter-Edgecombe M, Bales JW. Understanding text after severe closed-head injury: assessing inferences and memory operations with a think-aloud procedure. Brain Lang. 2005;94 (3):331–46.
58. McDonald S, Fisher A, Flanagan S, Honan CA. Impaired perception of sincerity after severe traumatic brain injury. J Neuropsychol. 2015. doi:10.1111/jnp.12086.
59. Powell GE, Wood RL. Assessing the nature and extent of neurobehavioural disability. In: Rl W, Macmillan T. editors. Neurobehavioural disability and social handicap following traumatic brain injury. East Sussex: Psychology Press; 2001. p. 65–90.
60. McDonald S, Flanagan S. Social perception deficits after traumatic brain injury: interaction between emotion recognition, mentalizing ability, and social communication. Neuropsychology. 2004;18(3):572–79.
61. McDonald S, Gowland A, Randall R, Fisher A, Osborne-Crowley K, Honan C. Cognitive factors underpinning poor expressive communication skills after traumatic brain injury: theory of mind or executive function? Neuropsychology. 2014;28(5):801–11.
62. Hinchliffe FJ, Murdoch BE, Chenery HJ. Towards a conceptualization of language and cognitive impairment in closed-head injury: use of clinical measures. Brain Inj. 1998;12(2):109–32.
63. Brookshire RH, Nicholas LE. Comprehension of directly and indirectly stated main ideas and details in discourse by brain-damaged and non-brain-damaged listeners. Brain Lang. 1984;21 (1):21–36.
64. Bryan KL. The right hemisphere language battery. 2nd Ed. London: Whurr Publishers Ltd; 1996.
65. Joanette Y, Ska B, Côté H. Protocole Montréal d'Évaluation de la Communication. Isbergues: Ortho Édition; 2004.
66. McDonald S, Flanagan S, Rollins J, Tasit: KJ. A new clinical tool for assessing social perception after traumatic brain injury. J Head Trauma Rehabil. 2003;18(3):219–38.
67. The Psychological Corporation. WAIS-IV Technical Manual. San Antonio: Author; 2008.
68. Heaton RK. Wisconsin card sorting test manual. Odessa, FL: Psychological Assessment Resources, Inc; 1993.
69. Wechsler D. WMS-III Administration and scoring manual. San Antonia, TX: The Psychological Corporation; 1997.
70. Delis DC, Kaplan E, Kramer JH. Delis–Kaplan executive functioning system. San Antonia, TX: The Psychological Corporation; 2001.
71. Baron-Cohen S, Wheelwright S, Hill J, Raste Y, The PI. "Reading the Mind in the Eyes" test revised version: A study with normal adults, and adults with Asperger syndrome or high-functioning autism. J Psychol Psychiatry. 2001;42(2):241–51.
72. Davis MH. A multidimensional approach to individual differences in empathy. JSAS Catalogue Selected Doc Psychol. 1980;10:85.
73. Delis DC, Kramer JH, Kaplan E. Ober BA. California verbal learning test – second edition, adult version. San Antonio, TX: The Psychological Corporation; 2000.
74. Strauss E, Sherman EM, Spreen O. A compendium of neuropsychological tests: administration, norms, and commentary. Oxford, UK: Oxford University Press; 2006.
75. R Core Team. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria; 2012. ISBN 3-900051-07-0, Available from: http://www.R-project.org/
76. Apperly IA, Samson D, Humphreys GW. Domain-specificity and theory of mind: evaluating neuropsychological evidence. Trends Cogn Sci. 2005;9(12):572–77.
77. Apperly IA, Samson D, Chiavarino C, Humphreys GW. Frontal and temporo-parietal lobe contributions to theory of mind: neuropsychological evidence from a false-belief task with reduced language and executive demands. J Cogn Neurosci. 2004;16 (10):1773–84.
78. Barrash J, Tranel D, Anderson SW. Acquired personality disturbances associated with bilateral damage to the ventromedial prefrontal region. Dev Neuropsychol. 2000;18(3):355–81.
79. Wood RL, Williams C. Inability to empathize following traumatic brain injury. J Int Neuropsychological Soc. 2008;14(02):289–96.