Epilepsy & Behavior 101 (2019) 106582

Contents lists available at ScienceDirect

Epilepsy & Behavior

journal homepage: www.elsevier.com/locate/yebeh

Brief Communication

The visuospatial pattern of temporal lobe epilepsy

Giulia Maria Tallarita, Annalisa Parente, Anna Rita Giovagnoli *

Department of Diagnostics and Applied Technology, Fondazione IRCCS Istituto Neurologico Carlo Besta, Milano, Italy

ARTICLE INFO

Article history:
Received 27 May 2019
Revised 5 September 2019
Accepted 19 September 2019
Available online 6 November 2019

Keywords:
Temporal lobe epilepsy
Chronic brain lesions
Mesial temporal lobe epilepsy
Visuospatial functions
Memory
Learning

ABSTRACT

Purpose: Unlike temporal lobe lesions, temporal lobe epilepsy (TLE) has no definite effects on visuospatial functions. This retrospective study evaluated these functions in patients with TLE, aiming to clarify their relationships to TLE laterality and magnetic resonance imaging (MRI)-detected brain lesions.
Methods: The Raven Colored Progressive Matrices (RCPM), Attentive Matrices (AM), Trail Making Test A (TMTA), Street Completion Test (SCT), Rey Complex Figure Copying (RCFC) and Delayed Reproduction (RCFDR), and Corsi Blocks Span (CBS) and Supraspan Learning (CBSSL) were used to assess different visuospatial functions in 198 patients with TLE and 90 healthy subjects.
Results: In 169 patients (83 left), MRI revealed focal temporal lobe lesions [unilateral mesial temporal lobe sclerosis (MTLS) in 88 cases]. The patients with left or right TLE obtained normal scores on the RCPM, AM, TMTA, SCT, and RCFC, but their scores were significantly low on the CBS, CBSSL, and RCFDR. The patients with MTLS obtained lower scores in comparison with the controls and the patients without lesions, whereas those with other lesions obtained low scores only on the CBSSL and those without lesions performed normally.
Conclusions: Temporal lobe epilepsy does not affect nonmemory visuospatial functions but significantly impairs visuosopatial memory and learning. This pattern is independent of TLE laterality, in keeping with a modality-specific memory model. On the contrary, the type of temporal lobe lesion is relevant to the severity of impairment.

1. Introduction

Temporal lobe epilepsy (TLE), the most common form of human epilepsy, may have deleterious effects on cognitive functions. Most studies of TLE have focused on memory and language. Memory impairment, a common symptom of medial temporal lobe (MTL) damage, is often revealed by immediate story recall, working memory, and delayed verbal or nonverbal memory tasks. Chronic compromise of naming, verbal fluency and comprehension, theory of mind, and executive functions have been related to temporal or extratemporal lobe damage [1–3].

Visuospatial cognition, an ability to understand the visual representations and spatial relationships between objects, includes visual analyses and syntheses, visuospatial construction and planning, and judgment of line orientation [4]. The visuospatial domain also comprehends storage, retrieval and transformation of visual or spatial stimuli, generation and rotation of mental images, the binding of object attributes, closure speed, and scanning skills, which are important to cognitive and behavioral pattern [4]. These functions pertain to intertwined subdomains processing object or space attributes and their semantic associations supported by different anatomical/functional areas. Ungerleider and Mishkin [5] first suggested that the visual system may be decomposed into two pathways: a dorsal pathway concerned with spatial properties and a ventral pathway concerned with object identification. In the recent years, it has been acknowledged that the dorsal occipitoparietal and ventral occipitotemporal pathways cooperate conveying object visual and spatial attributes, contributing to the construction of mental representations [6]. The role played by the dorsal pathway has been further detailed comprehending the processing of object form and motion and spatiotemporal integration, as a basis for object-directed actions [7]. While the ventral and dorsal cortex are devoted to represent variant and invariant object shapes derived from the changing information received from the retina [7], the posterior parietal cortex is involved in spatial awareness supporting the perceptual and semantic processes until object recognition, contributing to object-related actions [8].

Little attention has been given to these functions in patients with TLE. Grant et al. found no differences between patients with TLE and healthy controls on two low-level visual tasks [9]. Other studies revealed that TLE is associated with normal visuospatial functions, despite memory impairment [10]. On the contrary, recent works have suggested that the MLT and anterior temporal lobe (ATL) may be critical for perceptual and recognition functions [11–13]. Human lesion studies have shown object processing impairments in patients with MLT damage [12], while functional neuroimaging studies have provided evidence of hippocampus activation during the discrimination of complex scenes

* Corresponding author at: Department of Diagnostics and Applied Technology, Fondazione IRCCS Istituto Neurologico Carlo Besta, Via Celoria 11, 20133 Milano, Italy.
E-mail address: annarita.giovagnoli@istituto-besta.it (A.R. Giovagnoli).

https://doi.org/10.1016/j.yebeh.2019.106582
1525-5050/

[13]. The hippocampus also plays a role in processing the conjunctions of spatial attributes and ambiguous objects [11,13].

In brief, TLE has shown no definite impact on visuospatial functions in contrast with the impairment documented in patients with MTL and ATL lesions. This retrospective study evaluated a series of visuospatial functions in patients with TLE, aiming to clarify the type and severity of impairment and its relationships to TLE laterality and the presence and type of temporal lobe lesions.

2. Material and methods

2.1. Participants

From 2005 to 2015, a series of patients with right or left TLE [14], without other neurological disorders or psychiatric illness, were evaluated. Adult healthy subjects with negative history of neurological or psychiatric illnesses were controls. Eligibility criteria were as follows: age ≥ 18 years, years of schooling ≥ 5, normal abstract reasoning and verbal comprehension on the Raven Colored Progressive Matrices (RCPM) and Token Test (TT), respectively, and magnetic resonance imaging (MRI)-detected normal brain or focal no-progressive lesions. The study protocol was approved by the hospital review board, and all of the participants gave their written informed consent to the clinical and instrumental examinations, in accordance with the Declaration of Helsinki.

2.2. Neuropsychological assessment

The Attentive Matrices (AM), Trail Making Test A (TMTA), Street's Completion Test (SCT), Rey's Complex Figure (RCF) Copying and Delayed Reproduction, and Corsi's Blocks Span (CBS) and Supraspan Learning (CBSSL) evaluated spatial exploration and attention, visuomotor coordination, degraded figures integration and recognition, copying of spatial stimuli and spatial long-term memory, span, and learning. The RCPM assessed spatial matching and reasoning [3].

2.3. Statistical analysis

One-way analysis of variance (ANOVA) and chi^2 test were used to compare age, years of schooling, or gender distribution between the patients and the controls, as well as the presence and the type of MRI-detected temporal lobe lesion. T-tests were used to compare the age at epilepsy onset, disease duration, monthly seizure frequency in previous six months, and AED number. One-way ANOVA and post hoc Bonferroni's tests were used to compare the neuropsychological test scores between the patients with left and right TLE and the controls, setting the significance level as $p \leq 0.01$. Separate one-way ANOVAs compared the test scores between the patients with mesial temporal lobe sclerosis (MTLS) or other lesions, the patients without MRI-detected lesion, and the controls.

3. Results

3.1. Participants

A hundred and ninety-eight Italian-speaking patients with drug-resistant left (n = 101) or right (n = 97) TLE were evaluated. Ninety healthy controls were recruited from among the hospital visitors and staff and external people (Table 1). In 99 patients with right (n = 49 right) or left (n = 39) TLE, MRI revealed the presence of MTLS that was associated with cortical dysplasia in 11 cases. Different lesions (cortical dysplasia, dysembryoplastic neuroepithelial tumor, low-grade glioma, cavernoma, focal posttraumatic atrophy) were observed in 47 patients with left TLE and 34 patients with right TLE. Fifteen patients with left TLE and 14 patients with right TLE showed no MRI-detected lesions. The patients with left and right TLE and the controls were very similar in age, the years of schooling, gender distribution, and the RCPM and TT scores. The patient groups were very similar in the type of brain lesions, the age at seizures onset, epilepsy duration, monthly seizure frequency, and AED number.

Table 1
Demographic and clinical features of patients with temporal lobe epilepsy and healthy subjects.

	Patients with left TLE N = 101	Patients with right TLE N = 97	Healthy subjects N = 90
Female/males	50/51	43/54	51/39
Age	37.79 ± 10.06	37.72 ± 9.73	41.49 ± 15.62
Schooling (years)	12.45 ± 3.55	11.93 ± 3.62	12.87 ± 3.65
Age at seizure onset	19.48 ± 13.95	19.62 ± 13.45	
Disease duration	18.19 ± 13.27	17.84 ± 12.71	
Seizure frequency	7.25 ± 7.75	9.24 ± 11.74	
Number of AEDs	2.14 ± 0.85	2.24 ± 0.76	
Patients with MTLS	39	49	
Patients with other TL lesions	47	34	

TLE, temporal lobe epilepsy. AED, antiepileptic drug. MTLS, mesial temporal lobe sclerosis. TL, temporal lobe.

3.2. Neuropsychological performance

Table 2 summarizes the mean neuropsychological test scores. One-way ANOVA showed significant between-group differences on the CBS [$F(2,281) = 11.27$, $p < 0.001$], CBSSL [$F(2,235) = 19.09$, $p < 0.001$] and RCFDR [$F(2,281) = 7.36$, $p = 0.001$] because of lower scores in the patients with left or right TLE in comparison with the controls, whereas there were no differences between the patient groups. No differences were found at other neuropsychological tests.

Separate one-way ANOVAs comparing the patients with different temporal lobe lesions revealed significant differences for the CBS [$F(3,280) = 8.23$, $p < 0.001$], CBSSL [$F(3,234) = 18.59$, $p < 0.001$] and RCFDR [$F(3,280) = 5.62$, $p = 0.001$]. Post hoc analyses showed that, in comparison with the controls, the patients with MTLS or other brain lesions had lower CBSSL scores, while the patients with MTLS also had lower CBS and RCFDR scores, and the patients without MRI-detected temporal lobe lesion showed no deficits. The patients without lesion performed better than the patients with MTLS, albeit the differences were not significant.

4. Discussion

This study assessed different visuospatial functions in patients with left or right drug-resistant TLE associated with nonprogressive temporal lobe lesions or normal brain structures. The visuospatial pattern was characterized by normal integration and recognition of degraded figures, spatial reasoning and exploration, visuomotor coordination, and visuoconstructive capacity. Visuospatial span, long-term memory, and learning were significantly impaired independently of TLE laterality, whereas the presence and type of temporal lobe lesion affected these functions.

The results suggest that, in patients with drug-resistant TLE, some nonmemory visuospatial functions are well-retained, maybe because of the integrity of the temporoparietal–occipital areas underlying the processing of visual and spatial information [15]. The SCT, which involves the analysis and integration of object features into a meaningful form [16], was normally passed by the patients. This is in favor of the integrity of the visual perceptual/semantic occipital–temporal pathways and occipital–parietal cortex in TLE [9,16]. It is worth to note that we cannot exclude the impairment of unexplored visuospatial functions, such as discrimination of complex object and scenes, conjunctions of

Table 2
Neuropsychological test scores of patients with temporal lobe epilepsy and healthy subjects.

	Patients with left TLE	Patients with right TLE	Healthy subjects	Between-group comparisons		Patients with left TLE vs healthy subjects	Patients with right TLE vs healthy subjects
				F	p	p	p
Raven's Colored Progressive Matrices	32.52 ± 2.52	32.61 ± 2.69	33.38 ± 2.58	3.06	0.050	NS	NS
Token Test	34.39 ± 1.37	34.58 ± 1.41	34.94 ± 0.96	4.42	0.013	NS	NS
Attentive Matrices	55.20 ± 4.69	55.27 ± 4.98	56.22 ± 4.08	1.42	NS	NS	NS
Trail Making Test A	33.60 ± 11.36	33.72 ± 10.96	32.24 ± 12.60	0.45	NS	NS	NS
Rey Complex Figure Copying	34.06 ± 2.01	33.80 ± 2.67	34.52 ± 1.61	2.58	NS	NS	NS
Rey Complex Figure Delayed Reproduction	18.12 ± 6.38	17.87 ± 7.20	21.24 ± 6.18	7.36	0.001	0.004	0.002
Street Completion Test	9.91 ± 1.90	9.79 ± 1.91	9.46 ± 1.99	1.36	NS	NS	NS
Corsi Blocks Span	5.19 ± 0.93	5.27 ± 0.91	5.78 ± 0.90	11.23	<0.001	<0.001	0.001
Corsi Blocks Supraspan Learning	21.49 ± 6.30	20.10 ± 6.69	25.93 ± 2.52	19.09	<0.001	<0.001	<0.001

TLE, temporal lobe epilepsy. Patients with right TLE vs patients with left TLE: no differences.

spatial attributes, and recognition of ambiguous objects and faces, which are supported by the MTL [11–13].

On the contrary, impaired visuospatial memory and learning may reflect an involvement of the medial and lateral temporal lobe structures that are generally linked to the registration, encoding, and retrieval of new or stored information [17]. Indeed, in amnesic individuals, MRI revealed an extensive damage to the hippocampus complex and entorhinal and ventral perirhinal cortex [18]. The studies in rats and nonhuman primates also highlighted the role played by the MTL in memory and provided an animal model for human memory [19].

It is worth noting that we found no significant differences between the patients with left and right TLE on visuospatial memory or learning, which provides strong evidence that these functions are independent of the hemispheric side of brain damage. Unlike verbal memory and learning, which are strictly related to language dominance, visuospatial memory and learning are supported by bihemispheric neural networks [4]. Moreover, the encoding of verbal stimuli may be more specific than the encoding of visuospatial material which usually implies the mental representation of figural features and stimulus naming, therefore engaging bilateral brain areas. In this study, the material-specific model embracing complete lateralization of memory functions based on the type of stimulus (verbal, visuospatial) is counteracted by a view concerning the type of process [20]. In this regard, Saling [20] proposed the modality-specific memory model, suggesting that verbal and visuospatial traces are not entirely lateralized. Previous studies also failed to establish an association between right temporal lobe resection and postoperative decline of nonverbal memory [21]. Moreover, recent functional neuroimaging studies have underlined that the right hemisphere does not inevitably surpass the left hemisphere on visuospatial tasks. Right hemisphere activity would be more important in the case of complex higher-level visuospatial abilities, whereas simple or low-level abilities would be equally represented in both hemispheres [22]. Mehta et al. [23] described an important left hemisphere involvement in the visuospatial processes, as well as a more focal representation of spatial abilities in the left hemisphere.

In the present study, visuospatial learning and memory were more impaired in the patients with MTLS in comparison with the controls and the patients without temporal lobe lesion, whereas, in comparison with the controls, the patients with other lesions showed minor impairments, and those without lesion performed normally. This further underlines the importance of the MTL to memory and learning, as well as the unique pathogenic role played by MTLS in the neurobehavioral phenotype of TLE. Unlike previous findings [24], present results support the idea that the impact of MTL lesion may overcome the negative effects of the epileptic discharges on visuospatial learning and memory, although the spreading of the epileptic discharges within and outside the temporal lobes may affect other cognitive functions.

These results have to take into account some limitations. The study design was retrospective, allowing the analysis of only some visuospatial test scores. Such tests did not tap particular visuospatial abilities supported by the temporal lobe.

5. Conclusions

Present findings add evidence to differential cognitive patterns of drug-resistant TLE. Temporal lobe epilepsy does not affect major nonmemory visuospatial functions, but can significantly impair short- and long-term visuospatial memory and learning. This visuospatial pattern appears independent of TLE laterality, in keeping with a modality-specific memory model, whereas the type and location of temporal lobe lesions are relevant to the severity of impairment. Future studies are needed to determine comprehensively the visuospatial abilities linked to the temporal lobe, comparing patients with different focal epilepsies.

Declaration of competing interest

The study was in part supported by institutional funding for current clinical research. The authors have no conflict of interest to report. 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.

Acknowledgments

The authors are grateful to Giuliano Avanzini, Giorgio Battaglia, Simona Binelli, Marco De Curtis, Silvana Franceschetti, Marina Casazza, Roberto Spreafico, and Flavio Villani who sent patients for neuropsychological examination.

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