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Visuospatial learning and memory in children pre- and posttemporal lobe resection: Patterns of localization and lateralization

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ABSTRACT

In children with epilepsy, the impact of surgery including or sparing the mesial temporal lobes (TLs) on visuospatial memory has not been thoroughly investigated, and a clear pattern of hemispheric lateralization has not been observed. The primary aim of this study was to examine visuospatial learning and memory outcomes in children with epilepsy prior to and one year after surgical excision, to determine whether outcomes differed as a function of the localization and lateralization of surgical excisions. Forty-six children who underwent unilateral TL surgery with sparing of the mesial structures (TL group, N = 21, 16 left) or including mesial structures (TL + M group, N = 25 children, 12 left) were retrospectively recruited. Outcomes on the Children's Memory Scale (CMS) Dot Locations subtest (learning, immediate, and delayed recall scores) were examined prior to and following epilepsy surgery. Results revealed significantly reduced visuospatial memory (delayed recall) in the TL + M compared with the TL group after surgery. Despite this significant postoperative difference, there was no significant change in learning, immediate, or delayed recall scores in either group. However, inspection of individual change scores showed that fewer children in the TL + M group improved in delayed recall after surgery (7.2%) compared with children in the TL group (30%) whereas a similar proportion of children in the TL + M (30.4%) and TL (23.3%) groups showed a decline. There were no significant differences in learning or memory scores as a function of seizure laterality before or after surgery and no differences in change over time. Seizure outcome, age at surgery, age at seizure onset, and percentage life with epilepsy were not related to visuospatial learning or memory outcomes; however, greater number of antiepileptic drugs (AEDs) following surgery was related to poorer visuospatial memory (delayed recall) in the TL + M group. In summary, the results show that visuospatial learning and memory performance do not seem to show a significant decline following TL resections in childhood, regardless of whether or not surgery includes the mesial TL and involves the left or right hemisphere. However, although mesial TL excisions might not result in a deficit in visuospatial memory, they may hinder progressions made after surgery. Further research is needed to examine how resection of the mesial TL (alone or in combination with lateral TL structures) affects visuospatial memory outcomes in children, as well as to investigate the degree to which other treatment factors, such as medication, may affect visual memory outcomes.

1. Introduction

An accumulated body of evidence from adults has shown that the mesial temporal lobes (TLs) play a critical role in memory for stimuli of multiple modalities [1]. In adults with epilepsy, mesial TL damage has been associated with significantly larger memory impairments in both verbal and visuospatial domains [2], with surgical resection of the mesial TL related to poorer verbal and visual memory outcomes [3,4]. Among children, less is known about the impact of mesial TL resection on memory outcomes. One recent study by Law et al. [5] found a decline in verbal memory following resections of lateral plus mesial, but not lateral only, left TL structures in children. The impact of mesial TL resection on visuospatial memory in children with epilepsy has not been thoroughly investigated. Understanding how pediatric epilepsy surgery affects visuospatial learning and memory is important for accurate preoperative assessments, as well as for understanding the brain structures recruited when encoding and recalling information presented in verbal or visual forms.

To date, few longitudinal studies have examined whether visuospatial memory outcomes differ in children after surgery that includes or spares mesial TL structures [6]. Kuehn et al. [6] found no differences between pre- or postoperative visuospatial memory scores among

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children who had TL resections including ($N = 5$) or sparing ($N = 15$) the hippocampus. Similarly, in another study that examined the impact of presurgical magnetic resonance imaging (MRI)-documented mesial TL pathology on change in visuospatial memory scores pre- to postoperatively, the authors found no significant differences in change scores as a function of mesial TL pathology [7]. A larger number of cross-sectional studies have examined whether visual memory outcomes differ in children with and without mesial TL damage, either before or after surgery however ;; however, outcomes from these studies have been mixed [8,9]. Gascoigne et al. [9] found no significant differences in immediate or delayed recall on a visuospatial memory task (a design locations task) in children with TL epilepsy as a function of hippocampal pathology; their sample included a mixture of pre- and postsurgical children. In contrast, Gonzalez et al. [8] found that children with mesial TL pathology (all presurgery) performed more poorly on a different visuospatial memory task (a box maze paradigm) compared with children without mesial TL damage. These contradictory findings may relate to the use of different tasks or differing characteristics of the children included in their samples. The results demonstrate the need for further research into whether mesial TL damage is related to visuospatial memory in children before and after surgery or is related to a decline in visual memory outcomes over time.

In addition to the site of resection, the side of pathology has also been related to memory outcomes [10]. Adults with left TL damage have greater impairments on verbal memory tasks whereas adults with right TL pathology tend to have larger impairments on visuospatial memory tasks; although this relationship between right-sided pathology and visual memory impairment has not always been observed [11,12]. Consistent with these findings, surgical resection of the right or left TL in adults with epilepsy has been associated with a decline in visuospatial and verbal memory, respectively [4]. Despite these material-specific memory impairments in adults with epilepsy, findings from children with epilepsy have not reported such a clear-cut pattern of lateralization, either before or after surgery. Studies examining children prior to epilepsy surgery have reported no significant differences between children with right- and left-hemisphere seizure foci on visuospatial memory tasks [8,13]. Similarly, no differences were documented as a function of seizure laterality in a study that included a mixture of pre- and postsurgical children on a visuospatial design locations task [9]. However, in a study that examined postsurgical children only, Hepworth and Smith [14] found that children who had undergone right TL resections had poorer visuospatial learning and immediate memory scores compared with children who underwent left TL resection at a one-year follow-up. It is not clear whether surgery was the cause of the visuospatial memory deficit in the right TL group, as the study did not collect information about the children's presurgical performance.

Longitudinal studies examining visuospatial memory following unilateral TL resections in children have also produced mixed results. Gleissner et al. [15] found no significant change in visuospatial memory one year after right or left TL resections and no significant differences in outcomes between the groups. In another study, Jambaque et al. [16] similarly found no change in visuospatial memory scores pre- to postsurgery in patients who had undergone right or left TL surgery; however, they found that children with right TL lesions performed more poorly on a visuospatial recall task than children with left TL lesions, both before and after surgery. Longitudinal studies examining broader aspects of visual memory (i.e., face recognition, figural memory) following TL excisions have similarly not found consistent lateralizing patterns. One study reported poorer postoperative visual memory performance (on a face recognition task) among children who underwent right compared with those who had left TL excisions [17] whereas other studies have found no differences between left and right TL groups [18–20]. Variability in findings could relate to the domains of visual memory assessed, the tasks used, or other characteristics of the participant groups. For instance, some studies included children who underwent resection of mesial structures only [16] whereas others included patients with both mesial and lateral TL resection but did not compare the groups [21].

Notwithstanding the site and side of surgical excision, the impact of TL resection on visual learning and memory in children with epilepsy (more broadly) requires further investigation, as outcomes from longitudinal studies have been mixed [22,23]. Postsurgical improvements in some aspects of visual memory have been found in some studies [17,24] whereas other studies have reported a decline [7] or no change in visual memory outcomes [17–20,25–27]. These differing results may relate to the domains of visual memory assessed and/or the tasks used; for instance, improvements have been documented on tasks assessing face recognition [17,24] but not on other visually mediated memory tasks [17]. Visual memory is a complex multicomponent skill that involves memory for faces, scenes, geometric objects, or spatial locations. The ability to learn and remember visual information involving a spatial component in the absence of person-specific cues is a discrete aspect of nonverbal memory, which may be less likely to be encoded using language strategies and rely on the functioning of different brain regions compared with other aspects of visual memory (e.g., face recognition). As such, visuospatial memory may be differentially impaired depending on the site and side of surgery.

Finally, other epilepsy-related treatment factors, such as seizure outcome, age at surgery, and number of AEDs, may also relate to visuospatial memory outcomes in children. Improved seizure control [7,17,19] and a reduction in AEDs [7] have been related to better postoperative memory outcomes (verbal and visual) in children. Age at surgery has mostly been unrelated to memory outcomes, although these findings are limited because of the restricted age range of children at surgery [5,7,16,28]. At present, it is not clear whether these relationships are the same for all groups of children, or whether they differ depending on site and side of surgical excision.

The primary aim of this study was to investigate visuospatial learning and memory in children prior to and one year after surgical resection of the TL. We were interested in whether children's memory performance following surgery, as well as change over time, differed as a function of the localization and lateralization of surgical excision. The secondary aim of the study was to examine whether epilepsy variables (i.e., age at surgery, percentage life with epilepsy, seizure outcome, age at seizure onset, number of AEDs) were related to visuospatial learning or memory outcomes.

2. Materials and methods

2.1. Study design

Children were retrospectively recruited from a clinical database at the Hospital for Sick Children in Toronto. A pretest–posttest design was used to assess potential change in visuospatial learning and memory outcomes one year after unilateral TL epilepsy surgery. The study was approved by the hospital research ethics board.

2.2. Participants

The sample consisted of 46 children who had undergone unilateral TL resection. They were subdivided into four groups based on laterality of resection and whether or not the mesial structures were spared in the resection. There were 21 children (16 left) who underwent TL surgery with sparing of the mesial structures (TL group) and 25 children (12 left) who had a temporal lobectomy that included resection of mesial structures (TL + M group). Children were eligible to participate if they had a Full Scale Intelligence Quotient (FSIQ) ≥70 and completed a selected task assessing visuospatial memory before and after surgery. Children were excluded if they had undergone prior epilepsy surgery or if surgical resection included extratemporal lobe structures. Presurgery data were unavailable for 3 children (1 left lateral and 2 left mesial); however, because we were interested in outcomes following

surgery, as well as change over time, these children were included in analyses examining outcomes at follow-up.

2.3. Measures

Visuospatial learning and memory was assessed with the Children's Memory Scale (CMS) Dot Locations subtest [29]. The CMS is a comprehensive measure that assesses visual and verbal learning and memory in children aged 6 to 16 years [29]. In the Dot Locations subtest, children must learn and remember the location of an array of dots, which are placed in various locations within a box. In the learning trials, they are given three trials to place response chips in locations in a grid that corresponds to a target stimulus. In the immediate memory trial, children are shown a target stimulus once, followed by a distractor stimulus, and then asked to recall the location of the target stimulus immediately. In the delayed recall trial, children are asked to recall the location of dots shown during the 3 learning trials after a 30-minute delay. The subtest yields three scores, representing learning, immediate recall, and delayed recall ($M = 10$, standard deviation (SD) $= 3$). FSIQ was assessed in all children with the Wechsler Intelligence Scale for Children.

2.4. Statistical analyses

Data were analyzed using the Statistical Package for Social Sciences (SPSS, version 25.0). Inspection of data distributions with histograms and Shapiro–Wilk tests showed that data were normally distributed, and there were no significant outliers. One-way analysis of variance (ANOVA) and chi-square tests were used to compare groups on demographic, cognitive, and epilepsy variables. Two-way ANOVAs were used to examine whether there were significant differences in visuospatial learning or memory scores as a function of seizure laterality, surgical site, or seizure outcome using presurgery, postsurgery, and change scores. Repeated measures ANOVAs examined change in visuospatial learning and memory scores from pre- to postsurgery for the entire group with epilepsy and for each of the 4 subgroups studied: left TL, left TL + M, right TL, and right TL + M. Individual analysis of change was assessed with chi-square tests of independence, with children categorized into those who improved, declined, or showed no change in performance pre- to postsurgery; change was defined as a difference of ≥1 SD (i.e., 3 points). Pearson's correlations examined the strength of relationships between epilepsy variables and visuospatial learning and memory scores. Effect size estimates were obtained for ANOVA using Cohen's d (0.3 = small, 0.5 = medium, 0.8 = large), which were calculated in Excel using a standard formula ($M_{group\ 1} - M_{group\ 2} / SD_{pooled}$). An alpha of 0.05 was used for all analyses. All tests were two-tailed.

3. Results

3.1. Participant characteristics

Table 1 summarizes demographic, cognitive, and epilepsy variables for participants as a function of site and side of resection. One-way ANOVAs comparing the four groups on demographic, cognitive, and epilepsy variables revealed no significant differences between groups on any variables measured.

3.2. Temporal lobe resection and visuospatial learning and memory outcomes

Table 2 summarizes means and SDs of visuospatial learning and memory scores presurgery, postsurgery, and change scores for each group. Correlations revealed no significant relationship between

Table 1
Characteristics of children included: means (standard deviations) or frequencies.

	Left TL		Right TL		Test of between-group difference	*p*-Value
	Left TL ($N = 16$)	Left TL + M ($N = 12$)	Right TL ($N = 5$)	Right TL + M ($N = 13$)		
Sex (M/F)	10/6	6/6	3/2	9/4	$\chi^2 = 0.996$	0.802
Handedness (L/R)	1/15	2/11	0/5	1/11	$\chi^2 = 3.070$	0.800
IQ at baseline						
FSIQ	90.13 (10.56)	89.17 (12.39)	100.00 (20.39)	91.31 (10.87)	$F_{3,49} = 0.936$	0.432
VIQ	86.44 (12.03)	93.33 (12.53)	101.80 (23.86)	89.92 (9.85)	$F_{3,49} = 1.900$	0.144
PIQ	100.13 (14.28)	90.92 (13.54)	108.40 (18.11)	97.54 (14.73)	$F_{3,49} = 1.896$	0.145
Age at testing						
Age at baseline (years)	11.59 (2.79)	12.20 (1.97)	11.51 (3.66)	12.22 (2.86)	$F_{3,49} = 0.211$	0.888
Age at follow-up (years)	13.41 (2.72)	14.32 (2.04)	13.64 (4.04)	13.64 (4.04)	$F_{3,49} = 0.239$	0.869
Age at seizure onset (years)	7.45 (4.47)	6.43 (4.55)	5.06 (4.89)	6.63 (3.89)	$F_{3,49} = 0.406$	0.750
Percentage life with epilepsy (%)	34.31 (28.71)	44.75 (33.46)	46.45 (35.21)	39.36 (32.19)	$F_{3,49} = 0.332$	0.803
Age at surgery (years)	12.32 (2.67)	13.15 (1.99)	12.61 (3.96)	12.72 (3.06)	$F_{3,49} = 0.205$	0.892
Seizure outcome at follow-up						
Seizure-free/ongoing seizures	8/8	9/3	4/1	8/5	$\chi^2 = 2.534$	0.469
Medication						
AEDs at baseline (total number)	1.56 (0.63)	1.67 (0.65)	1.40 (0.89)	1.62 (0.96)	$F_{3,49} = 0.153$	0.927
AEDs at follow-up (total number)	2.00 (0.63)	1.75 (0.45)	1.20 (0.45)	1.62 (0.87)	$F_{3,49} = 2.118$	0.112
Language representation[a]						
Left hemisphere (typical)	8	8	2	6		
Right hemisphere (atypical)	4	1	0	3		
Bilateral (atypical)	1	3	1	1		
Pathology[b]						
Tumor (DNET, low grade glioma)	7	3	3	5		
Malformation of cortical	2	1	0	1		
Dual pathology[c]	2	1	2	3		
Gliosis	4	3	0	2		
Medial temporal sclerosis	1	2	0	0		
Vascular malformation	0	1	0	1		
No discernable pathology (unknown)	0	1	0	1		

TL, temporal lobe; FSIQ, full scale intelligence quotient; VIQ, verbal intelligence quotient; PIQ, performance intelligence quotient; AED, antiepileptic drug; DNET, dysembryoplastic neuroepithelial tumor.

[a] Language lateralization missing for 8 participants: 3 left lateral, 2 right lateral, and 3 right mesial; all participants in whom language lateralization was missing were right handed.

[b] Pathology was determined by histopathological analysis following surgical resection.

[c] Dual pathology refers to two etiologically independent pathologies. All tests were two-tailed.

Table 2
Mean scores (standard deviations) for visuospatial learning and recall pre- and postsurgery.

	Left TL		Right TL	
	Left TL ($N = 16$)	Left TL + M ($N = 12$)	Right TL ($N = 5$)	Right TL + M ($N = 13$)
Presurgery				
Learning	10.80 (3.63)	8.90 (4.61)	10.60 (2.60)	10.23 (1.92)
Immediate recall	10.93 (3.58)	9.20 (4.21)	10.60 (2.88)	10.85 (2.06)
Delayed recall	11.53 (2.19)	10.60 (3.03)	10.60 (3.78)	11.00 (1.73)
Postsurgery				
Learning	11.13 (2.19)	8.67 (2.35)	8.20 (5.02)	9.62 (3.45)
Immediate recall	11.56 (2.07)	8.25 (2.60)	9.20 (4.87)	14.08 (17.66)
Delayed recall	11.25 (2.52)	8.25 (3.33)	11.40 (2.88)	10.08 (2.72)
Learning change score	0.40 (3.89)	−0.40 (4.48)	−2.40 (5.77)	−0.62 (4.37)
Immediate recall change score	0.67 (3.60)	−1.10 (3.63)	−1.40 (4.98)	3.23 (18.42)
Delayed recall change score	−0.47 (0.82)	−1.50 (3.50)	0.80 (3.19)	−0.92 (3.35)

Negative change scores indicate worse performance postsurgery compared with presurgery.
Preoperative and change scores missing for 3 children: 1 left TL and 2 left mesial TL.

learning or memory change scores and FSIQ, verbal intelligence quotient (VIQ), or performance intelligence quotient (PIQ). A repeated measures ANOVA was conducted to examine whether there were significant changes in visuospatial learning or memory scores following TL resection for the entire group (collapsed across side and site of surgical resection). Findings revealed no significant change in learning ($F_{1,42} = 0.403$, $p = 0.529$, $d = 0.191$), immediate recall ($F_{1,42} = 0.245$, $p = 0.623$, $d = 0.149$), or delayed recall ($F_{1,42} = 1.637$, $p = 0.208$, $d = 0.386$) scores for the overall group.

3.2.1. Laterality and site of resection

Two-way ANOVAs examined whether there were significant differences in visuospatial learning or memory scores as a function of surgical site (TL or TL + M) or seizure laterality (left or right) presurgery or postsurgery. Findings revealed a significant main effect for surgical site in delayed recall postsurgery ($F_{1,42} = 5.471$, $p = 0.024$, $d = 0.708$): children who had mesial TL structures resected (of the left or right hemisphere) performed more poorly than children who underwent resection sparing mesial structures postoperatively (Fig. 1). There were no other significant effects for surgical site ($ps = 0.272$–0.806) or seizure laterality ($ps = 0.291$–0.783) and no significant interaction effects ($ps = 0.053$–411) in learning, immediate, or delayed recall scores at pre- or postsurgical assessment.

To further examine the effects of side and site of surgical resection on learning and memory outcomes, two-way ANOVAs were conducted using change scores. Findings from these analyses revealed no significant main effects for seizure laterality (learning, $F_{1,39} = 1.060$, $p = 0.310$, $d = 0.318$; immediate recall, $F_{1,39} = 0.101$, $p = 0.753$, $d = 0.098$; delayed recall, $F_{1,39} = 0.577$, $p = 0.452$, $d = 0.235$) and surgical site (learning, $F_{1,39} = 0.113$, $p = 0.739$, $d = 0.102$; immediate recall, $F_{1,39} = 0.161$, $p = 0.690$, $d = 0.121$; delayed recall, $F_{1,39} = 1.290$, $p = 0.263$, $d = 0.344$) and no significant interaction effects (learning, $F_{1,39} = 0.779$, $p = 0.383$, $d = 0.276$; immediate recall, $F_{1,39} = 0.805$, $p = 0.375$, $d = 0.277$; delayed recall, $F_{1,39} = 0.081$, $p = 0.778$, $d = 0.088$). Repeated measures ANOVAs were conducted to examine whether there was a significant change pre- to postsurgery for any of the four subgroups; findings similarly showed no significant change in learning or memory scores from pre- to postsurgery in any of the four subgroups ($ps = 0.209$–0.784).

Finally, to determine whether children's immediate and delayed recall scores differed, paired samples t-tests were conducted. Analyses revealed no significant differences in immediate or delayed recall scores at presurgery or postsurgery in any of the four subgroups ($ps = 0.077$–0.721).

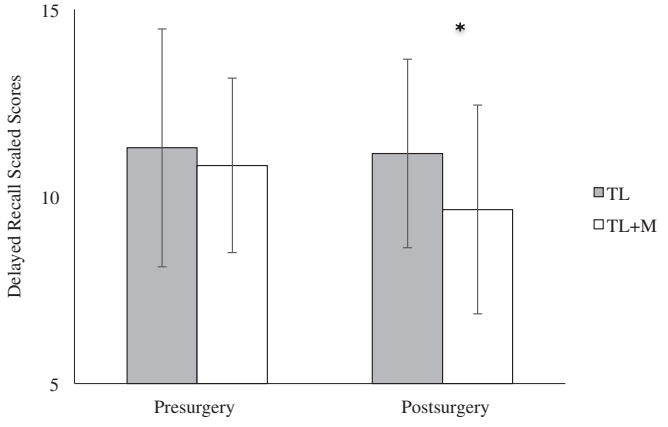

Fig. 1. Performance of children who underwent temporal lobe (TL) resection including lateral only or lateral plus mesial TLs on the Children's Memory Scale (CMS) Dot Locations subtest pre- and postsurgery. *Significant difference between groups, $p = 0.008$.

3.2.2. Seizure outcome

Two-way ANOVAs were conducted to examine the impact of seizure outcome (seizure-free or ongoing seizures) on visuospatial learning and memory outcomes, taking into account the site of resection (TL or TL + M). There were no significant main effects for seizure outcome ($ps = 0.466$–0.939) and no significant interaction effects ($ps = 0.210$–0.804). Consistent with the prior analysis, a significant main effect was found for surgical site postsurgery in delayed recall ($F_{1,42} = 7.709$, $p = 0.008$): after surgery, children who had undergone resection of mesial TL structures had significantly poorer delayed recall scores compared with children in which surgery spared the mesial TL (Fig. 1).

3.2.3. Age at seizure onset, percentage life with epilepsy, age at surgery, and number of AEDs

Correlations between epilepsy variables and visuospatial learning and memory scores were examined as a function of site of resection (TL or TL + M). For the TL + M group, greater number of AEDs after surgery was significantly correlated with poorer learning ($r = -0.485$, $p = 0.014$) and delayed recall ($r = -0.609$, $p = 0.001$) scores after surgery but not with immediate recall ($r = -0.297$, $p = 0.149$); number of AEDs before surgery was not related to learning ($r = 0.315$, $p = 0.144$), immediate ($r = 0.292$, $p = 0.177$), or delayed recall ($r = 0.061$, $p = 0.781$) scores before surgery in the TL + M group. For the TL group, number of AEDs was not related to learning, immediate, or delayed recall scores either before or after surgery ($ps = 0.097$–0.999). Age at surgery, age at seizure onset, and percentage life with epilepsy were not related to learning or memory scores in the TL or TL + M group ($ps = 0.207$–0.805).

Table 3
Percentage of children in each group showing an improvement or decline in visuospatial learning and memory pre- to postsurgery.[a]

	Lateral		Right TL	
	Left TL	Left TL + M	Right TL	Right TL + M
Learning				
Improvement	26.7	30.0	0	38.5
Decline	26.7	30.0	40.0	38.5
Immediate recall				
Improvement	20.0	20.0	20.0	15.4
Decline	20.0	30.0	40.0	30.8
Delayed recall				
Improvement	20.0	0	40.0	15.4
Decline	26.7	30.0	20.0	30.8

[a] Children whose scores changed by more than 1 SD (i.e., 3 points) between pre- to postsurgical assessments were classified as improving or declining. All other children were classified as 'no change', and their data are not shown in this table.

3.2.4. Individual analysis of change in visuospatial memory outcomes

Table 3 summarizes the proportion of children in each group who showed an improvement or deterioration (i.e., >1 SD or 3 points) in visuospatial learning or memory scores pre- to postsurgery. Chi-square tests revealed no significant difference in the proportions of children in each group showing improvements, deteriorations, or no change in performance. Further analyses were conducted with groups pooled into site (TL + M or TL) and side (left or right) of surgery; chi-square tests from these analyses were also not significant.

4. Discussion

In this longitudinal study, we investigated visuospatial learning and memory in children one year after unilateral TL resection and examined whether outcomes differed as a function of the site and side of surgical excision. Findings revealed a significant difference following surgery in children's visuospatial memory scores depending on whether or not the mesial structures were included in the resection: children who had mesial TL structures resected (TL + M group) performed more poorly in recall of visual object locations at a 30-minute delay compared with children who had mesial structures spared (TL group). In contrast, there were no significant differences in memory outcomes as a function of the laterality of excision or seizure outcome, nor any relationships between memory outcomes and children's age at surgery, age at seizure onset, or percentage life with epilepsy.

Consistent with the role of the hippocampus in memory function [30], and with some prior studies of children [8] and adults with epilepsy [31], we found that children with mesial TL lesions had significantly larger visuospatial memory impairments than children without mesial TL pathology, but only after surgery. Although there was no significant change in learning, immediate, or delayed recall scores in either the TL or TL + M groups, inspection of individual change scores showed that only 7.2% of children who had mesial structures resected improved following surgery, compared with 30% of children for whom mesial structures were spared. Interestingly, a similar percentage of children in both groups showed a decline in delayed recall scores: 30.4% and 23.3% in the TL + M and TL groups, respectively. These findings show that the between-group difference after surgery was due to fewer children in the TL + M group improving, rather than a difference in the number of children who declined. There are several interesting implications from these findings. First, the similar rates of deterioration suggest that resection of lateral TL structures may be sufficient to cause a visuospatial memory deficit, in at least a portion of children. Second, the lower rate of improvement in TL + M cases might suggest that resection of mesial structures hinders progression of visuospatial memory in childhood; although the between-group difference could have also related to other treatment factors such as medication, as number of AEDs was significantly related to poorer delayed recall after surgery in TL + M cases. Finally, it appears as though the combination of these risk factors (i.e., a surgical lesion plus greater number of AEDs) may be especially detrimental to visuospatial memory outcomes.

In this study, we found no significant changes in visuospatial learning or memory scores in any of the subgroups studied. This finding is consistent with past longitudinal studies that have similarly found no decline in visuospatial memory following surgery nor differences in change scores depending on whether surgery included the mesial TLs [7,12] and left or right hemisphere [15–20]. Although some prior adult studies have found a decline in visuospatial memory following mesial TL resections [4], others have only found a relationship between mesial TL pathology and verbal, but not visual, memory outcomes [30]. In children, a recent study by Law et al. [5] found significantly reduced verbal memory following left temporal resections that included both lateral and mesial TL structures, one year after surgery. The current findings and those of past studies [7,12] suggest that resection of the TL is not associated with a significant decline in children's visuospatial learning or memory scores, regardless of whether or not surgery includes mesial TL structures.

We found no evidence for material specificity in visuospatial memory impairments in our sample; there were no significant differences between children with left and right-sided TL lesions before or after surgery and no differences in change in performance over time. These findings support a body of literature showing that visual memory impairments in children with epilepsy may not follow the same lateralizing pattern as in adults [9,23,32,33]. Our findings are at odds with results from Hepworth and Smith [14], who found significantly larger visuospatial memory impairments (using a picture location task) among children with right TL lesions after surgery [14]. It is possible that our results differed from theirs as a result of using a different task. Alternatively, Hepworth and Smith [14] themselves hypothesized that the postoperative difference may have been due to factors other than laterality of surgical excision, such as more severe disease presentation in right versus left TL cases, as more children in the right TL group were taking AEDs and fewer were seizure-free.

Age at surgery, age at seizure onset, and percentage life with epilepsy were not related to visuospatial learning or memory outcomes in our sample. In addition, visuospatial learning and memory scores did not differ as a function of seizure outcome, with no changes found pre- to postoperatively even among children who were seizure-free. Prior studies have similarly found no relationship between seizure freedom and memory outcomes in children following epilepsy surgery [18,20,34]. As suggested by Oitment et al. [18], the lack of relationship between seizure freedom and memory suggests that memory problems may be associated with an underlying pathological substrate in epilepsy, rather than the presence of seizures themselves. From a clinical perspective, these results suggest that seizure freedom following surgery should not be viewed as a guarantee for better outcomes in memory functioning.

A limitation of the current study was the retrospective nature of data collection, which restricted our analyses to variables that were collected at the time of surgery. We used of single task to measure visuospatial learning and memory, and although it was an objective behavioral measure, corroborative data from other sources were not available. Moreover, our data did not allow us to examine whether outcomes differed as a function of the task or visual modality examined (i.e., face recognition, design location, dot location). This may be important, as some prior studies have documented postsurgical improvements in other aspects of visual memory, such as face recognition [17,24]. Another limitation is that we compared children who underwent lateral TL resections including or sparing mesial TL structures. We did not include children for whom surgery only included the mesial TL; outcomes for these children may differ from children for whom both lateral and mesial TL structures are removed. Although Gonzalez et al. [8] found no significant difference in visuospatial memory scores between children with

"lateral only, mesial only, or lateral plus mesial TL pathology", they only examined children prior to surgery; and the impact of surgical resection of these regions in children requires further investigation. The significant postoperative difference in delayed recall that we observed between TL + M and TL cases needs to be examined further to determine whether the difference was due to a lack of improvement in visuospatial memory in TL + M cases or related to other aspects of treatment such as medication. Finally, the relatively short duration of follow-up is a limitation, as children may show greater change in visuospatial learning and memory over time and/or a larger difference between groups (TL + M, TL) may emerge; thus, assessing children at longer follow-up periods (≥2 years) is important in future studies.

5. Conclusions

The present study has shown that visuospatial learning and memory performance does not seem to show a significant decline following TL resections in childhood, regardless of whether or not surgery includes mesial TL structures and involves the left or right hemisphere. Despite this, we found large variability in change for individual participants, and resection of the mesial TL was associated with a lower rate of improvement than lateral TL resections only. These findings suggest that while mesial TL excisions might not result in a deficit in visuospatial memory, they may hinder progressions made after surgery. Further research is needed to examine how resection of the mesial TL (alone or in combination with lateral TL structures) affects visuospatial memory outcomes in children, as well as broader aspects of visual memory and performance on more complex visuospatial memory tasks. A final implication of the results is that the Dot Location task does not distinguish between children with left or right TL epilepsy prior to surgery, a finding that should be considered carefully in the neuropsychological evaluation and predictions made from test results.

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Declarations of interest

None.

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