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The effects of model upper limb position on observer P300 event-related potential

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Summary

Study aim: This study reports on the characteristics of learners' information-gathering processes when receiving visual motor information by examining the influence of differences in model upper limb placement on observer attention.
Materials and Methods: The experiment, which was conducted with seven subjects, consisted of a visual oddball task in which subjects were instructed to push a button corresponding to the target image when it was presented on a screen. Two images were used in the task: a "front" image in which the upper limbs were placed in front of the trunk, and an "outside" image in which the upper limbs were placed outside the trunk. The variables measured were brainwaves during task performance, button push reaction time, and questionnaire responses. Brainwaves were recorded at the Fz, Cz, and Pz electrode sites and event-related potentials at the time of target image presentation were calculated. Grand mean waveforms and mean potentials were also compared for the P300.
Results: Comparisons of P300 amplification grand mean waveforms and mean potentials revealed that amplification was greater in the front condition than in the outside condition.
Conclusion: This finding indicates that differences in model upper limb placement greatly affect observer attention.

Keywords: P300 event-related potential – Upper limb placement – Motor learning.

Introduction

In his social learning theory, Bandura [2, 3] demonstrated modeling, which is the learning of behavior by observing others. Learning through observation is the primary process in learning skills such as movement and sport, where an instructor's example is required.

However, many previous studies on motor learning have focused on examinations of the model's skill level, status, and verbal explanations from the perspective of how instruction is conducted instead of investigating which aspects of presented movements drew learners' attention, or how learners perceive such movements [17, 20]. For example, a study on *kansei* (sensibility) information processing revealed the characteristics of information processing during movement observation [13]. Sakata et al. [13] examined where observers' eyes were directed when observing a dancer's bodily expressions and found that observers often focused on the dancer's fingers and upper limbs. These findings suggest that the upper limbs and fingers frequently convey emotion and will through gestures; therefore, it is conceivable that people tend to place more focus on these movements in order to understand others' emotions in everyday life.

Indeed, upper limb movements not only express emotion, but also perform many day-to-day actions; it has been reported that these movements are perceived differently depending on the space in which they are performed. Studies on the effect of kinesthetic information memory on motor performance [14-16] have demonstrated that upper limb movements performed in front of the trunk are reproduced more accurately than movements performed outside the trunk. This suggests that the space in front of the trunk is strongly related to body part information such as the midline and the shoulders, and is thus perceived more easily. Based on these findings, it is thus conceivable that the characteristics of eye focus reported in *kansei* information processing research and observers' familiarity with movements are involved in learning movements, and that a great deal of attention is focused on the upper limbs because they perform multiple everyday

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movements. Furthermore, as with the space in front of the trunk, movements in spaces strongly related to body part information are expected to not only draw increased observer attention, but also to increase the information processing resources necessary for cognition.

Event-related potentials (ERPs) have been widely used as indicators of the amount of processing resources for visual stimuli. An ERP is the brain potential response to a specific stimulus or event. The positive amplification observed roughly 300 ms following stimulus presentation is called the P300; this amplification has been used to indicate the processing resources necessary for performing tasks and allocating attention to stimuli [4, 5, 7, 9, 19].

Because upper limb movement is the primary factor in bodily activity, clarifying the effects of upper limb placement on learner P300 at the time of movement presentation is expected to yield useful knowledge for both instructors and learners of movement. Therefore, the present study conducted an experiment with stimuli depicting different positions of the upper limbs in relation to the trunk in order to clarify the effects of model upper limb placement on the P300.

Material and Methods

1. Subjects

Subjects for the current study were recruited using an advertisement on the campus bulletin board. The subjects were seven healthy, right-handed female university students with a mean age of 21 ± 0 years. We obtained written informed consent from all the participants of this study, and the research was approved by the local Committee of Ethics.

2. Experimental task

The task used in this study was a visual stimulus reaction time task. Subjects were instructed to press a button quickly in reaction to the target stimuli. Two types of stimuli were used, namely, an image in which the upper limbs were placed within shoulder-width ("front") and an image in which the upper limbs were spread beyond shoulder-width ("outside"; Figure 1). The condition in which the former image was the target was termed the "inside condition," and the condition in which the latter image was the target was termed the "outside condition." Trials for both conditions were conducted 45 times (three sets of 15 trials). The interstimulus intervals were randomized between 4000 and 5000 ms. The presentation frequencies of the standard and target stimuli were 80% and 20%, respectively; these presentations were randomized.

3. Experiment apparatus and electroencephalography (EEG) recordings

EEGs were recorded with a multi-purpose portable bio-amplifier and recording device (Polymate AP 1000, Digitex Lab Co). We attached Ag/AgCl electrodes to the Fz, Cz, and Pz electrode recording sites as described in the international 10-20 system [1]. The reference electrodes attached to both earlobes were unipolar leads, and the time constant was set at 5 s. ERP data [11] for analysis was taken from the Fz, Cz, and Pz midline electrodes. In order to monitor the addition of electrooculogram (EOG) artifacts in the EEG, we also recorded vertical movement in the left eye. The same device was used to record image presentation and button press reaction time. The time constant for the EOG and stimulus signal was set at 0.3 s and sampling time was 5 ms.

4. Experiment procedure

Subjects sat in a chair in a sealed room and received explanations of the experiment procedure and

Front condition **Outside condition**

Figure 1. In the front condition, arms were placed within the shoulder-width and in outside condition, arms were spread beyond the shoulder-width

task. Electrodes were then attached and the task was conducted. When each set was completed, subjects were asked to respond to a two-dimension mood scale [12] and give a self-rated concentration level during the task. The response scale of the latter ranged from 0 (subject could not concentrate at all) to 5 (subject was able to concentrate very well). Subjects were also asked to report their feelings and thoughts during the trials.

5. Data processing

Reaction time was measured as the length of time from target stimulus presentation to button press.

In order to isolate ERP waveforms, we performed signal averaging for each electrode site and condition for each subject for an interval of 1000 ms (from 200 ms before stimulus presentation to 800 ms after stimulus presentation). Trials in which EOG artifact addition was observed were excluded from the averaging, and cases with fewer than 10 valid trials were excluded from further analysis. The P300 component was defined as the maximum positive electric potential that occurred before the 250–500 ms latency range; latency and amplitude were then measured. Baseline amplitude was measured as the average electric potential during a 100 ms interval before stimulus presentation [11].

6. Statistical analyses

Mean and SD were calculated for negative and positive arousal on the two-dimension mood scale [12] and self-rated concentration level. Comparison between conditions was performed with the *t*-test while comparison between the electrode positions in the average potential of P300 amplitude was conducted with analysis of variance (ANOVA).

Results

1. Reaction time

Mean and SD for the button press reaction times for both conditions and for the questionnaire scores are shown in Table 1.

Table 1. Mean (±SD) reaction times (RT), positive arousal score, negative arousal score, and self-rated concentration by condition

	Front	Outside
RT(ms)	430.68 ± 71.5	423.65 ± 77.0
Positive arousal score	3.05 ± 1.8	3.33 ± 1.8
Negative arousal score	–4.62 ± 1.3	–4.33 ± 1.4
self-rating concentration	2.62 ± 0.7	2.62 ± 0.5

1.1 Statistical analysis

Mean and SD were calculated for negative and positive arousal on the two-dimension mood scale [12] and self-rated concentration level. No significant differences were observed in paired *t*-tests for the reaction times of either condition, suggesting no difference in task difficulty between conditions.

In addition, no significant differences were observed between conditions for two-dimension mood scale scores and self-rated concentration levels, confirming through psychological indicators that the two conditions did not differ in level of difficulty.

2. P300 amplitude and latency

Grand average ERP waveforms for each electrode recording site and condition are shown in Figure 2.

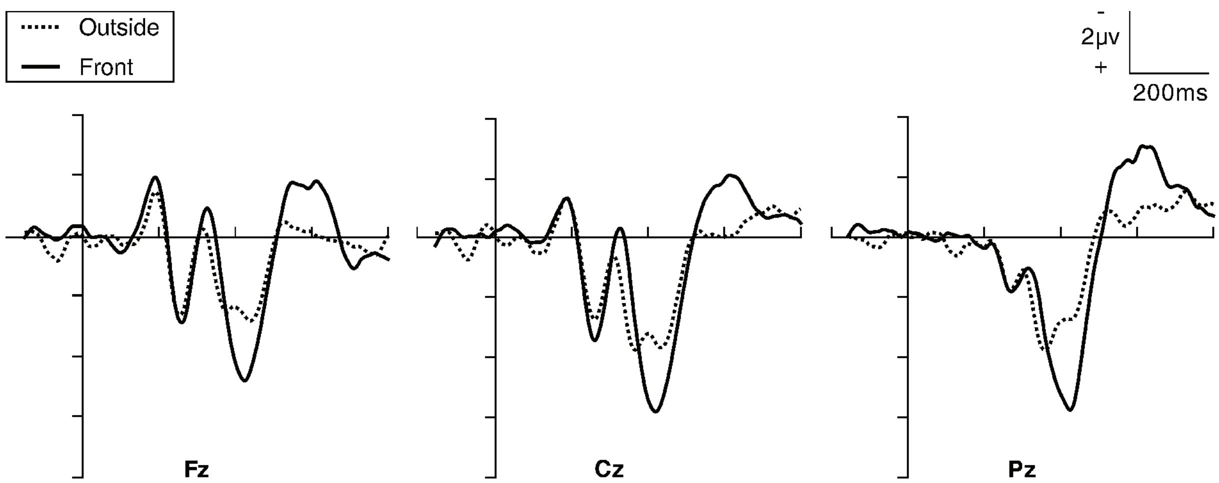

Figure 2. The average P300 waveforms recorded at Fz, Cz, and Pz electrode sites for the outside (dotted line) and front (solid line) conditions

Generally, P300 amplitude and latency were larger for the inside condition than for the outside condition at all electrode recording sites. P300 latency showed no significant differences between conditions.

2.1 Statistical analysis

The mean and SD for electric potential from 250–500 ms after stimulus presentation are shown as mean P300 amplitudes in Figure 3. The two-way layout ANOVA (condition (Front/Outside) vs. electrode recording site (Fz/Cz/Pz)) revealed main effect of condition ($F_{(1, 84)} = 3.59$, $p < 0.01$), with the P300 amplitude being larger for the front condition than the outside condition. Furthermore, the main effect was accepted between electrode recording sites ($F_{(2, 84)} = 3.59$, $p < 0.05$). There were no significant interactions.

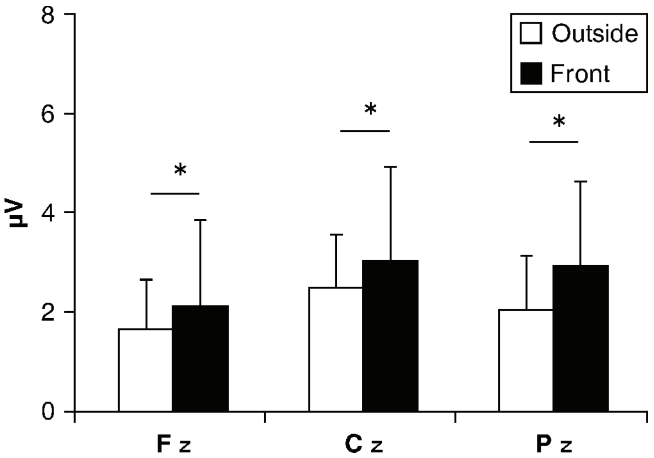

Figure 3. The mean (±SD) P300 amplitude of outside (white bar) and front (black bar) conditions recorded at Fz, Cz, and Pz electrode sites.*denotes p value < 0.01

Discussion

Learner observation of models is one of the primary processes in motor learning, such as during exercise, sport, and rehabilitation. However, while information unique to the model's actions and the learner's information-gathering processes are important themes, they have not been examined in much detail [20]. Therefore, the present study examined the P300 in response to different images of upper limb placement in order to clarify the effects of presented upper limb placement on observers' information-gathering processes.

Comparisons of the observed P300 waveforms and mean potentials revealed that the P300 was significantly larger for the image where the upper limbs were placed within shoulder-width (front) than for the image where the upper limbs were extended beyond shoulder-width (outside). This suggests that subjects paid more attention during the front condition than the outside condition and that more processing resources were mobilized before subjects responded.

Although P300 latency has been found to increase with task difficulty [8, 18], the difference in P300 latency between conditions in this study could not be explained as such because there were no significant differences in reaction time or P300 latency, and therefore no difference in task difficulty. This shows that a difference in attention is not affected by the difficulty of the task.

Thus, a more probable explanation for the greater P300 amplitude in the front condition in this study is that it is related to greater familiarity with the placement of the upper limbs in front of the trunk than to the sides of the trunk. Indeed, Gooey et al. [6], while studying body position sense, referred to the space in front of the trunk as the normal working space and suggested that, because this space is used frequently in daily life, special significance is formed in neural representation. Furthermore, as referred to in *kansei* information processing, upper arm movements performed in front of the trunk function as communication tools and are thought to be related to increased attention [13]. Gestures, which are non-linguistic communication tools, are also commonly expressed with the upper limbs using the space in front of the trunk. Therefore, the space in front of the trunk is important for understanding others, which may lead to increased observer attention.

However, although the present study clarified differences in the level of observer attention according to upper limb placement, it was conducted on only female college students, thereby limiting the generalizability of the results. Therefore, further studies on men and other age groups are required. Additionally, the present study contains information regarding only upper limb placement in face-to-face presentations; thus, it is necessary to clarify the characteristics of learner cognition regarding other types of visual motor information, such as other body parts and rear presentations, in future studies.

To summarize, the purpose of this study was to clarify the characteristics of learners' information-gathering processes, when receiving visual motor information, by examining the influence of differences in model upper limb placement on observer attention. In the experiment we measured the P300, using a "front" image in which the upper limbs were placed in front of the trunk and an "outside" image in which the upper limbs were placed outside the trunk i.e. an oddball task. The comparison of P300 amplification grand mean waveforms and mean potentials revealed that amplification was greater in the front condition than in the outside condition. Our results showed that placement of the model upper limb has an effect on the observer's attention and especially in front of the torso resulted in higher attention.

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