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Klinikum Bremen-Ost
Ein Team. Ein Ziel. Ihr Wohlbefinden.

I. Introduction

Theta activity is prominent in the hippocampus of most mammals and has also been found in the septum, mammillary bodies, anterior thalamus, the entorhinal and the cingulate cortex. It may index encoding and retrieval success of episodic memory [1, 2]. To investigate this hypothesis, we studied event related theta oscillations in a young patient (KT) with a left hemisphere thalamic infarct (MRI scan on the right), who suffered from a profound verbal memory impairment. We predicted a specific decrease of theta, especially over temporal areas, in a recognition paradigm, which involves episodic memory performance.

II. Method

We assessed visual evoked potentials via checkerboard stimulation (VEP, via a visual oddball experiment (VOP), a 2-back paradigm and a running recognition paradigm (RRP, two trials). EEG was recorded in a dimly lit, soundproof and electromagnetically shielded room using ten Ag-AgCl electrodes (locations: F4, F5, C4, C5, P3, P4, T5, T6, O1, O2) and two EOG electrodes placed above and to the right of the right eye. Linked earlobes served as reference; epochs contaminated by eye or other artefacts were manually rejected. The analysis of event-related oscillations consisted of two steps [2]: 1) digital filtering of the data in the theta frequency range (4-7 Hz); 2) calculation of a mean amplitude enhancement factor (EF) for a post-stimulus time window from 0-800 ms. EF was defined as the maximum peak-to-peak amplitude (R) normalized to a prestimulus baseline. EF was computed for each trial. The baseline was defined as the root mean square (rms) value in the time window of –500 to 0 ms prior to stimulus onset.

III. Results

The patient showed a verbal but not a visual memory impairment, without other cognitive deficits (see Table 1 and neuropsychological results). Compared to an age, gender and education matched control group (see Table 2 and 3), we found a reduced frontal theta activity in the memory task comprising the F3, F4, and C4 electrodes on both RRP series. As can be seen in Figure 3 (on the right) theta activity was increased at parietal and temporal electrode sites for the RRP but not for the 2-back task, and not during the VEP and the VOP.

IV. Conclusion

We conclude that in our patient a lesion in the thalamus led to increase led to a compensatory increase of theta at postcentral electrode sites irrespective of task structure, but to a frontal theta activity decrease in a verbal episodic memory task. These results (1) confirm a specific role of theta activity in memory processing involving a cortico-hippocampal interplay, and (2) that theta may be involved in different (frontal and hippocampal-postcentral) processes or subsystems, explaining the frontal de- and the postcentral increase.

1. Neuropsychological Results

Table 1: Results in the California Verbal Learning Tasks (alternative versions)

Dates	tr1	tr2	tr3	tr4	tr5	inf	sfr	scr	lfr	lcr	reco	err
12.12.2003 *	7	6	7	5	6	6	1	1	nd	nd	10	0
06.02.2004	4	6	7	6	6	4	0	2	0	2	7	4
19.04.2004 +	8	7	7	11	8	5	4	5	5	5	11	1
06.10.2004 ~	6	7	7	10	9	6	6	6	2	3	n.d.	
29.11.2005	7	7	7	8	7	4	4	5	3	3	11	6

Abbreviations: tr: Learning trial; inf: interference list; sfr: short delay free recall; scr: short delay cued reca
lfr: long delay free recall; lcr: long delay cued recall; reco: recognition hits; err: recognition false alarms
* investigation done at the rehab-unit
+ first investigation after a training period with VILAT-G
~ at this investigation we used the auditory verbal learning test

In the revised Wechsler Memory Scale (rWMS; Wechsler, 1987) KT's verbal memory IQ was 57, which is more than two standard deviations below the age corrected population mean. His visual memory IQ was 81, but still below one standard deviation of the population mean. Delayed recall was below 50, which is outside the score range given by the Wechsler Memory Scale norms.

He scored normally on the Recurring Figures Test (RFT; Percentile of 43; Rixecker, 1978). The Rivermead Behavioural Memory Test (RBMT; Wilson et al., 1992) was used to assess verbal memory for text information. Short-term memory was above the cut-off score (10 items), but delayed retrieval was impaired (4 items). Two complete examinations with the Lern & Gedächtnistest (LGT-3) showed a scaled score of 42 and 48 respectively for visual memory, which is just inside one standard deviation of the population norm, and a score of 23 for verbal memory on both occasions, which is almost 3 standard deviations below the population mean.

There were no apparent impairments in executive functioning. He was able to detect all categories in the Modified Wisconsin Card Sorting Test (MWCST; Nelson, 1976) and made only one perseverative error, and 8 non-perseverative errors. The age corrected scaled score for the Behavioural Assessment of the Dysexecutive Syndrome (BADS; Alderman et al., 1996) was 102. On a phonological fluency task (Leistungsprüfsystem (LPS) Subtest 6; Horn, 1983) KT achieved a percentile of 50. On the semantic fluency test (animals for 1 minute) his score of 15 words suggested a slightly impaired performance. We also used the object alternation task of the TAP (Zimmermann & Fimm, 1992). In this task KT was rather slow (937 msec, percentile 8) but he made only 5 errors (percentile 18). His performance on the Block Design Test (age corrected scaled score of 9) was also within the age corrected population norms.

2. Experimental and brain oscillatory results

Table 2: Behavioural scores (mean, minimum and maximum on the various tasks for the control group and KT

	Healthy controls			KT
	Mean	Min.	Max.	
RRP Trial 1 RT	647.8	484	905	716
RRP Trial 1 om	1.45	0	8	3
RRP Trial 1 Comm	3.64	2	10	3
RRP Trial 2 RT	749.7	511	1069	719
RRP Trial 2 om	4.82	1	9	9
RRP Trial 2 comm	6.82	1	11	2
2-BACK RT	591.9	335	876	662
2-BACK om	4.18	0	11	7
2-BACK comm	3.64	0	15	2
VOP RT	456.9	353	530	484
VOP om.	0.09	0	1	0
VOP comm.	0.55	0	2	0

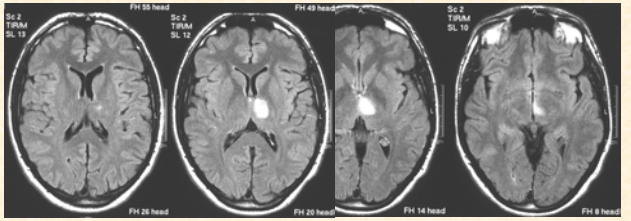
Abbreviations: RRP = Running recognition paradigm, VERP: Visual oddball paradigm, om: Omissions, comm.: Commissions

Table 3: Theta EF scores (mean and sd) of the control group for the various tasks at different electrode sites

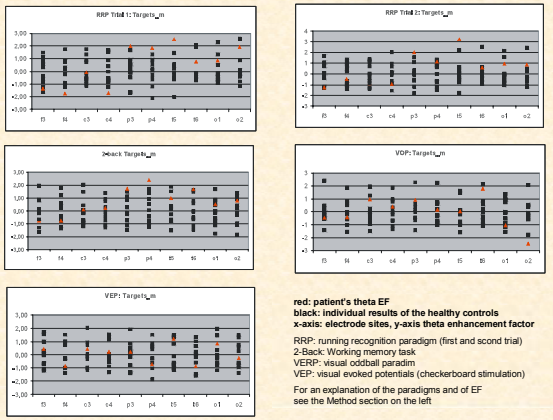
	RRP Trial 1		RRP Trial 2		2-back		VERP		VEP	
	m	Sd	m	Sd	m	sd	m	sd	m	sd
f3	1.64	0.13	1.56	0.14	1.93	0.23	1.95	0.22	2.69	1.12
f4	1.69	0.17	1.57	0.15	1.86	0.25	2.06	0.33	2.81	1.16
c3	1.61	0.18	1.58	0.17	1.96	0.34	1.96	0.23	3.47	1.34
c4	1.66	0.14	1.56	0.16	1.86	0.29	2.10	0.43	3.34	1.57
p3	1.66	0.19	1.58	0.27	1.78	0.23	1.94	0.26	2.97	1.04
p4	1.60	0.12	1.60	0.23	1.69	0.27	2.00	0.32	3.31	1.46
t5	1.67	0.28	1.71	0.28	1.90	0.33	1.86	0.30	2.17	1.41
t6	1.72	0.32	1.65	0.36	1.89	0.45	1.85	0.25	2.62	0.88
o1	1.75	0.38	1.76	0.53	1.85	0.32	1.82	0.23	3.35	1.44
o2	1.68	0.29	1.76	0.42	1.84	0.36	1.90	0.15	4.20	2.02

3. MRI Scan of the patient's lesion

(T2W/Flair, 29/10/2003, TR 6000, TE 100, slice 21/22)



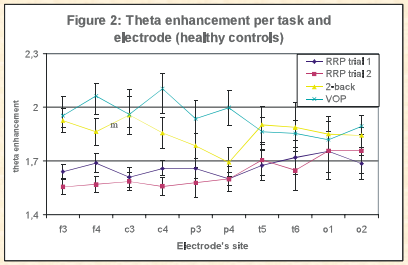
4. Theta enhancement factor of KT and the healthy controls for the experimental tasks and electrode's site



red: patient's theta EF
black: individual results of the healthy controls
x-axis: electrode sites, y-axis theta enhancement factor

RRP: running recognition paradigm (first and scond trial)
2-Back: Working memory task
VERP: visual oddball paradim
VEP: visual evoked potentials (checkerboard stimulation)

For an explanation of the paradigms and of EF see the Method section on the left



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(3) **Schmiedt, C.; Brand, A.; Hildebrandt, H.; Basar-Eroglu, C.: Event-related theta oscillations during working memory tasks in patients with schizophrenia and healthy controls. Cognitive Brain Research, 25, 2005,**