The Journal of International Advanced Otology

Int Adv Otol 2014; 10(1): 14-8 • DOI:10.5152/iao.2014.003

Original Article

Effects of Button Pressing and Mental Counting on N100, N200, and P300 of Auditory-Event-Related Potential Recording

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OBJECTIVE: The aim of this study was to determine the difference in the effects of button pressing and mental counting on N100, N200, and P300 in auditory event-related potential recording when target and nontarget tones are presented in an oddball paradigm.

MATERIALS and METHODS: The subjects were 56 young male adults whose average age was 22.0±2 years. In this study of auditory event-related potential, 2 KHz and 1 KHz tone bursts were used as the target and nontarget stimuli, respectively. The subjects were instructed to press a button with their right thumb when the target stimuli were presented in the first session and with the left thumb in the second session, and to mentally count in the third session.

RESULTS: In first and second sessions, the appearance percentages of P300, N200, and N100 in response to the target stimuli were 90%, 82%, and 98%, respectively. In the third session, the appearance percentages of P300, N200, and N100 in response to the target stimuli were 30%, 40%, and 94%, respectively. The differences in the peak latency and amplitude of P300 between button pressing and mental counting were not statistically significant.

CONCLUSION: Button pressing can elicit an appearance percentage of auditory event-related potential threefold that of mental counting. N200 and P300 could reflect psychological effects but N100 could not.

KEY WORDS: N100, N200, P300, event-related potentials, general attention, selective attention

INTRODUCTION

When the oddball paradigm was used in studying selective attention or cognition electrophysiologically, the P300 of auditory event-related potential (AERP) was observed for the first time by Sutton et al. [1]. Since then, it has been developed as an objective tool by Hillyard et al. [2] and Squires et al. [3] for evaluating perceptive or cognitive ability. Using this oddball paradigm, N100 and N200, as well as P300 are recorded. However, the correlation of these three waves remains unclear.

The purpose of this study was to reveal the different effects of button pressing and mental counting on N100, N200, and P300 in AERP recording when target and nontarget tones are presented. In previous studies, the characteristic features of N100, N200, and P300 were assumed to be sensation originating from the auditory primary cortex [4], preattentive detection [5, 6], and selective attention [5-7], respectively. Our aim in this study was to determine the appearance percentages and the characteristic features of N100, N200, and P300 of AERP in normal subjects performing different tasks and to elucidate the electrophysiological mechanism of central auditory processing.

MATERIALS and METHODS

Subjects

The subjects were 56 young adult males, whose average age was 22.0±2 (range 18-26) years.

Sound Stimuli and Recording

ME2200 (Nihon Koden Co, Tokyo, Japan) was used to generate acoustic stimuli and record AERP. The envelope of sound stimuli was a tone burst of 1-100-1 msec. An oddball paradigm was used to deliver two tone bursts. The target tones, as rare stimuli, were 30

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Submitted: 05.12.2013 **Accepted:** 15.02.2014

stimuli of 2 kHz tone bursts; the nontarget tones, as frequent stimuli, were 120 stimuli of 1 kHz tone bursts. The ratio of nontarget stimuli to target stimuli was 4:1, and 150 stimuli were presented in random order.

The subjects were stimulated binaurally via headphones in the right and left ears at 70 Sound press level (SPL). All the stimuli were delivered at a rate of 1/sec.

Electrophysiological activity was recorded from three different electrode positions at Fz, Cz, and Pz. A ground electrode was placed on the forehead. Impedance was maintained below 3 kΩ. Artifacts were automatically rejected at±60 µV, and a band pass filter was set at 0.5-100 Hz. The eye of grome (EOG) (eye movements) and electromyogropy (EMG) of the right and left thumbs for button pressing were recorded simultaneously.

The subjects were seated in a comfortable chair and instructed to close their eyes but remain awake, and to press a button or mentally count the target tones when the stimuli were heard.

The trial order was as follows: first session, pressing a button with the right thumb for the target stimuli; second session, pressing a button with the left thumb for the target stimuli; and third session, mental counting of the target stimuli.

Analysis of AERP Recording and EOG and EMG of the Thumb
The prestimulus latency was 100 msec and the poststimulus latency was 900 msec. The ground zero µV was defined as the average evoked potential at the prestimulus latency. The average numbers were 30 for the target tones and 120 for the nontarget tones for the AERP of brain waves, and the EOG and EMG of the right or left thumb were recorded simultaneously. Later, offline, the grand average of all the AERP of the 49 subjects for button pressing and the 17 subjects for mental counting was calculated and analysed statistically.

Statistical Analysis
In order to compare P300, N200, and N100 amplitudes/latencies under the combination of target stimulus button pressing and mental counting, SPSS software for statistical test was used for multiple comparisons (Games-Howell). In the test, the peak amplitude/latency of P300, N200, and N100 in the averaged waveform for an individual subject was used as a sample.

RESULTS
The AERP of a 26-year-old male, a representative case, performing three tasks are shown in Figure 1. In button pressing with the right and left thumbs for the target tone, the appearance percentages were 98% for N100, 82% for N200, and 88% for P300. In mental counting, the appearance percentages were 99% for N100, 40% for N200, and 30% for P300. The appearance percentages of N100, N200, and P300

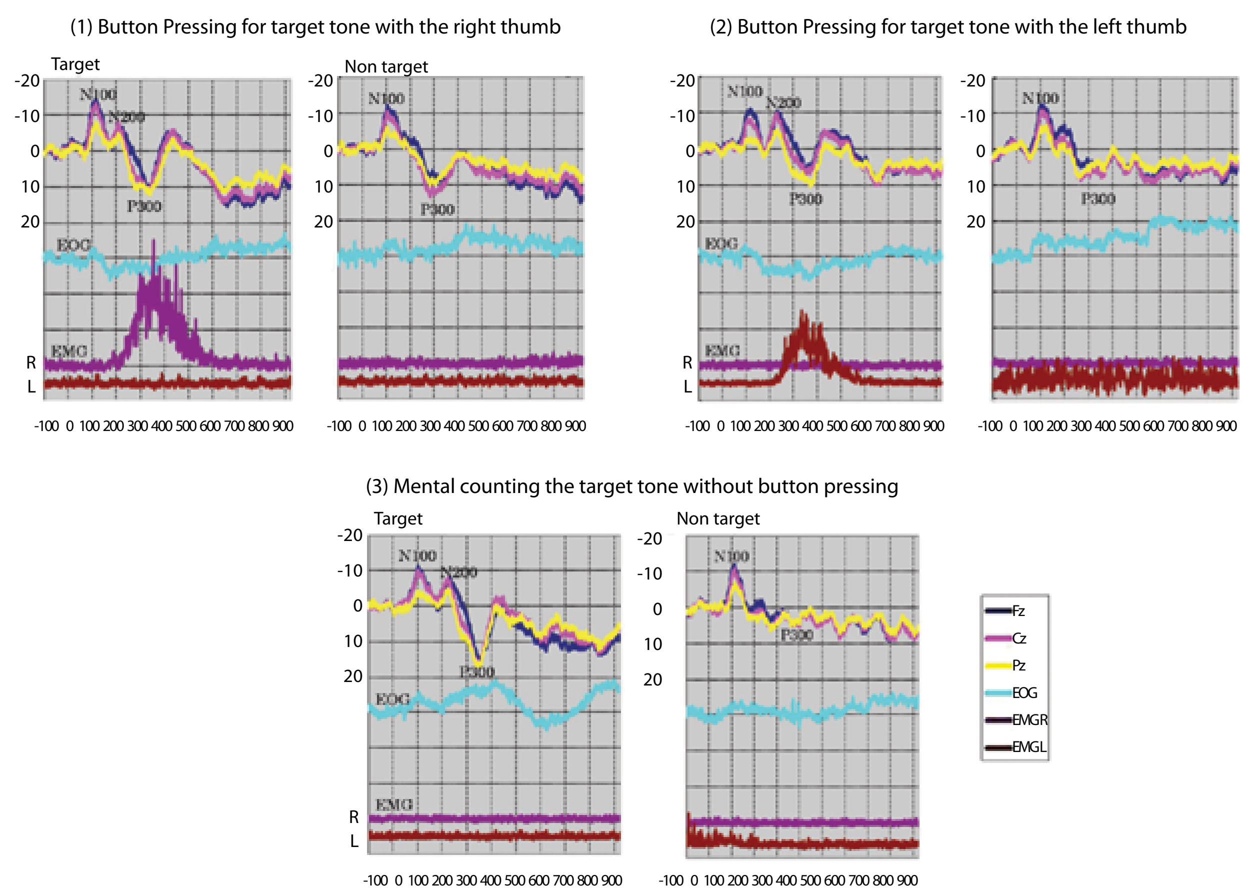

Figure 1. AERP of a 26-year-old male. Fz, Cz and Pz as a representative case. EOG indicates electrooculography and EMG indicates evoked electromyography of the right or left thumb

AERP: auditory event-related potential; EOG: eye of grome; EMG: electromyography for the 56 subjects are summarised in Figure 2. The grand average of the AERP of the target, and nontarget tones and its subtraction from the AERP of the target tone minus the nontarget tone at the Pz electrode in pressing the right and left buttons for 49 subjects and those in mental counting for 17 subjects are shown in Figure 3, of the 56 subjects, 49 for button pressing and 17 for the mental counting had their P300 wave components clearly recorded. Statistical results of multiple comparisons of P300 using SPSS software are summarised in Table 1. Our statistical analysis during the Pz recording [5] revealed significant differences between button pressing and mental counting in N200 and P300, but not in N100.

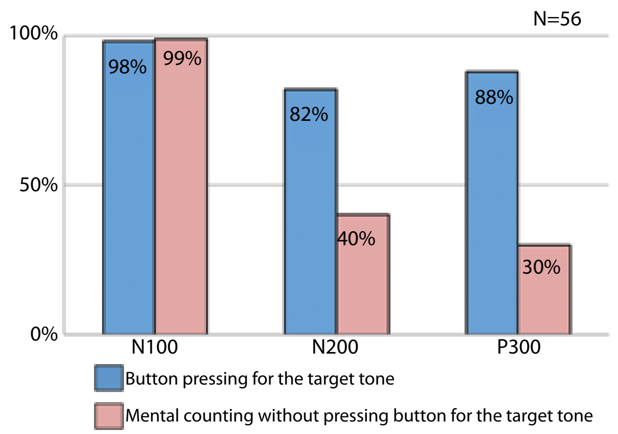

Figure 2. Comparison of appearance percentages of N100, N200, and P300 between button pressing and mental counting for target tone. No difference in appearance percentage of N100 but marked differences in the appearance percentages of N200 and P300 were observed

Subtraction of the AERP from the target tone minus that from the nontarget tone led to the disappearance of N100 but the distinct appearance of N200 and P300. In the three tasks, the amplitude of the target in P300 and N200 was significantly bigger than that of the nontarget but the latency was not significantly different. For the grand average AERP, the P300 amplitude was larger at Pz than at Fz and Cz. Moreover, the latency and amplitude of the AERP of the target tone were not statistically significant between button pressing and mental counting (Table 1). The latency and amplitude of N100 were not significantly different in the three tasks, for both target and nontarget tones.

DISCUSSION

Our study revealed that button pressing and mental counting for the target tone resulted in marked differences in the appearance percentage of N200 and P300 but not N100. In this study, the order of the appearance percentages of button pressing for the target

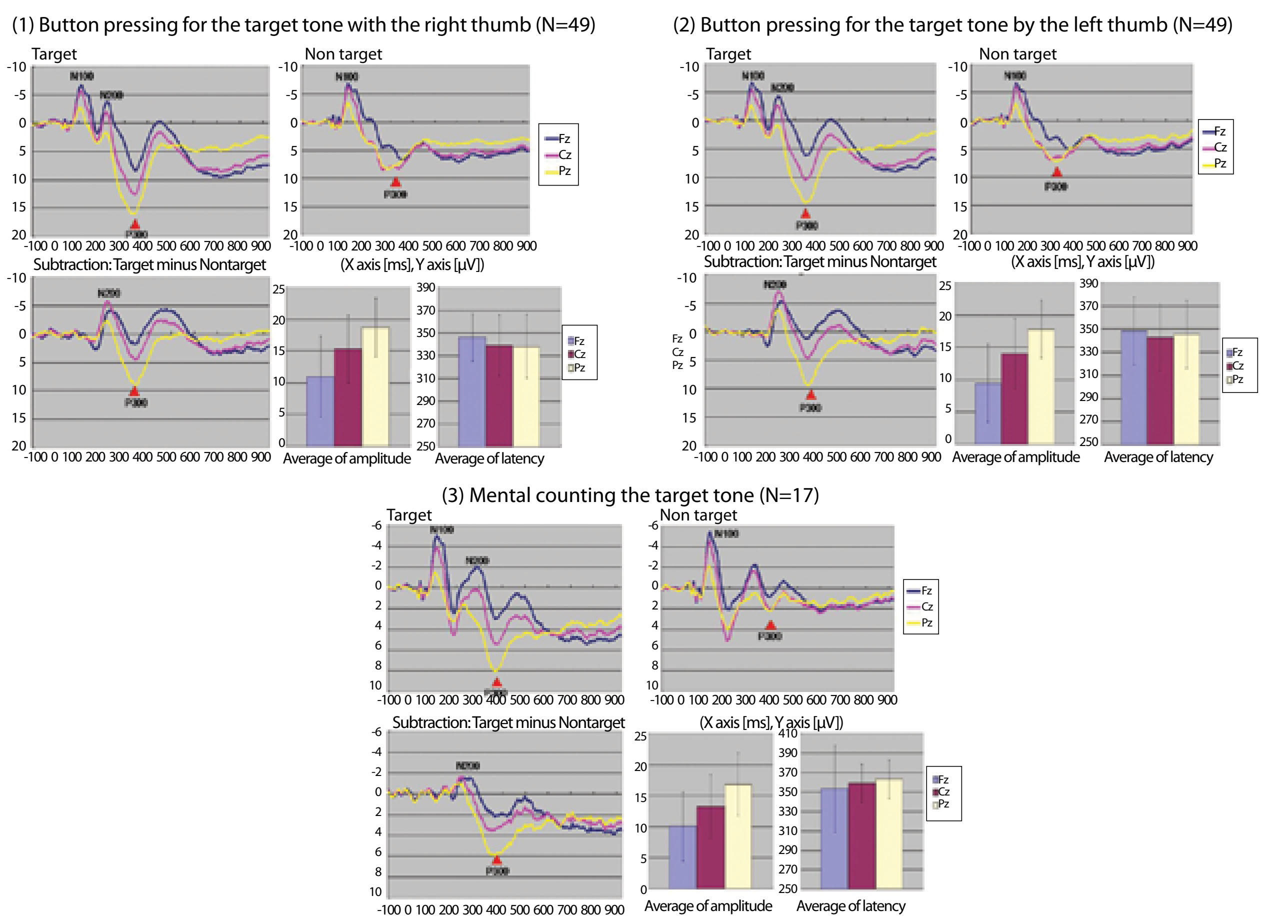

Figure 3. Grand average of AERP of target and nontarget tones and results of subtraction from target minus nontarget potentials of both AERP are shown in the lower-left panel with a bar graph of mplitudes at Fz, Cz and Pz in the lower-right panel in (1), (2) and (3). By subtraction, N100 disappears but N200 and P300 clearly appear as distinct subtracted potentials

AERP: auditory event-related potential

Table 1. Summary of statistics (multiple comparisons [Games-Howell] SPSS) P300 at Pz recording

1. Button pressing: Latency and Amplitude between target and nontarget tones	
(1) Latency	Right: target v.s. nontarget n.s. Left: target v.s. nontarget n.s. Right: target v.s. Left: target n.s.
(2) Amplitude	Right: target v.s. nontarget p<0.01 Left: target v.s. nontarget p<0.01 Right: target v.s. Left: target n.s.
2. Mental counting: Latency and Amplitude	
(1) Latency	Target v.s. nontargetn.s.
(2) Amplitude	Target v.s. nontarget p<0.01
3. Button pressing (target) and mental counting (target): Latency and Amplitude	
(1) Latency	Right: target v.s. mental counting: target p<0.05 Left: target v.s. mental counting: target n.s. Right: target v.s. Left: target n.s.
(2) Amplitude	Right: target v.s. mental counting: target n.s. Left: target v.s. mental counting: target n.s. Right: target v.s. Left: target n.s.

tone was N100 (98%)>P300 (90%)>N200 (83%); on the other hand, that of mental counting for the target tone was N100 (94%)>N200 (40%)>P300 (30%) (Figure 2). The characteristic features of each wave were sensation for N100 [2, 4], preattentive detection for N200 [6-7], and selective attention or cognition for P300 [8-13]. The latency and amplitude of the AERP for button pressing and mental counting did not differ significantly.

The functional abilities and generators of N100, N200, and P300 in the brain have been reported. N100 is involved in general attention, and its generator is regarded as the primary auditory cortex [2, 4]. P300 is involved in selective attention or cognitive ability, and its generators are regarded to be the hippocampus or limbic system and cerebral cortex [8-12]. N200 is involved in preattentive detection and superimposed with mismatch negativity, and its generator, although not known, can be included in the generators of P300 [6, 7, 13, 14]. In our study, it was clear that N200 and P300 were endogenous potentials because even mere mental counting could elicit them well in spite of the low appearance percentages.

Meanwhile, mental counting depends on the subject's concentration, attention, perception, cognition, and memory as positive factors but is easily affected by adaptation, habituation, mental fatigue in attention, and others as negative factors. Thus, the low appearance percentages of N200 and P300 in mental counting could be caused by the influence of negative factors. However, it is very important that mental counting showed a 30% appearance of P300 and a 40% appearance of N200, which were elicited only by the brain's selective attention or cognitive ability. Moreover, it should be emphasised that the grand average of the AERP of P300 and N200 did not differ significantly in latency or amplitude (Table 1).

Button pressing can increase general attention (N100), preattentive detection (N200), and selective attention (P300) through the brain feedback circuit in the auditory and motor systems, and can result in the reinforcement of perceptive and cognitive abilities in auditory information processing in the oddball paradigm. However, the lower appearance percentage for mental counting may have been caused by the lack of a feedback system. In the presence of an operational feedback circuit, mental counting can keep general attention, preattentive detection, and selective attention.

In conclusion, the apperance percentages of N200 and P300 were significantly affected by button pressing and mental counting for the target tone, probably because N200 and P300, but not N100, depend on psychological effects in the limbic system and higher functions. However, our most important finding is that it is possible to elicit endogenous potentials such as N200 and P300 by mental counting only.

Ethics Committe Approval: Ethics committee approval was received for this study from the ethics committee of Utunomiya Hospital/Tochigi, Japan/2013.

Informed Consent: Written informed consent was obtained from patients who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - K.K., T.F.; Design - K.K., T.F.; Supervision - K.K., T.F.; Funding –B.I.; Materials - B.I., N.M.; Data Collection and/or Processing - T.F., N.M.; Analysis and/or Interpretation - K.K., T.F.; Literature Review - K.K., T.F.; Writing - K.K., T.F.; Critical Review - K.K., T.F.; - Other - B.I., N.M.

Acknowledgements: Authors thank Ms. Sekiguchi for secretarial assistance.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study has received no financial support.

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