Planen · Erkennen · Urteilen
Kognitive Neuropsychologie

Memory requirements in motor learning

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Problem

Skill acquisition (here: motor learning) requires many repetitions to obtain improvements (e.g., decrease of reaction time) while working on a task (Haider & Frensch, 1997). Motor learning can be supported by memory search (Nissen and Bullemer, 1987; Logan, 1988). Finally, reduction of cognitive load is assumed to be related to automation (Newell and Rosenbloom, 1981; Anderson, 1982). We wanted to combine these findings from behavioral data with physiological (here: EEG) data. High EEG theta, induced by hippocampal memory loops, is well known in memory search (Bösel et al., 1993; Raghavachari et al., 2001). Reduction of cognitive load should be indicated by high EEG alpha2 (Bösel et al,1990), caused by thalamo-cortical loops.

Assumptions

Motor movement containing recurring parts supports automation and evokes EEG theta as well as EEG alpha2 patterns unlike the work on random sequences.

Recurring motor movement should cause

- a higher increase of EEG theta due to memory search,
- a higher increase of EEG alpha2 due to a stronger reduction of cognitive load,
- and over time a stronger improvement with respect to reaction time.

Methods

We used a task that required pressing a key out of 5 in a certain sequence of finger movements. Movement was triggered by visual stimuli consisting of a sequence of 6 numbers (out of 5).

Example trial:

3 5 4 3 2 4

Requested motor movement: pressing corresponding keys according to the shown sequence.

Two conditions were tested between subjects:

experimental group:
stimuli containing recurring parts

control group:
completely varied sequences

Subjects had to perform a training block and four experimental blocks, each with 60 trials. There were intermissions between the blocks.

Variables

- Mean reaction time (RT) per trial for each block
- Event-related EEG theta/alpha2 as difference score between mean values of blocks 1-4 and mean value of the training block
- Amount of declarative knowledge about recurring parts in the sequences

EEG Measurement and Analysis

EEG was derived according to the 10-20 system (Fig.1), amplified (Synamps Neuroscan, low pass filter 100 Hz, high pass filter 0.1 Hz), and analysed for certain derivation points by windowed FFT of event-related segments (Vision analyser). The segments started with stimulus onset lasting 1024 ms.

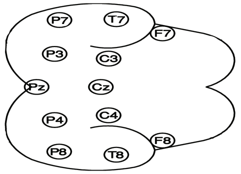

Fig.1: Important Electrodes (after EEG 10-20 System)

Results

For all results:

🟧 Mean Experimental Group

🟦 Mean Control Group

▨ Mean Both Groups

For the statistical details see below.

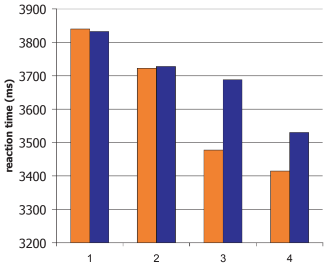

Fig.2: Course of mean reaction time per trial over the 4 experimental blocks.

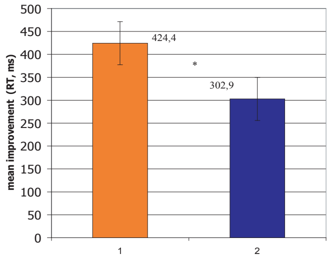

Fig.3: Improvement with respect to reaction time, compared between experimental and control group. For the statistical test, starting speed served as control variable.

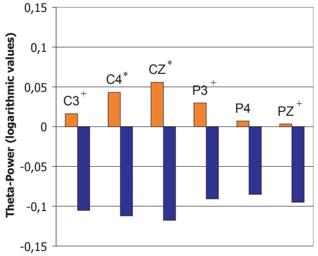

Fig.4: Difference values of EEG-theta between the blocks 1-4 and four electrode blocks; compared between experimental and control group.

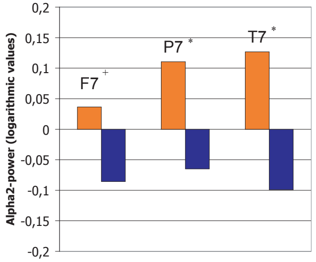

Fig.5: Difference values of EEG-alpha2 between the blocks 1-4 and the training block;
left hemisphere;
compared between experimental and control group.

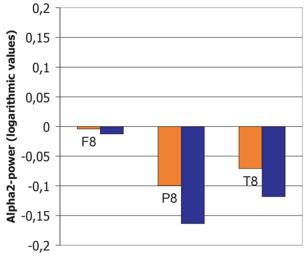

Fig.6: Difference values of EEG-alpha2 between the blocks1-4 and the training block;
right hemisphere;
compared between experimental and control group.

Post-hoc Analysis

- There is a negative correlation between overall speed (mean reaction time over all blocks) and the amount of declarative memory that was derived with a questionnaire: r=-0,46 (p=0,046; contolled for age). As this correlation is constant over all the single blocks we assume that fast reaction times support declarative memory and not vice versa (compare Frensch & Miner, 1994).
- Improvements are visible between the blocks and not within the blocks (see Fig. 7). So the effects of learning occur only after intermissions. The lower RTs at the beginning of each block are assumed to be an effect of concentration.

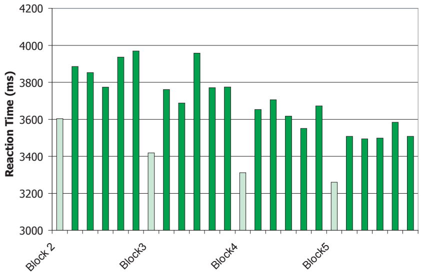

Fig.7: A more detailed course of reaction time over and within the 4 experimental blocks.

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Statistical Details

Fig.3: Improvements with respect to RT

F=3.339, df=1, p=0.038; controlled for starting speed

Fig.4: Difference of EEG-theta power between the blocks 1-4 and training block

Electrode	Average difference (EEG-Power)	t-Test T	df	Significance (1-tailed)
C3	0,122+	1,678	6,538	,070
C4	0,155*	2,868	10	,008
CZ	0,173*	2,546	10	,015
P3	0,121+	1,668	10	,063
P4	0,092	1,172	10	0,134
Pz	0,098+	1,684	6,387	,070

Fig.5: Difference of EEG-alpha2 power between the blocks 1-4 and the training block, left hemisphere

Electrode	Average difference (EEG-Power)	t-Test T	df	Significance (1-tailed)
F7	0,122+	1,581	10	,072
P7	0,175*	2,780	10	,010
T7	0,226*	2,512	10	,015

Fig.6: Difference of EEG-alpha2 power between the blocks 1-4 and the training block, right hemisphere

Electrode	Average difference (EEG-Power)	t-Test T	df	Significance (1-tailed)
F8	0,008	0,165	10	0,436
P8	0,064	0,694	10	0,252
T8	0,047	0,754	10	0,234

Fig.7: Pairwise comparison between the blocks and the succeeding blocks

BLOCK	BLOCK	Average Difference (RT)	SE	Significance (2-tailed)
1	2	108,405*	36,870	,033
2	3	143,492***	30,753	,000
3	4	109,779**	26,974	,001

Subjects:

Fig.2,3,7: N=40 (32 female, mean age 26,5)

Fig.4,5,6: N=12 out of the 40 (10 female, mean age 29,5)

All subjects were right handed and with normal or corrected to normal sight.

+ $p < 0.10$
* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$

Literature

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