A Psychophysiological Study of Auditory Accessory Effects in a Visual Choice Reaction Task

Tohoku Psychologica Folia
1993, **52**, 13-19

A PSYCHOPHYSIOLOGICAL STUDY OF AUDITORY ACCESSORY EFFECTS IN A VISUAL CHOICE REACTION TASK[1]

By

NAKANO YOSHIKI (中野良樹)[2] and MARUYAMA KINYA (丸山欣哉)[2]

(*Tohoku University*)

A reaction time to a visual stimulus is shortened by a near simultaneous auditory stimulus. This intersensory facilitation is effective even when subjects are required to ignore the auditory stimulus. In this case the auditory stimulus is called accessory in the sense that it is irrelevant to the task. The P300 component of event related potential was used to identify when the evaluation of visual stimulus has terminated. Eighteen subjects were divided into two groups, in one they were required speeded response and another the accuracy was emphasized. The accessory facilitated both of the RT and the P300 latency. Moreover, the facilitation of these two measures was almost the same degree under both instructions. These results suggested that the accessory facilitated processes before the stimulus evaluation, and not influenced on processes that follows the evaluation as movement execution. This inference supports the hypothesis that the accessory serves as a supplemental warning signal in this experimental paradigm.

Key words: intersensory facilitation, reaction time, P300, accessory stimulus.

INTRODUCTION

A reaction time to a visual stimuli as a flash or letters is shortened when a auditory stimulus is presented near simultaneously. This intersensory facilitation between the visual and auditory modality is effective even if subjects cannot predict the presentation of the auditory stimulus, and they are instructed not to attend it. In this case the auditory stimulus is termed "accessory stimulus", in the senses that is irrelevant to the visual reaction task.

This accessory effect has been explained by two hypotheses, the energy summation and the preparation enhancement. The former assumes that stimulus intensities are summated across sensory modalities causing stronger excitement of neurons than visual alone (Bernstein, Rose, & Ashe, 1970 ; Nickerson, 1973). The latter assumes that a readiness to respond is enhanced by the accessory stimulus. Sanders (1980) called this effect of the accessory "immediate arousal" that reduced the distance to a movement. Nickerson (1973) suggested that both of the effects play a role in producing intersensory facilitation. He also predicted that the two effects produced the largest facilitation in different temporal relationships between the two sensory stimuli. More precisely, the energy summation produces maximum effects when the two stimuli reach the central nervous system at the same time. On the other hand,

1. A part of this study was supported by Grand-in-Aid for Scientific Research on Priority Areas, 1993 (No.04236107).

2. Department of Psychology, Faculty of Arts and Letters, Tohoku University, Kawauchi.Aoba-ku, Sendai 980-77, Japan.

the preparation enhancement predicts that longer the accessory precedes the visual stimulus, at least less than a few hundred milliseconds, larger the degree to which the response is facilitated.

The serial stage model (Sternberg, 1969) predicted that these two effects should occur in different processing stages. Such that, the energy summation occurred in earlier processes involved the stimulus detection and stimulus evaluation (Schmidt, Gielen, & van den Heuvel, 1984). The preparation enhancement influenced directly on later stages as motor adjustment (Sanders, 1980). This model contains few problems. For example, although the accessory is presented before the visual imperative stimulus, it can influence directly on later processes. In this case, the accessory must bypass earlier processes without changing them.

We conducted psychophysiological approach to these questions using the P300 component of the event related potentials (ERPs). The P300 component is elicited by a stimulus containing significant information for subjects. The label of P300 indicates that it is a positive voltage shift with a latency range of 250～500 msec. The P300 component has been investigated in conjunctive with RT to estimate the relationship between it's latency and cognitive processes (Duncan-Johnson 1981). Recently several investigators suggested that the P300 latency reflected the duration of the stimulus evaluation, and independent of the response selection or movement execution (Donchin & Coles, 1988 ; Verleger, 1988). The P300 latency was influenced by stimulus intensity (Jodo & Inoue, 1990) or discriminability (McCarthy & Donchin, 1981), while they were not influenced by instructions for response speed (Kutas, McCarthy, & Donchin, 1977; Pfefferbaum, Ford, & Johnson, 1983).

This study examined following two issues. First, whether the auditory accessory facilitates the processes before the evaluation of the visual stimulus. If so, the P300 latency must be shortened by the accessory. Second, whether the effects of the accessory on RTs and ERPs are changed by loading of movement speed. For this purpose, subjects were divided into two groups that were differentiated in emphasis for response speed, and the extent of the facilitation was compared between them.

Method

Subjects: Eighteen male and two female volunteers, ranged from 19 to 27, participated in this experiment. All of them were right handed except one male subject. They had normal or corrected normal vision.

Stimulus: Three light emitting diodes (LEDs) that were located vertically constructed visual stimuli. The middle red LED served as a fixation point, it's luminance was 10 cd/m^2. The other two, upper and lower, green LEDs served as imperative signals (ISs), their luminance were 2 cd/m^2. The ISs were distant 1 cm above and below from the fixation point. The subjects observed the visual stimuli apart from 50 cm. The auditory stimulus was 80 dB SPL, 1000 Hz pure tone, which delivered binaurally via headphone. It served as a warning signal and an accessory stimuli.

Procedure: At the beginning of a trial, the auditory signal presented for 200 msec followed by the fixation signal. After a 1200 msec foreperiod, a lower or upper LED was presented for

50 msec. The task was to press one telegraph key if the upper LED was presented, and the other key to the lower one. The key assignment to ISs was counterbalanced across subjects. The fixation point disappeared 1000 msec after the IS (Fig. 1). The subjects were divided into two groups. They were received different instructions about responses. In one, the subjects were instructed to respond as fast as they could (Speed instruction). In the other, the subjects were emphasized accurate responses (Accuracy instruction). The auditory accessory stimulus was presented for 80 msec preceding the IS by 300 msec. The subjects were told that they could ignore it. Successive trials separated by an 2000 msec interval. The experimental session consisted of 9 blocks each contained 40 trials. The first block was assigned to a warm-up. Preceding the experiment, the subjects served a training of 200 trials.

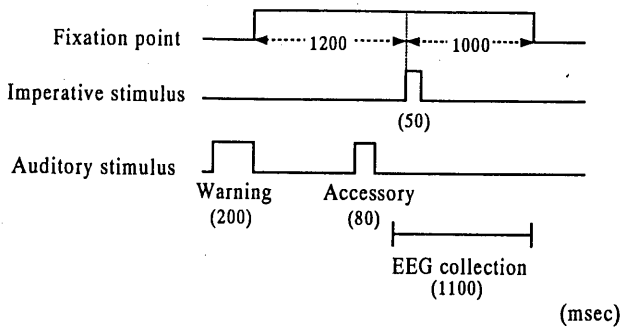

Fig. 1. The procedure of stimulus presentation in one trial. Trials are separated by a 2 sec interval each other.

Recording: EEG was collected from Fz, Cz, Pz by Ag-AgCl electrodes referencing right ear-lobe. Vertical EOG was recorded from electrodes above and below the right eye. The signals were amplified by bioelectric amplifier (MEG-2100: Nihon Kohden) with the time constant of 2 sec, and their upper bandpass limit was 100 Hz. The data were digitized on-line at a 2 msec sampling rate. The sampling epoch was starting 100 msec before the IS, and lasting for 1100 msec.

Results

Behavioral Data: Table 1 shows mean RTs and SDs for each accessory conditions and response instructions across subjects. There was no difference between response in right and left hand. The factor about response hands was eliminated from the analysis. The two factors (Speed vs Accuracy × accessory) analysis of variance (ANOVA) was performed on mean RTs. In the Speed instruction group, the mean RT was about 80 msec shorter than in the Accuracy one [$F(1,18)=65.1:p<.01$]. Moreover The accessory shortened the RT under both of the instructions [$F(1,18)=38.5:p<.01$]. There was no interaction between the instruction and the accessory presentation.

Table 1. Mean reaction times and standard deviations (msec) for each accessory conditions under two instructions (Speed vs Accuracy).

	Speed		Accuracy	
	RT	SD	RT	SD
No accessory	291	20	372	34
Accessory	274	12	351	31

Psychophysiological data: EEG data was averaged across trials with time-locked to the IS. Trials having a response error and contaminating by artifacts, as eye-blinking, were eliminated from averaging. Figure 2 shows the IS-synchronized grand averages for three

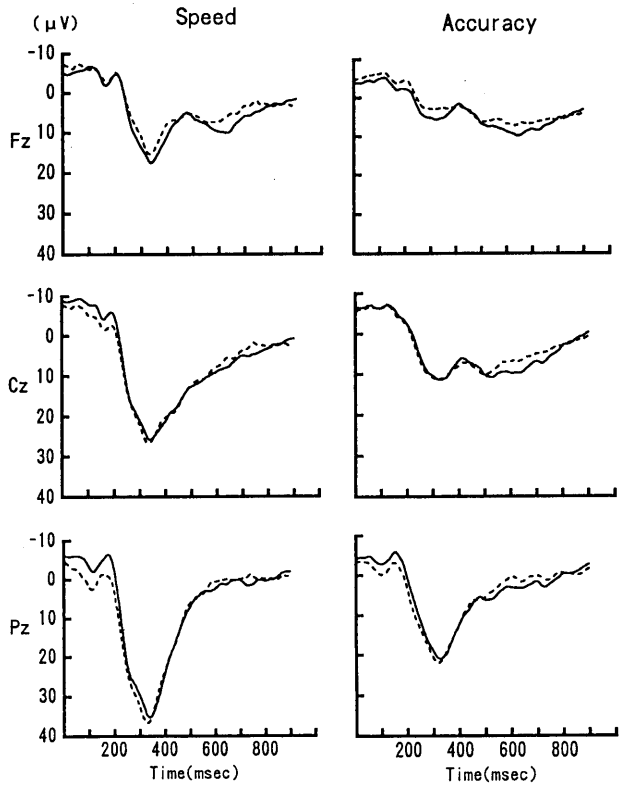

Fig. 2. Grand average of stimulus-synchronized ERPs for accessory (dashed line) and non-accessory (solid line) condition at Fz, Cz, Pz. The left wave forms is Speed group's and the right is Accuracy group's.

electrodes' locations. Peak latencies of P300 were identified as the maximum positive point between 200 msec and 400 msec post-IS in waveforms. The P300 amplitudes were the relative value to the 100msec pre-IS baseline. Figure 3 and 4 shows mean P300 latencies and amplitudes across subjects. These data were submitted separately to three factors ANOVA. The factors were response instructions (2), accessory presentation (2), and electrodes' locations (3). For the P300 latency, there was a significant interaction between the accessory and locations. The tests on simple effects (LSD method) showed that the accessory shortened the P300 latency only at Pz ($p<.01$). There was no difference between the two instruction groups. For the P300 amplitude, there was a significant difference between electrode's locations. Their relations were Pz>Cz>Fz ($p<.05$).

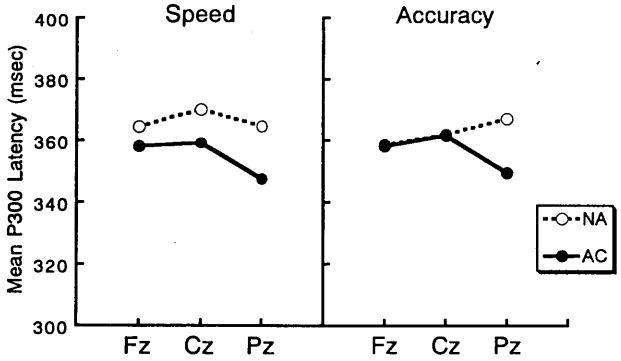

Fig. 3. Mean P300 latencies at Fz, Cz, Pz in two instruction groups, Speed (left) and Accuracy (right). Open circles with dashed lines indicate non-accessory conditions (NA), and closed circles with solid lines are accessory conditions (AC).

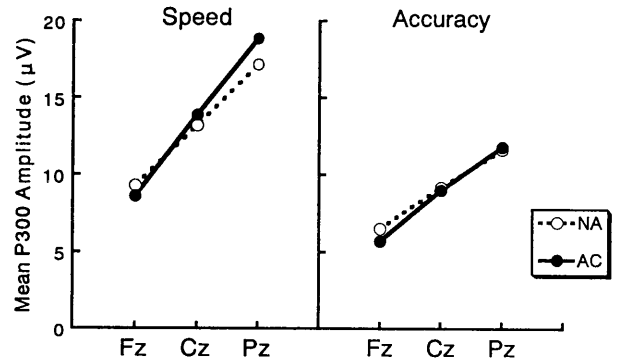

Fig. 4. Mean P300 amplitudes at Fz, Cz, Pz in two instruction groups. See also the caption in Fig. 3.

Discussion

The accessory shortened not only the RT but also the P300 latency regardless of instruction about response speed. Moreover, degrees of facilitation were approximately the same about the P300 latency and the RT. This result, thus, manifests that the intersensory facilitation by the auditory accessory has occurred before evaluation of the visual IS. This inference contradicts to the preparation enhancement. Does this mean that the intersensory facilitation should be ascribed to the energy summation? The accessory was separated by the 300 msec interval from the visual IS. Energy between the two modalities could not be summated under such the long interval.

The other possibility is that the accessory serves as a supplemental warning signal (Bernstein, 1970). In our experiment, the foreperiod duration (FP) between the warning signal and the IS was 1200 msec. Such the FP makes subjects uncertain to moderate timings for motor preparation. Probably the accessory decreased this time uncertainty, and it produced the reduction of RTs. The time uncertainty also affects P300 latencies. Fiori, Ragot and Renault (1992) reported that the longer FP (5000 msec) made the P300 latency longer than the shorter one (500 msec). They ascribed this result to the delay of the motor pre-initiation that took place before the stimulus evaluation. Probably the accessory stimulus decreased the time uncertainty before the IS was presented.

Another manipulation adopted in this experiment was instructions for response speeds. It altered the criteria for initiate the movement. Under the speed instruction, the subjects executed the movement immediately after or even before the termination of stimulus evaluation. Under the accuracy instruction, the subjects withheld the movement until accumulating the enough information for the response. Thus such manipulations influenced on processes just before the movement initiation. This inference is supported by the result in this experiment and previous studies (Kutas et al., 1977 ; Pfefferbaum et al., 1983) suggesting that the P300 latencies indicate little difference under both speed and accuracy instructions.

It must be noted that both of the P300 latency and the RT did not show interactions between the instructions and the accessory presentation. Within the logic of additive factor methods (Sternberg, 1969), this additivity predicts that the two experimental factors influence on different processing stages. According to the Sanders's (1990) review for the stage model, the manipulation of response speeds affects on later stages as the motor programming or the motor adjustment. So, the effect of the accessory is independent of the processes just before the movement execution. Although the preparation enhancement predicted that the accessory facilitated such later processes (Sanders, 1980 ; Schmidt, Gielen, & van den Heuvel, 1984), the results indicated that the accessory affected on earlier processes before the stimulus evaluation. The alternative explanation is that the accessory serves as a supplemental warning signal. That help the subjects to construct an expectation to the IS and the response. Further investigation must clarify whether the accessory enhances the expectation to the IS or the preparation to the response.

References

Bernstein, I. H. **1970** Can we see and hear at the same time? Some recent studies of intersensory facilitation of reaction time. *Acta Psychologica*, **33**, 21-35.

Bernstein, I. H., Rose, R., & Ashe, V. M. **1970** Energy integration in intersensory facilitation. *Journal of Experimental Psychology*, **86**(2), 196-203.

Donchin, E., & Coles, M. G. H. **1988** Is the P300 component a manifestation of context updating. *Behavioral Brain Sciences*, **11**, 357-374.

Duncan-Johnson, C. C. **1981** P300 latency: A new metric of information processing. *Psychophysiology*, **18**, 207-215.

Fiori, N., Ragot. R., & Renault, B. **1992** Effect of target position on the sequential organization of processing stages. *Biological Psychology*, **33**, 157-171.

Jodo, E., & Inoue, K. **1990** Effects of practice on the P300 in a Go/NoGo task. *Electroencephalography and Clinical Neurophysiology*, **76**, 249-257.

Kutas, M., McCarthy, G., & Donchin, E. **1977** Augmenting mental chronometry: The P300 as a measure of stimulus evaluation time. *Science*, **197**, 792-795.

McCarthy, G., & Donchin, E. **1981** A metric for thought: A comparison of P300 latency and reaction time. *Science*, **211**, 77-79.

Nickerson, R. S. **1973** Intersensory facilitation of reaction time: the energy summation or the preparation enhancement. *Psychological Review*, **80**, 489-509.

Pfefferbaum, A., Ford. J., & Johnson. R., Jr. **1983** Manipulation of P3 latency: Speed vs accuracy instructions. *Electroencephalography and Clinical Neurophysiology*, **55**, 188-197.

Sanders, A. F. **1980** Stage analysis of reaction processes. In G. E. Stelmach, & J. Requin (Eds.), *Tutorials in motor Behavior*. North-Holland: Amsterdam, pp. 331-354.

Sanders, A. F. **1990** Issues and trends in the debate on discrete vs continuous processing of information. *Acta psychologica*, **74**, 123-167.

Schmidt, R. A., Gielen, S. C. A. M., & van den Heuvel, P.J.M. **1984** The locus of intersensory facilitation of reaction time. *Acta psychologica*, **57**, 145-164.

Sternberg, S. **1969** The discovery of processing stage: extensions of Donders' method. *Acta Psychologica*, **30**, 276-315.

Verleger, R. **1988** Event related potentials and cognition: A critique of the context updating hypothesis and an alternative interpretation of P3. *Behavioral Brain Sciences*, **11**, 343-356.

(Received September 6, 1993)
(Accepted November 22, 1993)