ATTENTION SCORES AND ERP COMPONENTS IN SENSOMOTOR TASK

S. Georgiev[1], Y. Lalova[2], V. Ivanova[1], D. Philipova[1]

Institute of Physiology, Bulgarian Academy of Sciences, Sofia 1113, Bulgaria[1];
Institute of Psychology, Bulgarian Academy of Sciences, Sofia 1113, Bulgaria[2]

Attention scores and ERP components in sensomotor task – S. Georgiev, Y. Lalova, V. Ivanova, D. Philipova – Homeostasis 44, 3, 2006 – Attention as a psychological characteristic could be described with additional behavioural and electrophysiological parameters. The purpose of this work was to investigate the relationship between attention parameters (Attention test – Brickenkamp d2) – concentration performance, processing speed, rule compliance (accuracy) and the changes in various ERP components (indicating sensory and cognitive information processing) in healthy volunteers. EEG (Fz, Cz, Pz, C3' and C4') was recorded in two series. In the first series, without any task, the persons had to listen to low frequency (800 Hz) and higher frequency (1000 Hz) tones presented in randomized order. In the second task condition, they had to react to a low tone by pressing a button with the right hand and react to a high tone in the audio sequence by pressing a button with the left hand. ERPs were averaged for each series, tone and electrode position.

In the sensory-motor task series, we observed a relationship between parameters of the P3 component and the concentration performance attention parameter. We found a significantly shorter P3 latency and higher P3 amplitude in persons with higher concentration performance.

As a whole, the obtained data showed that the attention processes concerning concentration performance could be related predominantly to the main cognitive and modality independent P3 component.

Keywords: *ERPs, P3, attention, cognitive processing, Brickenkamp d2 test*

INTRODUCTION

Event-related potentials (ERPs) are brain waves related to specific events, such as the presentation of a stimulus, and reflect neuronal activity patterns associated with perceptual and cognitive processing. Of the various ERP waveforms, the P50, N100 and P200 components are considered to be the indices of early attention selection and sensory memory following stimulus delivery, while N200 and P300 reflect the later cognitive processing concerned with stimulus classification and decision making. The N100 component, a negative peak with a latency of about 80 to 200 ms, corresponds to an initial "orientation" response but is also involved in stimulus classification: the decision to further process information or ignore it (Fabiani, Gratton, & Coles, 2001; Kok, 1997). N100 amplitude is also related to arousal (Bruce, Scott, Shine, & Lader, 1992) and it is larger with increases in attention requirements (Maclean, Ohman, & Lader, 1975; Pritchard, 1981) whether automatic or directed (Ford, Roth, Menon, & Pfefferbaum, 1999). The P200 component is bound up with the orienting response; it may represent an inhibition of sensory input from further processing (Hegerl & Juckel, 1993; Schupp, Lutzenberger, Rau, & Birbaumer, 1994) and is normally associated with automatic stimulus identification and discrimination (Lindholm & Koriath, 1985). The N200 evoked about 180 ms following the presentation of a stimulus goes negative in response to a deviation in the form or context of a prevailing stimulus (Patel and Azzam, 2005) and it could be linked with the cognitive processes of stimulus identification and distinction (Hoffman 1990).

The main cognitive component is modality independent P300 wave (Sutton 1965). The P300 latency indexes the speed of stimulus classification resulting from the discrimination of one event from another (Polich, 2006 review). P300 amplitude is considered to reflect the brain activity that is required in the maintenance of working memory and in the updating of a mental model of the stimulus environment. P300 mapping is a highly sensitive parameter by which it is possible to measure slight degrees of reduced vigilance (Engelhard et al. 1992).

Attention abilities are usually evaluated as part of a larger cognitive or neurophysiological assessment (Sohlberg, Mateer, 2001). In the interpretation of ERP data and components, it is very important to evaluate the role of attention processes and to assess which ERP component could reveal the most sensitive attention parameters as a psychological construct.

For this purpose, we investigate the relationship between attention scores achieved in a psychological test and the changes in various ERP components in healthy volunteers. To test attention, we used a Brickenkamp d2-test (1994). The d2 test of attention is considered to be the standard instrument for measuring concentration, processing speed and attention in both clinical and applied settings and it has been used extensively in the areas of physiology, clinical neuropsychology and in the evaluation of cognitive processes, for instance, after taking drugs. (Schreiber et al. 1991, Blankertz 2002, Evers et al. 2003, Lalova, J. et al., 2003, Philipova, D. et al. 2004).

METHODS

Twenty five healthy volunteers (9 males and 16 females, mean age 32.2 ± 2.8 years, who gave their written informed consent before investigation) participated in the study. All subject were right-handed (Annett, 1982). The subject was comfortably seated in an ergonomically designed chair within a soundproof, electrically screened chamber monitored by a Canon Video System. The hand and forearm were positioned along the armrests. The index finger was immobilized within a rigid rail attached to a pull-push force transducer: its output signal was proportional to the isometric force produced. An electroencephalogram (bandpass filtered between 0.3–70 Hz) was recorded from Fz, Cz, Pz, C3' and C4', using Ag/AgCl "Nihon-Kohden" electrodes with reference to both processi mastoidei, according to the system 10–20. An electrode placed on the forehead served as ground. An oculogram was recorded from m. orbicularis oculi dex.

100 computer generated acoustic stimuli – 1000 Hz (high) and 800 Hz (low) tones with an intensity of 60 dB, duration 50 ms and interstimulus interval 2.5 – 3.5s were transmitted to the subjects in a randomized order. After a short practice period, the subject participated in a section of 100 trials each – a passive series (passive listening without any task) and a sensory-motor task series in which the subjects were asked to respond as quickly as possible by depressing the relevant key with their index finger (with the left hand to a high frequency tone and with the right hand to a low frequency tone). ERPs were averaged for each record (Fz, Cz, Pz, C3', C4'), series and tone separately.

The following response parameters of movement execution were defined:

Motor reaction time – from stimulus presentation to the onset of voluntary force production. Force peak latency – from stimulus presentation to the force peak amplitude.

Response force duration – from force onset to force end.

Execution time – from stimulus onset to movement end.

Immediately after the end of the EEG recording, each subject completed an attention test (Brickenkamp d2 test): the subjects were presented with a sheet of 14 rows each containing a random sequence of 47 "d" and "p" characters – 658 items total. The task

Homeostasis 3_44 6.12.2006 15:29 Stránka 121

of the subject was to identify and cross out all the doubly underlined 'd's' within the predetermined time of 20 seconds per row. We used the following measures:

Processing speed – given by total number of processed items.

Concentration Performance – given by number of correctly underlined items (the speed and accuracy of performance).

Rule compliance – given by the percentage of errors within the total number of processed items (accuracy).

A computer program was used to apply Mann-Whitney U-test of statistical data processing and correlation analysis.

RESULTS

Minimum, maximum and median scores achieved in the **d2 test** for various performace measures:

Processing speed: min score=233 items; max score=656 items; median score=481 items;

Concentration performance: min score=78 items; max score=278 items; median score=178 items;

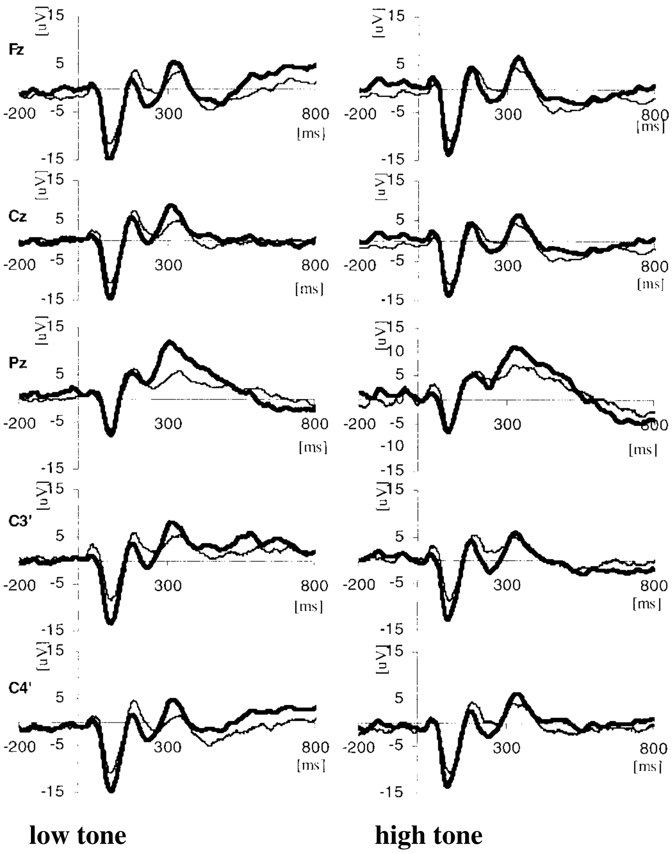

Fig. 1. Grand average ERP waveforms for Fz, Cz, Pz, C3' and C4' in sensory-motor task series in persons with low (thin lines) and high (thick lines) concentration performance.

Rule compliance: min score (high rule compliance) =0.8%; max score (low rule compliance) =17.8%; median score=6%;

On the basis of the median score values, we divided the participants into pairs of groups (matched for age, sex, education): participants with low processing speed vs. high processing speed; participants with low rule compliance vs. high rule compliance; participants with low concentration performance vs. high concentration performance;

Passive series:

Processing speed: The Mann-Whitney U-test data did not show any significant latency or amplitude differences for N1 and P2 between the participants with low processing speed and high processing speed.

Rule compliance: We did not find any significant latency or amplitude differences for N1 or P2 between the participants with low rule compliance and high rule compliance.

Concentration Performance: The subjects with a higher concentration performance index had higher, but not significantly so, N1 and P2 amplitudes in all records and shorter N1 and P2 latencies. Only the P2 latency reached significance at Fz (U=33; p<0.03) and at Cz (U=36.5; p<0.04) records for the low tone.

Sensory-motor series:

Processing speed: In the sensory-motor task condition we found a shortening of the N1 and P2 latencies in subjects with fewer processed symbols, namely with a lower processing speed, in comparison with subjects with a higher processing speed. This effect was significant for the N1 latency at Fz (U=33.5; p<0.02) and Cz (U=37.5; p<0.02) for the high tone and at Pz (U=35.5, p<0.02) for the low tone.

Rule compliance: The latencies and amplitudes of ERP components for the two groups divided by error percentages were inconsistent and did not reach a significant difference.

Concentration Performance: Subjects with more underlined correct symbols (namely with high concentration performance) showed shorter P3 latency in all EEG records for the both tones. The significant difference was found for the P3 latency at Fz (U=42,5; p<0,05), Cz (U=42; p<0.05), Pz (U=33; p<0.02), C3' (U=24; p<0.01) and C4' (U=24; p<0.01) records for the high tone. The P3 amplitude was significantly higher in persons with a higher concentration performance at Cz (U=40; p<0.04); Pz (U=36; p<0.03); C4' (U=31; p<0.04) for the low tone (at Fz p<0.08, U=45) and at Fz (U=40; p<0.04); Cz (U=37; p<0.03); Pz (U=41; p<0.05); C4' (U=17; p<0.04) for the high tone (Fig. 1, Fig. 2).

In addition, we applied correlation analysis for an evaluation of the interrelation between ERP components and concentration performance parameters. We found following significant positive correlations between P3 amplitude and the concentration performance attention parameter:

for the low tone at Fz (r=0.48; p<0.05); Cz (r=0.45; p<0.05); Pz (r=0.47; p<0.05); C3' (r=0.42; p<0.07), C4' (r=0.45; p<0.05);

for the high tone at C4' (r=0.63; p<0.05); marginally nonsignificant were correlations at Fz (r=0.43, 0.1 >p >0.05), Cz (r=0.39, 0.1 >p >0.05) and C3' (r=0.40, 0.1 >p >0.05).

Reaction Time data are presented in fig. 3. We did not find significant RT differences between groups with a high or a low processing speed or between those with high or low concentration performance. The group with low rule compliance showed longer RT parameters but only the difference for the right hand execution parameter was significant (1069±37 ms vs 910±49 ms, p<0.022, U=17).

Homeostasis 3_44 6.12.2006 15:29 Stránka 123

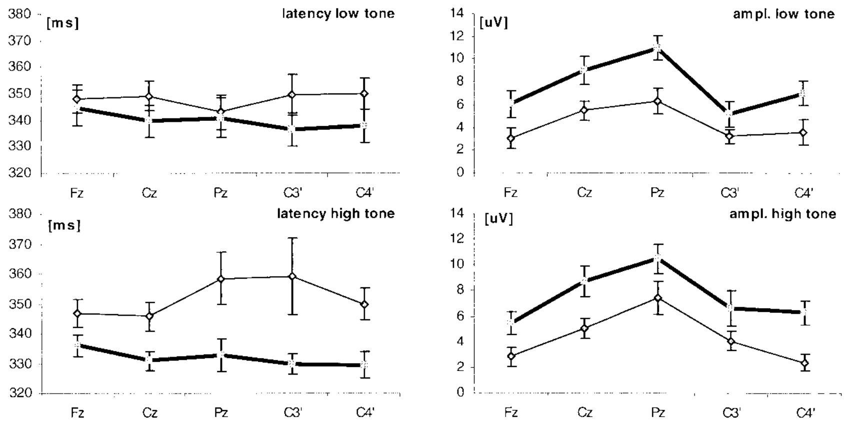

Fig. 2. Mean latency and amplitude parameters of P3 component in discrimination task condition, in persons with low (thin lines) and high (thick lines) concentration performance.

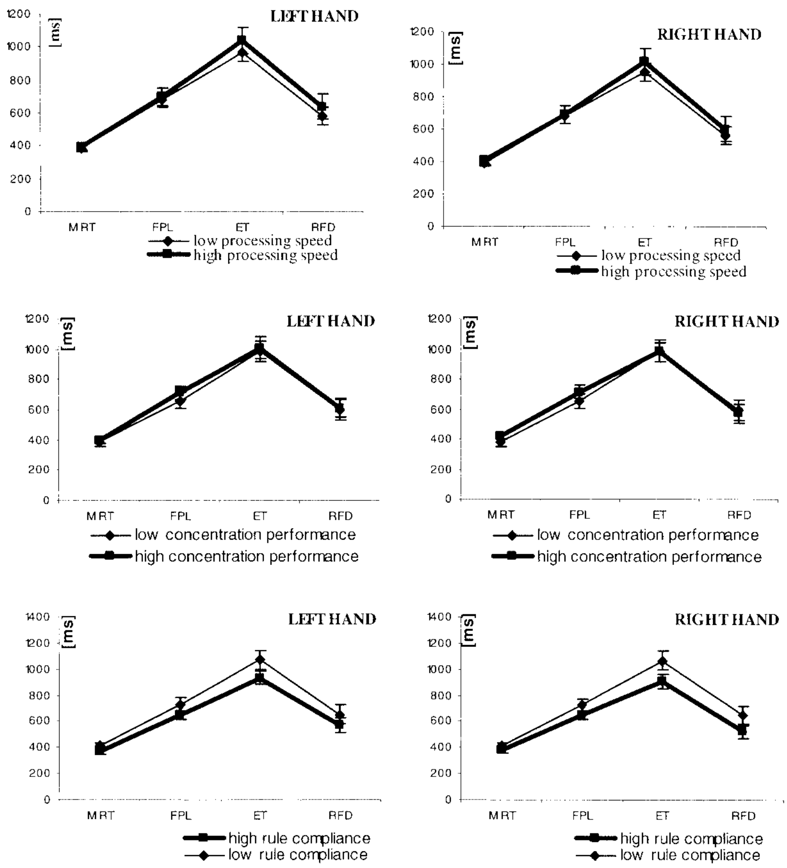

Fig. 3. Response time parameters in ms.

DISCUSION

In the literature, there are a number of papers concerning endogenous event-related brain potentials and psychometric performance evaluated by d2 test (Schreiber et al.1991, Evers et al. 2003, Mozolic et al. 2004, Seidl et al. 2004, Philipova et al. 2004 al.). On the basis of the correlation between d2 test and early part of Contingent negative variation (CNV) in children (go-no go task) Mozolic et al. 2004 concluded that CNV paradigm may be used for studying of attention processes.

In this work, we have investigated the interrelation between ERP components received in passive listening series and under discrimination task conditions (binary sensory-motor setting with both the low and high tones as targets) and a d2 attention test.

We did not find any convincing interrelation between early ERP components and attention d2 test in passive or sensory-motor task series. These results as well as the discrepant findings for occasional shortening of the latencies of early ERP components in subjects with lower processing speed could be explained on the basis of the different sensory modality of early modality dependent acoustic N1 and P2 components and the visual attention d2 test.

The response time from stimulus presentation to key press is related to both cognitive and motor processing. We did not find any interrelation between d2 attention test and response parameters of movement execution.

In the sensory-motor task series, we observed a relationship between parameters of the P3 component of ERPs and the concentration performance attention parameter determined by the d2 test. The P3 component is commonly considered to be an index of stimulus evaluation and categorization which is independent of sensory modality and response execution. We found a significantly shorter P3 latency and higher P3 amplitude in persons with a higher concentration performance. The P3 latency data corresponding with the cognitive processing time reflect the time for evaluation of stimuli and include task relevant decision making processes. The shortening of P3 latency showed that the persons with a higher concentration performance had a shorter cognitive processing time.

The interpretation of the P3 amplitude as a phenomenon accompanying mental processes is very complex. Data in the literature suggest that P3 amplitude depends on expectations about the stimulus, on the meaning of the stimulus information, on whether the task is relevant, on memory and selective attention processes (Johnson et al. 1986), emotion and motivation (Carillo-de-la Pena, Cadaviera, 2000). The P3 amplitude differences obtained between groups divided according to concentration performance suggest arousal differences between them. The amplitude of P3 shows the allocation of brain energy resources (Kok, 1997) and the modification in neuronal activity during the cognitive process. Our data suggest that the persons with high concentration performance who showed higher P3 amplitude have been using greater neuronal resources in cognitive processing.

Taken as a whole, the data obtained reveal that the attention processes concerning d2 test concentration performance could be related predominantly to the main cognitive and modality independent P3 component and that the concentration performance test is highly informative of cognitive processing at central brain level.

Acknowledgement:
This research was supported by National Science Fund – grant L 1413, 2004–2007.

REFERENCES

Annett M., Handedness. – In: Divided visual field studies of cerebral organization (Ed. J. G. Beamond). London, Academic Press, 1982

Blankertz B., Schäfer C., Dornhege G. And Curio G., Single trial detection of EEG error potentials:

A tool for increasing BCI transmission rates. In Artificial Neural Networks — ICANN, 1137–1143, 2002
Brickenkamp R., Test d2, Aufmerksamkeits-Belastungs-Test (8th ed.). Gottingen: Hogrefe; 1994
Bruce M., Scott N., Shine P., Lader M., Anxiogenic effects of caffeine in patients with anxiety disorders; Arch Gen Psychiatr, 49, 867–869, 1992
Carrillo-de-la-Pena M.T., Cadaveira F., The effect of motivational instructions on P300 amplitude. Neurophysiologie Clinique-Clinical Neurophysiology, 30(4), 232–239, 2000
Engelhard W., Friess K., Hartung E., Sold M., Dierks T., EEG and auditory-evoked potential P300 compared with psychometric test in assessing vigilance after benzodiazepine sedation and antagonism, Br J Anaesth, 69, 75–80, 1992
Evers S., Ruchenschmidt J., Frese A., Rahmann A., Hustedt I-W., Impact of Antimigraine Compounds on Cognitive processing: A placebo-controlled crossover study. The Journal of head and face pain, 43, 10, 1102 – 1108, 2003
Fabiani M., Gratton G. & Coles M. G., Event-related brain potentials: methods theory and applications. In J. T. Caccioppo, L. Tassinari, & G. G. Bernston (Eds.), Handbook of Psychophysiology (pp. 53–84). Cambridge: Cambridge University Press; 2001
Ford J. M., Roth W. T., Menon V., & Pfefferbaum A., Failures of automatic and strategic processing in schizophrenia: comparisons of event-related brain potential and startle blink modification. Schizophrenia Research, 37, 149–163, 1999
Hegerl U. & Juckel G., Intensity dependence of auditory evoked potentials as an indicator of central serotonergic neurotransmission: a new hypothesis. Biological Psychiatry, 33, 173–187, 1993
Hoffman J. E., Event-related potentials and automatic and controlled processes. In: Rohrbaugh J. W., Parasuraman R., Johnson R. Jr. editors. Event Related Brain Potentials. New York: Oxford University Press, pp, 145–157, 1990
Johnson R., A triarchic model of P300 amplitude. Psychophysiology, 23, 367–384, 1986
Kok A., Event-related-potential (ERP) reflections of mental resources: a review and synthesis, Biological Psychology, 45, 19–56, 1997
Lalova J., Grigorova V., Georgiewa P., Relation between attention scores and training effects in a visual-manual task; Comptes rendus de l'Academie bulgare des Sciences, tome 56, 11, 59–64, 2003
Lindholm E. & Koriath J. J., Analysis of multiple event related potential components in a tone discrimination task. International Journal of Psychophysiology, 3, 121–129, 1985
Maclean V., Ohman A. & Lader M. H., Effects of attention, activation and stimulus regularity on short term 'habituation' of the averaged evoked response. Biological Psychiatry, 3, 57–69, 1975
Mozolic B. E., Davies P. L., Segalowitz S. J., Gawin W. J., Contingent negative variation and attention in children. Presented at the 44th Annual meeting of the Society of Psychophysiological research, Santa Fe, Oct. 20–24, 2004
Patel H. S. and Azzam N. P., Characterization of N200 and P300: Selected Studies of the Event-Related Potential, Int. J. Med. Sci, 2(4), 147–154, 2005
Philipova D., Tsenova B., Iwanovitsch A., Bognar-Steinberg, Influence of antivertiginous combination preparation of cinnarizine and dimenhydrinate on event-related potentials, reaction time and psychomotor performance – a randomized, double-blind, 3-way crossover study in healthy volunteers. International Journal of clinical pharmacology and therapeutics, vol. 42(4), 218–231, 2004
Polich J., Criado J. R., Neuropsychology and neuropharmacology of P3a and P3b, International Journal of Psychophysiology, 60, 172–185, 2006
Pritchard W. S., Psychophysiology of P300, Psychological Bulletin, 89, 506–540, 1981
Schreiber H., Stolz-Born G., Rothmeier J., Kornhuber A., Kornhuber H. H., Born J., Endogenous event-related potentials and psychometric performance in children with risk for schizophrenia, Biol. Psychiatry, 15, 30 (2), 177–89, 1991
Schupp H. T., Lutzenberger W., Rau H. & Birbaumer N., Positive shifts of event-related potentials: a state of cortical disfacilitation as reflected by the startle reflex probe, Electroencephalography & Clinical Neurophysiology, 90, 135–144, 1994
Seild R, Peryl A., Nicham R., Hauser E., A taurine and caffeine-containing drink stimulates cognitive performance and well-being, Amino Acids, 19, 635–642, 2000
Sohlberg M. M., & Mateer C. A., Cognitive rehabilitation: An integrative neuropsychological approach (pp. 337–370 – Managing challenging behaviors). New York: Guilford. 2001
Sutton S., Baren M., Zubin J., John E. R., Evoked potential correlates of stimulus uncertainty, Science, 150,1187–8, 1965

Presented at
CIANS Conference, Milan, Italy, June 17–18, 2006

S.G., Institute of Physiology,
Bulgarian Academy of Science,
*Acad. Bonchev str., bl.23, Sofia 1113, Bulgaria**