CHARACTERISTICS OF EVENT RELATED POTENTIALS ELICITED BY TRAINS OF TEETH CLENCHING IN HUMANS

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Abstract
Event related potentials were recorded on the human scalp during a foot pedal task, a hand gripping task, and a teeth clenching task. These were carried by targeting four trains of clicks, each at an interval of 1 sec, which were repeated 20 times at random frequencies. The brain potentials were recorded from midline-frontal (Fz), -central (Cz) and -parietal (Pz) sites using surface electrodes. Positive potentials like P3 were elicited predominantly at the frontal site (Fz); those for the clenching task were slower and smaller. The magnitudes of the P3 potentials showed rough facilitation with trains of movement of the tasks. If it is assumed that the observed potentials involve an inhibition or reset of motor neurons referring to the tasks, the facilitation might be expedient for the neurons to recover the potential condition more quickly, which is important in preparing for the next action.

Key words: ERP—P3-like potential—Clenching—Facilitation—Human brain

INTRODUCTION
It has been widely reported that the human brain generates event related potentials (ERPs) which are recorded as positive-negative wave forms on the scalp. Each wave form is complex, but three components are roughly classified as the endogenous potentials; a contingent negative variation (CNV), which is a slowly increasing negative potential preceding an expected stimulus; a positive potential peaking about 300 msec after task-relevant stimuli (P3); and a long slow wave (SW), which is positive and peaks between about 500–700 msec. Because the P3 (more precisely, the P3b) is especially obvious and easily recorded, it has been studied in many types of paradigms since the first report by Sutton et al.17,18. The P3 potential, which is popularly accepted to reflect the cognition of events in the mental process, is recorded mainly at the midline of the human scalp and is generally known not to depend on physical stimulus properties, such as modality...
or intensity, but on the context of the task\textsuperscript{(14–16)}. In the dental field, there have been no reports on the P3 potential for jaw movements. Therefore, in this paper, we examined how the P3 potential is elicited during a teeth clenching task, and compared the results with those during a simple tasks by the hand and foot.

The ERPs are usually studied by averaging each potential elicited by a number of repetitive tasks. The signal-averaging technique is useful to thoroughly observe the characteristics of the potentials through a trial sequence, but it is difficult to describe the aspects of any changes in the wave form that may happen with repetition. It is probable that the cognition of any type of event is more or less affected by preceding experiences or actions. From this respect, in the present experiment, a paradigm of repeating trains of the clenching was used to examine whether the ERPs change or not with the repetition.

MATERIALS AND METHODS

Experiments were conducted in accordance with the policies and principles in the Declaration of Helsinki. Fifteen healthy subjects, eight male and seven female, aged 18 to 48, were examined in this study. Only subjects who did not blink during pre-tests were selected to avoid contaminating EOG artifacts in the EEG recordings. In the clenching task, a small silicon chip was clenched by the incisor teeth (The use of the incisor teeth could minimize EMG artifacts of the temporalis muscles more than the use of the molar teeth). For comparison, tasks of gripping a rubber ball in the palm of the right hand and pushing a pedal switch with the right foot were also conducted. In this study, these are respectively called the teeth clenching task, the hand gripping task and the foot pedal task. Click sounds of square pulse, a duration of 2 msec and an intensity of about 60 dB (SPL), were binaurally delivered via earphones as the target stimuli, and the subjects were instructed to perform a task as fast as possible. Four trains of target clicks, each at intervals of 1 sec, were repeated 20 times with a random frequency of 0.08–0.12 Hz. The subjects closed their eyes during the experiments, and all experiments were carried out in a dimly lit silent room.

The brain potential was recorded from Fz, Cz, and Pz on the scalp using conventional disc electrodes. The reference electrodes were placed on the right and left ear lobes. The potentials were amplified through a filter ranging from 0.5 to 100 Hz (−3dB, −6dB/oct), converted to a digital figure, and then, processed by a computer system. Muscle activities on the right side referring to the tasks were also recorded simultaneously; these were amplified and rectified bipolarly. They included the masseter muscle for the teeth clenching task, the flexor carpi ulnaris muscle for the hand gripping task, and the gastrocnemius muscle for the foot pedal task. The brain potentials and the electromyograms (EMGs) were averaged 20 times (The rectified EMGs were not integrated because they were smoothed through the averaging process). Each task series of recordings was conducted two times and the better record with respect to noise and potential height was adopted. Peak to peak height and the peak latency from the target click were calculated; the height was expressed as relative value to that (100) for the foot pedal task at the fourth click. If the potential shaped a plateau, the values were calculated at the point that seemed to be the middle.

RESULTS

It is well known that the ERPs strongly depend on mental condition or psychological factors. In this study, obvious potentials were obtained from 12 of 15 subjects; those of the others were too small to discriminate or were incomplete throughout the three task series. Fig. 1 shows averaged recordings of a male subject (28 years) for four trains in the foot pedal task (A), the hand gripping task (B), and the teeth clenching task (C) at Fz, Cz, and
Fig. 1 Averaged P3-like potentials at Fz, Cz, and Pz for four train movements in a food pedal task (A), a hand gripping task (B), and a teeth clenching task (C) of one subject. The four pulses of the lowest trace in each record indicate the onset of target click sound, and the following upward deflection is the averaged rectified EMG of the corresponding muscle referring to the task. *-mark in the record for the teeth clenching task shows an EMG artifact of the temporal muscle. •: P3-like potential, Τ: CNV, ⋄: SW, ⋄: click signal.
In the records of the foot pedal task and the hand gripping task, positive potentials were elicited at around 250 msec after each target click, which were prominent mostly at Fz. In the record of the teeth clenching task, a positive potential was also elicited at Fz.
although it was small and slow. In this experimental paradigm, the largest potential was recorded at Fz in all the other participants. The positive potential is quite similar to a so-called “P3 potential”, however, this is called “P3-like potential” in this paper because the P3 potential has been popularly reported to be the largest at the parietal region (Pz) of the scalp. The so-called “CNV” was observed especially at Fz in the record of the foot pedal task, which started before the second stimulus and lasted to the final stimulus. In both the records of the foot pedal task and the hand gripping task, the so-called “SW” was also observed following the P3-like potential for the fourth click. The CNV and the SW in the foot pedal and hand gripping task were often observed in other subjects, but usually not in only one subject. The positive potential for the teeth clenching task tended to be slow and small in many subjects, but some subjects elicited the potential as prominently as that for the foot pedal or hand gripping task (for example subjects-c, f, and i in Fig. 2).

In the records of Fig. 1, the P3-like potential for the foot pedal task and the hand gripping task tended to develop from the first to the fourth train. The slow positive potential for the teeth clenching task also showed similar development. Although the degree differed among the subjects, this potential development with the trains of task was often observed. Fig. 2 shows changes in the relative height of the positive potential at Fz with four trains of the three types of task in 12 subjects; the graphs are arranged in order of age. The patterns of the potential change show variation with the subjects, but the graphs roughly demonstrate that the potential for the first train was the smallest and for the fourth train was largest in every task. This development tended to be obvious in the subjects who elicited relatively large potentials; the potential magnitude of subjects-f, g, i, was small in every task, and their graphs do not show the obvious development.

The latencies of P3-like potential from the target click for the foot pedal task and the hand gripping task were calculated; they tended to shorten with the trains: means (± SD) for the first to fourth trains in the 12 subjects were 413 (± 125), 393 (± 148), 363 (± 132) and 340 (± 113) msec for the foot pedal task, and 385 (± 135), 364 (± 103), 321 (± 91) and 310 (± 92) msec for the hand gripping task, which were not so different from the data being reported as the P3 latency 3-5,17,18. The values (± SD) for the teeth clenching task were 588 (± 161), 545 (± 131), 543 (± 123), 584 (± 174) msec, but these were not very accurate because the decision of the potential peak was difficult in many recordings.

DISCUSSION

Although there were some exceptions, the main characteristics of the potential for the teeth clenching task were to eventually be smaller and slower than those for the hand gripping or foot pedal task. The simplest assumption is that the potential for the clenching task arises from a deeper area in the brain than that for the hand or foot task. The RC (register-capacity) property of the brain tissue becomes larger with the distance between the potential generating loci and the recording site, which distorts the potential so that it becomes smaller and slower. The area corresponding to mastication is known to be in the lateral inside region of the motor cortex, whereas the areas corresponding to motor functioning of the foot and the hand exist more to the center. Although the source of generation of ERPs, including the P3, has not been completely determined, and the neural mechanism in the generation has not yet been fully explained, the functional topography of the motor cortex may explain the difference in the ERP magnitude to some extent.

The facilitation of the potential with stimulus trains as observed in the present study is not a rare phenomenon by synaptic potentials, but is generally explained as an increase in the amount of neurotransmitters from presynaptic terminals. However, what meanings are there in the facilitation observed in
the present experiment? Some investigators have asserted that P3 potential relates to closure or deactivation of cognitive processing epochs\(^2\,20\). If the potential reflecting the P3 inhibits the activity of neurons of the motor site, the greater the potential, the stronger the inhibitory effect on neurons referring to the tasks. This should be expedient in quick recovery in the potential to the basic (or resting) level, which must be important in preparing for the next action.

An interesting aspect of P3 is the elicitation by an absent stimulus when the event of stimulus absence provides information or is salient for the subject\(^9,12–14,18,21\). Even under such missing stimulus conditions, the potential of motor neurons triggering the task must be adequately adjusted to fully generate action potentials by some endogenous expectancy process. As a result, the potential must return to the basic level, independently of whether the sensory stimulus comes or not. The idea that cell activities reflecting P3 play a recovering role in the potential condition of neurons by an inhibitory process seems to explain this missing stimulus P3 phenomenon well. In the present study, the P3-like potential for the first movement of the trains was generally small, and this suggests that such an endogenous expectancy process was hard to develop in the first movement under the present experimental paradigm.

It is unclear whether the P3-like potential recorded at the frontal site in the present study is a change in the typical P3 or a distinct type of potential generated from a different neural source. It is difficult to determine whether the potential elicited in one paradigm is the same potential observed in another one. However, it has also been reported that positive waves like P3 are elicited predominantly at the midline frontal region in some experimental paradigms; these are named frontal or novelty P3\(^1,7,8,10,11,19,22\). Gemba and Sasaki\(^6\) also reported that neurons in the frontal lobe generate a prominent potential that plays an important role in suppressing motor actions, although it appears as a negative wave on the scalp. In this case, it is certain that the frontal region of the brain plays an important role in cognition of jaw movement and other motor activity.

**REFERENCES**


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