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Visual ERP P3 amplitude and latency in standalone and embedded visual processing task

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***Abstract*— Event-related potentials (ERPs) of a visual processing task are compared with and without a simultaneous external working memory load. Ten adults participated the same measurement session on three separate days. Results for visual ERP P3 amplitude and reaction time (RT) are presented for both task conditions. Both the reaction time of the visual task and the respective P3 latency increased during high memory load. It was also found that P3 amplitude and reaction time correlated only under the high memory load condition. The results indicate that visual P3 to a simple processing task is affected by external working memory load.**

I. INTRODUCTION

Human cognitive processes related to the allocation of attention and stimulus comparison have traditionally been studied with event-related potentials (ERP) of the electroencephalogram (EEG), and especially the P3 component is considered to reflect these processes [1]. It is typically recorded in tasks where the participants are required to focus their attention towards specific visual, auditory or somatosensory stimuli and either discriminate stimuli that differ from the stimulus stream according to some feature or to perform another stimulus-related task. The P3 is a large and robust response with a positive polarity peaking approximately at or after 300 ms after the stimulus onset, depending on the stimulus type and task. The locations of origin of the P3 have been proposed to contain multiple subcomponents including ones in the hippocampus and in the temporo-parietal junction [2], [3]. The P3 response is quantified according to its amplitude and latency. Typically, larger P3 responses are associated with better performance, but also with higher relevance of the presented stimulus. The latency of the P3 is typically interpreted as a measure of the speed of task performance, and shorter P3 latencies are typically associated with better cognitive performance. The P3 response amplitude and latency tend to be negatively correlated, but this correlation is partially proposed to stem from a latency variation of individual trials or from differences in those neural events that precede the generation of the P3 [1].

When a simple visual task like judging the symmetry of a figure across its vertical axis is performed, the typical P3 response recorded after the presentation of the visual stimulus reflects the processing capacity and speed of the individual participant. When, however, the participant is performing another primary task like a working memory (WM) task, and this task is interrupted by a simple visual task, the P3 response to the simple visual task reflects both the cognitive load of the primary task and the processing capacity available for the simple task. We wanted to investigate the effects of embedding the simple symmetry judgement task in the midst of a demanding WM task on the P3 response amplitude and latency and on task performance and reaction time (RT).

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II. METHODS

The study consisted of three identical test sessions, performed on separate measurement days. Ten voluntary adults participated in all 3 sessions. Each measurement session was preceded with a different breakfast (protein, carbohydrate and no-energy).

The measurement days were identical and contained a variety of different experimental neurophysiological tasks. Here the focus is on two tasks, a pure figure symmetry determination task (Sym) and an embedded version of the same task (ESym) where the processing takes place under WM load. Both measurements were made consecutively between 11:30 and 12:00.

Sym is an easy processing task that consists of repeated presentation of black-and-white figures. The subject identifies whether the presented figure is symmetric with respect to its vertical axis and answers symmetric/asymmetric by pressing the corresponding button. A total of 160 figures was presented.

ESym contains a complex span working memory task with the figure symmetry determination as an interfering secondary task. A schematic of the stimulus sequence in shown in Fig. 1. In the complex span task the subject has to memorise the locations of red squares within a matrix of possible locations. The number of successive locations to memorise varied from 2 to 7 and there were three repetitions of each length. The WM task is very demanding and requires high level of concentration. The number of figures presented was 81.

EEG was measured using NeurOne (Mega Electronics, Kuopio, Finland) at a sampling rate of 500 Hz with a 125 Hz low-pass filter. Standard 10-20 system electrode locations [4] were used for channels Fz, F3, F4, Cz, C3, C4, Pz, P3, P4, O1 and O2, all referenced to the left mastoid. Four EOG channels were also recorded. Blinks were corrected using independent component analysis (ICA) based signal space projection method [5]. The data was epoched at

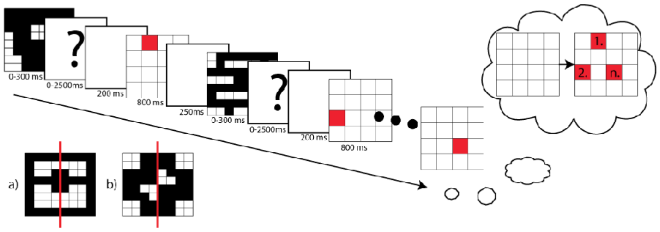

Fig. 1: The symmetry span task.

$-100 \dots 1200$ ms around the presentation times of correctly identified symmetry figures. Amplitude threshold rejection with 65 μV threshold was used to reject large artifacts.

ERPs were analysed using EEGLAB [6]. Prior to averaging epochs were band-pass filtered from 0 to 20 Hz and baseline corrected using $-100 \dots 0$ ms as the baseline time range. RT was defined as the delay between the figure appearing on screen and the correct answer button being pressed.

The visual processing task performance was measured as the percentage of correctly answered stimuli. For the WM task, a memory span measure was determined based on the number of successive, correctly remembered locations.

The statistical significance testing of difference in mean was done using the Wilcoxon signed-rank test because the data represents a repeated measurements structure. The significance testing of correlation was based on the Pearson's product-moment correlation coefficient.

III. Results

It was found that the diet did not affect P3 amplitudes, latencies or RT. Moreover, the performance measures percent correct and span had no significant correlations with P3 amplitude/latency or RT in either of the tasks. The same was also true for P3 amplitude and latency which did not correlate with each other.

The average ERPs for the Sym and ESym tasks are shown in Fig. 2. It is seen that the ESym P3 has a lower amplitude and higher latency than the Sym P3. Only the latency difference is statistically significant (p=0.004).

Scatter plots of P3 amplitude and RT for both tasks are shown in Figs. 3 and 4. An increase in RT is clearly seen in ESym compared to Sym. Also the lower P3 amplitudes in ESym are visible. The correlation between P3 amp and RT is higher in ESym. The observation numbering in all scatter plots corresponds to different subjects. Due to missing data there is one to three observations per subject.

A scatter plot of P3 amplitude and latency is shown in Fig. 5. The correlation is not significant.

Basic statistics for RT and P3 amplitude/latency as well as the correlation coefficient for P3 amplitude with RT are presented in Table I. The RT was 165 ms longer (p=0.01) and the P3 latency 97 ms longer (p=0.004) in the ESym task than in the Sym task, when comparing subject averages over the three test sessions. The correlation of RT and P3 amplitude is significant only in the ESym task (p=0.0001).

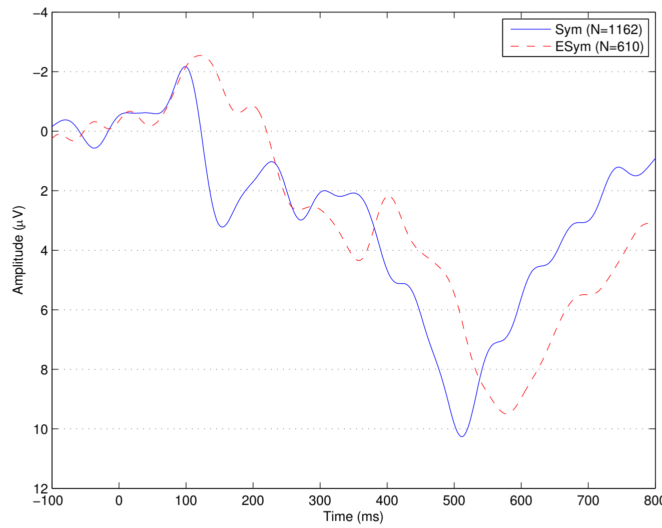

Fig. 2: Group average ERP for the Sym and ESym tasks. Only correctly answered symmetry figures are included in the average.

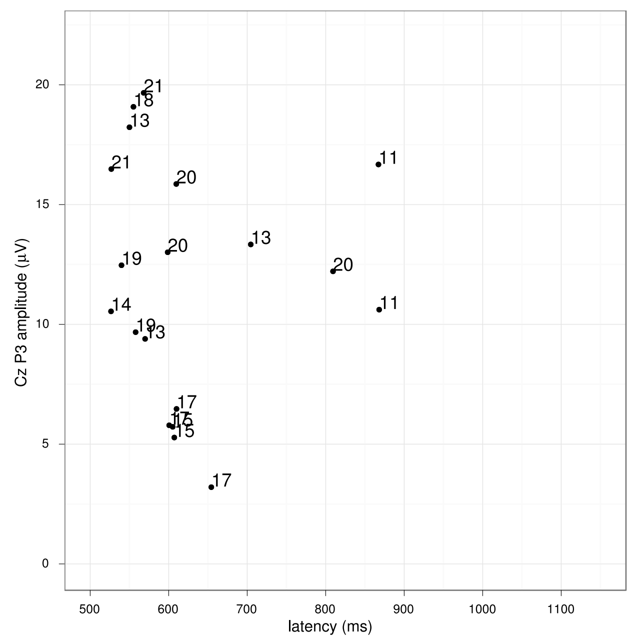

Fig. 3: P3 amplitude as a function of RT in the Sym task.

TABLE I: Mean, standard deviation (SD) and correlations.

	Sym	ESym
RT mean ± SD	625 ± 106 ms	790 ± 167 ms
P3lat mean ± SD	489 ± 87 ms	586 ± 37 ms
P3amp mean ± SD	12.3 ± 4.8 μV	10.7 ± 5.7 μV
correlation P3amp–RT	-0.04	-0.73

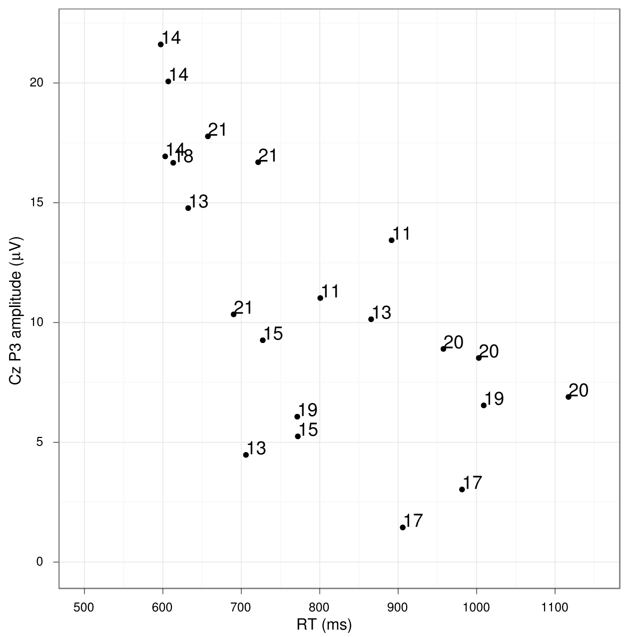

Fig. 4: P3 amplitude as a function of RT in the ESym task.

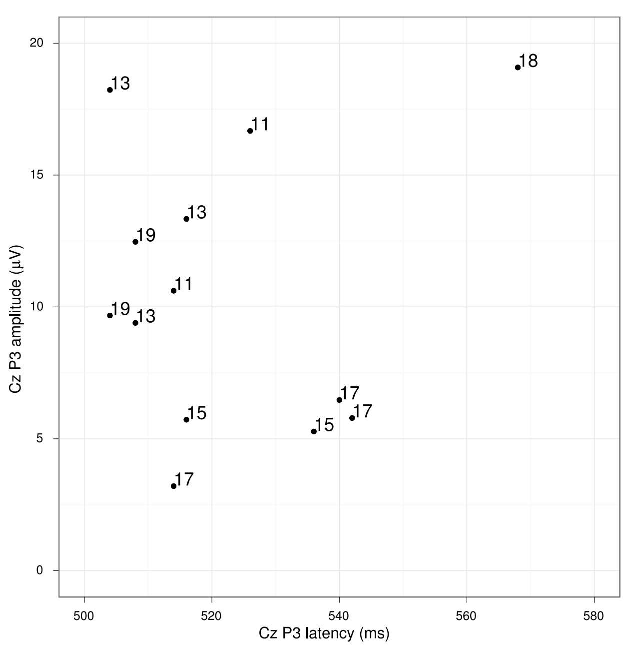

Fig. 5: P3 amplitude as a function of latency in the Sym task.

IV. Discussion

The increase in task difficulty increases RT and makes it more variable (see Table I and Figs. 3-4). This is a natural observation as the WM task engages resources otherwise available for figure processing.

It can be seen from Figs. 3-4 that the P3 amplitude decreases with increasing RT in the ESym task. Interestingly this relationship is observed only in the difficult ESym task but not at the easy but fast-paced Sym (Fig. 3).

Another observation is that in ESym task (Fig. 4) the data points of the individual subjects from the three consecutive test sessions show more replicability than in the Sym task (Fig. 3). It seems that inter-individual differences increase whereas intra-individual variability decreases under the more demanding ESym task. It is not clear why individual results become more consistent under higher mental load. One possibility is that the ESym task requires more careful concentration leading to more consistent results. The Sym task, although fast-paced, is also quite boring which in turn might lead to more frequent lapses in attention. But on the other hand, the difficulty of ESym task could also cause difficulties in performing the secondary visual processing task.

It should be noted that the ESym task leaves it to some extent to the subject to decide which task of the two he considers most important. Despite the careful instructions it is possible that some subjects consider the figure processing task as the primary one. This would obviously have an effect on both the P3 and RT.

The above mentioned changes in inter and intra-individual variabilities explain, at least partially, the better correlation of P3 amplitude with RT in the ESym task. Consistently performing subjects with large inter-subject differences in P3 amplitude and RT lead to a good correlation.

In contrast to findings by Polich & Kok [1], the negative correlation between P3 latency and amplitude in Fig. 5 is weak and non-significant. If the data point corresponding to subject 18 was removed, the correlation is still non-significant (p=0.076). The use of a visual stimulus might play a role here as the negative correlation result applies to auditory stimuli.

V. Conclusion

Visual P3 ERP is clear and prominent both under simple processing task and under high working memory load. The presented results indicate that a simultaneous working memory load changes the relationship between the P3 amplitude and RT in a visual processing task. A larger data set is needed to gain more insight as to what actually causes this phenomenon.

VI. Acknowledgements

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