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The right hemisphere's contribution to discourse processing: A study in temporal lobe epilepsy

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ABSTRACT

Objective: Discourse skills - in which the right hemisphere has an important role - enables verbal communication by selecting contextually relevant information and integrating it coherently to infer the correct meaning. However, language research in epilepsy has focused on single word analysis related mainly to left hemisphere processing. The purpose of this study was to investigate discourse abilities in patients with right lateralized medial temporal lobe epilepsy (RTLE) by comparing their performance to that of patients with left temporal lobe epilepsy (LTLE).
Methods: 74 pharmacoresistant temporal lobe epilepsy (TLE) patients were evaluated: 34 with RTLE and 40 with LTLE. Subjects underwent a battery of tests that measure comprehension and production of conversational and narrative discourse. Disease related variables and general neuropsychological data were evaluated.
Results: The RTLE group presented deficits in interictal conversational and narrative discourse, with a disintegrated speech, lack of categorization and misinterpretation of social meaning. LTLE group, on the other hand, showed a tendency to lower performance in logical-temporal sequencing.
Significance: RTLE patients showed discourse deficits which have been described in right hemisphere damaged patients due to other etiologies. Medial and anterior temporal lobe structures appear to link semantic, world knowledge, and social cognition associated areas to construct a contextually related coherent meaning.

1. Introduction

Discourse skills imply the inference of meaning from larger multi-sentence units called discourse: conversations, narrations or instructions, rather than expressing or receiving isolated words or sentences (AbdulSabur et al., 2014; Abusamra, Côté, Joanette, & Ferreres, 2009; Johns, Tooley, & Traxler, 2008). Discourse study enables society characterizes language functioning to its full extent. Deficits in discourse processing affect interpersonal communication and text comprehension, and thus could impact the whole educational career and social life (Cornoldi & Oakhill, 1996).

Processing discourse successfully requires building a mental model that is maintained in an active fashion, being revised and updated as new information becomes available (Johns et al., 2008). This includes constructing a coherent microstructure - the relationship between individual incoming sentences - and macrostructure - the knowledge of the overarching message or theme that organizes sentences into a unified whole - and making the correct inferences about that which is not explicit (Johns et al., 2008; Prat, Long, & Baynes, 2007). Thus, sentence information meaning is integrated and combined with the prior discourse, world knowledge, information about the speaker and semantic information from extra-linguistic domains to get a message-level representation (Hagoort & van Berkum, 2007).

In the last decades there has been an increasing interest in studying how the right hemisphere (RH) contributes to communi-

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cation and social skills. In patients with right brain hemisphere damage (RHD) - due to stroke or head trauma - a wide range of language and communication deficits have been described at a discourse, pragmatic, lexico-semantic, and prosodic level (Abusamra et al., 2009; Ferré, Fonseca, Ska, & Joanette, 2012; Ferré, Ska, Lajoie, Bleau, & Joanette, 2011a; Johns et al., 2008). Ferré et al. (2012) found that 50–78% of patients with RHD caused by stroke lesions have language deficits. Regarding discourse skills in particular, patients with RHD produce less informative and coherent discourse than that of control subjects, while maintaining a similar number of enunciations. In addition, these individuals often speak tangentially (i.e. introducing personal digressions and critiques), make inappropriate comments, and stray off topic (Abusamra et al., 2009; Johns et al., 2008). At a receptive level, they fail to integrate elements of a story into a coherent whole and fail to infer the correct pragmatic and social interpretations (Abusamra et al., 2009; Ferré et al., 2012; Marini & Ph, 2012).

Until the last decades, the most widespread neurobiological model for language was the classical left-perisylvian Wernicke-Lichtheim-Geshwind model. This model is incomplete for several reasons: lesion in both Broca's and Wernicke's region can impair language production and comprehension, it does not describe other relevant fiber tracts beyond the arcuate fasciculus, and does not explain higher-order, language-communication skills that are subserved throughout both hemispheres (Hagoort & Indefrey, 2014; Poeppel, Emmorey, Hickok, & Pylkkanen, 2012). Recent approaches include a dual stream model (Hickok & Poeppel, 2004, 2007) which describes a dorsal phonological route (sounds into words) mostly represented in the dominant hemisphere, and a ventral semantic route (sounds into meaning) with bilateral representation. In the last years, evidence from functional neuroimaging methods enabled to describe other cortical and subcortical areas involved in language (Price, 2012). Catani and Bambini (2014) proposed a social communication and language evolution, and development model (SCALED), that extends the dual-stream model and includes frontal, fronto-parietal and temporo-parietal networks. This model consists of five levels, from the representation of informative actions and communicative intentions, to lexico-semantic processing, syntactic analysis and pragmatic integration.

Although functional Magnetic Resonance Imaging (fMRI) studies in healthy population have shown broadly bilateral activation of language attention and theory of mind-associated cortical areas during discourse production and comprehension, some studies have shown that inferring meaning from pragmatic and social contexts seems to be more represented at the right or non-dominant hemisphere (AbdulSabur et al., 2014; Mar, 2011; Mason & Just, 2009; Swett et al., 2013). Theory of mind (ToM) - involves the construction of a theory concerning one's own or others' affective and epistemic mental states - is one of complex social cognition abilities that contribute to construct mental representations of social relations and to flexibly use them in the social environment (Giovagnoli et al., 2011).

The anterior temporal lobes have been related to different functions such as being a domain-general semantic hub, having a domain-specific role in social or 'person-related' processing, being a personal episodic and semantic memory store and mediating the access to emotional and social contexts for meaning construction (Baez, Rattazzi, Gonzalez-gadea, & Torralva, 2012; Kennedy & Adolphs, 2012; Petrides, 2013; Price, 2012; Wong & Gallate, 2012).

Medial Temporal Lobe Epilepsy (TLE) is the most frequent type of pharmacoresistant epilepsy in young adults which can lead to epilepsy surgery. It is described as a localized form of epilepsy that involves brain networks of medial temporal lobe, amygdala, hippocampus, uncus, parahipocampal gyrus, and the entorhinal cortex. The main cause of lesional TLE is the hippocampal sclerosis, in over 80% of cases (Cendes, 2005; Tatum, 2012). The functional and structural properties of the abnormal epileptogenic networks and their anatomic location contribute to the defined electro-clinical syndrome and the individual's clinical characteristics (Bell, Lin, Seidenberg, & Hermann, 2011; Gleichgerrcht, Kocher, & Bonilha, 2015; Hermann, Meador, Gaillard, & Cramer, 2010; Richardson, 2012). The main goals of the neuropsychological evaluation in TLE are the detection of cognitive deficits and prediction of cognitive surgical outcome (assessing functional integrity of the tissue to be resected and cognitive reserve of the rest of the brain), (McAndrews & Cohn, 2012).

Most of the previous literature about interictal language evaluation in TLE adults has focused on the production and comprehension of single word and sentence -level analysis, evaluating mainly quantitative aspects of word production like semantic and phonologic fluency or naming abilities (Bartha-Doering & Trinka, 2014; Bell, Seidenberg, Hermann, & Douville, 2003; Hamberger & Tamny, 1999; Lomlomdjian, Solis, Medel, & Kochen, 2011; Trebuchon Da Fonseca et al., 2009). Few studies have evaluated conversational discourse (Bartha, Benke, Bauer, & Trinka, 2005; Howell, Saling, Bradleyt, Samuel, & Hospital, 1994) and narrative discourse production (Bell, Dow, Watson, Woodard, & Seidenberg, 2003; Field, Saling, & Berkovic, 2000), but most of them did not analyze the epileptic zone (EZ) laterality. Many recent studies in TLE patients showed deficits in ToM abilities (Broicher et al., 2012; Giovagnoli et al., 2011; Schacher et al., 2006), however little is known about social communication abilities in this population.

The goal of this study was to investigate discourse abilities in patients with right lateralized medial temporal lobe epilepsy (RTLE) by comparing their performance to that of patients with left TLE (LTLE). Right hemisphere structures associated with discourse performance may be affected by the EZ directly or indirectly and, given reports in the RHD literature, they would be expected to produce interictal deficits in narrative and conversational discourse abilities in RTLE patients.

2. Methods

2.1. Ethical approval and participants consent

All participants provided written informed consent approved by the Institutional Ethics Committee at Ramos Mejia Hospital and El Cruce Hospital, which follows the guidelines of the Declaration of Helsinki.

2.2. Participants

From December 2011 to November 2015, 74 patients with pharmacoresistant TLE and unequivocal lateralized EZ were included for this study: 34 with a right epileptic zone (RTLE) and 40 with a left EZ (LTLE). Subjects were evaluated by the same professional team at the Epilepsy Center, Ramos Mejia Hospital, Buenos Aires and at the National Neuroscience and Neurosurgery Center, El Cruce Néstor Carlos Kirchner Hospital, Florencio Varela, both in Argentina.

Inclusive criteria were: subjects from 18 to 50 years-old, with at least seven years of formal education (completed primary school in Argentina), Full Scale IQ > 80, clearly defined EZ, and strong right handedness determined by the Edinburgh Inventory and the Grooved Pegboard Test (Lezak, 2012). Patients were not included if they had history of psychiatric disorders, other neurological diseases, or a clinical condition that could modify cognitive performance. In order to determine lateralization and localization of the EZ, video-EEG monitoring was performed in all patients over a mean period of five days. A high-resolution Magnetic Resonance Imaging (MRI) study with epilepsy protocol was conducted for every patient.

TLE patients had early-onset disease (mean age 14.16 years; SD 9.75) and prolonged illness duration (mean 20.42 years; SD 12.26). RTLE group was matched to LTLE group by sex (38 males, 36 females), age (mean: 34.75; SD 10.68), education (mean 12; SD 3.09), and general cognitive status (Total IQ mean 94.27, SD 12.69). There were no significant differences in the use of antiepileptic drugs and seizure frequency between both groups (see Table 1). MRI studies determined hippocampal sclerosis in 54 cases (31 LTLE/23 RTLE), focal cortical dysplasia (FCD) subtype II in three cases (2 LTLE/1 RTLE), dysembryoplastic neuroepithelial tumor (DNT) in five cases (2 LTLE/3 RTLE), cavernoma in one RTLE patient and normal MRI in 11 cases (5 LTLE/6 RTLE). No statistical differences were found regarding lesion type between TLE groups.

2.3. Neuropsychological protocols

We used previously validated tests that have normative values for Argentine adult populations (Burin & Drake, 2007; Ferreres et al., 2007; Goodglass, Kaplan, Barresi, 2005; Lomlomdjian et al., 2011; Oddo, Consalvo, Silva, D'Alessio, & Kochen, 2003; Weschler, 2006). The neuropsychological evaluation protocol was completed during the video-EEG study period, was divided into two or three sessions and had a total mean duration of six hours. It was performed by one of three examiners who were blind to TLE lateralization and other clinical information and were assigned randomly to each case. Cognitive tests' written forms, verbatim and video recordings were then scored by two independent examiners achieving high inter-rater reliability in all tests (Cohen's kappa value 0.82). The results of the neuropsychological evaluation were compared to those of the normal population matched for age, sex, and formal education. For each patient, the raw values of the cognitive tests were normalized to a Z score. A deficit or impairment in each test was established when performance was below the Z -1.5 or below percentile 5.

2.3.1. General neuropsychological evaluation

A general neuropsychological assessment was performed according to our Epilepsy Center Presurgical Protocol (Lomlomdjian et al., 2011; Oddo et al., 2003). Evaluated cognitive domains included: intelligence quotient estimation, attention, working memory, executive functions, verbal and visual memory, language and social cognition (Table 2).

Table 1
Demographic and clinical information.

Demographic and clinical characteristics	LTLE Mean (SD)	RTLE Mean (SD)	LTLE vs. RTLE Independent samples *t*-test or Pearson's Chi-square test
N	40	34	
Age (years)	35 (10.81)	34.2 (10.74)	t = 0.116 (72) *p* = 0.908
Sex M/F	20/20	18/16	X^2 = 0.071(1) *p* = 0.818
Education (years)	11.47 (3.13)	12.76 (2.85)	t = 1.778 (72) *p* = 0.080
Epilepsy onset (age)	13.81 (7.91)	14.01 (11.33)	t = 0.284 (72) *p* = 0.777
Illness duration (years)	20.91 (12.96)	20.15 (11.61)	t = 0.232 (72) *p* = 0.817
Number of AEDs	2.28 (0.78)	2.35 (0.88)	t = 0.213 (72) *p* = 0.563
Use of topiramate (N)	10	8	X^2 = 0.014(1) *p* = 1
Weekly seizure frequency	1.3 (0.36)	1.2 (0.28)	t = 0.316 (72) *p* = 0.433

No statistical difference was found between groups. N = number of cases, M = male, F = female, AEDs = antiepileptic drugs, t = Student's *t* test value, X^2 = Pearson's Chi-square value, DoF = degrees of freedom and *p* = *p value.*

2.3.2. Social cognition domain: Faux Pas test

This Theory of Mind test adapted to Spanish version (Burin & Drake, 2007) was included to evaluate comprehension of social situations. Understanding a faux pas requires understanding both a mental state of belief or knowledge and some empathic understanding of how the person in the story would feel (Stone, Baron-cohen, & Knight, 1998). Subjects must recognize social faux pas (FP) in 20 stories (ten with FP and ten without FP). The examiner reads each story out loud while the text remains in front of the subject who can read it again whenever necessary. After, they must answer the following questions to assess their recognition of FP: "Did anyone say something they should not have said?" and "what did he/she say?" If they answer "yes", they are asked these four questions to measure understanding of social norms: 1. "who said something they should not have say?" 2. "Why should he/she not have said that?" 3. "Why did he/she say that?" and 4. "How did he/she feel?" Participants are then asked to answer two comprehension control questions to assess their understanding and retention of contextual details. Detecting or rejecting FP correctly attracts 1 point per story (maximum 10 points for stories with and without FP). Social norms comprehension questions (stories with FP) add 1 point, with a maximum score of 40 points. Comprehension control questions add 1 point each (for a maximum of 40 points). We calculated a Theory of Mind Index = (FP total correct answers of questions "who" + "what" + "why" + non-FP total correct answers)/maximum score of 40.

2.3.3. Discourse evaluation protocol

To evaluate discourse abilities we included four tests.

2.3.3.1. Conversational discourse subtest from the MEC protocol. The purpose of this subtest from the Montreal Protocol for the Evaluation of Communication (MEC) (Joanette, Ska, & Coté, 2004) is to examine verbal and non-verbal behavior in conversational situations, including the analysis of pragmatic aspects of discourse. The test consists of a minimum of a ten-minute conversation, between the patient and the examiner, on about two different topics. Audio recorded conversations were then analyzed by two examiners, considering the presence or absence of 19 communication-deficit behaviors which were scored on a 2-1-0 scale (2 = communication-deficit behavior not observed, 1 = behavior rarely observed or subtle and 0 = frequent or marked behavior) with a maximum score of 38 points. The scale includes the following components: lexico-semantic (e.g. two or more anomias or paraphasic errors observed), conversational (e.g. misses the conversation topic, e.g. does not respect the turn-talking), general pragmatic (does not understand indirect speech acts more than once), discourse pragmatic (e.g. cannot express ideas clearly), prosody (e.g. has a monotonous prosody) and extra-linguistic aspects (e.g. eye-to-eye contact). We used the Spanish version of the test validated by Ferreres et al. (2007).

2.3.3.2. Complex Ideational Material subtest (CIM) from the Boston diagnostic aphasia examination – third edition. This test (Goodglass et al., 2005) was included to evaluate auditory sentence and text comprehension using paired questions with a yes or no answer. This subtest has two parts. The first part consists of four sets of paired questions, with complex grammatical constructions that gradually increase in length (e.g. does a stone sink in water?/does a cork sink in water?). The second part consists of eight paired questions referring to four short stories (e.g. a story about someone trying to arrive on time to take a train: did Mr. Lopez arrive on time to take the train?/did Mr. Lopez lose the train? Both paired ques-

Table 2
General Neuropsychological Evaluation.

Neuropsychological test	LTLE	RTLE	LTLE vs. RTLE	TLE Performance
	Mean (SD) N = 40	Mean (SD) N = 34	Student's *t*-test or Mann Whitney *U* test	Total% deficit (N)
IQ WAIS-III				
Full scale IQ	93.93 (11.81)	94.93 (13.98)	t = 0.22 [72] *p* = 0.827	–
Verbal IQ	93.06 (12.85)	93.53 (15.61)	t = 0.56 [72] *p* = 0.574	–
Performance IQ	95.03 (13.74)	97.68 (12.23)	t = 0.57 [72] *p* = 0.615	–
Attention				
Direct digit span	5.14 (1.05)	5.25 (1.29)	t = −0.38 [70] *p* = 0.705	27% (20)
Trail making test A	46.52 (26.42)	46.25 (30.4)	t = 0.04 [72] *p* = 0.970	48.6% (36)
Working memory				
Inverse digit span	3.69 (1.10)	3.93(1.27)	U = 463.5 Z = −0.566 *p* = 0.572	31.1% (23)
Executive functions				
WCST categories	4.65 (2.42)	4.00 (2.72)	U = 319.5 Z = −0.902 *p* = 0.367	41.9% (31)
WCST perseverative errors	15.69 (13.65)	13.61(7.81)	t = 0.65 [63] *p* = 0.357	17.6% (13)
Trail making test B	107.5 (57)	112.64 (68.14)	t = −0.33 [72] *p* = 0.744	59.4% (44)
Stroop test colors x words	39.21 (14.58)	37.39 (8.58)	t = 0.53 [66] *p* = 0.600	16.2% (12)
Verbal memory				
RAVLT A5 learning	10.92 (2.18)	10.54 (2.32)	t = 0.67 [72] *p* = 0.503	27% (20)
RAVLT A7 delayed recall	7.11 (3.47)	7.43 (3.33)	t = −0.37 [72] *p* = 0.713	48.6% (36)
RAVLT recognition	13.94 (1.55)	13.43 (1.77)	U = 417 Z = −1.264 *p* = 0.206	10.85% (8)
Visual memory				
RCFT copy	31.95 (3.49)	33.07 (2.65)	U = 412.5 Z = −1.252 *p* = 0.211	40.5% (30)
RCFT delayed recall	17.61 (5.78)	16.62 (6.12)	t = 0.66 [72] *p* = 0.513	48.6% (36)
RCFT recognition	20 (1.85)	19.07 (2.54)	t = 1.69 [72] *p* = 0.096	40.5% (30)
Verbal fluency				
Phonemic	17.28 (6.34)	19.46 (9.35)	t = −1.06 [45.3] *p* = 0.294	47.3% (35)
Semantic	21.25 (5.95)	23.50 (9.63)	t = −1.08 [42.5] *p* = 0.284	58.1% (43)
Visual naming				
BNT	43.56 (9.61)	43.54 (9.80)	t = 0.01 [70] *p* = 0.994	55.4% (41)
Social cognition				
Faux pas ToM index	0.81 (0.09)	0.66 (0.15)	t = 4.09 [47.1] *p* < 0.001*	56.7% (42)
Non-faux pas stories	9 (1.32)	8.83 (1.23)	t = 0.02 [69] *p* = 0.985	–
Faux pas stories recognition	8.41 (1.29)	6.66 (2.48)	t = 3.82 [62] p < 0.001*	

Epilepsy center pre-surgical protocol raw values, IQ scores and performance level = percent of cases deficient performance (Z ≤ −1.5 or percentile ≤ 5), N = number of cases, t = Student's *t* test value, U = Mann Whitney *U* test value, [ ] = degrees of freedom, z = Kolmogorov Smirnov Z value, *p* = significance p value, (*) = statistical significant level. WAIS-III = Weschler Adult Intelligence Scale – Third Edition (entire test) IQ score; Digit span WAIS-III: maximum span, Trail Making Test A and B: response time (seconds); WCST = Wisconsin card sorting test: number of categories completed and number of perseverative errors; Stroop test: words x colors; RAVLT = Rey Auditory Verbal Learning Test (maximum score 15) learning of list A (trial A5) delayed recall (trial A7) and recognition task; RCFT = Rey complex figure test: figure copy, delayed recall (maximum score 36) and recognition task (maximum score 24); Verbal fluency with phonemic and semantic restrictions: total correct words in two minutes; BNT = Boston Naming Test: total of correct (maximum score 60).

tions must be answered correctly to get one point and the maximum score is 12 (4 points for sentence comprehension and 8 points for text comprehension). In the third story of this test, we also scored the presence or absence of the ability to detect mischievous behavior, which can be an indication of theory of mind (a hotel guest that is carrying his own fire escape -a rope- might leave without paying his bill).

2.3.3.3. Picture arrangement subtest (PA) from the Weschler adult intelligence scale third edition (WAIS-III). This test (Weschler, 2006) was included to evaluate logical-temporal sequencing. Subjects are presented with a series of cards that are similar to comic strips, which must be arranged in the correct order so as to create a coherent story. In our protocol, all 11 stories were presented independent of performance, because we also analyzed narrative production. After ordering the cards, subjects were asked to narrate the story and were scored on 0-1-2 scale, depending on whether they could narrate the story's main components (1), as well as infer the story's meaning (2), or not reach sufficient criteria to score (0). A Story Index was calculated by dividing the narrative score (maximum of 22 points), by the sequencing score (maximum of 22 points).

2.3.3.4. Narrative discourse subtest from MEC protocol. This subtest from MEC protocol (Ferreres et al., 2007; Joanette et al., 2004) aims at examining partial and integrated narrative comprehension, retelling, and Theory of Mind (ToM). Theory of Mind refers to the ability to attribute internal mental states to others, as well as reasoning about one's own mental state. To understand the interactions of characters in a story, the subject has to attribute thoughts, goals and intentions to the characters (Mason & Just, 2009). The examiner reads a narrative text divided into five paragraphs. After each paragraph is read, the subject must retell it in his or her own words. Then the text is read again in the integral version and the subject must be able to retell it from start to finish. When retelling the complete story, macrostructural aspects (e.g. the context of the story, the trigger element, consequences, reactions, etc.) are considered and only main ideas are scored (with a maximum of 13 points) in contrast to irrelevant details of the narration. In addition, 12 text-interpretation questions (maximum of 12 points) and social inference processing (presence or absence) are included.

2.4. Statistical analysis

TLE groups were matched for age, sex, and years of education. Raw scores were converted to Z-values and were also classified into either "normal" or "deficient" performance**.** Kolmogorov–Smirnov analyses were performed and four cognitive variables violated normality: Inverse digit span (z = 1.51, *p* = 0.022), Wisconsin card sorting test-categories (z = 1.56, *p* = 0.017), Rey auditory verbal learning test-recognition (z = 1.91, *p* < 0.001), and Rey complex figure-copy (z = 1.73, *p* = 0.005). The rest of the variables had normal distribution. We compared discourse performance by lesion laterality groups (RTLE vs. LTLE) and with other cognitive domains, clinical and demographic variables. According to each variable type and distribution we used Student's *t*-test or Mann Whitney *U* test Pearson and Spearman correlation tests, contingency tables, Chi-square test, and binary logistic regression analysis. Bonferroni correction for family wise errors type I was performed to establish the statistical significance level. All comparisons that were significant at the $p < 0.001$ were reported. Statistical analysis was carried out using the Statistical Package for the Social Sciences (SPSS version 20).

3. Results

3.1. General neuropsychological assessment

Within the general neuropsychological evaluation, shown in Table 2, we observed in TLE population frequent impairment in most of the cognitive domains, especially in executive functions, social cognition, memory and language tasks. No significant differences were found between RTLE and LTLE patients both at raw scores and performance level comparisons except for social cognition domain which is described below (Table 2).

3.2. Social cognition domain: Faux Pas test

TLE patients showed frequent deficits in this social cognition task (56.7%), with a tendency to be more frequent in RTLE group (LTLE 42.5% vs RTLE 73.5%, $X^2 = 8.069$ (1) $p = 0.007$) and Theory of Mind index was significantly lower in RTLE group (t = 4.09 (47.1) $p < 0.001$) (Table 2). Detection of faux pas stories was significantly lower in RTLE group (t = 3.82 (62) $p < 0.001$) while no differences were found in non-faux pas stories rejection. In addition, comprehension and interpretation of social situations laterality effect being poorer in RTLE group with a tendency to give erroneous or literal interpretations: "Why did the person say that?" (LTLE mean score 6.83 SD 1.72) vs RTLE mean score 3.93 SD 2.08, t = 4.79 (68) $p < 0.001$) and "Why should he/she not have said that?" (LTLE mean score 7.82 SD 1.19 vs RTLE mean score 6.06 SD 2.27, t = 4.26 (45.8) $p < 0.001$), (see Appendix A.5).

3.3. Discourse evaluation protocol

3.3.1. Conversational Discourse test

The evaluation of conversational discourse showed that RTLE patients compared to LTLE patients had significantly lower scores in (t = 4.59 (40.4) $p < 0.001$) (Table 3) and poorer performance as 73.5% of RTLE vs. 20% of LTLE patients showed deficits in this task ($X^2 = 23.16$ (1) $p < 0.001$) (Table 4). The most frequent communication behaviors observed were difficulties to keep the discourse theme and stay on topic, difficulties to express ideas in a concise way, and to comprehend indirect and metaphoric language (see Appendix A.1 for an example). Some patients (5 cases) also showed poor eye-to-eye contact and a monotonous prosody. The LTLE group showed lower scores only if anomias or a difficulty to initiate speech or take turns was found; otherwise performance was normal.

3.3.2. Complex Ideational Material test

We observed oral comprehension difficulties (at different complexities: from sentence to text comprehension) in 48.6% of TLE patients, with no significant differences regarding EZ laterality. In the third story, the inference of social meaning was significantly worse in RTLE patients, deficient in 41.2% of subjects vs. 7.5% in LTLE group ($X^2 = 13.75$ (1) $p < 0.001$) (see Appendix A.2 for an example). Failure in social meaning inference determined deficient total CIM performance in RTLE (same 14 cases) in contrast to LTLE group that even with general comprehension difficulties could infer social situations properly (Tables 3 and 4).

Table 3
Discourse evaluation protocol: raw scores and indexes.

Discourse evaluation protocol	LTLE N = 40	RTLE N = 34	LTLE vs. RTLE
	Mean (SD)	Mean (SD)	t-value (DoF) *p*-value
Conversational Discourse Test			
Conversational D. (max. 38)	36.94 (1.66)	33.73 (3.49)	t = 4.59 (40.4) $p < 0.001$*
Complex Ideational Material test			
Total CIM (max. 12)	10.1 (1.59)	10.41 (1.49)	t = −0.63 (72) $p = 0.527$
Picture arrangement test			
L-T sequencing (max. 22)	9.29 (4.86)	11.73 (3.70)	t = 2.25 (63) $p = 0.028$
Story production (max. 22)	14.54 (4.47)	10.74 (4.92)	t = 2.65 (41) $p = 0.011$
Story index	2.18 (1.46)	1.04 (1.46)	t = 3.12 (41) $p = 0.003$
Narrative discourse test			
Core information (max. 13)	10.79 (2.17)	9.17 (2.81)	t = 2.60 (62) $p = 0.011$
General comprehension (max. 12)	11.12 (1.17)	9.80 (2.28)	t = 2.85 (42.1) $p = 0.007$

Student's *t* test for independent variables SD = Standard deviation value; t = Student's *t* test value; (DoF) = Degrees of Freedom; *p* = bilateral significance p value; (max.) = maximum score for each variable-test.
* Statistical significant level.

3.3.3. Picture Arrangement test

When we measured logical-temporal sequencing, almost 30% of TLE patients showed deficits in placing the different parts of the story in the correct order. LTLE patients showed a tendency to lower scores in this task (t = 2.25 (63) $p = 0.028$) and higher amount of cases with deficient performance (LTLE 45% vs. 11.7%) ($X^2 = 7.31$ (1) $p = 0.008$) as shown in Tables 3 and 4. In contrast, RTLE compared to LTLE, in narrative production showed a tendency to lower scores (t = 2.65 (41) $p = 0.011$) and a statistically significant worst performance given that 73.5% (25 cases) of RTLE vs. 22.5% (9 cases) failed in this task ($X^2 = 14.36$ (1) $p < 0.000$). This inverse behavior was observed also when comparing the Story Index (narrative score/sequencing score), with a trend towards lower scores for RTLE group compared to LTLE group (t = 3.12 (41) $p = 0.003$) (Table 3). In RTLE patients we observed difficulties for telling core components, interpreting the meaning of a story, and a tendency to add non-existent information (see Appendix A.3 for an example).

3.3.4. Narrative Discourse test

TLE patients failed to accurately retell core components of the entire story in 28% of cases. The RTLE group compared to the LTLE group showed a tendency to obtain lower scores (t = 2.60 (62) $p = 0.011$) and a higher percentage of deficient performances when producing these macrostructural elements (50% vs. 27.5%; $X^2 = 5.60$ (1) $p = 0.029$) (Tables 3 and 4). We observed that RTLE patients were not able to organize information hierarchically; rather, they produced secondary details or extra information (see Appendix A.4 for an example). The structured questionnaire revealed that 50% of TLE had deficient scores and no significant differences were found between groups (Table 3). Specific laterality effect was observed in inferring the story's social meaning, as none of LTLE patients had failed in this task, while 38.2% (13 cases) of RTLE patients did ($X^2 = 16.47$ (1) $p < 0.001$) (Table 4).

Table 4
Discourse protocol: performance level.

	LTLE n = 40	RTLE n = 34	Total TLE	LTLE vs. RTLE
Discourse evaluation protocol	Deficit% (n)	Deficit% (n)	Deficit%	X^2 -value (DoF) *p-value*
Conversational discourse				
Conversational discourse	20 (8)	73.5 (25)	44.6	X^2 = 23.16 (1) p < 0.001*
Complex Ideational Material				
Total CIM	55 (22)	41.2 (14)	48.6	X^2 = 0.54 (1) p = 0.491
Social CIM	7.5 (3)	41.2 (14)	22.9	X^2 = 13.75 (1) p = 0.001*
Picture arrangement				
Logical temporal sequencing	45 (18)	11.7 (4)	29.7	X^2 = 7.31 (1) p = 0.008
Narrative production	22.5 (9)	73.5 (25)	45.9	X^2 = 14.36 (1) p < 0.001*
Narrative discourse				
Core information	27.5 (11)	50 (17)	37.8	X^2 = 5.60 (1) p = 0.029
General comprehension	40 (16)	58.8 (20)	50	X^2 = 4.33 (1) p = 0.060
Social inference	0 (0)	38.2 (13)	17.5	X^2 = 16.47(1) p < 0.001*

Contingency tables, X^2 = Chi square value; (DoF) = degrees of freedom; p = bilateral significance p value; n = number of cases. Deficient performance = 1.5 standard deviations below control mean.
* Statistical significance level = 0.001.

3.4. Statistical analysis of clinical demographic and cognitive findings

3.4.1. Correlation analysis

Pearson's and Spearman's correlation coefficients were calculated according to each variable's distribution, to determine the association between discourse performance and clinical, demographic and other cognitive variables. Lower education level correlated with a poor logic-temporal sequencing in Picture Arrangement (Pearson's r 0.409, p < 0.001). No other significant correlations were found between discourse protocol and education level, however, Narrative and Conversational Discourse subtests from MEC were already adjusted by education (≤ or >10 years of formal education). No other demographic or clinical variable was significantly associated with discourse performance.

Regarding the analysis with other cognitive domains included in the general neuropsychological evaluation, Verbal IQ level showed correlation with verbal comprehension (Total CIM task: Pearson's r 0.372, p = 0.002), while Executive IQ correlated with logic-temporal sequencing ability (Picture Arrangement: Pearson's r 0.421, p < 0.001). In addition, verbal memory (Rey Auditory Verbal Learning Test delayed recall-list A7) correlated with Narrative Discourse core information production (Spearman's r 0.275, p = 0.028). Executive functions analysis revealed correlation with Picture Arrangement test – logic-temporal sequencing with TMT B (Spearman's r 0.340, p = 0.009) and with WCST perseverative errors (Spearman's r 0.412, p = 0.003), while Picture Arrangement test – narrative production task correlated with WCST non-perseverative errors (Spearman's r 0.373, p = 0.012). Moreover, executive abilities correlated with social situation comprehension abilities: TMT B with social inference – CIM test (Spearman's r 0.362, p = 0.009) and WCST- categories and non-perseverative errors with Faux Pas test- ToM Index (Spearman's r 0.355, p = 0.008 and r 0.304, p = 0.003 respectively). Finally, social cognition Faux Pas test (ToM Index) correlated with Conversational Discourse test (Pearson's r 0.407, p =< 0.001) Narrative Discourse – core information production (Pearson's r 0.455, p =< 0.001) and Picture Arrangement- narrative production task (Pearson's r 0.384, p = 0.004).

3.4.2. Logistic regression

Variables that showed significant correlations were selected and included for regression analysis. Binary logistic regression analysis was performed to evaluate: 1. Right epileptic zone laterality prediction, 2. Deficient discourse outcome prediction (deficit ≤ −1.5 SD). Cognitive variables (general neuropsychological and discourse protocol tests) were dichotomized according to deficient performance (deficit ≤ −1.5 SD), except for IQ which was dichotomized into low (IQ 80-89) or high (IQ ≥ 90) performance. Dichotomous clinical variables included for logistic regression were: epileptic zone laterality (left vs. right), early epilepsy onset (≤12 years old), prolonged illness duration (≥10 years) and low education level (≤10 years or incomplete secondary school).

First, logistic regression analysis confirmed lateralizing value of discourse abilities evaluation. Right epileptic zone laterality was predicted by a deficient performance in Conversational discourse task (B = −2.54, Wald = 20.18, p < 0.001, OR 12.75); CIM test - social inference (B = −2.31, Wald = 11.01, p < 0.001, OR 10.11), Picture Arrangement - narrative production task (B = −3.78, Wald = 11.48, p < 0.001, OR 9.33), Narrative Discourse - core information production (B = −1.16, Wald = 5.42, p < 0.020, OR 3.19), and social inference tasks (B = −1.87, Wald = 8.63, p = 0.003, OR 6.51) (Table 5a).

Second, logistic regression analysis with covariates was used to evaluate the influence that other clinical variables cognitive domains could have on discourse performance deficient outcome other than right epileptic zone laterality. This analysis revealed that in narrative discourse comprehension and production tasks right epileptic zone laterality predicted a deficient outcome, but discourse performance was also influenced to a lesser extent by deficits in other cognitive domains. Deficits in verbal memory (RAVLT list A7 delayed recall: B = −1.56, Wald = 6.69, p = 0.010) and social cognition (ToM index Faux Pas test: B = −1.41, Wald = 4.25, p = 0.039) predicted Narrative Discourse test - core information deficient production, while social inference failure in this test was predicted by deficits in executive functions (TMT B test: B = −2.98, Wald = 5.69, p = 0.017). Also, deficits in social cognition influenced narrative production in Picture Arrangement test (ToM index Faux Pas test: B = −1.91, Wald = 4.84, p = 0.028) (Table 5b).

No other cognitive or clinically correlated variables survived regression analysis.

4. Discussion

The purpose of this study was to investigate narrative and conversational discourse skills in patients with right lateralized medial TLE compared to LTLE patients. We found poorer performance and more frequent discourse deficits in the right group compared to the left one.

Regarding discourse production, we observed deficits in categorizing information in a hierarchical order, keeping the main information as a guide (i.e., macrostructure management), expressing ideas concisely and, in some cases, a tendency to a disintegrated,

Table 5a
Binary logistic regression: right laterality prediction.

DV: right laterality	Likelihood ratio test	X^2 cox snell	R^2 nagerlkerke	B (SE)	Wald (DoF) *p-value*	OR (CI)
Conversational discourse	$X^2 = 24.28(1) p < 0.001$	0.280	0.376	−2.54 (.56)	20.18(1) $p < 0.001$	12.75 (4.2–38.7)
Constant				1.09 (.41)	7.24(1) $p = 0.007$	
CIM social CIM	$X^2 = 14.29(1) p < 0.001$	0.176	0.236	−2.31 (.69)	11.01(1) $p = 0.001$	10.11 (2.6–39.6)
Constant				1.54 (.63)	5.86(1) $p = 0.015$	
Picture arrangement narrative	$X^2 = 22.97(1) p < 0.001$	0.408	0.555	3.78 (1.12)	11.48(1) $p = 0.001$	9.33 (2.7–31.7)
L-T sequencing	$X^2 = 15.62(1) p < 0.001$			−3.56 (1.20)	8.75 (1) $p = 0.003$	.19 (.06-0.6)
Constant				−1.12 (.47)	5.68 (1) $p = 0.017$	
Narrative discourse core information	$X^2 = 5.62(1) p = 0.018$	0.073	0.098	−1.16 (.49)	5.42(1) $p = 0.020$	3.19 (1.2–8.5)
Constant				0.43 (.39)	1.27(1) $p = 0.261$	
Social inference	$X^2 = 10.12(1) p = 0.001$	0.128	0.171	−1.87 (.64)	8.63(1) $p = 0.003$	6.50 (1.8–22.6)
Constant				1.18 (.57)	4.24 (1) $p = 0.039$	

Binary logistic regression– Forward Likelihood Pruning, DV = dependent variable – right laterality, *Independent variable = deficient performance in discourse test.* Constant = constant in the equation, CIM = Complex Ideational Material, OR = odds ratio: risk of right laterality with deficient performance; (CI) = confidence interval 95%.

Table 5b
Binary logistic regression: discourse performance.

DV: discourse protocol	Likelihood ratio test	X^2 cox snell	R^2 nagerlkerke	B (SE)	Wald (DoF) *p-value*
Conversational D.					
ZE laterality (R)	$X^2 = 14.75$ (1) $p < 0.001$	0.225	0.302	−2.21(.64)	11.77(1) $p = 0.001$
Constant				1.15(.47)	6.06(1) $p = 0.014$
Total CIM					
Verbal IQ (<95)	$X^2 = 10.14$ (1) $p = 0.001$	0.128	0.171	1.72(.58)	8.75(1) $p = 0.003$
Constant				−1.28(.51)	6.42(1) $p = 0.011$
Social CIM					
ZE laterality (R)	$X^2 = 14.23(1)$ $p < 0.001$	0.222	0.337	−2.37(.72)	11.01(1) $p = 0.001$
Verbal IQ (<95)	$X^2 = 4.32(1)$ $p = 0.038$			1.59(.85)	3.49 (1) $p = 0.062$
Constant				−1.45(.78)	3.45 (1) $p = 0.063$
Picture arrangement narrative					
ZE laterality (R)	$X^2 = 9.55(1)$ $p = 0.001$	0.359	0.489	−2.38(.83)	8.23 (1) $p = 0.004$
ToM index faux pas	$X^2 = 5.45$ (1) $p = 0.020$			−1.91(.87)	4.84 (1) $p = 0.028$
Constant				1.57(.68)	5.21 (1) $p = 0.032$
Picture arrangement L-T sequencing					
ZE laterality (R)	$X^2 = 7.76$ (1) $p = 0.005$	.113	.157	1.63(.63)	6.63 (1) $p = 0.010$
Constant				−1.79(.54)	11.01 (1) $p = 0.001$
Narrative discourse core information					
ZE laterality (R)	$X^2 = 3.97(1)$ $p = 0.046$	0.251	0.368	−1.22(.62)	3.83 (1) $p = 0.050$
Verbal memory	$X^2 = 7.29(1)$ $p = 0.007$			−1.56(.60)	6.69 (1) $p = 0.010$
ToM index faux pas	$X^2 = 4.67$ (1) $p = 0.031$			−1.41(.68)	4.25 (1) $p = 0.039$
Constant				1.26(.54)	5.40 (1) $p = 0.020$
Narrative discourse social inference					
ZE laterality (R)	$X^2 = 7.12(1)$ $p = 0.008$	0.396	0.634	−2.83(1.26)	5.05(1) $p = 0.025$
Trail making test B	$X^2 = 8.26(1)$ $p = 0.004$			−2.98(1.29)	5.69(1) $p = 0.017$
Constant				1.26(.54)	5.40(1) $p = 0.020$

Binary logistic regression–Forward Likelihood Pruning. *DV = dependent variable –deficient performance in discourse protocol*, independent variables = verbal IQ <95, ZE right laterality, deficient performance in cognitive tests ($Z \le 1.5$) verbal memory = Rey auditory verbal learning test- delayed recall, constant = constant in the equation.

self-referential, and excessively detailed speech as seen in the Narrative and Conversational Discourse Tests and the narrative production task of the Picture Arrangement Test. Our findings concur with what was described by Field and collaborators (Field et al., 2000) and Bell and collaborators (Bell et al., 2003) who found narrative production deficits in English-speaking TLE populations, with difficulties in speaking concisely and recounting a story's core information, although hemisphere laterality of the EZ was not taken into account in their investigations. Also, our findings agree with descriptions in other RH lesional pathologies that showed uninformative discourse dissociated from lexical or syntactic impairments (Ferré et al., 2012; Joanette et al., 2008) with tangential speech that lacks thematic progression (Johns et al., 2008).

Both RTLE and LTLE individuals had a poor performance in verbal fluency and naming tasks, a finding that has been widely described in this population, although the lateralization value of these deficits remains controversial (Bartha-Doering & Trinka, 2014). At spontaneous speech evaluation in the Conversational Discourse Test, LTLE patients who had lower scores presented anomias and poor verbal fluency. This coincides with a previous study from Howell RA (Howell et al., 1994) who described poorer fluency and longer pauses during speech in LTLE patients compared to RTLE group. Even though in TLE patients as a whole we found deficits in naming and fluency tasks, the performance in word level analysis did not correlate with spontaneous speech during complex communicative situations where other executive, attentional, and linguistic processes can be implied.

LTLE patients also had a trend towards having more difficulties to arrange a sequential story in the right order (in the Picture Arrangement Test). However, even if the story was sequenced incorrectly, LTLE patients could still retain important information, infer the appropriate meaning and explain a story coherently unlike RTLE patients (see Appendix C). Logical-temporal sequencing abilities like this one have been described as a left hemisphere function as seen in lexical and motor sequencing tasks (Heim et al., 2012) and in tasks where rearrangement of materials sequentially based on linguistic-conceptual rules are required (Chan, Ryan, & Bever, 2013). As far as we know, this is the first time this deficit has been described in epilepsy patients.

When we evaluated discourse comprehension, RTLE patients showed deficits in meaning inference processing especially for social meaning (e.g., detecting mischievous behavior, faux pas). Even when general information was comprehended correctly, RTLE patients gave inaccurate interpretations as observed in the CIM, Narrative Discourse Test and Faux Pas Test (ToM index and faux pas stories questions "Why" and "Why not"). These results coincide with many previous studies of RHD patients that show comprehension deficits due to distorted inference processing in the RH, where patients cannot extract the correct or most relevant global meaning from stories, figurative expressions, indirect speech acts, or facial and vocal cues (Blake, 2009; Joanette et al., 2008; Johns et al., 2008; Marini & Ph, 2012). While there are similarities with our findings, other studies with RHD patients involve different pathophysiological basis and lesion sites variability, which encompasses in most of cases fronto-temporal cortical and subcortical areas and does not include medial temporal lobe.

Mechanisms underlying discourse deficits have been controversial. There could be a combination of overlapping deficits in macrostructure management and an impairment of inference processing. Regarding macrostructure elements management most authors suggested that RHD patients would remain sensitive to main ideas - that rely on explicit information related to macrostructure - but may be impaired in their ability to use them to create an organizing macrostructure, extract implicit information or use such elements to integrate context and previous knowledge (Joanette et al., 2008; Johns et al., 2008). In our study, we found that macrostructure impairments were associated with executive and memory difficulties (e.g. mental flexibility - inhibition abilities correlated with logic-temporal sequencing Picture Arrangement test, or WCST-categorization and verbal memory abilities correlated with narrative production in Picture Arrangement and Narrative Discourse tests) which would lead to deficits in keeping and organizing macrostructure elements, while context integration and pragmatic use of language would be the distinctive role in language processing of the right hemisphere. Concerning inference processing, one prevailing view is that the right hemisphere activates broader semantic fields than the left hemisphere, which produces a fast and selective semantic activation (Jung-Beeman, 2005). In RHD patients there would be a deficit that prevent information to activate meanings and to detect thematic information (Jung-Beeman, 2005). Another view is the Suppression Deficit Theory, which states that there is a deficit in suppressing multiple-competing meanings that are initially activated and represented, but are eventually irrelevant or incompatible (Basnáková, Weber, Petersson, van Berkum, & Hagoort, 2013; Blake, 2009). Our findings demonstrated that inference ability was particularly impaired in RTLE patients and was associated social cognition and executive deficits (e.g. Social CIM correlation with TMT B, Faux Pas test correlation with WCST–categorization and with narrative tests- Picture Arrangement and Narrative Discourse). RTLE patients would therefore neither be able to keep alternative meanings active and select the appropriate one according to the context, nor detect the main theme or conclusions of the discourse.

Regarding the relation between discourse and social cognition deficits, we found that misunderstanding a story's social meaning was significantly lateralized to RTLE, as seen in both linguistically simple and complex tests (CIM, Narrative Discourse, and Faux Pas tests). Both groups showed deficits in the Faux Pas Test, as previously described by other authors (Broicher et al., 2012; Giovagnoli et al., 2011; Schacher et al., 2006). Although TLE patients as a whole had poor performance in a high-order ToM test like the Faux Pas Test, RTLE group had significant differences in the ability to detect and interpret faux pas stories (social situation comprehension "why" and "why not" questions), while non faux pas stories rejection showed no differences. Evidence from ToM studies in TLE using non-verbal inputs suggested that some social cognition processing could be affected in this population (Broicher et al., 2012; Schacher et al., 2006), while pragmatic aspects of language related to RH processing could also explain these deficits (Frank, 2010).

The ToM network is involved in many discourse-related tasks - used to infer implicit meaning from what is actually written or said (Hagoort & Indefrey, 2014). RTLE can affect networks beyond the medial temporal lobe (Hermann et al., 2010). Difficulties in comprehending and retelling stories, as well as inferring the social meaning of stories (e.g. recognizing faux pas) can be explained by dysfunctions in circuits that include the right temporo-parietal junction, the dorsomedial prefrontal cortex, posterior cingulate cortex and precuneus, which have been seen to subserve narrative discourse (AbdulSabur et al., 2014) and a ToM-protagonist perspective network (Mason & Just, 2009). This network seems to generate expectations about how the protagonists of stories will act on the basis of understanding their intentions (Hagoort & Indefrey, 2014; Mason & Just, 2009). The SCALED model (Catani & Bambini, 2014) also refers to these networks at a prefrontal dorsolateral network (level 2), involved in communicative intentions and inference processing, and a temporo-parietal network (level 5) related to pragmatic integration and high level social cognition.

In our study, discourse deficits showed laterality effect beyond the influence of executive function and theory of mind, as shown in logistic regression analysis. This finding could be due to the role the right hemisphere has on discourse processing, by the integration of these functions to pragmatic use of language. Several quantitative imaging and neurophysiological studies suggested that in TLE structural and functional network abnormalities (e.g. gray matter volume loss, white tracts integrity, cortical reorganization, functional connectivity) extend beyond mesial temporal areas to neocortical parietal, temporal and frontal areas as well as thalamus (Bell et al., 2011; Gleichgerrcht et al., 2015; Richardson, 2012). Right medial and anterior temporal lobe structures and their connections seem to have a key role in discourse comprehension. The potentially affected networks would involve temporal anterior and medial areas, posterior temporal areas (Superior Temporal Gyrus and Superior Temporal Sulcus), and prefrontal areas related to communication, domain-general semantic integration, and domain-specific social-related processing (AbdulSabur et al., 2014; Mar, 2011; Wong & Gallate, 2012). These regions link areas associated to semantics, world knowledge, and social cognition, resulting in the construction of a coherent context (Catani & Bambini, 2014; Wong & Gallate, 2012).

We should note a number of possible limitations to this study. The study included patients who have prolonged illness and use multiple antiepileptic drugs. While no cognitive differences were found between patients using or not Topiramate, patients were not evaluated before and after they use that drug. Patients with other lesions than hippocampal sclerosis were quite small and prevented us from splitting the sample into subgroups according to the lesion type. Functional impact and professional-academic outcome was not measured. As it is known, epilepsy has a social burden that exceeds cognitive impairments. Therefore, we considered it important to assess quality of life and social impact in objective and subjective ways, and will incorporate an anthropology project in future studies.

5. Conclusions

Our results allow us to provide additional evidence of the right temporal lobe's important involvement in discourse processing.

RTLE patients presented deficits in comprehending central ideas, making adequate inferences, and expressing themselves concisely and coherently.

The anterior temporal lobe seems to process information that is personally relevant as a domain-general semantic hub with a bias towards social information (Wong & Gallate, 2012). Therefore, the impairment of the anterior temporal lobe could cause deficits in social inference-making, as well as conversational discourse where personal information is particularly relevant. Furthermore, the bilateral temporal poles have been seen to play a role in generating specific semantic associations in text comprehension in fMRI studies (Swett et al., 2013). Given our findings, the right medial and anterior temporal lobe regions - which would partake in a broader semantic activation (Jung-Beeman, 2005) - and their connections to a ToM-protagonist network seem to be critical in linking areas associated to semantics, world knowledge, and social cognition, which would enable the construction of a coherent context and suitable inference-making (Basnáková et al., 2013; Mar, 2011; Mason & Just, 2009).

The complex nature of discourse makes it difficult for patients to be fully aware of these deficits, even though they produce significant impairments in communication and text comprehension, which weakens educational and professional opportunities. Certain deficits in discourse processing were more frequent than other known general cognitive impairments in temporal lobe epilepsy. Conversational and narrative discourse deficits showed epileptic zone lateralization value and could help in epilepsy surgery decision making. It is therefore important to evaluate these skills in RTLE patients to detect potential deficits and offer discourse therapy if necessary (Cornoldi and Oakhill, 1996; Ferré, Ska, Lajoie, Bleau, & Joanette, 2011b). For future research, we will compare TLE patients' pre- and post-surgical treatment and measure other pragmatic aspects of language with neuropsychological, electrophysiological, and neuroimaging methods.

Disclosure

None of the authors has any conflict of interest to disclose. We confirm that we have read the Journal's position on issues involved in ethical publication and affirm that this report is consistent with those guidelines.

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Appendix A

A.1. Conversational Discourse test

1. Sample from the Conversational Discourse Test of participant A.M. who has RTLE, which shows a fluent but tangential, disintegrated speech with difficulties in both expressing ideas in a concise way and in turn-taking (the ellipses points indicate pauses during speech):

Examiner: You told me that at the beginning of your seizures you sometimes have a pleasant feeling. What is that feeling like? Could you describe it a bit more?

A.M.: I used to have it at school and wouldn't tell anyone. It didn't seem bad. Then it became more frequent, and I had a seizure and that's when they diagnosed me.

Examiner: And what was that feeling like? What is it similar to?

A.M.: That was before… when I was about eight. At that age I used to like to play soccer… that's how it was… One day, while playing soccer, it happened. I didn't have problems at school [the participant goes on to talk about his classmates and his academic performance, which is left out in this sample]. I had good grades until I had 10 seizures in a single day but… because I didn't have medication; it was hard for me to get it. I had a test. Math? Uh, I don't remember… And that changed me, it was before and after [sic]… From then on, it was hard for me to concentrate… Wait, what?… Oh! The feeling I have during seizures… It was something nice. It would happen at school… It was like—I don't know… It's hard for me to explain… I had them [pleasant feelings] from 8 to 12. If you tell, they don't believe you. People don't believe kids… What was that saying from the story?… From the fable where if you lie then they won't believe you? I don't know. I think it was different when I was older, uh… Then I left college because everything was twice the effort. Now I regret it a bit… Although I shouldn't regret it, right? You do what you can. It was very difficult back then!

Examiner: Do you remember what the feeling was like when the seizures started?

A.M.: Oh! I don't know. It was something similar to that… nice… although, it rarely happens now.

2. Sample from the Conversational Discourse Test of participant G.F. who has RTLE that shows difficulties in interpreting indirect language and humor:

Examiner: Hello, I'm sorry for the delay. Would you like some coffee? My treat.

G.F.: I had breakfast and was told that a doctor would come see me. Was I supposed to fast?

Examiner: No, I'm just offering you something to drink, and I apologize for the delay.

G.F.: Are you asking me out, doctor?

Examiner: No [the examiner giggles]. I mean to say that I'll pay for the coffee if you would like one, to compensate you for my delay.

G.F.: Oh… I saw the wedding ring, thought it was weird. Why are you laughing?

Examiner: I'm surprised by what you said.

G.F.: So you're not married? Do you wear a fake wedding ring to scare off men? [said seriously in a confused manner].

A.2. Complex Ideational Material test

1. Example of a deficit in comprehending social intention by participant H.F. who has RTLE. The third story is about a man who enters the hotel carrying a suitcase and rope. The employee asks what the rope is for. The guest answers that the rope is his own emergency exit. The employee then requires him to pay his hotel stay up front.

Standard questions:

Did the client arrive with anything unusual?

H.F.: Yes.

Did the hotel employee trust this guest?

H.F.: Yes.

H.F. is then asked why he thought the guest was asked to pay up front. H.F. responds: "Nowadays you have to be careful, people don't want to pay. It's better to charge before and be safe." The examiner asks: "Why do you think the guest brought a rope?" H. F. responds: "Maybe he wanted to hang his clothes… or rob a bank. I don't know, everyone does what they want."

Participant V.C. who has LTLE answers that the employee did not trust the guest. When asked why, V.C. answered: "Because he was carrying a rope and thought he might not pay." The examiner asked: "Why? Why do you think he brought the rope?" V.C. replied: "To escape without paying or to commit suicide... The story doesn't say. That's what I think."

A.3. Picture Arrangement test

Example of story FUGA (i.e. "escape" in English), which has four pictures that must be placed in the correct order to tell a story.

Correct sequence:

First picture F: two police officers are searching for an escaped prisoner who is hiding behind a bush.

Second picture U: the prisoner is spying on a woman, who is bathing in the river. Her dress is laid out on the shore.

Third picture G: the male prisoner puts her dress on while she bathes in the river. His clothes are now on the shore.

Fourth picture A: the prisoner, dressed as a woman, is chased by two female police officers. The dress has a number on the backside.

Example of a poorly sequenced (0 points) and well narrated performance (2 points):

UFGA sequence: "A prisoner is escaping, and the police are chasing him. He's hiding behind trees and saw a women bathing in the river. He found her clothes and exchanged them for his. He put the women's dress on and started running. But the other police officers found him." The examiner asks why and the participant answers: "Because the woman in the river was also a fugitive."

Example of a well sequenced (2 points) and poorly narrated performance (0 points):

FUGA sequence: "A man runs. The police follow him. The police officers leave, and he's spying on a women who is bathing in the river. He also wants to bathe. But when he comes out of the water, he gets confused and puts the women's clothes on and the women [police officers] chase him. The examiner asks why and the participant answers: So that he returns the clothes.

A.4. Narrative Discourse test

This test separates main ideas from secondary information. Main ideas include 13 items within a frame (1. a man named John; 2. he digs a hole; 3. he is almost finished), a conflict (4. the hole caves in), an internal plan (5. he has an idea/strategy), the plan's execution (6. he leaves his clothes near the hole; 7. he hides his tools; 8. he climbs a tree), the consequences (9. the neighbor thinks he's buried in the caved-in hole; 10. he asks for help; 11. the neighbors dig out the caved-in hole), and the reactions (12. John climbs down the tree; 13. He thanks his neighbors).

Example of how participant C.V., who has LTLE, retold the story: "The farmer, John, is digging a hole. The next day, he comes up to the hole and sees it's half-filled with dirt. He has an idea: He puts his hat and shirt near the hole's edge, he hides his pick and shovel, and climbs up a tree. A neighbor passes by to talk, and when he sees the clothes he gets scared and thinks he's buried in the hole... and calls the other neighbors. They start digging the hole to find John... When John sees they're finished emptying out the hole, he climbs down the tree and says thank you and that they were a big help... because they did his job." Score: 12 of 13.

Examiner: What did you think of John's approach?

C.V.: He betrayed his friends to get out of doing his own work; [it was] wrong.

Examiner: What title would you give this story?

C.V.: John, the con artist.

Example of how participant C.A., who has RTLE, retold the story: "John one morning went to work and to make a hole. He made a pretty deep hole on his farm. The next day, in the early morning, when he went to see it [the hole]... the hole caved in, and the hole was completely covered with dirt... He stopped to think for a while. He left his clothes and hat, the pick and the shovel in the hole. A neighbor came by to talk to him, because they were friends, and saw the clothes and that John was at the bottom of the hole. He started screaming to save him. They came to rescue him, and John said thank you very much to the neighbors for helping him." Score: 7/13.

Examiner: What did you think of John's approach?

C.A.: He was thankful. The neighbors were probably really scared.

Examiner: What title would you give this story?

C.A.: John, the farmer.

A.5. Social cognition: Faux Pas test

Example of a faux pas story and corresponding questions:

Julia just moved to her new apartment. She had bought new curtains for her bedroom. When she was finished decorating her apartment, her best friend Alice arrived. Julia showed her around the apartment and asked: "Do you like my bedroom?" Alice answered: "Those curtains are horrible. I hope you change them for some new ones."

Questions answered by RTLE patients C.M.:

Examiner: Did anyone say something they shouldn't have said or something awkward?

C.M.: Yes

Examiner: Who said something they shouldn't have said or something awkward?

C.M.: Alice.

Examiner: What did she say?

C.M.: That the curtains were horrible, and that she should change them for new ones.

Examiner: Why did she say it?

C.M.: The friend had bad taste, and she [Alice] was mad she [Julia] had a new house.

Other answers to the last question by patients with RTLE:

G.F.: Envy makes you lose friends.

G.L.: She [Alice] probably felt superior. Ha! A decorator.

An answer to the last question of a patient with LTLE:

F.M.: She didn't realize they were new. Since she thought they were ugly, she told her she better change them and buy some new ones. It wasn't on purpose.

References

AbdulSabur, N. Y., Xu, Y., Liu, S., Chow, H. M., Baxter, M., Carson, J., & Braun, A. R. (2014). Neural correlates and network connectivity underlying narrative production and comprehension: A combined fMRI and PET study. *Cortex, 57* (2015), 107–127. http://dx.doi.org/10.1016/j.cortex.2014.01.017.

Abusamra, V., Côté, H., Joanette, Y., & Ferreres, A. (2009). Communication impairments in patients with right hemisphere damage. *Lifespan and Disability, XII*(1), 67–82.

Baez, S., Rattazzi, A., Gonzalez-gadea, M. L., & Torralva, T. (2012). *Integrating intention and context : assessing social cognition in adults with Asperger syndrome*, 6(November), 1–21. doi: http://dx.doi.org/10.3389/fnhum.2012.00302.

Bartha, L., Benke, T., Bauer, G., & Trinka, E. (2005). Interictal language functions in temporal lobe epilepsy. *Journal of Neurology, Neurosurgery, and Psychiatry, 76*(6), 808–814. http://dx.doi.org/10.1136/jnnp.2004.045385.

Bartha-Doering, L., & Trinka, E. (2014). The interictal language profile in adult epilepsy. *Epilepsia*, 1–14. http://dx.doi.org/10.1111/epi.12743.

Basnáková, J., Weber, K., Petersson, K. M., van Berkum, J., & Hagoort, P. (2013). Beyond the language given: the neural correlates of inferring speaker meaning. *Cerebral Cortex (New York, N.Y. : 1991)*, 1–7. http://dx.doi.org/10.1093/cercor/bht112.

Bell, B., Dow, C., Watson, E. R., Woodard, A., & Seidenberg, M. (2003). Narrative and procedural discourse in temporal lobe epilepsy. *Journal of the International Neuropsychological Society*, 733–739.

Bell, B., Lin, J. J., Seidenberg, M., & Hermann, B. (2011). The neurobiology of cognitive disorders in temporal lobe epilepsy. *Nature Reviews. Neurology, 7*(3), 154–164. http://dx.doi.org/10.1038/nrneurol.2011.3.

Bell, B. D., Seidenberg, M., Hermann, B. P., & Douville, K. (2003). Visual and auditory naming in patients with left or bilateral temporal lobe epilepsy. *Epilepsy Research, 55*(1–2), 29–37. http://dx.doi.org/10.1016/S0920-1211(03)00110-4.

Blake, M. L. (2009). Inferencing processes after right hemisphere brain damage: effects of contextual bias. *Journal of Speech, Language, and Hearing Research, 52*(2), 373–384. http://dx.doi.org/10.1044/1092-4388(2009/07-0172).

Broicher, S. D., Kuchukhidze, G., Grunwald, T., Krämer, G., Kurthen, M., & Jokeit, H. (2012). "Tell me how do I feel"–emotion recognition and theory of mind in symptomatic mesial temporal lobe epilepsy. *Neuropsychologia, 50*(1), 118–128. http://dx.doi.org/10.1016/j.neuropsychologia.2011.11.005.

Burin, D., & Drake, M. A. H. (2007). *Evaluación Neuropsicológica en Adultos* (First). Buenos Aires: Paidós.

Catani, M., & Bambini, V. (2014). A model for social communication and language evolution and development (SCALED). *Current Opinion in Neurobiology, 28C*, 165–171. http://dx.doi.org/10.1016/j.conb.2014.07.018.

Cendes, F. (2005). Mesial temporal lobe epilepsy syndrome: an updated overview. *Journal of Epilepsy and Clinical Neurophysiology, 11*(3), 141–144. http://dx.doi.org/10.1590/S1676-26492005000300006.

Chan, S., Ryan, L., & Bever, T. G. (2013). Brain & language role of the striatum in language: Syntactic and conceptual sequencing. *Brain and Language, 125*(3), 283–294. http://dx.doi.org/10.1016/j.bandl.2011.11.005.

Cornoldi, C., & Oakhill, J. V. (1996). *Reading and comprehension difficulties: processes and interventions*. Mahwah NJ: Lawrence Erlbaum Associates Inc..

Ferré, P., Fonseca, R. P., Ska, B., & Joanette, Y. (2012). Communicative clusters after a right-hemisphere stroke: are there universal clinical profiles? *Folia Phoniatrica et Logopaedica: Official Organ of the International Association of Logopedics and Phoniatrics (IALP), 64*(4), 199–207. http://dx.doi.org/10.1159/000340017.

Ferré, P., Ska, B., Lajoie, C., Bleau, A., & Joanette, Y. (2011a). Clinical focus on prosodic, discursive and pragmatic treatment for right hemisphere damaged adults: what's right? *Rehabilitation Research and Practice, 2011*, 131820. http://dx.doi.org/10.1155/2011/131820.

Ferré, P., Ska, B., Lajoie, C., Bleau, A., & Joanette, Y. (2011b). Clinical focus on prosodic, discursive and pragmatic treatment for right hemisphere damaged adults: what's right? *Rehabilitation Research and Practice, 2011*, 1–10. http://dx.doi.org/10.1155/2011/131820.

Ferreres, A., Abusamra, V., Cuitiño, M., Côté, H., Ska, B., & Joanette, Y. (2007). *Protocolo MEC. Protocolo para la evaluación de la comunicación de montreal*. Buenos Aires: Neuropsi Ediciones.

Field, S. J., Saling, M. M., & Berkovic, S. F. (2000). Interictal discourse production in temporal lobe epilepsy. *Brain and Language, 74*(2), 213–222. http://dx.doi.org/10.1006/brln.2000.2335.

Frank, C. K. (2010). Linguistic effects on the neural basis of theory of mind. *The Open Neuroimaging Journal, 4*, 37–45. http://dx.doi.org/10.2174/1874440001004020037.

Giovagnoli, A. R., Franceschetti, S., Reati, F., Parente, A., Maccagnano, C., Villani, F., & Spreafico, R. (2011). Theory of mind in frontal and temporal lobe epilepsy: cognitive and neural aspects. *Epilepsia, 52*(11), 1995–2002. http://dx.doi.org/10.1111/j.1528-1167.2011.03215.x.

Gleichgerrcht, E., Kocher, M., & Bonilha, L. (2015). Connectomics and graph theory analyses: Novel insights into network abnormalities in epilepsy. *Epilepsia, 56*(11), 1660–1668. http://dx.doi.org/10.1111/epi.13133.

Goodglass, H., Kaplan, E., & Barresi, B. (2005). *Boston diagnostic aphasia examination* (Third Edition- spanish version). Editorial Médica Panamericana.

Hagoort, P., & Indefrey, P. (2014). The neurobiology of language beyond single words. *Annual Review of Neuroscience, 37*(1), 347–362. http://dx.doi.org/10.1146/annurev-neuro-071013-013847.

Hagoort, P., & van Berkum, J. (2007). Beyond the sentence given. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences, 362*(1481), 801–811. http://dx.doi.org/10.1098/rstb.2007.2089.

Hamberger, M. J., & Tamny, T. R. (1999). Auditory naming and temporal lobe epilepsy. *Epilepsy Research, 35*(3), 229–243. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/10413318.

Heim, S., Amunts, K., Hensel, T., Grande, M., Huber, W., Binkofski, F., & Eickhoff, S. B. (2012). The role of human parietal area 7A as a link between sequencing in hand actions and in overt speech production. *Frontiers in Psychology*, 1–9. http://dx.doi.org/10.3389/fpsyg.2012.00534. 3.

Hermann, B., Meador, K. J., Gaillard, W. D., & Cramer, J. A. (2010). Cognition across the lifespan: Antiepileptic drugs, epilepsy, or both? Comorbidities at baseline. *Epilepsy and Behavior, 17*(1), 1–5. http://dx.doi.org/10.1016/j.yebeh.2009.10.019.

Hickok, G., & Poeppel, D. (2004). Dorsal and ventral streams: a framework for understanding aspects of the functional anatomy of language. *Cognition, 92*(1–2), 67–99. http://dx.doi.org/10.1016/j.cognition.2003.10.011.

Hickok, G., & Poeppel, D. (2007). The cortical organization of speech processing. *Nature Reviews. Neuroscience, 8*(5), 393–402. http://dx.doi.org/10.1038/nrn2113.

Howell, R. A., Saling, M. M., Bradleyt, D. C., Samuel, F., & Hospital, A. (1994). Interictal language fluency in temporal lobe epilepsy. *Cortex, 5*(30), 469–478. http://dx.doi.org/10.1016/S0010-9452(13)80342-5.

Joanette, Y., Ansaldo, A. I., Kahlaoui, K., Côté, H., Habilidades, L. A. S., Perspectivas, L., & Clínica, T. Y. (2008). Impacto de las lesiones del hemisferio derecho sobre las habilidades lingüísticas : perspectivas teórica y clínica. *Revista de neurología, 46*(8), 481–488.

Joanette, Y., Ska, B., & Coté, H. (2004). *Protocole montréal d'évaluation de la communication*. Isbergues, France: Ortho Édition.

Johns, C. L., Tooley, K. M., & Traxler, M. J. (2008). Discourse impairments following right hemisphere brain damage: A critical review. *Language and Linguistics Compass, 2*(6), 1038–1062. http://dx.doi.org/10.1111/j.1749-818X.2008.00094.x.

Jung-Beeman, M. (2005). Bilateral brain processes for comprehending natural language. *Trends in Cognitive Sciences, 9*(11). http://dx.doi.org/10.1016/j.tics.2005.09.009.

Kennedy, D. P., & Adolphs, R. (2012). The social brain in psychiatric and neurological disorders. *Trends in Cognitive Sciences, 16*(11), 559–572. http://dx.doi.org/10.1016/j.tics.2012.09.006.

Lezak, M. D. (2012). *Neuropsychological assessment (fith editi)*. London: Oxford University Press.

Lomlomdjian, C., Solis, P., Medel, N., & Kochen, S. (2011). A study of word finding difficulties in Spanish speakers with temporal lobe epilepsy. *Epilepsy Research*. http://dx.doi.org/10.1016/j.eplepsyres.2011.06.016.

Mar, R. A. (2011). The neural bases of social cognition and story comprehension. *Annual Review of Psychology, 62*, 103–134. http://dx.doi.org/10.1146/annurev-psych-120709-145406.

Marini, A., & Ph, D. (2012). Characteristics of narrative discourse processing after damage to the right. *Hemisphere, 1*(212), 68–78.

Mason, R. A, & Just, M. A. (2009). Comprehension of narratives. October, 3(1) (pp. 1–15), doi: http://dx.doi.org/10.1111/j.1749-818X.2008.00122.x.The.

McAndrews, M. P., & Cohn, M. (2012). Neuropsychology in temporal lobe epilepsy: influences from cognitive neuroscience and functional neuroimaging. *Epilepsy Research and Treatment, 2012*, 925238. http://dx.doi.org/10.1155/2012/925238.

Oddo, S., Consalvo, D., Silva, W., D'Alessio, L., & Kochen, S. (2003). Behavior mesial temporal lobe epilepsy and hippocampal sclerosis : cognitive function assessment in Hispanic patients. *Epilepsy & Behavior, 4*, 717–722. http://dx.doi.org/10.1016/j.yebeh.2003.09.008.

Petrides, M. (2013). *Neuroanatomy of language regions of the human brain, 1st edition neuroanatomy of language regions of the human brain, 1st edition (First)*. Academic Press.

Poeppel, D., Emmorey, K., Hickok, G., & Pylkkanen, L. (2012). Towards a new neurobiology of language. *Journal of Neuroscience, 32*(41), 14125–14131. http://dx.doi.org/10.1523/JNEUROSCI.3244-12.2012.

Prat, C. S., Long, D. L., & Baynes, K. (2007). The representation of discourse in the two hemispheres: an individual differences investigation. *Brain and Language, 100*(3), 283–294. http://dx.doi.org/10.1016/j.bandl.2006.11.002.

Price, C. J. (2012). A review and synthesis of the first 20years of PET and fMRI studies of heard speech, spoken language and reading. *NeuroImage, 62*(2), 816–847. http://dx.doi.org/10.1016/j.neuroimage.2012.04.062.

Richardson, M. P. (2012). Large scale brain models of epilepsy: dynamics meets connectomics. *Journal of Neurology, Neurosurgery, and Psychiatry, 83*(12), 1238–1248. http://dx.doi.org/10.1136/jnnp-2011-301944.

Schacher, M., Winkler, R., Grunwald, T., Kraemer, G., Kurthen, M., Reed, V., & Jokeit, H. (2006). Mesial temporal lobe epilepsy impairs advanced. *Social Cognition, 47*(12), 2141–2146. http://dx.doi.org/10.1111/j.1528-1167.2006.00857.x.

Stone, V. E., Baron-cohen, S., & Knight, R. T. (1998). Frontal lobe contributions to theory of mind. *Journal of Cognitive Neuroscience*, 640–656.

Swett, K., Miller, A. C., Burns, S., Hoeft, F., Davis, N., Petrill, S. a., & Cutting, L. E. (2013). Comprehending expository texts: the dynamic neurobiological correlates of building a coherent text representation. *Frontiers in Human Neuroscience, 7*, 853. http://dx.doi.org/10.3389/fnhum.2013.00853.

Tatum, W. O. (2012). Mesial temporal lobe epilepsy. *Journal of Clinical Neurophysiology: Official Publication of the American Electroencephalographic Society, 29*(5), 356–365. http://dx.doi.org/10.1097/WNP.0b013e31826b3ab7.

Trebuchon Da Fonseca, A., Guedj, E., Alario, F. X., Laguitton, V., Mundler, O., Chauvel, P., & Liegeois-Chauvel, C. (2009). Brain regions underlying word finding difficulties in temporal lobe epilepsy. *Brain, 132*(10), 2772–2784. http://dx.doi.org/10.1093/brain/awp083.

Weschler, D. (2006). *Weschler adult intelligence scale-third edition*. Buenos Aires: Editorial Paidós.

Wong, C., & Gallate, J. (2012). The function of the anterior temporal lobe: a review of the empirical evidence. *Brain Research, 1449*, 94–116. http://dx.doi.org/10.1016/j.brainres.2012.02.017.