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POST-TASK CHANGES IN VISUAL P300 AND THEIR REVERSIBILITY THROUGH BRIEF HYPERVENTILATION

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Abstract : Long hours of continuous, mental task reportedly increase the average auditory P3 latency of the normal subjects significantly, a change that is thought to be related to mental fatigue. We have tried out several protocols of varying task difficulty and duration in an effort to study the onset of the assumed fatigue-related changes. The present study shows that changes in visual event-related potential occur in less than two minutes if the task is sufficiently rigorous. The changes occur both in latency and in amplitude. Moreover, the changes are reversible with a brief (30 second) period of hyperventilation. The changes were most marked at Fz. Following the difficult task, the P3 amplitude at Fz decreased from 8.588μV ± 0.966 to 5.800μV ± 0.795 and the P3 latency increased from 368 ± 4 ms to 380 ± 3. Following hyperventilation, the P3 amplitude at Fz reverted to 8.457 ± 5 and the P3 latency reverted to 371 ± 5 ms. These observations call for further investigations on the cause of the post-task changes and their quick reversibility.

Key words : event-related potentials task difficulty
mental fatigue hyperventilation

INTRODUCTION

Event-related potentials (ERP) are useful as an index of cognitive functions in both health and disease (1–3). These potentials are mostly elicited with a two-stimuli discrimination task, commonly known as the odd-ball paradigm. The subject is asked to distinguish between two stimuli, one of which is frequent and is to be ignored, and the other infrequent or target which is to be either counted or responded to with button-pressing. The response to the infrequent, target stimulus is consistently associated with a positive brain potential in the electroencephalogram that is recorded simultaneously. This positive wave, after it is enhanced through averaging, is called the P3 wave as it occurs roughly 300 ms after the presentation of the target stimulus.

Numerous studies have studied the factors, specially various stimulus paradigms, affecting the P3 characteristics. However, there is only one reported study on the effect of fatigue on P3 (4). In that study, fatigue was produced by six hours of mental calculating task. The ERP

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parameters were studied in auditory mode and correlated with subjective fatigue symptoms and plasma catecholamine levels. Since then, we have tried to observe how a difficult task (hereafter called the 'challenging' task) affects the characteristics of the P3 recorded immediately thereafter. In doing so, we have experimented with different durations of the challenging task, the modality of the challenging task (both auditory and visual) and the modality of the oddball stimulus (auditory and visual). In the present experiments, we have reduced the duration of the challenging (visual) task markedly, to less than 2 minutes and noted the changes in visual P3 recorded immediately after the challenge task. Furthermore, we have tried to reverse those changes through hyperventilation.

MATERIALS AND METHODS

Continuous 3-electrode encephalogram were recorded using NuAmps® and SCAN® (Neuroscan labs) in 10 intelligent and motivated subjects (all males between the age 19 and 26 years) while they performed psychometric tasks generated through STIM®. The sample size was constrained by the availability of subjects (undergraduates and postgraduate medical students) who would were willing to spare one-hour for the recording in between classes. The task comprised identifying and pressing a button on seeing a blue circle (1 cm diameter) on the screen. The blue circle (target) appeared with a probability of 0.1 intermixed with other (non-target) geometrical shapes of different colors. Although higher stimulus probability (0.2) is recommended, we have used 0.1, hoping to record bigger P3 waves. The only drawback was that the duration of recording had to be increased appropriately for obtaining 40 eprochs. Two types of task-protocols, differing mainly in the rate of stimulus delivery, were used. In the 'slow' protocol, interstimulus interval was 0.70s and the duration of stimulus presence on the screen was 0.1s. The respective values in the 'fast' protocol were 0.35s and 0.02s. The target stimulus presented itself in a pseudorandom sequence and the random seed number for the stimulus protocol was different in each session. The experiment was divided in four successive sessions. Sessions A, C and E comprised the slow protocol. Session B contained the fast protocol. Session D consisted of a 30 second period of hyperventilation (See Table I). Each session began immediately after the preceding session. The time lapse between the sessions was due to the few seconds required to load the programs (from slow to fast stimulation mode).

The EEG was recorded with chlorided silver electrodes from three standard midline scalp locations (Fz, Cz and Pz) of

TABLE I : Sequence of test protocol. Each session followed the preceding session as quickly as possible, usually 15 to 30 seconds.

Session-A	Stimulus presented at SLOW rate. The ERP recorded is called PRE-TASK ERP.
Session-B	Stimulus presented at FAST rate. The task of responding by pressing the button immediately is called CHALLENGE TASK or simply, THE TASK. The ERP was not recorded.
Session-C	Stimulus presented at SLOW rate. The ERP recorded is called POST-TASK ERP.
Session-D	Hyperventilation for 30 seconds. The ERP was not recorded.
Session-E	Stimulus presented at SLOW rate. The ERP recorded is called POST-REST ERP.

the 10–20 International System, all referred to the right mastoid electrode. Linked mastoid (recommended) could not be used as reference due to a defect in the electrode designated for the left mastoid. However, since the experimental design sought comparisons electrode-for-electrode, it was felt that taking right mastoid as reference would not affect the results. The impedance was kept below 5 kOhms. The amplifiers were set to a high frequency cut-off of 40 Hz. The EEG was sampled continuously at 500 Hz. Eye movements (EOG) were recorded from above and below the right eye. Ocular artifact reduction algorithm was applied to the EEG to eliminate ocular artifacts. The continuous EEG were segmented into 1000 mS epochs, starting 200 ms before target stimulus delivery and ending 800 mS after it. Each session of continuous EEG yielded 43 epochs. Regardless of the correctness of the subject response to these stimuli, the epochs were averaged, synchronizing the stimulus point. The averaged potentials for non-target stimuli are derived separately and subtracted from the averaged response to target stimulus. The group averages of the amplitude and latency of the ERP were calculated separately for sessions A, C and E, electrode-for-electrode, and the paired t-test (2-tailed) was applied for evaluating the significance of the mean difference between the ERP parameters of session A and C, as well as sessions C and E.

RESULTS

The results of the study are summarized in Tables II and III which gives the amplitude and latency changes in the visual P3 respectively. Each P3 waveform was obtained by averaging 43 epochs on an average. Occasionally, one or two epochs had to be rejected due to the presence of unknown artifacts but the total number of epochs always remained above 40. There was hardly any error during the slow tests and nearly all subjects responded correctly on all trials. As expected, the amplitude tends to increase and the latency tends to decrease progressively from Cz to Pz. Following the challenge task, there is a consistent reduction in P3 amplitude at each electrode. The reduction was maximum (2.788 μV) and significant ($P<0.01$) in the Fz electrodes. The prolongation in P3

TABLE II : Visual P3 amplitude and latency (mean, SD and SE) at Fz, Cz and Pz during different recording sessions.

	Recording sessions	*Mean amplitude*	*Std. Deviation*	*Std. Error Mean*	*Mean latency*	*Std. Deviation*	*Std. Error Mean*
Fz	Pre-task	8.588	3.055	0.966	368	14	4
	Post-task	5.800	2.516	0.795	380	17	5
	Post-rest	8.457	2.406	0.761	371	16	5
Cz	Pre-task	8.928	2.579	0.815	364	20	6
	Post-task	7.775	4.686	1.482	376	22	7
	Post-rest	9.890	2.608	0.825	377	20	6
Pz	Pre-task	8.714	3.185	1.007	350	23	7
	Post-task	8.275	2.643	0.836	361	28	9
	Post-rest	9.515	2.491	0.788	359	22	7

TABLE III : P-values obtained through Student's t-test for comparison of means (P3 amplitudes and latencies).

	Significance (2-tailed) of mean amplitude difference (df=9)	*Significance (2-tailed) of mean latency difference (df=9)*
Fz(pre-task) – Fz(post-task)	0.002	0.004
Fz(post-task) – Fz(post-rest)	0.000	0.016
Cz(pre-task) – Cz(post-task)	0.379	0.011
Cz(post-task) – Cz(post-rest)	0.154	0.942
Pz(pre-task) – Pz(post-task)	0.633	0.000
Pz(post-task – Pz(post-rest)	0.166	0.619

latency (12.1 ± 3.8) too was significant (P<0.01) at Fz but the maximum prolongation occurred at Cz (12.8 ± 3.2). Following hyperventilation, these changes showed a tendency to revert to their pre-task levels. The restoration, in terms of amplitude, was near complete in all the leads, and actually surpassed the pre-task level at Cz and Pz. However, when compared to the post-task level, the change was significant only at Fz. The restoration in terms of latency was significant only at Fz. The mean reaction time was 327 ± 51 ms before task, 340 ± 55 ms after task and 335 ± 52 ms after rest. The prolongation was however not statistically significant. A typical P3 record obtained is shown in Fig. 1.

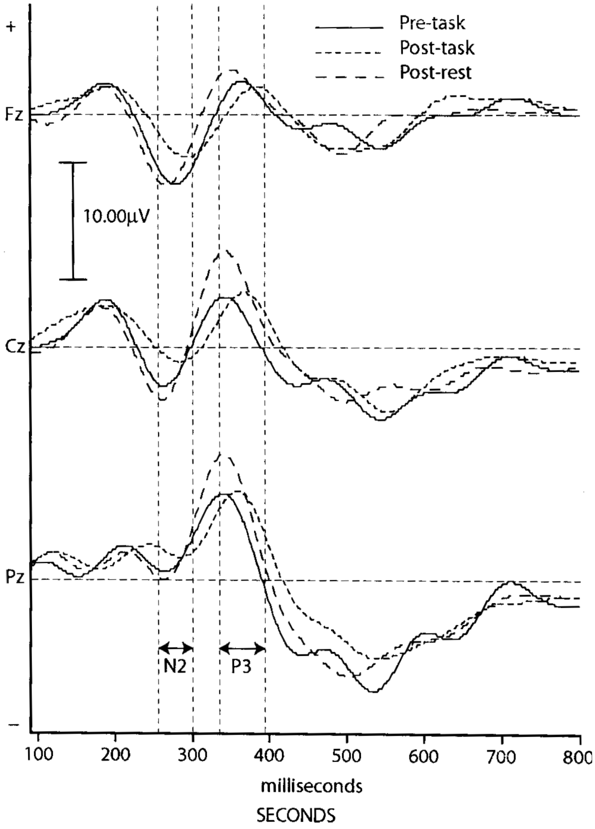

Fig. 1 : Visual P3 recorded from a subject (26 year male) from three midline electrodes Fz, Cz and Pz. Three records obtained in three different sessions (pre-task, post-task and post-rest) have been superimposed (using the pre-stimulus baseline) to show the changes associated with task and rest. The latency changes (described in text) are consistent at all the three electrode sites. The post-task reduction of amplitude however is apparent only if one considers the peak-to-peak voltage.

DISCUSSION

The design of the present experimental protocol was arrived at on the basis of a series of past experiments, wherein several different types and duration of 'challenging task' were experimented with. The search was for the briefest challenge-task that would consistently induce post-task changes. Several considerations shaped the stimulus paradigm. First, we wanted the stimulus protocol to be identical throughout, except for its speed, so that the subject was familiar with the protocol and did not have queries in the middle of the experiment. This was important since little time was to be wasted in between sessions in giving instructions to the subject. Second, we wanted to ensure that the ‘challenge task’ was not so difficult that subjects got demotivated or gave up midway. A random interstimulus-interval made the task too difficult when run at a high speed. Since a constant interstimulus interval would be expected to lower the P3 amplitude, the target probability was reduced from the usual 20% to 10% to compensate.

In our experiments, the P3 was not recorded during the challenge task. Initially, the P3 during the challenge task were recorded and analyzed and it was found that the amplitude was very low. In fact, the wave was nearly flat. It is known that the P3 amplitude decreases with task difficulty (5, 6) but the speed and difficulty level of the challenge task in our study seems to have dwarfed the P3 greatly. Hence, we stopped recording it any further. The following discussion relates only to the P3 characteristics before and after the challenge task, as well as after hyperventilation.

Similar changes as observed in our study (P3 latency prolongation) have been reported in earlier work too, but in a different context. The first of them was by Kasada et al. (4) who reported the after-effects of 6 hours of continuous mental arithmetic, hoping that the changes would signify fatigue. However, the ERP changes recorded did not show significant correlation either with the subjective symptoms of fatigue or with blood concentrations of catecholamines. Their only reason for concluding that the ERP changes were fatigue related was that the subjects reported subjective symptoms of fatigue at the conclusion of the 6-hour task. A year later, we reported a similar post-task prolongation of auditory P3 latency (7) but on an entirely different premise, that the changes were related to the I.Q. of the subjects. The task comprised a 10-minute session in which the subjects repeated in reverse order strings of digits read out to them. We argued that since the latency was prolonged more in the more intelligent subjects, fatigue was an unlikely cause of the changes. Subsequently, we repeated the experiments using both auditory challenge task (same as before) as well as visual challenge task (8). The visual task consisted of 10 minutes of reading laterally inverted text. Although not validated statistically, the changes were again attributed to difference in mental ability, with those who performed better in the challenge task generally showing a greater P3 latency prolongation. Based on the substantial literature reporting I.Q.-dependent P3 changes, a hypothesis was proposed that sought to reconcile some of the contradictory past observations on P3-I.Q relationship (9). The post-task changes were next studied in the visual P3 on a larger series of 22 subjects (10). It was observed that following a visual challenge task (mental rotation of shapes) for 10 to 15 minutes, the P3 latency increased in most but also decreased in a few. It was however increasingly felt during the course of these experiments, many of them unreported, that the changes that were being observed were occurring in the first minute itself of the challenge task and that the later part of the task was largely redundant in inducing further P3 changes. Moreover, since the latency changes were bidirectional, probably there were two underlying causes that were pushing the ERP parameters in opposite directions and that had to be resolved. We assumed that the effect of a challenge task is the outcome of a variable susceptibility of different subjects to general alertness or fatigue, or even some other factors like ‘mental ability’. We therefore made two changes in the experimental design: first, we made the challenging task difficult but brief, hoping to elicit only one type of response; and second, we added hyperventilation to the protocol to reverse the changes, whatever they were, hoping that a consistent reversal would prove that the changes were for real. Hyperventilation was tried out for reversing the post-task changes because it was one of the options available for diverting the brain from any mental activity and was preferred hoping that the light-headedness caused by it would minimize any mental activity. Moreover, as compa red to relaxation techniques, hyperventilation is a more objective procedure and better defined physiologically.

The changes described above are interesting because of at least two reasons. First, the time course of the changes are quite short, considering that the post-task changes, that are highly significant at Fz, take only two minutes to develop. In the same way, the changes get restored to the pre-task level equally promptly in 30 seconds. Second, although the changes are seen at all the midline electrodes, that they are highly significant at Fz and not statistically significant at others suggest that the post-task effects are most marked and consistent in the frontal lobe.

Although mental fatigue remains one of the possible causes of the post task changes observed in our study, that is by no means certain. There is no statistically significant prolongation of the reaction time (pre-task = 0.324 ± 0.044, post-task = 0.336 ± 0.042 and post-rest = 0.332 ± 0.035), which goes against fatigue as a cause. Moreover, any fatigue observable in the reaction time could be a motor fatigue brought about by the brisk button-pressing during the challenge task. Moreover, it seems unlikely that a two-minute task can cause fatigue since real-life situations often demand much more intense and prolonged stretches of mental activity. It could be possible that the challenge-task triggers the entry of the brain into a ‘cognitive mode’ and that the observed changes are a reflection of the same (9). The generators for the P3 response are located in multiple brain regions including inferior parietal lobule, frontal lobe, hippocampus, medial temporal lobe, locus ceruleus (11), and the fact that the changes are most prominent in the frontal lobe, which is known to be involved in deep thinking, could be because the challenge task draws most upon the frontal lobe functions, affecting the P3 recorded subsequently.

The reversibility of the changes through hyperventilation may be due to a restoration of the brain to a relaxed mode. However, the same cannot be concluded with certainty through the present experiments and it is possible that the reversibility of the post-task changes were simply due to their fading away with time. However, the results we have obtained makes 'fading away' an unlikely possibility because in Cz and Pz, the amplitude of P3 after hyperventilation overshot the pre-task P3 amplitude. Certain reported changes (12, 13) in auditory evoked potentials during menstrual cycle, notably, the shortening of the latencies of P2 and N2 in the mid-luteal phase only, could be due to the slight hyperventilation caused by higher level of progesterone. Hence, regardless of the cause(s) of the post-task changes, the results our study underlines the importance of the immediate task history (specially, excessive mentation) when experimenting with parameters related to P3 latency and amplitude. Further experiments, incorporating randomization of stimus protocol, would be required for ascertaining the causes of the observed changes.

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