Artikel Penelitian

P300 as Neurophysiological Measurement and Its Correlation with Digit Span

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Abstract

It was just in the last two decades that the neuroscientists have broader insight in understanding the relation between cognitive process and brain anatomy organization . Some researchers then begin to pay attention to P300, which is a component of event-related potential (ERP), for which its psychological correlation has been extensively studied.

The study was conducted to investigate the correlation between P300 and digit span. We administered an auditory oddball ERP task to 38 healthy male students aged 20-22 years. P300 latency and amplitude was recorded at Fz and Cz in steady state, speed maximizing task, and cunt and accuracy maximizing task. The result showed P300 latencies ranged 268 to 502 mseconds, averaged 393.9 to 404.5 mseconds and 8.2-12.5% coefficient of variation. P300 amplitude ranged 2.68-31.6 µV, averaged 9.5-15.4 µV and 41-56% coefficient of variation. No correlation found between P300 latency and amplitude in steady state, speed maximizing task, count and accuracy maximizing task, on Fz and Cz, except for count and accuracy maximizing task in Fz location. No correlation found between P300 latency and digit span in steady state, speed maximizing task, count and accuracy maximizing task, on Fz and Cz: neither between P300 amplitude and digit span,

***Keyword**: event related potential (ERP), P300,digit span, auditory task*

Introduction

Literature study showed that learning process seems to be studied more by the psychology and pedagogy experts. In the first half of this century, neurobiologist thought that higher mental functions, such as learning, cognitive, thinking, and memory processes are part of psychology and philosophy domain. But, on the other hand, some psychometric evaluations are considered lengthy and monotonous. In addition, every school and institution often use different system and criteria in evaluation. It was just in the last two decades that the neuroscientists have broader insight in understanding the relation between cognitive process and brain anatomy organization (Goldman Rakic 1992).[1] In that period, they started to develop the application of neurological basics as diagnostic measurement to differentiate, among others, individuals having attention disorder and learning disabled compare to normal population, as well as gifted children among the normal population (Lubar et al. 1992, Saletu 1994).[2,3] In the studies of cognitive process, efforts have been made to produce a broad spectrum normative as well as patient group data. One of the most recent one is based on the endogenous electrophysiological components typically elicited to certain types of stimuli, the so called event-related potentials (ERP). The ERP component consists of , among others, N100, N4 and P300.

Some researchers then begin to pay attention to P300, which is a component of event-related potential (ERP), for which its psychological correlation has been extensively studied (Saletu et al. 1991, Bentin and Mc Carthy 1994).[4,5] This P300 terminology was derived from the wave polarity that showed positive deflection appeared around 300 mseconds after stimuli presentation, measured on several location on the head midline, namely, parietal (Pz), vertex (Cz), and frontal (Fz). The ERP component P300 is considered a cognitive neuroelectrical indicator of CNS activity (Regan 1989)[6], involved with the processing of new information when attention is engaged to update memory representations (Pollich 1996)[7]. P300 latency referred as the time period beginning from the onset of stimuli up to its peak. In a simple auditory discriminative task, the latency is about 300 mseconds, while in a complex decision making process the latency may take 400-800 mseconds or even longer (Saletu 1994, Guyton 1998).[3,8]

P300 latency can be regarded as a measure of the relative timing of the stimulus evaluation process, indicating an upper limit on categorization and stimulus evaluation time (Coles et al. 1995)[9], or the time taken to allocate resources and engage memory updating. P300 latency is affected by stimuli discriminability (McCarthy and Donchin 1981).[10]

Whereas P300 amplitude is held to index attentional resource allocation when memory updating is engaged (Pollich 1996)[7]. P300 amplitude appeared as a response to task relevant stimuli and inversely proportional to the probability of stimuli appearance. Afterward, Hillyard found that difficult auditory discriminative task happened to produce higher P300 amplitude. Pollich presumed that the P300 amplitude variation was due to the variation of the number of nerve recruitment that was required to undertake the certain task. Furthermore, ERP constitute the only noninvasive method that resolves the dynamic pattern in the human brain down to millisecond range, and may define a valuable framework within which behavioral or introspective data may be interpreted (Brandels and Lehman 1986).[11]

The question of scalp distribution effects of P300 amplitude and latency of considerable importance in addressing the question of which specific neural generators may underline the P300 component. It is reasonable to assume that surface EEG predominantly reflects the activity of cortical neurons close to the particular electrode (Westbrook 2000).[12] This does, however, depend both on differences in the depth and orientation of the neurons, as well as individual variability in craniocerebral topography (Steinmetz et al. 1989).[13] The exact relationship between ERP measured at the scalp and the corresponding process in the brain is not yet fully understood (Paller et al. 1992).[14] Depth electrode and magnetic field studies (Shinba 1999)[15] suggest that the P300 component reflects electrical events originating in the medial temporal areas, most likely including the hippocampal structure and the amygdale. The component should thus be related to tasks with high memory demands. The hippocampal formation is located inside the medial temporal lobe, and so it maybe difficult to measure hippocampal activity at the scalp. Paller et al. (1992) argue that neural generators not dependent upon the medial temporal lobe are responsible for most of the P300 obtained in scalp recordings, but the same events that activate these generators also instigate (bring about, activate, initiate) medial temporal lobe activity. The recommendation that P300 should be measured at Pz (Picton et al. 2000).[16] reflects the fact that this component, at least in young subjects is best observed parietally (Friedmann et al. 1997, Pollich and Heine 1996).[17,7] In a young sample auditory P300 amplitude and latency were the most negatively correlated and tightly coupled over the frontal-central and medial-lateral recording areas. On the other hand, Pollich (1991)[18] found a negative correlation between P300 latency and its amplitude amongst Alzheimer patients but not in control subjects.

Relations between P300 measures and cognitive neurophysiological measures have been reported (e.g Egan et al. 1994, O'Donnel et al. 1992; Pellosi et al. 1992; Reinvang 1999).[19,20,21,22] An interesting question regards to which extent the relationship between activation recorded from various scalp areas and neurophysiological measures, and the strongest correlations were generally found between matrices, block design and digit span, in the midline and left fronto-temporal electrodes (Fjell and Walhovd 2001).[23] Pollich et al. (1983)[24] found the correlation between digit span and ERP measures. Some research showed that there were some differences in P300 components between groups of students having learning difficulty and the groups of normal students.

Based on the above information, it would be interesting to study the correlation of P300 and digit span amongst the college students. This research aims to collect base data on the correlation of P300 latency and amplitude with digit span amongst students on auditory task in (a) steady state, (b) speed maximizing task, and (c) count and accuracy maximizing task, recorded at Fz and Cz locations.

Method

This work is considered as an explorative analytical observational and study because there is limited data available in Indonesia regarding P300 latency and amplitude. Samples were taken as a cluster to get quite homogenous ones. The subjects for this study were male students of the sixth semester from one of the Medical Faculty in Jakarta. These subjects were selected by considering that their program in the higher education, directly or indirectly, would motivate them to join this research.

Inclusion criteria were: male; 19 to 22 years old; in good health , proofed by routine physical check-up; normal hearing condition as examined with audiometry; have never experienced any convulsion, including the family history; willingness to join the research noted by signing the Informed Consent

Exclusion criteria: subject who was under medical treatment; subject who was not examined completely and subject whose P300-recording was unreadable

Procedure: The measured parameters in this examinations were P300 latency and amplitude, and digit span. P300 were examined in a comfortable (air-conditioned) room. After the examination, the subject were asked to fill in a motivation form. Procedure of the examination was a modification of Geisler's (1992). P300 were measured in the morning (9 to 12 am), after meal, by using Neuropack Four Mini Evoked Potential Measuring System Nihon Kohden MEB-5304K. Surface electrode Ag-AgCl model NM-312S was used. Due to lack of facility, only two active electrodes were installed, at the crown of head (Cz) and at the frontal midline (Fz) with 10/20 system. Reference electrodes were placed at both auricular lobes, connected. Ground electrode was placed on the forehead (Fpz location).

Before the examination, the subject was laid-down for 20 minutes. The subject was calmly lay-down, closed his eyes, and made minimum movement to avoid interferences during the recording. Auditory stimuli were sent through earphone, in the form of repetitive two specific tones with 60 dB SPL intensity, 100 mseconds plateau, and 10 mseconds rise-fall. **Frequent** 500 Hz stimuli were sent with 2 second interstimuli interval and randomly intermitted by 1500 Hz **rare** stimuli, with a ratio of 4:1 until 20 rare-stimuli. Recording was done from 100 mseconds prestimuli until 900 mseconds post-stimuli with a sensitivity of 12.5 μV per division. Artefact rejection was set at ± 3 divisions. The subject was given 3 blocks of stimuli, each contained 20 rare stimuli. Between each block, the subject was rested for 2-3 minutes. Before giving the **first block**, the subject was informed and asked to concentrate in recognizing the given stimuli without doing any tasks (**steady state**). At the **second block**, the subject was instructed to push a button with his right thumb as soon as he heard the rare stimuli and the left thumb as he heard the frequent stimuli (**speed maximizing task**). At the **third block**, the subject was asked to push a button (as in the second block) as soon as he heard every stimulus while avoiding any error to the minimum and counting by-heart the rare stimuli (**count and accuracy maximizing task**).

P300 latency will be calculated from the onset of stimuli until the highest positive deflection during 200 to 500 mseconds. The amplitude was measured as potential difference between the highest positive deflection and the previous negative crest.

Digit span was examined by giving sets of forward digit and backward digit. Examiner read one digit per second, begin with 3 digits, and the examinee repeat the spelled digit. Forward score was noted as the highest total digits repeated correctly before 2 consecutive faults. Backward score was noted as the highest total digits repeated backward correctly before 2 consecutive faults. Digit span score consists of the total of forward and backward score.

Result and Analysis

The subject age ranged from 19-20 years with the average of 19 years. In this homogenous samples one could expect a relatively high accuracy of relationship between the P300 latency and cognitive process. So as to say that the shorter latency correspond with faster cognitive process. The students in this research were all taken from sixth semester medical students. Whereas the samples taken in other countries were generally laboratory and hospital workers, general community and employees. Based on the motivation scores, examined just after the P300 measuring, as high as 65% of the participants stated that this research was interesting, showing that the motivation of the subjects in doing the research was relatively high. This is important because the motivation is fundamental to the majority of aware behavior. The subject with good motivation can be expected to do his task optimally so that lessen the possible bias.

Results of examinations on P300 latency at Fz and Cz locations are tabulated in Table 1. It ranged from 268 to 502 mseconds, averaged 393.9 to 404.5 mseconds and 8.2-12.5% coefficient of variation. Considering the subjects measured, one could then expect shorter latencies in medical students (Jakarta research) compared to laboratory and hospital workers or general community and employees (other countries research). But on the contrary the P300 latency resulted from this research ranged from 268 to 502 mseconds (Table 1). It is quite longer from the result of Goodin *et al.* (1978), Synduko *et al.* (1982), Brown *et al.* (1983), Picton *et al.* (1984) and Pollich *et al.* (1985) as cited by Pollich (1986) [25] which was ranged 250-350 mseconds’. The scores obtained from motivation forms indicated that the motivation was relatively high 65%), therefore, the length of P300 latency logically did not correspond to the lack of attention. The possibility of attention deficit disorder could also be low, or even eliminated, considering that all subjects have already passed their high school level. Another possibility is the environment and internal factor which is apparently different when the samples of the other countries research is compared to the samples in this study. It is quite possible that genetic factor, the involved neuron population or even enzymes and neurotransmitter, as noted by Geisler (1992)[26], affect the student P300 latency.

The research from other countries did not specify the interindividual variation amongst the individuals. However, in this study the coefficient of variation was relatively small (8-13%), indicating relatively small interindividual variation of time needed for stimuli evaluation process was. Again, genetic factor might play the role.

Table 2 shows the P300 amplitude ranged 2.68-31.6 μV, averaged 9.5-15.4 μV and 41-56% coefficient of variation. The research in other countries did not described sufficient data about P300 amplitude. However, result of this study was not in accordance to the Smith’s, as cited by Pritchard (1981)[27], that was 15-18 μV without mentioning the coefficient of variation. On the other hand, this research showed relatively high variation in P300 amplitude, ranged from 3.33-30.7 μV with 41-56% coefficient of variation. It showed that the individual variation was sufficiently high in P300 amplitude. This result could mean a great variation of difficulty experienced by the students, and it could also mean a great variation of nerve recruitment that was required to undertake the certain task. The situation might be caused by, among others, high variation in genetic, environmental factors, included the socio-economic condition of the subjects, as well as the relatively different experiences factor before entering the university. Their different experiences would result different memory storage, different memory retrieving, and different information processing method and strategy. Furthermore, it was possible that for implementing the same task could result different neural recruitment for different individuals. The effect of socio-economic, experience, and environmental factors on P300 amplitude need further study.

Data on normality test shows normal distribution on digit span, whereas P300 latencies and amplitudes show abnormal distribution. Normality test on logarithmic transformed data shows a normal distribution on P300 latencies and amplitudes. Therefore, the analysis was further elaborated on logarithmic transformed data, except for digit span, using SPSS software.

As for P300 latency and amplitude, there is no correlation in all tasks (steady state, speed maximizing, count and accuracy maximizing), on both recording locations (Fz and Cz), except for count and accuracy maximizing task on forehead electrode (Fz) with $r=-0.345$ and $\alpha=0.034$. It is in line with Pollich (1991)[18] who found no correlation in control (normal) subjects.

Digit span score ranged 9-14, averaged 11 and 11 % coefficient of variation. The study showed no correlation between P300 latency and digit span in all tasks (steady state, speed maximizing, count and accuracy maximizing), on both recording locations (Fz and Cz). Neither between P 300 amplitude and digit span. The result was not in line with Pollich's (1983).[24] Since there are differences between P300 latencies and amplitudes obtained in this study compared to other countries', it is quite possible that genetic, as well as environmental factor, play some roles.

Conclusion

a) There are differences in P300 latencies and amplitudes obtained in this study compared to other countries'
b) No correlations between P300 latency and amplitudes in steady state, speed maximizing task, count and accuracy maximizing task, on Fz and Cz
c) There is a correlation (r=0.345, α=0.034) between P300 latency and amplitude in count and accuracy maximizing task on Fz
d) There is no correlation between P300 latency and amplitude in count and accuracy maximizing task on Cz
e) between P300 latency and digit span in all tasks (steady state, speed maximizing, count and accuracy maximizing), on both recording locations (Fz and Cz)
f) There is no correlation between P300 latency and digit span in steady state, speed maximizing task, count and accuracy maximizing task on Fz and Cz, neirher with P300 amplitude

Table 1. P300 latency (and Logaritmic transformation)

No	MLA3 (msec)	log MLA3	MLA4 (msec)	log MLA4	MLB3 (msec)	log MLB3	MLB4 (msec)	log MLB4	MLC3 (msec)	log MLC3	MLC4 (msec)	log MLC4
1	502	2.70	500	2.70	432	2.64	426	2.63	428	2.63	434	2.64
2	430	2.63	426	2.63	350	2.54	350	2.54	446	2.65	446	2.65
3	362	2.56	362	2.56	358	2.55	358	2.55	382	2.58	388	2.59
4	398	2.60	410	2.61	348	2.54	372	2.57	398	2.60	398	2.60
5	346	2.54	346	2.54	400	2.60	404	2.61	426	2.63	430	2.63
6	406	2.61	422	2.63	396	2.60	398	2.60	406	2.61	408	2.61
7	368	2.57	368	2.57	354	2.55	352	2.55	392	2.59	388	2.59
8	328	2.52	328	2.52	436	2.64	438	2.64	394	2.60	392	2.59
9	458	2.66	456	2.66	388	2.59	390	2.59	430	2.63	428	2.63
10	402	2.60	408	2.61	382	2.58	378	2.58	416	2.62	416	2.62
11	404	2.61	410	2.61	388	2.59	390	2.59	376	2.58	378	2.58
12	416	2.62	418	2.62	382	2.58	380	2.58	396	2.60	412	2.61
13	416	2.62	416	2.62	390	2.59	388	2.59	430	2.63	436	2.64
14	442	2.65	436	2.64	454	2.66	456	2.66	422	2.63	422	2.63
15	362	2.56	360	2.56	382	2.58	386	2.59	418	2.62	414	2.62
16	450	2.65	458	2.66	456	2.66	454	2.66	456	2.66	452	2.66
17	434	2.64	442	2.65	406	2.61	404	2.61	428	2.63	422	2.63
18	410	2.61	430	2.63	416	2.62	456	2.66	408	2.61	410	2.61
19	382	2.58	378	2.58	402	2.60	402	2.60	492	2.69	498	2.70
20	378	2.58	378	2.58	476	2.68	478	2.68	416	2.62	416	2.62
21	448	2.65	440	2.64	328	2.52	334	2.52	438	2.64	424	2.63
22	304	2.48	304	2.48	368	2.57	370	2.57	390	2.59	390	2.59
23	298	2.47	294	2.47	404	2.61	402	2.60	390	2.59	398	2.60
24	304	2.48	304	2.48	380	2.58	376	2.58	366	2.56	366	2.56
25	396	2.60	396	2.60	390	2.59	392	2.59	386	2.59	386	2.59
26	316	2.50	318	2.50	268	2.43	294	2.47	328	2.52	314	2.50
27	472	2.67	446	2.65	376	2.58	368	2.57	452	2.66	452	2.66
28	406	2.61	410	2.61	376	2.58	344	2.54	356	2.55	354	2.55
29	426	2.63	430	2.63	398	2.60	398	2.60	380	2.58	380	2.58
30	442	2.65	442	2.65	428	2.63	428	2.63	440	2.64	438	2.64
31	420	2.62	420	2.62	392	2.59	390	2.59	374	2.57	376	2.58
32	376	2.58	376	2.58	350	2.54	360	2.56	352	2.55	352	2.55
33	454	2.66	452	2.66	436	2.64	428	2.63	378	2.58	378	2.58
34	386	2.59	386	2.59	380	2.58	376	2.58	382	2.58	378	2.58
35	456	2.66	458	2.66	430	2.63	430	2.63	420	2.62	420	2.62
36	400	2.60	418	2.62	458	2.66	458	2.66	426	2.63	426	2.63
37	354	2.55	356	2.55	392	2.59	392	2.59	348	2.54	354	2.55
38	324	2.51	324	2.51	420	2.62	410	2.61	394	2.60	398	2.60
X	396.7	2.6	398.1	2.6	393.9	2.6	395.0	2.6	404.2	2.6	404.5	2.6
SD	49.8	0.1	49.6	0.1	39.3	0.0	38.0	0.0	33.2	0.0	33.9	0.0
Covar	12.5%	2.2%	12.5%	2.2%	10.0%	1.7%	9.6%	1.6%	8.2%	1.4%	8.4%	1.4%

MLA3 = P300 latency in steady state, on Fz location

MLA4 = P300 latency in steady state, on Cz location

MLB3 = P300 latency in speed maximizing task, on Fz location

MLB4 = P300 latency in speed maximizing task, on Cz location

MLC3 = P300 latency in count and accuracy maximizing task, on Fz location

MLC4 = P300 latency in count and accuracy maximizing task, on Cz location

Table 2: P300 Amplitude (and logarithmic transformation)

No	AA3 (uV)	log AA3	AA4 (uV)	log AA4	AB3 (uV)	log AB3	AB4 (uV)	log AB4	AC3 (uV)	log AC3	AC4 (uV)	log AC4
1	11.00	1.04	12.10	1.08	19.10	1.28	19.60	1.29	3.57	0.55	5.68	0.75
2	7.24	0.86	11.70	1.07	12.10	1.08	15.70	1.20	10.00	1.00	9.17	0.96
3	5.05	0.70	4.24	0.63	9.77	0.99	9.01	0.95	7.42	0.87	6.74	0.83
4	15.70	1.20	15.90	1.20	9.01	0.95	12.80	1.11	11.60	1.06	12.50	1.10
5	11.70	1.07	16.90	1.23	9.84	0.99	15.00	1.18	15.60	1.19	22.60	1.35
6	10.70	1.03	14.50	1.16	21.30	1.33	25.10	1.40	25.30	1.40	30.70	1.49
7	6.74	0.83	6.67	0.82	2.68	0.43	5.91	0.77	7.58	0.88	7.58	0.88
8	5.81	0.76	7.06	0.85	10.80	1.03	8.33	0.92	7.42	0.87	4.74	0.68
9	12.40	1.09	17.70	1.25	5.08	0.71	8.93	0.95	9.24	0.97	15.70	1.20
10	7.81	0.89	10.60	1.03	13.00	1.11	16.90	1.23	17.80	1.25	19.60	1.29
11	10.80	1.03	12.10	1.08	19.80	1.30	22.80	1.36	20.40	1.31	24.10	1.38
12	7.06	0.85	10.50	1.02	7.24	0.86	8.65	0.94	8.49	0.93	9.84	0.99
13	9.14	0.96	12.70	1.10	13.20	1.12	14.90	1.17	27.60	1.44	31.60	1.50
14	30.70	1.49	24.20	1.38	9.51	0.98	16.20	1.21	9.40	0.97	13.60	1.13
15	7.34	0.87	8.23	0.92	11.80	1.07	22.70	1.36	14.50	1.16	21.40	1.33
16	4.51	0.65	5.05	0.70	10.20	1.01	11.10	1.05	10.00	1.00	10.10	1.00
17	3.33	0.52	3.93	0.59	8.07	0.91	8.49	0.93	11.70	1.07	10.20	1.01
18	8.65	0.94	9.32	0.97	13.20	1.12	14.10	1.15	21.30	1.33	20.80	1.32
19	15.90	1.20	14.60	1.16	18.40	1.26	14.80	1.17	20.70	1.32	23.00	1.36
20	4.74	0.68	5.55	0.74	3.75	0.57	4.01	0.60	13.40	1.13	19.50	1.29
21	5.08	0.71	5.31	0.73	10.40	1.02	11.30	1.05	13.20	1.12	14.60	1.16
22	5.42	0.73	6.09	0.78	6.59	0.82	8.26	0.92	8.93	0.95	9.82	0.99
23	13.50	1.13	15.90	1.20	14.50	1.16	17.10	1.23	10.20	1.01	11.50	1.06
24	6.56	0.82	11.30	1.05	4.82	0.68	6.30	0.80	6.98	0.84	8.49	0.93
25	7.89	0.90	9.32	0.97	8.41	0.92	16.30	1.21	9.40	0.97	15.40	1.19
26	5.83	0.77	10.30	1.01	24.20	1.38	28.90	1.46	13.70	1.14	13.60	1.13
27	7.32	0.86	7.58	0.88	13.80	1.14	20.40	1.31	15.20	1.18	20.40	1.31
28	7.97	0.90	6.67	0.82	6.43	0.81	7.24	0.86	7.76	0.89	14.80	1.17
29	10.70	1.03	17.90	1.25	14.60	1.16	19.10	1.28	11.90	1.08	16.20	1.21
30	6.90	0.84	10.00	1.00	10.80	1.03	12.10	1.08	19.10	1.28	26.10	1.42
31	6.41	0.81	11.60	1.06	12.40	1.09	15.40	1.19	8.31	0.92	12.50	1.10
32	9.06	0.96	10.30	1.01	11.20	1.05	13.20	1.12	19.20	1.28	20.20	1.31
33	9.38	0.97	8.23	0.92	15.60	1.19	18.20	1.26	9.92	1.00	6.74	0.83
34	25.70	1.41	28.20	1.45	28.80	1.46	28.80	1.46	7.73	0.89	13.80	1.14
35	15.20	1.18	18.60	1.27	20.30	1.31	16.60	1.22	25.40	1.40	26.70	1.43
36	8.72	0.94	13.00	1.11	16.30	1.21	22.30	1.35	12.50	1.10	16.60	1.22
37	7.40	0.87	11.50	1.06	3.67	0.56	8.91	0.95	3.07	0.49	6.74	0.83
38	6.90	0.84	10.40	1.02	16.30	1.21	18.20	1.26	10.80	1.03	11.80	1.07
X	9.53	0.93	11.47	1.02	12.29	1.04	14.83	1.13	12.80	1.06	15.40	1.14
SD	5.39	0.20	5.22	0.20	5.79	0.23	6.13	0.20	5.91	0.21	6.93	0.21
Covar	56.5%	21.1%	45.5%	19.4%	47.1%	22.2%	41.3%	17.5%	46.2%	19.7%	45.0%	18.2%

AA3 = P300 amplitude in steady state, Fz location
AA4 = P300 amplitude in steady state, Cz location
AB3 = P300 amplitude in speed maximizing, Fz location
AB4 = P300 amplitude in speed maximizing, Cz location
AC3 = P300 amplitude in count and accuracy maximizing, Fz location
AC4 = P300 amplitude in count and accuracy maximizing, Cz location

Table 3: *Digit span score*

Subject	forward	backward	score
1	7	6	13
2	8	6	14
3	8	4	12
4	5	4	9
5	8	5	13
6	7	4	11
7	6	4	10
8	8	5	13
9	6	4	10
10	6	5	11
11	7	3	10
12	6	5	11
13	7	3	10
14	6	4	10
15	6	5	11
16	6	4	10
17	6	5	11
18	6	5	11
19	6	4	10
20	6	4	10

Table 3: Digit span score

Subject	forward	backward	score
21	6	5	11
22	7	3	10
23	7	5	12
24	6	5	11
25	7	6	13
26	6	4	10
27	8	4	12
28	6	5	11
29	7	3	10
30	9	3	12
31	6	4	10
32	7	3	10
33	7	5	12
34	6	4	10
35	6	5	11
36	7	5	12
37	8	4	12
38	7	3	10
X	6.7	4.3	11.0
SD	0.86	0.87	1.16
Covar	13%	20%	11%

Table 4. correlations of P300 latency, P300 amplitude, and digit span

Task	Electrode Location	Latency	Amplitude	Latency vs amplitude		Latency vs digit span		Amplitude vs digit span	
				r	α	r	α	r	α
Steady state	Fz	MLA3	AA3	0.158	0.343	0.058	0.729	-0.160	0.339
	Cz	MLA4	AA4	0.057	0.733	0.049	0.768	-0.110	0.510
Speed maximizing	Fz	MLB3	AB3	-0.031	0.855	0.145	0.374	0.047	0.779
	Cz	MLB4	AB4	-0.074	0.661	0.085	0.617	0.070	0.676
Count and accuracy maximizing	Fz	MLC3	AC3	0.345(*)	0.034	0.157	0.318	0.157	0.318
	Cz	MLC4	AC4	0.267	0.105	0.162	0.331	0.162	0.331

*correlation is significant at the 0.05 level (2-tailed)

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