Slow rhythmic EEG, abstract concepts and short reaction times

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Problem

Controlled attention to task-related stimuli and supervision of task-related operations or strategies activate partly the same areas of the central executive. This was shown in fMRI studies mainly for attention to stimuli and cognitive operations in Wisconsin Card Sorting Test (WCST, cf. Konishi et al., 1999).

Usually complex operations (e.g. attention and processing of feedback in WCST) require *high cerebral activity* and *prolonged* response times than simple responses (e.g. instructed attention). On the other hand high activations related to *effort* or to supervision of strategies could cause *short* response times.

How to dissociate in EEG between high cerebral activity causing prolonged vs. high cerebral activity causing shortened response times?

Assumptions

EEG theta is a well known phenomenon in memory search tasks. Usually memory search requires time. But sometimes short response times in complex tasks are reported accompanied by increased power in both theta and slow alpha (alpha1) band (Pennekamp et al., 1994).

We use a task requiring the selection of digit value (which number?) or digit frequency (how many digits?) with an additional demand (comparison of the belonging quantity).

It is assumed that modest demands (*selection*, allowing the use of strategies) causes a significant increase in theta and alpha1 power, while not in case of slightly higher demands (*selection & maintenance;* cf. Rowe et al., 2000; Walter et al., 2001).

Approach

We used two tasks, a *control task* requiring the selection of digit value or frequency according to an instruction and a *comparison task* requiring selection of the smaller/larger quantity of digit value or frequency.

Demands of the *comparison task* were varied in two levels:
- Selection of the smaller/larger quantity and response to the quantity.
- Selection of the smaller/larger quantity and response to the maintained concept.

Modest demands (*selection*) allow the use of strategies (effort) and short reaction times, while not in case of slightly higher demands (*selection & maintenance*) causing prolonged reaction times.

Tasks

Features (digit value or frequency) of the stimuli (e.g. 4 4 4) have to be detected in a choice reaction task under three conditions.

One of the conditions served as **control task**:

(INSTR) "*Amount of value/frequency?*": Key press according either digit value or frequency (2 x 40 trials).

The **experimental condition** consists of a comparison task, requiring the comparison of the quantity of digit value and frequency. Task demands are altered in two levels:

(SEL) "*Amount of smaller/larger value/frequency*": Key press according to the minor/major amount of digit value or count (2 x 20 trials).

(SEL&MAINT) "*Is smaller/larger amount represented by value/frequency?*": Key press according to the concept (digit value or frequency) corresponding to the minor/major quantity (4 x 10 trials).

Trials

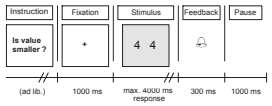
8 types of instructions were used in randomised trial blocks (with 40, 20 or 10 trials with respect to the conditions). Instruction was presented self-paced for each trial on screen, followed by a fixation cross (lasting 1000 ms). Then the stimulus was shown up to 4000 ms within which pressing the corresponding key was required.

In condition (SEL) the key corresponds with the smaller/larger quantity, e.g. with the thumb for digit value or frequency 1, with the index finger for digit value or frequency 2, and so on.
In condition (SEL&MAINT) the key corresponds to the match of the mentioned concept to the representation of the smaller/larger quantity, e.g. the index finger for "yes" and the ring finger for "no".

After four example items and 20 test trials, all conditions were to pass in randomised order, resulting in 160 trials.

Stimuli

The visual stimuli consisted of several arrangements of digit values (1,2,3,4,5) in different frequencies (e.g. 4 4 4). For example the stimulus set "4 4 4" shows the digit "4" three times (frequency = 3). Arrangements with the same quantity of digit value and frequency were excluded. Behavioural data were analysed only for relevant items with fixed quantitative distance between digit value and frequency.



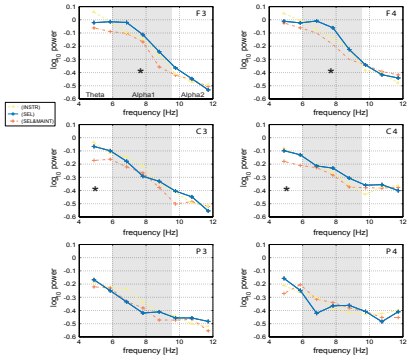
Reaction times

(1) There are remarkable RT differences between control task (INSTR) and comparison tasks.
(2) Slightly enhanced demands within comparison task results in enormous RT differences between the two comparison conditions (nearly 700 ms). This is assumed to be mainly caused by involvement of strategies in case of modest (SEL) vs. high task demands (SEL&MAINT).

Control condition	Comparison conditions	
(INSTR)	(SEL)	(SEL&MAINT)
"Amount of value/frequency?"	*"Amount of: smaller/larger value/frequency?"*	*"Is smaller/larger amount represented by value/frequency?"*
1071 ms	Mean RT *(p<.01)* **1168 ms**	**1860 ms**
.94	Mean errors /block *(p<.01)* .19	.81

ANOVAs

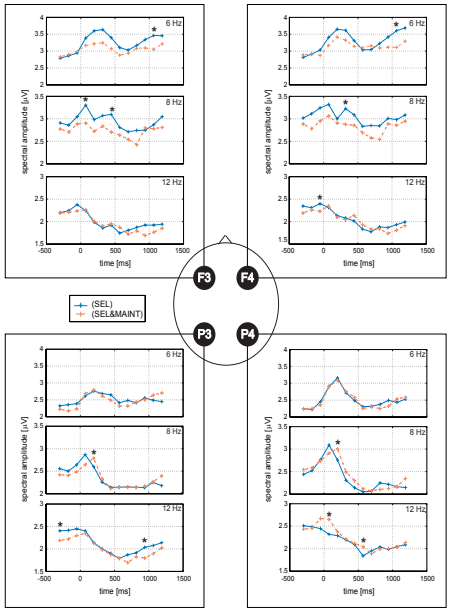
Frequency plots are shown for all three conditions. Overall ANOVA revealed significant differences between conditions (SEL) and (SEL&MAINT) within EEG theta band and EEG alpha1 band.
*p<0.05 for (SEL) vs. (SEL&MAINT)



Event-related frequencies

The time course of selected frequency values is shown for times 299 ms prior to stimulus onset to 1189 ms after stimulus onset. T-tests were calculated for each time point between the two comparison conditions.
*p<0.05

(1) There are significant differences in frontal EEG theta (6 Hz) and EEG alpha1 (8 Hz) in simple vs. hard comparison condition. This is ascribed to the presence of strategies (parietal effects are absent).
(2) In the harder comparison condition, effects are slightly delayed.

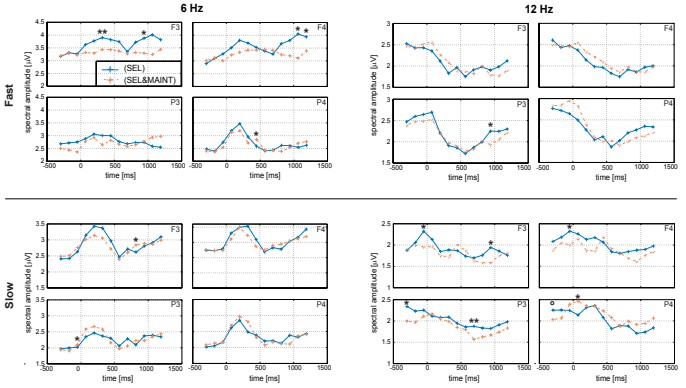


Fast vs. slow responders

Subject's sample was post hoc divided in two groups "Fast" and "Slow" with respect to the reaction time performance in the tasks (SEL) and (SEL&MAINT). Comparison was done within subjects to avoid influences of individual scalp differences. This reveals differences in frequency time course effects caused by strategies.
*p=0.054; *p<0.05; **p<0.001

(1) The mean EEG theta (6 Hz) effect of the whole sample as shown in the diagram "Event-related frequencies" seems to be produced mainly by fast responders with uniform strategies. Slow responders however show no early frontal EEG differences between the two comparison conditions. A greater diversity of strategies in slow responders is assumed.

(2) Given 12 Hz as indicator for diminished mental load, slow responders show systematically less load on frontal and parietal electrodes in the simpler comparison condition (SEL) within the 200 ms prior stimulus onset.



Subjects

16 students (8 male, 8 female, age 21-38, mean 27), all right handed (according to Edinburgh Handiness Inventory) and with normal or corrected to normal sight.

EEG measurement and analyses

EEG was derived from 16 scalp sites according to the 10-20 system against linked ears (32 channel Synamp Neuroscan amplifier, 500 Hz sampling rate, online band-pass filter 0.1-100 Hz). Artefact free epochs were analysed by von Hann windowed FFT of event-related segments of 1024 ms duration starting with stimulus onset (Vision Analyzer, band-pass filter 2-20 Hz).

Time-frequency analyses were done for channels F3, F4, P3, P4 by analysing segments of 2048 ms duration starting 548 ms prior to 1500 ms after stimulus onset. To ascertain the time course of frequency power, von Hann windows of 500 ms duration were shifted stepwise for 124 ms over the whole segment.

Literature

Pennekamp P, Bösel R, Mecklinger A, Ott H (1994) Differences in EEG-theta for responded and omitted targets in a sustained attention task. *Journal of Psychophysiology 8*, 131-141.

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