Effects of light stimulus upon simple reaction time and EP latency to the click presented with different SOA¹

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Click and light were presented in pairs with varying stimulus onset asynchronies (SOAs) and the subjects were asked to respond to the click onset. SRTs and EPs were obtained for two levels of click intensity and were plotted as a function of SOAs. As the related EP component, Nc, or the negative peak immediately following the click onset, was taken and the Nc recorded from Cz was analyzed. Although the larger Nc amplitudes occurred with shorter SRTs, no systematic changes in Nc amplitude were observed as a function of SOAs. Nc latencies, the variations of which were smaller for an intense click than for a faint one, were shorter for trials in which light preceded click ($\text{SOA} \leq 0$) than for click-alone trials, in correlation with SRTs. This fact suggests that the light given prior to click increased the arousal level and/or the processing speed. Bimodal facilitating effect of the internal processing speed upon SRTs was obtained at 50 ms of SOA.

Key words: evoked potentials (EPs), simple reaction time (SRT), stimulus onset asynchrony (SOA), bimodal stimulation, latency, facilitation.

Intensity of imperative stimulus and the foreperiod have been known as variables affecting simple reaction times (SRTs). The former (Nissen, 1977) is assumed to have a direct relation to stimulus processing in the sensory pathways as such. The latter (Niemi & Näätänen, 1981), i.e., onset interval between signal and imperative stimuli seems to influence non-specific activating processes. Thus these two are possibly involved in different functions, although the processes underlying them have not been identified so far.

To relate the effects of these two variables to each other, the present study manipulates both variables by presenting light and click bimodally and obtains both SRTs and evoked potentials (EPs) in a single paradigm.

EPs could be a promising measure to clarify the processes underlying SRTs. Some investigators have obtained relationships between EP amplitudes and SRTs.

Donchin and Lindsley (1966) reported that the shorter SRTs were correlated with the higher amplitudes of EPs. Morrell and Morrell (1966) found that intra-individual variability of SRTs was related to that of VEP (visually evoked potential) amplitudes of the predominant component. Morris (1971) demonstrated a relation between increased amplitudes of VEPs (N2, P2) and the faster SRTs. Furthermore, Karlin, Martz, Brauth, and Mordkoff (1971) obtained a similar relationship between SRTs and AEP (auditory evoked potential) amplitudes. These findings could be based on arousal or alertness which is activated by the non-specific projecting system of the ascending reticular formation.

There have been reported some studies which related SRTs to latencies of early EP components. This type of correlation was obtained in relation to light intensity (Dustman & Beck, 1965; Vaughan, Costa, & Gilden, 1966), retinal eccentricities of stimulation (Eason, Oden, & White, 1967), and spatial frequencies (Parker & Salzen, 1982). These could be determined by speed of the sensory processing.

In general, investigators who are con-

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cerned with relations of EP amplitudes upon SRTs have paid more attention on the activating function of sensory inputs, while those who relate EP latencies to SRTs are more concerned with speed of processing in sensory pathways. No studies have been reported which obtained these two EP measures in a single paradigm. The present study attempts to compare them.

In the experiment, click (S1) and light (S2) are presented in pairs with varying onset asynchronies (SOAs), and subjects are asked to respond to the click. It is probable that light elicits arousal or attention for $SOA < 0$ where S2 precedes S1 but that light causes no such effects for $SOA \geq 0$. Click intensities are also set at two levels, as they are expected to determine the speed of processing.

Bimodal facilitating effect upon SRTs has been demonstrated (Andreassi & Greco, 1975; Bernstein, Rose, & Ashe, 1970; Bernstein, Chu, Briggs, & Schurman, 1973; Hershenson, 1962; Hilgard, 1933; Morrell, 1967; Nickerson, 1973). When light and click were paired at an optimal intensity and with proper time relation, SRTs were shorter than those obtained for each of them singly. In the present study, EPs can be related to reductions in SRTs, if the facilitation occurs.

EPs from Cz are analyzed because this area produces auditory potentials and also it has a close relationship to motor responses.

Method

Subject

Subjects were four male university students. Their visual and auditory acuities were normal. All of them had experiences with SRT experiments.

Stimuli

As shown in Fig. 1, click and light were presented in pairs of eight SOAs; -200,

Fig. 1. Time sequence of the stimuli used in the experiment.

-100, -60, -30, 0, 50, 100, 500 ms.

Click² was a pure tone of 1 000 Hz. It was presented for 50 ms at either of two levels, intense (94 dB) and faint (74 dB)³. The intense click was perceived as fairly loud, while the faint one was slightly above threshold and just audible. To mask external cues, background white noise (69 dB) was given. Click and the white noise were presented binaurally through headphones.

Light was a disc of 2° in visual angle and was exposed at the intensity of 28 cd/m² for 50 ms.

Instrument and Apparatus

Stimulus presenting system. Figure 2 shows diagram of instrumentation. Timer 1 controlled the duration of click and triggered digital timer (National Electric Counter, VP-454A) which was used for SRT measurements. Timer 2 operated SOAs. Timer 3 controlled duration of light, triggering a pulse to onset light.

² The auditory stimuli in the present study may be better described as the tone burst. We conventionally call it click in relation to the related studies cited in the introduction.

³ Click intensity levels were measured by a microphone of an audiometer attached to the headphone directly.

Click was generated by an oscillator (Nippon-Keisoku Audio Oscillator, M.D., CR-223AS). White noise was given through a tape deck (Teac, ff-80). Both of them were delivered through headphones (Pioneer SE-30) after being mixed by sound mixer (Teac, MB-20). Light was projected on a white screen through diaphragm inserted in the optical path by a projector (Kodak Ectagraphic Slide Projector) with DC power supply (Sanso Power Supply, KD-300). An electromagnetic shutter (Sanwa Shutter Driver)

controlled duration of light.

Recording system. EEGs were recorded monopolarly. Active electrodes were placed at Cz, Pz and Oz in 10-20 system while a reference electrode was on the right earlobe. As shown in Fig. 2, EEGs were amplified with a band pass of 0.53–30 Hz and were stored in the data recorder (Sony, FF-30a) together with trigger signals. They were processed later by a signal processor (San'ei, 7T08) to obtain EPs which were plotted on X-Y recorder (San'ei, 8U11).

Fig. 2. Diagram of the apparatus system.

Fig. 3. Evoked potentials for faint click recorded from Cz, Oz and Pz. From left to right, data are arranged for the SOAs of -60, 0, 50 ms. Onset of light is indicated by short vertical line and click onset is marked by triangle. Sweep time is 819.2 ms. Data from subject KO.

Each EP was averaged by summing 40 trials and recorded with sweeping time of 819.2 ms (1024 ms only for SOA of 500 ms.)

EEGs were monitored with a biophysiological (San'ei Polygraph, 141-6) while they were recorded. EOG was also recorded to detect eyeblinks and the trials in which an eyeblink occurred were discarded from analysis.

Procedure

A subject, sitting in a dimly illuminated room, was asked to press a response key as soon as he heard click against the background white noise. A session consisted of ten conditions, i.e., eight SOAs plus single presentations of light and click. For each condition SRT trials were run at least 40 times with 4-s interval. A 3-min rest was given between conditions, and 5-

Fig. 4. Evoked potentials for each condition of faint click (left) and intense click (right) recorded from Cz. C indicates the click alone condition, and L indicates the light alone condition. Trigger point (onset of light) is indicated by short vertical line, and click onset is marked by small triangle on each trace. Sweep time is 819.2 ms except for the SOA of 500 ms.

min interval was inserted after every three conditions.

Each subject was given both intense and faint click sessions. The order of conditions and of sessions were both randomized.

Analysis of EP Data

Figure 3 illustrates the EP traces recorded from different areas (Cz, Pz, Oz) and for different SOAs (-60, 0, 50 ms). In the figure, the click onset is indicated by a solid triangle and the light onset (trigger point) by a vertical line.

As a response evoked by click, a large negative component was identified immediately after onset of the click. It was named Nc. Both latency and amplitude of the Nc component recorded from Cz were measured in order to correlate with SRT.

Result

EP Measures

Amplitudes of Nc component. Figure 4 illustrates EPs obtained from a subject (M1) for faint click (left) and for intense

click (right). Intense click evoked larger Nc amplitudes at each SOA than faint click did.

Figure 5 compares mean Nc amplitudes and mean SRTs plotted against SOAs in both click intensities. Within the same SOA, larger amplitudes occurred with shorter SRTs, and the tendency seemed consistent within subject. However, no systematic change in Nc amplitudes was observed when the amplitudes were plotted against SOAs.

Latencies of Nc component. Figure 6 shows Nc latencies plotted against SOAs for both click intensities.

For faint click, latency decreased over -200 -100 ms of SOA, then increased. At 50 ms of SOA, it reached the same level as obtained in click alone condition, and was kept at constant value of approximately 140 ms after that SOA.

Latencies for intense click were shorter than those for a faint one except -100 ms of SOA. Though their variation was remarkably smaller when compared with those for faint click, the differences among SOAs were still significant ($F(8/54)=5.81$, $p<.01$).

Fig. 5. Nc amplitudes for each SOA condition for faint click (white bars) and for intense click (black bars). SRTs to click plotted against SOAs for faint click (open squares) and for intense click (solid squares).

Compared with click alone, these latencies were significantly reduced over -100 ($t(3)=-5.91$, $p<.001$)– 0 ms ($t(3)=2.45$, $p<.05$) of SOA. Though the difference between click intensities was also significant

($F(1/54)=37.4$, $p<.001$), the two SOA functions were similar to each other in that both bottomed at -100 ms of SOA and reached the click alone level at 50 ms of SOA.

Fig. 6. Latencies of Nc component plotted against SOAs for faint click (upper) and for intense click (lower). Dots indicate latencies obtained from individual subjects, and solid line shows mean latencies.

Fig. 7. SRTs to click plotted against SOAs for faint click (upper) and for intense click (lower). Dots indicate SRTs obtained from individual subjects, and solid line shows mean SRTs.

Fig. 8. Latencies of Nc component plotted against SRTs. Open circles indicate the data obtained for intense click, while solid circles for faint click.

SRT Measure

Figure 7 gives SRTs plotted against SOAs for both click intensities. Difference in SRTs between the two click intensities was significant ($F(1/60)=36.8$, $p<.001$).

SRTs to faint click decreased over -200 – -100 ms of SOA, then increased and reached the level for click alone (236.3 ms) at 100 or 500 ms of SOA. SRTs to intense click also increased slightly for -200 – -50 ms of SOA, reaching the level for click alone (172.1 ms), and kept constant level after that. SRT variations among SOAs were significant ($F(9/60)=11.93$, $p<.01$).

Amount of time reduction from the click alone level was significant only for the SOA range -60 ($t(3)=2.68$, $p<.05$)– 0 ms ($t(3)=2.49$, $p<.05$) of intense click condition.

Bimodal facilitations were seen for both click intensities; over -200 – -50 ms of SOA for faint click and over -60 – 0 ms for intense click.

SRT to faint click alone (236.2 ms) was significantly longer than SRT to light

alone (177.9 ms) ($t(3)=6.61$, $p<.001$), while SRT to intense click alone (172.1 ms) was significantly shorter than that to light alone⁴ (201.8 ms) ($t(3)=5.66$, $p<.01$). And, consequently, the difference in SRTs between both click alone conditions was significant ($t(3)=28.5$, $p<.001$), which is congruent with the findings reviewed by other investigators (Nissen, 1977; Teichner, 1954).

Relation between SRT and EP Measures

Figure 8 shows relationship between SRTs and Nc latencies. It was obtained with data for eight SOAs plus click alone from four subjects. Coefficient of correlation was .579 and statistically significant

⁴ Two SRTs to light should be the same since light intensity was physically the same for both click conditions. But, as a fact, they differed. SRT to light alone was shorter by 23.9 ms in the faint click condition than in the intense click condition ($t(3)=3.25$, $p<.05$). The difference could be attributed to the fact that light appeared more impressive and flashy in the faint click condition owing to the sequential context produced by the bimodal stimulation.

Fig. 9. The relationship between mean SRTs and mean Nc latencies for faint click (upper) and for intense click (lower). Both are plotted as a function of SOAs.

($t(70)=5.97$, $p<.001$).

On the other hand, Nc amplitudes showed no significant coefficient of correlation with SRTs (coefficient of correlation was $-.096$, $t(70)=.81$, *n.s.*), though intense click tended to produce larger amplitudes than faint one did.

Figure 9 gives mean SRTs and mean Nc latencies plotted as a function of SOAs for the two click intensities. These two changed parallelly as a whole, though SRTs reached the click alone level at 100 or 500 ms, at later SOA than the latencies did.

Discussion

Our findings are related to those obtained by other investigators. Donchin and Lindsley (1966) demonstrated a relationship between SRTs and VEP amplitudes⁵. In their experiment, amplitudes of the N160-200 component were found to be larger when SRTs were shorter. In the

present study, larger Nc amplitudes and shorter SRTs were obtained for intense click when compared with those for faint click (see Fig. 5).

Vaughan et al. (1966) reported the relation between SRTs and VEP latencies. They changed the intensity of the imperative stimulus and observed that SRTs and latencies of the P₁ component varied correspondingly. In the present study, a significant correlation was found between SRTs and Nc latencies when those were measured at different SOAs.

Similarity of the findings between the study by Vaughan et al. and ours is worth noting because the similar effects were demonstrated by operating different parameters, i.e., the stimulus intensity level and the prestimulus time condition. This suggests that time and intensity have interchangeable effects upon internal processes underlying motor responses.

A well known fact is that a signal stimulus with foreperiods can reduce SRTs. Foreperiods in Donchin and Lindsley (1966) ranged from 1.0 to 2.5 s, while SOAs in the present study were from -200 to 500 ms. SRTs varied with EP amplitudes in the former study, while with EP

⁵ In this study the authors were mainly concerned with the effect of SRT given as a feedback information, not with the effect of interstimulus intervals.

latencies in the present study. The different SRT-related EP measures between the two studies suggest that longer foreperiods may increase the arousal or alertness level which reduces the stimulus processing time at one processing stage and that shorter SOAs may save processing at a different, and earlier stage.

For faint click, SRTs for -200 – 50 ms and Nc latencies for -100 – 0 ms of SOA were shorter than those in click alone. For intense click, only SRTs were reduced for -60 – 0 ms of SOA. Amount of these reductions was smaller for intense click than for the faint one. The difference in the amounts may be attributed, among all, to the intensity level relative to light. The two clicks differed not only in their absolute level but also in the subjective level relative to light. Secondly, the difference may be caused by a ceiling effect; both measures for intense click may have reached the level not capable of being accelerated by light any more. Intensities of light and click should be systematically varied in order to specify the crucial variable.

Another difference in the SOA function between two intensity levels of click was that the SRT reduction for 50 ms SOA was obtained only for faint click. SRT to faint click at 50 ms SOA was shorter than that to the click alone, although the difference failed to reach a conventional significance level ($t(3)=1.85$, $p<.1$). This SOA was approximately equal to the SRT difference between the click alone and the light alone conditions (58.3 ms)⁶. Thus the subjects would perceive both stimuli as presented simultaneously if the motor system functioned with equal speed in both cases. This is a kind of facilitating effect of intersensory stimulation upon SRTs, as

reported by some investigators (Bernstein et al., 1970, 1973; Helson, 1964; Hershenson, 1962; Morrell, 1967; Nickerson, 1973). Andreassi and Greco (1975) demonstrated reduction in SRTs to light and the amplitude augmentation of N2 component which occurred in the bimodal stimulation. They obtained this effect by presenting two stimuli with delay equal to the time difference in SRT (JRT) or N2 latency ($JN2$). In the present study reduction appeared in SRT, but not in the Nc latency.

In the present study the Nc component was taken as the EP measure. Nc is a distinct component which followed the click presentation. To make the click-related effect clearer Nc from Cz was measured. However, it is questionable that any light-related component, say N1, might have been compounded with it, since the two evoked potentials actually occurred in a close temporal relation in our paradigm. It could be argued that a purely click-related component could exist if the EP wave for light alone was subtracted from the EP wave in bimodal stimulation. However, the two stimuli interact to cause a unitary internal process which underlies motor responses in the bimodal stimulation with brief SOAs. This process may not be a linear summation of the light-elicited and the click-elicited processes. Although our view mentioned here should be tested in further studies, the high coefficient (.579) of Nc latencies with SRTs already gives the partial support for it.

As is well known, SRTs and their variance depend upon the paradigm used in the experiment. In the present study, 40 trials were run successively with 4-s interval for each condition. Our subjects, therefore, would tend to time the click onset more easily. One of them showed extraordinarily short SRT to faint click over -100 – -60 ms of SOA. Such quick responding may be partly due to the paradigm with fixed interval. SOAs could be

⁶ In the intense click condition, SRT for the click alone was shorter than the light alone by 29.7 ms. Therefore click and light would have reached central nervous system at approximately same time for SOA of -30 ms. In fact, SRT was reduced in this SOA condition.

changed randomly trial after trial, and undoubtedly this is more desirable to exclude the subject's preparatory set. Though we ran each series of 40 trials with identical SOA for technical reasons, further measurements should be made by using a paradigm with random intervals.

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