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Note

ERP-P3 for Pictures Varies in Amplitude According to Stimulus Content[1)]

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This study explored whether the P3 event-related brain potential (ERP) is sensitive to the contents of pictures presented during a discriminative reaction time (RT) task. In the Stop-cars task, five categories of picture (cars, people, electronics, flowers, and landscapes) were presented randomly, with probabilities of .40, .30, .10, .10, and .10, respectively. Thirty-one participants were asked to respond to every stimulus that was not a car by pressing a button. Another twenty-one participants also engaged in a Stop-figures task, which was identical to the Stop-cars task except that simple geometric figures replaced the car stimuli. ERPs for equiprobable stimuli (electronics, flowers, and landscapes) were analyzed. Two types of P3s were seen at around 380 ms and 520 ms after stimulus onset. The first component (early P3) featured a parietal maximal and seemed equivalent to the "classical P3" (P3b). The second component (late P3) was more anteriorly distributed. For both tasks, the amplitudes of early P3 differed across the stimuli. Additionally, the early P3 elicited by electronics stimuli was larger during the Stop-figures task than during the Stop-cars task. It is well known that P3 (P3b) amplitudes can vary as a function of stimulus probability during a simple oddball task. However, the present results suggest that P3 amplitude for complex pictures in a discriminative RT task might be sensitive to stimulus content rather than probabilities.

Keywords: event-related brain potentials; early P3; late P3; picture content; stimulus probability

Event-related brain potentials (ERPs) are voltage fluctuations that are temporally associated with some physical and/or mental occurrence, and that contain components that span a continuum between exogenous and endogenous potentials (Picton et al., 2000). To date, numerous studies have examined the relationship between ERP components and various human cognitive functions.

One of the most extensively investigated ERP components is the P3 (P3b or P300). The P3 component is a large positive deflection that peaks between 300 and 800 ms after the occurrence of an attended, task-relevant event. Duncan-Johnson and Donchin (1977) used a simple oddball task to demonstrate that P3 amplitudes vary as a function of stimulus probability. There is therefore a general agreement that P3 amplitudes are indeed sensitive to the stimulus probability. On the other hand, a number of studies have reported that the P3s elicited by emotional pictures are larger than those elicited by neutral pictures (e.g., Akamine & Kida, 2001; Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Johnston, Miller, & Burleson, 1986). These latter studies suggest that P3 amplitudes can also be sensitive to the picture content.

Many have noted that the P3 is not a unitary brain potential, but instead represents a summation of activity from various widely distributed areas in the brain (e.g., Johnson, 1993; Kok, 2001). Several researchers have identified various subcomponents of P3 (e.g., Christensen, Ivkovich, & Drake, 2001; Falkenstein, Hohnsbein, & Hoormann, 1994; Kayser, Bruder, Tenke, Stewart, & Quitkin, 2000). Sugimoto, Nittono and Hori (2007) note that some studies have consistently shown an enhancement of late positive potential elicited by emotional pictures, and that these studies may analyze the component consisting of the P300 and subsequent positive slow wave. In our previous study, two types of P3s were elicited using color pictures presented during discriminative reaction time (RT) tasks (Akamine & Kida, 2004). Here, the early P3 peaked at around 380 ms after stimulus onset over parietal scalp sites. The late P3 peaked at around 520 ms after stimulus onset, with a central-parietal scalp distribution. The early

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P3 would be equivalent to the “classical P3” associated with the perceptual stage of processing. The late P3 might be similar to P-CR (Falkenstein et al., 1994), in that it reflects not the response selection itself but rather aspects of the cognitive processes that follow the overt reaction (e.g., closure of response selection, or a correctness check done after the response is made). However, there are few studies investigating the subcomponents of P3, as far as we know. It is not clear whether these components vary according to stimulus content and/or probabilities in the same way. The functional characterization of the late P3 remains unclear.

Purpose of the Present Study

To examine whether the amplitudes of early P3 and late P3 are sensitive to picture content, ERPs for three equiprobably-presented categories of picture (electronics, flowers, and landscapes) were recorded. In the present study, we used a Stop/NoStop task, which is a less commonly used discriminative RT task designed by Kida and Kawano (1996). In this paradigm, the participants are required not to make a motor response to a particular stimulus (Stop), but instead to respond to all other stimuli (NoStop). Our previous study (Akamine & Kida, 2004) showed that more participants produced two distinct positive peaks between 300 and 600 ms following stimulus onset during the Stop/NoStop task than during the traditional discriminative RT task (Go/NoGo task).

Two Stop/NoStop task conditions were used in the present study: A Stop-cars task and a Stop-figures task. In both tasks, the same four categories of picture (electronics, flowers, landscapes, and people) were assigned as NoStop stimuli. It was assumed that participants could discriminate more easily the Stop stimuli from the Nostop stimuli in the Stop-figures task than in the Stop-cars task. Thus, ERPs for the NoStop stimuli were recorded separately for each category and for each task. However, the ERP elicited by pictures of people was not analyzed, given that the stimulus probabilities for these pictures differed from those for the other categories.[2)]

Method

Participants

Fifty-two students at Aichi Gakuin University (37 women and 15 men; mean age = 22.0 years) participated in the study for pay.

Procedure

Stimuli. Six groups of colored picture were used in this study: Cars, simple geometric figures, electronics, flowers, landscapes, and people. The car and simple geometric figure categories each consisted of 20 different images. The people category included images of eight different ordinary people (neutral stimuli) and eight different images of people with some type of skin disease or external injury (negative emotional stimuli). The remaining three categories (flowers, electronics, and landscapes) each consisted of five different pictures.

The stimuli were presented one at a time on a computer screen positioned approximately 1 m in front of the participants. Each picture subtended a visual angle of 14.0° horizontally and 10.0° vertically, and was presented with a fixed stimulus onset asynchrony of 3,000 ms (500 ms on and 2,500 ms off).

Discriminative RT tasks. The participants performed either of two kinds of discriminative RT task. In the Stop-cars task (N = 31), pictures from the five categories (cars, people, electronics, flowers, and landscapes) were presented randomly with probabilities of 0.40, 0.30, 0.10, 0.10, and 0.10, respectively. The participants were required to respond to all pictures except for “cars” (i.e., people, electronics, flowers, and landscapes) by pressing a button with the index finger of their right hand.

In the Stop-figures task (N = 21), pictures of simple geometric figures were used instead of cars but the other pictures were the same as those used in the Stop-cars task. The participants’ task was to press a button in response to all pictures except the geometric figures with the index finger of their right hand.[3)]

Each task condition consisted of six blocks of 50 trials each. Participants were instructed to respond as accurately and quickly as possible. Fifty practice trials were given prior to complication of the tasks.

ERP Recording and Data Collection

Electrophysiological data were collected during the discriminative RT tasks. Electroencephalograms (EEG) were recorded from four midline sites, Fz, Cz, Pz, and Oz, referenced to linked earlobes. An electrooculogram (EOG) was recorded from the electrode located below the right eye. Electrode impedances did not exceed 10 kOhms. The EEG and EOG were amplified using the San-ei 360 system (time constant 3s, high-pass filter 30Hz). The data, together with trial information, were stored on a magnetic tape and processed offline. All recordings were digitized at 500 Hz. ERP waveforms were calculated separately for each participant, picture category, and task condition. The period between 200 ms before and 1,000 ms after the onset of each stimulus was averaged. The trials in which eye movements or blinks occurred and those trials that involved an incorrect response or no response were excluded from the averaging of ERPs. The averaged ERPs were aligned to a 200-ms prestimulus baseline. The following analyses were performed on the data of 51 participants; the data of one individual (a woman) who participated in the Stop-figures task had to be excluded from analysis due to excessive eye-blink artifacts.

ERPs showed the N1, P2 and N2 early components. These were followed by two large positive deflections with a latency range of 300–600ms after stimulus onset; these components were identified as early P3 and late P3 seen around 380 ms and 500 ms after stimulus onset, respectively. However, all ERPs did not clearly exhibit two positive peaks. For this reason, the early P3 amplitude was designated as the mean amplitude of the waveform over a 40-ms period between 360 and 400 ms. Similarly, the late P3 amplitude was designated as the mean amplitude of the waveform over a 40-ms period between 500 and 540 ms. The data at Oz had to be removed due to indistinct waveforms obtained from many of the participants. Therefore, analyses were performed only on data collected from the Fz, Cz and Pz sites.[4)]

Results

Behavioral Data

Table 1 presents the mean error rates and RT for each stimulus, in each task. Although the Stop stimuli induced more errors than did the NoStop stimuli, participants overall made relatively few errors.

The RT data were submitted to a two-way mixed analysis of variance (ANOVA) with the factors of task (Stop-cars task and Stop-figures task) and stimulus (electronics, flowers, and landscapes). Both main effects of task and NoStop stimulus were significant, F (1, 49) = 9.53, $p< .01$; F (2, 98) = 104.02, $p< .001$, respectively. A significant task × stimulus interaction was also obtained, F (2, 98) = 34.26, $p< .001$. The simple main effects of task were significant for the electronics and landscapes, F (2, 98) = 26.66, $p< .001$; F (2, 98) = 4.82, $p< .05$, respectively, but not for the flowers. Both RTs for the electronics and for the landscapes were longer in the Stop-cars task than in the Stop-figures task. In addition, the simple main effects of stimulus were significant for each task, F (3, 98) = 128.10, $p< .001$ in the Stop-cars task; F (3, 98) = 9.93, $p< .001$ in the Stop-figures task. Multiple comparison tests revealed that the RTs for the Stop-cars task were shortest for the flowers, followed by the landscapes and then the electronics. Furthermore, the RTs for the Stop-figures task were longer for the electronics than for both the flowers and landscapes, HSD (3, 98) = 14.36, $p < .05$.

ERP Data

Figure 1 shows grand-mean waveforms elicited by the NoStop stimuli for three categories (electronics, flowers, and landscapes) in each task. Table 2 presents the mean amplitudes of early P3 and late P3 at each electrode in each task.

Early P3. The early P3 was maximal at the Pz site. The early P3 amplitude data at the Pz site were submitted to a two-way ANOVA, as was done for the RT data. Although

Table 1: Mean Error Rates and Reaction Times

		Stop stimuli	NoStop stimuli				
			Neutral people	Negative people	Electronics	Flowers	Landscapes
Error rate (%)							
Stop-cars task							
	M	5.19	0.50	0.36	0.54	0.32	0.54
	SD	3.51	2.38	1.27	2.41	1.30	1.91
Stop-figures task							
	M	3.13	0.11	0.11	0.17	0.33	0.50
	SD	2.62	0.48	0.48	0.73	1.45	1.59
Reaction time (ms)							
Stop-cars task							
	M	—	384.9	406.5	448.9	383.9	400.4
	SD	—	36.2	38.6	30.6	39.0	40.6
Stop-figures task							
	M	—	366.3	365.2	382.6	363.8	372.2
	SD	—	56.5	52.8	53.0	53.4	52.1

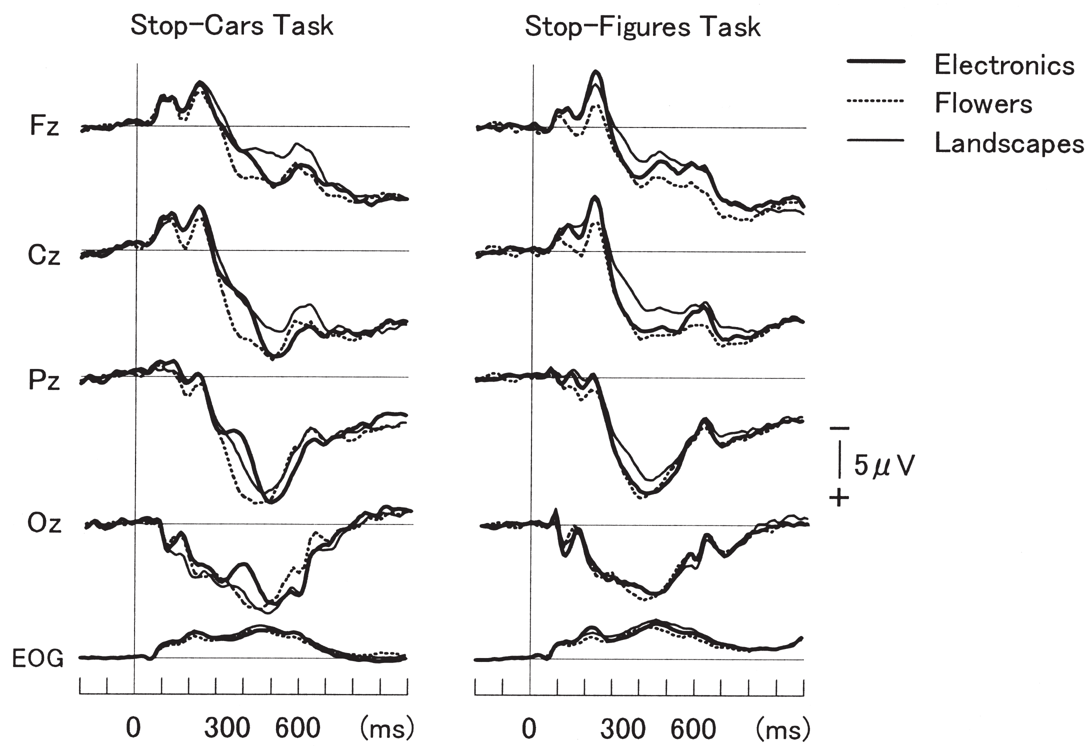

Figure 1: Grand mean ERP waveforms elicited by NoStop stimuli.

the main effect of task was not significant, the main effect of stimulus and the interaction between task and stimulus were both significant, F (2, 98) = 35.53, $p < .001$, and F (2, 98) = 18.16, $p < .001$, respectively. The simple main effect of task was significant for the electronics stimuli, F (2, 98) = 10.73, $p< .001$. The electronics stimuli elicited a larger early P3 in the Stop-cars task than in the Stop-figures task. However, there were no significant task differences in early P3 amplitude elicited by the flowers or the landscapes. In addition, the simple main effects of stimulus were significant for each task, F (3, 98) = 40.73, $p< .001$ in the Stop-cars task; F (3, 98) = 12.95, $p< .001$ in the Stop-figures task. Multiple comparison tests revealed that the early P3 amplitudes in the Stop-cars task were largest for the flowers, followed by the landscapes and then the electronics. In the Stop-figures task, the early P3 amplitudes yielded by the flowers and landscapes were both larger than those elicited by the electronics, HSD (3, 98) = 2.67, $p < .05$.

Late P3. The late P3 had a central-parietal scalp distribution. The amplitude data at the Cz site were also submitted to a two-way ANOVA.

The main effect of stimulus was significant, F (2, 98) = 16.72, $p < .001$, although the main effect of task and the interaction between task and stimulus were not significant. Multiple comparison tests involving the stimulus factor revealed that the late P3s elicited by the electronics and flowers were both larger than that elicited by the landscapes. However, there were no significant differences in late P3 amplitude between the electronics and flowers, HSD (3, 98) = 1.36, $p < .05$.

Discussion

In the present study, complex color pictures elicited two different positive waves between 300 and 600 ms after stimulus onset. While some participants produced two distinct positive peaks after the N1–P2–N2 complex, others produced a terraced positive wave (unclear peak) and a large positive peak between 300 and 600 ms after stimulus onset. The early P3 appeared over parietal scalp sites at around 380 ms after stimulus onset. The late P3 peaked at around 520 ms after stimulus onset, with a central-parietal scalp distribution. The characteristics of the ERP waveforms were exactly the same as those noted in our previous study (Akamine & Kida, 2004).

Although the color pictures in 3 categories (electronics, flowers, and landscapes) were presented equiprobably in both tasks, the early P3 amplitudes differed across the stimuli. Furthermore, the early P3 amplitudes elicited by

Table 2: Mean Amplitudes of Early P3 and Late P3 (μV)

			NoStop stimuli		
			Electronics	Flowers	Landscapes
Early P3					
Stop-cars task					
	Fz	*M*	3.45	6.20	2.72
		SD	5.19	4.77	4.67
	Cz	*M*	6.35	11.12	6.46
		SD	6.87	7.49	6.55
	Pz	*M*	8.38	15.41	11.09
		SD	5.28	6.41	5.89
Stop-figures task					
	Fz	*M*	6.69	7.55	4.12
		SD	4.92	4.00	4.02
	Cz	*M*	10.27	11.02	6.18
		SD	7.42	8.07	8.10
	Pz	*M*	14.68	15.69	11.84
		SD	7.64	7.98	7.88
Late P3					
Stop-cars task					
	Fz	*M*	7.76	7.75	4.52
		SD	6.27	4.53	5.84
	Cz	*M*	14.07	13.65	10.98
		SD	7.43	6.97	6.38
	Pz	*M*	16.77	14.86	14.58
		SD	5.70	6.05	5.40
Stop-figures task					
	Fz	*M*	5.84	7.84	4.51
		SD	7.35	5.78	5.46
	Cz	*M*	10.84	11.32	8.29
		SD	9.43	7.91	8.10
	Pz	*M*	13.38	12.28	11.71
		SD	6.33	6.55	6.15

the electronics stimuli were different across the two tasks. The early P3 noted here would have the same functional characterization as the classical P3 (P3b) associated with the perceptual stage of processing. Duncan-Johnson and Donchin (1977) demonstrated effects of stimulus probability on the classical P3 using a simple oddball task. However, the present study suggests that early P3 amplitude might be more sensitive to picture content than to probabilities, at least in a discriminative RT task that uses complex color pictures.

The amplitudes of late P3 also differed across the stimuli. It appears that late P3 amplitude might also be affected by picture content. The topographical differences between the early P3 and late P3 found in the present study support the proposal that the P3 consists of two separate components that each represent different neural generators, and that these components are produced by functionally distinct brain systems (Pfefferbaum & Ford, 1988). We have considered that the late P3 might be similar to P–CR (Falkenstein et al., 1994), and may therefore reflect aspects of the cognitive processes that follow an overt reaction (e.g., closure of response selection, or a correctness check after the response is made). However, the functional significance of the late P3 may be further elucidated in future studies.

Notes

1) We presented this study at the 49th Annual Meeting of the Society for Psychophysiological Research in October 2009, at the Berliner Congress Center.
2) We reported the ERP elicited by the NoStop people stimuli at the 25th Annual Meeting of the Japanese society for physiological psychology and psychophysiology in July 2007, at Sapporo Medical University.
3) We thank Keita Kogura, a graduate of Aichi Gakukin University, for his help with the experiment (the Stop-figures condition).
4) We reported the ERP elicited by the Stop cars stimuli and Stop figures stimuli in Journal of the Institute for Psychological and Physical Sciences, Vol. 1, pp. 63–69, in 2009.

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