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Attentional control in patients with temporal lobe epilepsy

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Abstract

Across different studies patients with temporal lobe epilepsy (TLE) demonstrate impairments on numerous measures of attentional control that are classically associated with frontal lobe functioning. One aspect of attentional control that has not been examined in TLE is the ability to execute two modality-specific tasks concurrently. We sought to examine the status of dual-task coordination in TLE. We further examined the cohorts' performance on a range of traditional measures of attentional control. Eighteen TLE patients and 22 healthy controls participated in the study. Dual-task performance involved comparing the capacity to execute a tracking and a digit recall task simultaneously with the capacity to execute the tasks separately. We also administered measures of: set shifting (odd-man-out test), sustained attention (elevator counting), selective attention (elevator counting with distraction) and divided attention (trail making test). We found that the proportional decrement in dual-task performance relative to single task performance did not vary between the groups (TLE = 92.48%; controls = 93.70%), nor was there a significant difference in sustained attention ($p > .10$). Patients with TLE did demonstrate marked deficits in selective attention ($p < .0001$), divided attention ($p < .01$) and set shifting ($p < .01$). These findings add to the knowledge about cognitive dysfunction in TLE, indicating that impairments in attentional control in TLE tend to be selective. The greatest deficits appear to be on tasks that invoke a high level of processing resources. In contrast, sustained attention is less compromised and the capacity to allocate cognitive resources appears to be normal in patients with TLE.

Keywords: Attentional control; temporal lobe epilepsy; dual-task; nociferous activity

Introduction

Patients with temporal lobe epilepsy (TLE) demonstrate impairments in a range of cognitive domains, including memory, IQ, language and visuospatial functions (Hermann et al., 1997). In addition, across different studies, deficits on tests of attentional control including the Wisconsin Card Sorting Test (Corcoran & Upton, 1993; Hermann & Seidenberg, 1995), the Stroop (McDonald et al., 2005) and Trail Making Test (TMT; Piazzini et al., 2006) have been widely reported. Although the control of attention has a longstanding association with frontal lobe functioning, these studies have led to the hypothesis that attentional control may be modulated by the hippocampus and related medial temporal lobe structures (Corcoran & Upton, 1993). Alternative views based on the principle of diaschisis postulate that impaired attentional control in TLE arises from anatomic abnormalities outside the temporal lobe (Riley et al. 2011), or from abnormal discharges propagating from nociferous epileptogenic medial temporal lobe structures to otherwise healthy frontal regions (Catenoix et al. 2005; Hermann and Seidenberg, 1995).

Attentional control however, encompasses multiple cognitive processes which may be differentially affected by TLE. One aspect of attentional control that, to our knowledge, has not been examined in these patients is the capacity to perform two distinct tasks concurrently. Although decrements in dual-task performance have been found in neuropsychological groups who are characteristically impaired on other tests of attentional control (Baddeley et al., 1997; Oram et al., 2005), other studies suggest that dual-task performance is dissociable from other forms of attentional control. For example, Dalrymple-Alford et al. (1994) found patients with Parkinson’s disease performed normally on traditional measures of attentional control but displayed significant dual-task impairments. In contrast, Baddeley et al. (1997) reported the reverse dissociation in a sample of frontal patients without behavioural problems.

To date, evaluating the status of attentional control in TLE has predominantly relied on drawing conclusions across different studies that have deployed different measures and tested different epilepsy cohorts. In order to provide a comprehensive evaluation of attentional control in TLE, we administered both a dual-task coordination test and a range of other attentional control measures, including set shifting, sustained attention, selective attention and divided attention tasks.

Method

Participants: Eighteen TLE surgery candidates (mean age = 35.6, SD = 8.9) who were referred by Hull and East Yorkshire Hospital NHS Trust for neuropsychological assessment participated in the study. The demographic and clinical features of the sample are presented in Table 1. All patients were on optimum anti epileptic medication but had epileptogenic abnormality. MRI scans confirmed unilateral hippocampal sclerosis to the left side in seven patients and to the right side in eleven patients. EEG evidence ascribed the focus of epileptogenic activity to the left side in the seven patients with left hippocampal sclerosis, to the right side in nine of the eleven patients with right hippocampal sclerosis and bilaterally in two right hippocampal patients. One right TLE patient had undergone an anterior temporal lobectomy and was being assessed as part of his post-surgical evaluation. A control group comprising 22 healthy adults (mean age = 36.1, SD = 13.7) were recruited through opportunity sampling. All participants had normal or corrected to normal vision.

[Insert Table 1 about here]

Procedure

Dual-task: The dual-task procedure involved participants conducting a tracking task and a memory span task simultaneously in accordance with the method described by Baddeley et al. (1997). Briefly, the tracking task involved placing a cross within each box of a winding trail of successive 4mm × 6mm boxes linked together by lines and presented on an A4 sheet of paper. The memory span task required participants to repeat lists of digit strings that were set at their own maximum span and read by the examiner at the approximate rate of two per second. Participants performed the tracking and memory span tasks separately for a period of two minutes each prior to performing both tasks concurrently for a period of two minutes.

A composite measure of dual-task performance (mu) was calculated according to the formula: mu = (1-[(Pm + Pt)/2]) * 100 (Baddeley et al., 1997). Here mu represents the combined change in dual-task performance relative to performance on the constituent tasks, where pm is the proportional change in memory performance and pt is the proportional change in tracking. Pm is calculated according to: (ps – pd)/ps, where ps is the proportion of digit strings recalled correctly under single task conditions and pd is the proportion of digit strings recalled under dual task. Pt is calculated according to: (ts – td)/ts, where ts is the number of boxes crossed under single task conditions and td is the number of boxes crossed under dual task conditions.

Other measures of attention: Auditory and visual attentional capacities were measured with digit span and spatial span respectively (see Lezak et al., 2012). The TMT (see Lezak et al., 2012) was used to measure divided attention; the elevator counting task from the Test of Everyday Attention (TEA-2; Robertson et al., 1994) measured sustained attention; the elevator task with distraction (TEA-3) was deployed to measure selective attention. The ability to maintain and shift mental set was assessed with the Odd-Man-Out test (OMO; Flowers & Robertson, 1985).

Results

The mean scores and standard deviations for the span and tracking tasks achieved under single and dual task conditions are displayed in Table 2.

[Insert Table 2 about here]

In order to ensure that any differences found between the groups reflect dual task deficits and not inflated single task differences, we followed Baddeley and colleagues (e.g. Cocchini et al. 2002) and excluded data from participants who scored below 70% accuracy under single-span conditions. Accordingly, data from four TLE patients (3 left-sided and 1 right-sided) was excluded from further analyses. A 2 × 2 ANOVA of memory span for the remaining participants, treating Group (TLE or control) as a between-subjects factor and condition (single or dual task) as a within-subjects factor did not reveal a main effect of group [$F(1, 34) = 3.556$, $p > .068$]. A main effect of condition was found [$F(1, 34) = 5.880$, $p < .021$] indicating that a higher proportion of digit strings were correctly recalled under single task conditions. The interaction between group and condition did not approach significance [$F(1, 34) = .501$, $p > .484$]. In contrast, a similar ANOVA for tracking performance revealed a main effect of group [$F(1, 34) = 12.125$, $p < .001$] indicating that patients with TLE surprisingly crossed a greater number of boxes than controls. The effect of condition failed to reach significance [$F(1, 34) = 3.736$, $p > .062$], the group and condition interaction was also not significant [$F(1, 34) = .094$, $p > .761$]. Notably, analysis of the proportional loss in performance from single to dual-task conditions on the individual tasks failed to reveal a significant group difference for both the memory span task [$t(34) = .867$, $p > .392$] and the tracking task [$t(34) = .394$, $p > .696$]. Indeed the composite index of dual performance (mu) showed that the dual task decrement was indeed almost identical between the two groups [$t(34) = .229$, $p > .782$].

The mean scores and standard deviations for the additional measures of attention are displayed in Table 3. Differences between the participant groups on TEA-2 and TEA-3 were analysed with t tests. Scores on the remaining tests were entered into four further 2×2 ANOVAs that treated group as a between-subjects factor and condition of the respective tests as a within-subjects factor. Patients with TLE demonstrated impairments in digit span [$F(1, 34) = 28.227$, $p < .0001$], spatial span [$F(1, 34) = 5.234$, $p < .028$], the TMT [$F(1, 34) = 11.836$, $p < .002$] and the OMO test [$F(1, 34) = 6.629$, $p < .015$]. None of the group and condition interactions were significant. There was no significant difference in the number of correct responses on TEA-2 [$t(34) = 1.694$, $p > .099$], although control participants produced more correct responses on TEA-3 [$t(34) = 4.779$, $p < .0001$].

[Insert Table 3 about here]

Discussion

The aim of the present study was to extend what is known about attentional control in patients with TLE, by examining in a single cohort, the status of dual-task coordination together with performance on a range of more traditional measures of attentional control. We found the proportional decrement in dual-task performance relative to single performance on each of the constituent tasks did not differ between the groups. Thus indicating that TLE does not impact upon the ability to allocate cognitive resources. In contrast, consistent with previous studies (e.g. Piazzini et al., 2006) TLE patients displayed a deficit on TMT-A and disproportionate deficit on TMT-B, revealing a dissociation between dual-task performance and divided attention. Unlike the dual-task paradigm in TMT-B the two sources of information are from the same modality and therefore the task is likely to be vulnerable to reduced processing capacity (c.f. Lonie et al., 2009). It has indeed been posited that deficits in attentional control in TLE might only manifest on tasks where the demand characteristics are particularly high (McDonald et al., 2005) and the findings from the present study appear consistent with this view. A particularly demanding aspect of attentional control is the capacity to resist distraction and selectively attend to a specific feature of a stimulus. A highly significant group difference on TEA-3 indicated a severe impairment in selective attention in our TLE patients, while performance on TEA-2 showed that basic sustained attention was intact. Moreover, our patients demonstrated an increased tendency to make perseverative errors on the OMO test. These usually occurred at the onset of a rule change, cognitive demand is greatest at this point as conflict between the previous rule and current rule arises. There was no evidence of TLE patients facing difficulty in maintaining set.

One possible caveat of the present study is that the contribution to the theoretical understanding of attentional control in TLE is somewhat limited, although the results are compatible with the view that attentional control is supported by dissociable subsystems and dual-task coordination is less sensitive to the effects of TLE than divided attention, selective attention or set shifting. Equally, our results can also be accommodated by the view that there is a unitary general pool of attentional resources that are allocated on demand until the resource is exceeded. Consequently attentional control deficits would be found in TLE on tasks that have increased cognitive load because the resource capacity of TLE patients is more likely to be reduced and therefore exceeded before that of healthy controls. Accordingly, dual-task performance might be intact in TLE on tasks where the demand on cognitive resources is lower. Further research could directly test this hypothesis by manipulating the processing constraints of the task. If dual-task coordination in TLE is dependent on cognitive demand, one might expect increasing the level of demand on the constituent tasks to produce a disproportionate degree of dual-task decrement in patients relative to controls (see Logie et al., 2004). In contrast, should dual-task coordination be resistant to the effects of TLE per se, any change in performance as a function of increased demand would be expected to parallel that of controls.

In sum, the frontal regions of the brain are vulnerable to nociferous activity in TLE (Catenoix et al. 2005) and structural abnormalities outside the temporal lobe have been linked to impaired frontostriatal connections in TLE (Riley et al. 2011). The functional consequences of these phenomena are deficits on a number of attentional control tasks that are commonly associated with the integrity of frontal structures. The main outcome of the present study however is the finding that impairments in attentional control in TLE tend to be selective. The greatest deficits appear to be on tasks that invoke a high level of processing resources, specifically, divided attention, selective attention and set shifting. In contrast, sustained attention is less compromised and dual-task performance appears to be normal in patients with TLE.

Table 1

Demographic and clinical features of patient and control groups

Participant variables	TLE (n = 18)	Controls (n = 22)
Sex (male/female)	12/6	13/9
Median age (range)	36 (19-63)	34.5 (18-57)
Median education (range)	11.5 (10-16)	11 (10-11)
Median age of seizure onset (range)	17 (2-54)	-
Median duration of epilepsy (range)	17 (3-42)	-
Number of Anti epileptic drugs (AEDs) per patient		
0-1 AEDs	6%	-
2-3 AEDs	72%	-
4-5 AEDs	6%	-
Not known	16%	-

Note: Frequently prescribed AEDs: 39% Carbamazepine; 28% Levetiracetam, Topiramate; 17% Clonazepam, Sodium valproate; 11% Clobozam, Gabapentin, Phenobarbitone, Pregabalin.

Table 2

Memory span (mean percent correct) and tracking performance (mean boxes crossed) under single and dual task conditions and composite measure (mu) of dual task performance

Measure	TLE (n = 14)	Controls (n = 22)	$p <$
Memory span			
Single (ps)	84.00 (7.64)	88.95 (8.02)	.074
Dual (pd)	76.79 (20.68)	85.00 (10.94)	.128
Tracking			
Single (ts)	171.21 (37.98)	132.68 (33.36)	.003
Dual (td)	160.14 (39.76)	124.63 (28.71)	.004
Dual Task			
Mu	92.48 (11.25)	93.70 (9.37)	.782

Standard deviations are in parentheses ()

Table 3

Performance of TLE patients and healthy participants on measures of attentional control

Measure	Max. Score	TLE	Controls	p <
Attention span				
Digits-F	12	7.00 (2.22)	9.64 (1.81)	.0001
Digits-B	12	5.21 (1.76)	8.18 (1.79)	.0001
Blocks-F	16	7.14 (2.38)	8.64 (2.06)	.054
Blocks-B	16	7.43 (2.82)	8.55 (1.97)	.177
Divided attention				
TMT-A	-	44.64 (14.15)	29.09 (9.11)	.0001
TMT-B	-	105.07 (53.04)	69.27 (26.17)	.011
TMT-B-A	-	60.43 (49.78)	40.18 (25.42)	.116
Sustained attention				
TEA-2	7	6.14 (2.07)	6.91 (0.43)	.099
Selective attention				
TEA-3	10	5.14 (3.13)	8.86 (1.52)	.0001
Set shifting				
OMO-1	48	43.57 (6.54)	46.77 (1.07)	.030
OMO-2	48	44.79 (5.44)	47.23 (1.19)	.049

Note: Scores for attention span, set shifting, selective and sustained attention is the mean percentage of correct responses as a function of task. The divided attention score is the mean time (secs) taken to complete the TMT. Standard deviations are in parentheses ()

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