Epilepsy Research 128 (2016) 102–112

Contents lists available at www.sciencedirect.com

Epilepsy Research

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

Activations in temporal areas using visual and auditory naming stimuli: A language fMRI study in temporal lobe epilepsy

Gloria G. Gonzálvez[a,b,1], Karin Trimmel[a,b,*,1], Anja Haag[a,b], Louis A. van Graan[a,b], Matthias J. Koepp[a,b], Pamela J. Thompson[a,b], John S. Duncan[a,b]

[a] Epilepsy Society MRI Unit, Epilepsy Society, Chalfont St. Peter, SL9 0LR, United Kingdom
[b] Department of Clinical and Experimental Epilepsy, UCL Institute of Neurology, Queen Square, London WC1N 3BG, United Kingdom

ARTICLE INFO

Article history:
Received 20 July 2016
Received in revised form 5 October 2016
Accepted 24 October 2016
Available online 29 October 2016

Keywords:
Temporal lobe epilepsy
Functional MRI
Auditory and visual naming tasks
Verbal fluency
Word finding difficulties
Language
Anterior temporal lobe

ABSTRACT

Objective: Verbal fluency functional MRI (fMRI) is used for predicting language deficits after anterior temporal lobe resection (ATLR) for temporal lobe epilepsy (TLE), but primarily engages frontal lobe areas. In this observational study we investigated fMRI paradigms using visual and auditory stimuli, which predominately involve language areas resected during ATLR.

Methods: Twenty-three controls and 33 patients (20 left (LTLE), 13 right (RTLE)) were assessed using three fMRI paradigms: verbal fluency, auditory naming with a contrast of auditory reversed speech; picture naming with a contrast of scrambled pictures and blurred faces.

Results: Group analysis showed bilateral temporal activations for auditory naming and picture naming. Correcting for auditory and visual input (by subtracting activations resulting from auditory reversed speech and blurred pictures/scrambled faces respectively) resulted in left-lateralised activations for patients and controls, which was more pronounced for LTLE compared to RTLE patients.

Individual subject activations at a threshold of T > 2.5, extent > 10 voxels, showed that verbal fluency activated predominantly the left inferior frontal gyrus (IFG) in 90% of LTLE, 92% of RTLE, and 65% of controls, compared to right IFG activations in only 15% of LTLE and RTLE and 26% of controls. Middle temporal (MTG) or superior temporal gyrus (STG) activations were seen on the left in 30% of LTLE, 23% of RTLE, and 52% of controls, and on the right in 15% of LTLE, 15% of RTLE, and 35% of controls.

Auditory naming activated temporal areas more frequently than did verbal fluency (LTLE: 93%/73%; RTLE: 92%/58%; controls: 82%/70% (left/right)). Controlling for auditory input resulted in predominantly left-sided temporal activations.

Picture naming resulted in temporal lobe activations less frequently than did auditory naming (LTLE 65%/55%; RTLE 53%/46%; controls 52%/35% (left/right)). Controlling for visual input had left-lateralising effects.

Conclusion: Auditory and picture naming activated temporal lobe structures, which are resected during ATLR, more frequently than did verbal fluency. Controlling for auditory and visual input resulted in more left-lateralised activations. We hypothesise that these paradigms may be more predictive of postoperative language decline than verbal fluency fMRI.

Abbreviations: AED, antiepileptic drugs; AN, auditory naming; AN-AR, auditory naming-auditory reversed; ATLR, anterior temporal lobe resection; BOLD, blood oxygenation level dependent; CPS, complex partial seizure; fMRI, functional magnetic resonance imaging; FuG, fusiform gyrus; HC, hippocampus; HS, hippocampal sclerosis; IFG, inferior frontal gyrus; ITG, inferior temporal gyrus; LTLE, left temporal lobe epilepsy; MFG, middle frontal gyrus; MTG, middle temporal gyrus; NART, national adult reading test; PHG, parahippocampal gyrus; PN, picture naming; PN-(SPc + F), picture naming-(scrambled pictures + blurred faces); RTLE, right temporal lobe epilepsy; SFG, superior frontal gyrus; SGS, secondary generalised seizure; STG, superior temporal gyrus; TLE, temporal lobe epilepsy; VF, verbal fluency.

* Corresponding author at: UCL Institute of Neurology, Queen Square, London, WC1N 3BG, United Kingdom.
E-mail address: k.trimmel@ucl.ac.uk (K. Trimmel).

[1] These authors contributed equally.

http://dx.doi.org/10.1016/j.eplepsyres.2016.10.009
0920-1211/

1. Introduction

Many individuals with medically intractable temporal lobe epilepsy (TLE) have word finding difficulties, particularly when seizure onset is lateralised to the speech-dominant hemisphere (Bell et al., 2003; Bonelli et al., 2011; Hamberger, 2015).

Anterior temporal lobe resection (ATLR) results in seizure remission in up to 80% of individuals with well-characterized TLE (de Tisi et al., 2011). Between 30% and 50% of individuals experience a significant reduction in naming abilities after resection of the speech-dominant temporal lobe (Bonelli et al., 2012; Davies et al., 1998). Left TLE patients with hippocampal sclerosis (HS) and left language dominance show increased recruitment of homologous right hemisphere areas, in addition to wider left hemisphere language areas for language processing, suggesting widespread language representation (Jensen et al., 2011).

Functional magnetic resonance imaging (fMRI) has a useful role in the pre-surgical assessment as a non-invasive predictor of language decline after an ATLR (Duncan, 2009). Most fMRI studies in epilepsy patients focus on expressive language tasks such as the verb generation or verbal fluency task, which primarily activate frontal lobe language areas (Bonelli et al., 2012; Centeno et al., 2014; Szaflarski et al., 2008; Woermann et al., 2003). Stronger preoperative activation in the left middle frontal region on a verbal fluency paradigm was predictive of greater decline in naming after left ATLR (Bonelli et al., 2012). Although sensitive to the occurrence of a significant decline, this activation pattern lacked specificity, with activation in the ipsilateral frontal lobe not always being associated with naming decline following temporal lobe resection (Bonelli et al., 2012).

Reorganisation of language networks occurs in both temporal and frontal networks in chronic epilepsy, and thus, it could be of value to include language tasks that primarily affect temporal lobe language networks (Thivard et al., 2005). Language paradigms that cause consistent activation in the to-be-resected anterior temporal lobe are less well established (Binder et al., 2011; Duncan, 2009), although semantic decision tasks developed by Binder et al. have been used to show temporal lobe language function (Binder et al., 2011; Janecek et al., 2013; Sabsevitz et al., 2003). Object naming paradigms involving visual (Hermann and Wyler, 1988) and auditory stimuli (Hamberger et al., 2001; Specht et al., 2009) may provide more specific predictions of naming difficulties after ATLR (Bookheimer et al., 1997; Rosazza et al., 2013; Schlosser et al., 1998, 1999).

We aimed to investigate language activation patterns using fMRI language tasks employing visual and auditory stimuli to identify language areas in the temporal lobes, which could be better predictors for postoperative word finding difficulties than verbal fluency fMRI.

2. Material and methods

2.1. Subjects

We studied 23 healthy controls and 33 patients with medically refractory TLE (20 left TLE (LTLE), 13 right TLE (RTLE)). These were sequential patients with a confirmed diagnosis of TLE undergoing presurgical assessment at the National Hospital for Neurology and Neurosurgery (NHNN). The age range for all subjects was 18–65 years. Control subjects had no history of epilepsy or any other chronic neurological or psychiatric disease. Exclusion criteria for all subjects were non-fluency in written and spoken English, pregnancy, any contraindication to MRI (e.g. metallic implants, pacemakers), and inability to give informed consent. An additional exclusion criterion for patients was history of a secondary generalised tonic-clonic seizure within 24 h prior to the study. Demographic and clinical data are summarized in Table 1.

Prolonged interictal and ictal EEG-video telemetry confirmed ipsilateral seizure onset zones in all patients. All patients underwent structural MRI at 3.0 T, including quantification of hippocampal volumes and T_2 relaxation times (Woermann et al., 1998). MRI identified hippocampal sclerosis (HS) in nine patients (8 left/1 right), dysembryoplastic neuroepithelial tumour (DNET) in five (1 left/4 right), cavernoma in five (4 left/1 right), focal cortical dysplasia and ganglioglioma in one patient each, both on the right, and 12 normal MRI (7 left/5 right).

All patients were native English speakers, English was the first language in 21 controls with the remaining two being fluent English speakers from before the age of five years (Centeno et al., 2014).

Handedness was determined using the Edinburgh Hand Preference Inventory (Oldfield, 1971). Four of 20 left TLE, one of 13 right TLE and one of 23 controls were left handed.

Controls (7 high school, eight undergraduates and eight postgraduates) had a higher education level than TLE patients (20 high school, nine undergraduates and four postgraduates; $F = 3.88$, $p = 0.03$). There was no difference between the groups in estimated intellectual level, as derived from performance on the National Adult Reading Test (NART (Nelson and Wilson, 1991); $F = 0.74$, $p = 0.5$).

The study was approved by the National Hospital for Neurology and Neurosurgery and the UCL Institute of Neurology Joint Research Ethics Committee. Written informed consent was obtained from all participants.

2.2. Neuropsychological tests

All subjects underwent neuropsychological testing prior to scanning to provide a measure of their linguistic proficiency. The measures employed were standardised clinical tests that form part of the pre- and post-surgical neuropsychological evaluations of TLE patients. Naming was assessed using the McKenna Graded Naming Test (McKenna and Warrington, 1983). This measure consists of thirty line drawings of objects and animals, placed in order of difficulty. The performance indicator is the number of items correctly named. In addition, participants completed a phonemic fluency test during which they had to say as many words beginning with the letter “S” in 60 s, followed by a semantic fluency test, which required subjects to name as many members of the category “animals” also in 60 s (Bird et al., 2004).

2.3. MR data acquisition

MRI studies were performed using a 3T General Electric Excite HDx scanner (GE, Wisconsin), using standard imaging gradients with a maximum strength of $40 mTm^{-1}$ and slew rate $150 TM^{-1} s^{-1}$. All data were acquired using the standard eight-channel RF receive head array coil and the body RF coil for transmission.

For fMRI, gradient-echo planar T2*-weighted images were acquired (TE = 25 ms, TR = 2000 ms), providing blood oxygenation level dependent (BOLD) contrast. Each volume comprised 40 contiguous 2.5 mm slices with a 24 cm field of view, 64×64 matrix, giving an in-plane pixel size of 3.75×3.75 mm. The field of view was positioned to maximise coverage of the frontal and temporal lobes and minimise signal drop-out from the temporal and orbitofrontal lobes. To mitigate geometric distortions, ASSET (The GE implementation of parallel imaging) was used.

All subjects underwent a standard structural MRI scanning protocol on the same scanner, which included a coronal 3D volumetric T1-weighted Inversion Recovery-Prepared Spoiled Gradient Recalled (IR-SPGR) sequence for coregistration as well as an oblique