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Effect of attention to preceding stimuli on the simultaneity perception between an auditory and visual stimulus

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ABSTRACT

This study focused on simultaneity perception characteristics of an auditory-visual stimulus. Experiments were carried out for evaluating the simultaneity between an auditory and visual stimulus when preceding stimuli were presented. As the test stimuli, we used a pure tone (1000 Hz and 80 dB SPL) and a white light (LED). Both stimuli had a duration of 10 ms. The preceding stimuli, which were the same as the test stimuli, were presented successively 20 times at an interval of 50 ms, followed by the test stimuli at an interval of 200 ms. There were four kinds of presentation pattern of the preceding stimuli as follows; only the sound stimuli were presented (sound attention test), only the light stimuli were presented (light attention test), both the sound and light stimuli were presented synchronously (sound-light synchronous attention test), and the sound or light stimuli were presented randomly (sound-light random attention test). The sound and light as the test stimuli had a stimulus onset asynchrony (SOA) from -160 to 160 ms, where a negative value indicates the sound was presented first. We presented the test stimuli to the experimental subjects in each condition and asked to answer which of the sound or light was perceived first. Then we evaluated the point of subjective simultaneity (PSS) of the test stimuli. As a result, the PSS shifted toward the sound precedence by 2 ms at the sound attention test, 10 ms at the light attention test, 9 ms at the sound-light synchronous attention test, and 15 ms at the sound-light random attention test.

INTRODUCTION

Numerous studies have been done on auditory and visual perceptions and there are a lot of reports even only in characteristics of the simultaneity perception between auditory and visual stimuli (Hershenson 1962; Aschersleben and Müsseler 1999; Stone et al. 2001; Sugita and Suzuki 2003; Fujisaki et al. 2004; Lewald and Guski 2004; Arnold, Johnston, and Nishida 2005; Zampini, Shore, and Spence 2005; Zampini et al. 2005). In these reports, Zampini et al. carried out experiments of the simultaneity perception of pairs of auditory and visual stimuli focusing on participants' attention at varying stimulus onset asynchronies (SOAs) (Zampini, Shore, and Spence 2005). In their experiments, the participants were instructed to attend either to the auditory or to the visual modality, or else to divide their attention equally between the two modalities. Then they showed that the point of subjective simultaneity (PSS) shifted as a function of the attention condition.

On the other hand, in the present study, we investigated the simultaneity between an auditory and visual stimulus by employing preceding auditory or/and visual stimuli to strongly manipulate the attention toward auditory or/and visual modalities. As the preceding stimuli, we used a continuous train of an auditory stimulus (sound attention test), a continuous train of a visual stimulus (light attention test), synchronized trains of an auditory and visual stimuli (sound-light synchronous attention test), and a random train of an auditory or visual stimulus (sound-light random attention test). Then we evaluated the PSS shift depending on the attention condition.

EXPERIMENTS

We investigated the simultaneity perception between an auditory and visual stimulus when various auditory-visual stimuli were presented in advance.

Stimuli

We employed a pure-tone sound having a 60 dB SPL at a frequency of 1000 Hz and a white light of LED (LP-10HW3B) as the auditory and visual stimulus, respectively. The both stimuli had a duration of 10 ms. The auditory stimulus had a linear fade-in and fade-out of 2.5 ms each in order to reduce transient responses.

Apparatus

We carried out experiments to evaluate the simultaneity perception in a soundproof room (D-30). Figure 1 shows a block diagram of the experimental apparatus. Signals of the auditory stimuli were reproduced using a CD player (XL-V1-N, Victor) and sent to an amplifier (TA-FA50ES, Sony). And then the auditory stimuli were presented to the experimental subject via headphones (MDR-Z600, Sony). The LED light was controlled by a lighting controller (LMD01, Fitdesign), and the timing of the emission was adjusted using trigger signals sent to the controller from the CD player. An experimental subject seated on a chair installed at a distance of 2 m from the LED light. The testing space was divided completely by a blackout curtain so that to avoid interferences of other light sources.

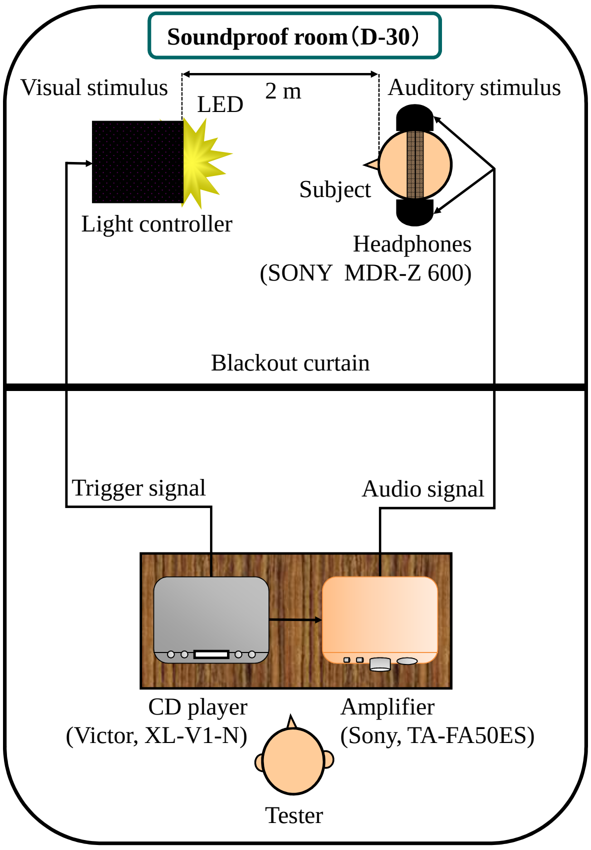


Figure 1: Experimental apparatus. The auditory stimuli were presented via headphones to the subject. The visual stimuli were presented using a LED light controlled by a light controller.

Procedures

To investigate the simultaneity perception characteristics between the auditory and visual stimulus when various auditory-visual stimuli were presented in advance, we tested in cases of the following four preceding stimuli;

- a continuous train of the auditory stimulus (sound attention test),
- a continuous train of the visual stimulus (light attention test),
- synchronized continuous trains of the auditory and visual stimuli (sound-light synchronous attention test), and
- a random train of the auditory or visual stimulus (sound-light random attention test).

Figures 2 (a) to (d) show patterns of the preceding stimuli in the above tests, respectively.

Sound attention test

Twenty auditory stimuli were successively presented at an interval (between the onset of one stimulus to the onset of the next one) of 50 ms as the preceding stimuli (Fig. 2 (a)), where each stimulus was the same as the auditory test stimulus, then followed by the auditory and visual test stimulus.

Light attention test

Twenty visual stimuli were successively presented at an interval of 50 ms as the preceding stimuli (Fig. 2 (b)), where each stimulus was the same as the visual test stimulus, then followed by the auditory and visual test stimulus.

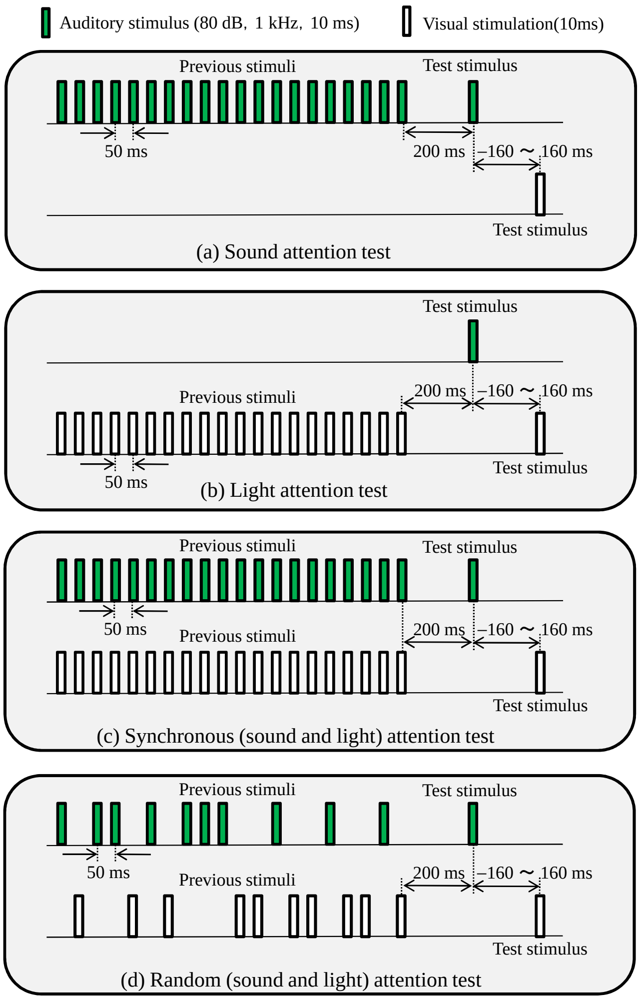


Figure 2: Presentation patterns of the preceding stimuli. (a), (b), (c), and (d) correspond to the tests of sound attention, light attention, sound-light synchronous attention, and sound-light random attention, respectively.

Sound-light synchronous attention test

Both auditory and visual stimuli were presented synchronously 20 times continuously at an interval of 50 ms as the preceding stimuli (Fig. 2 (c)), then followed by the auditory and visual test stimulus.

Sound-light random attention test

The auditory or visual stimuli were presented randomly at an interval of 50 ms as the preceding stimuli (Fig. 2 (d)), where each auditory and visual stimulus was presented 10 times respectively, then followed by the auditory and visual test stimulus.

Test stimuli

We presented the auditory and visual test stimulus 200 ms after the onset of the last preceding stimulus. We set the nine different stimulus onset asynchronies (SOAs) between the auditory and visual test stimulus as 0, ±20, ±40, ±80, and ±160 ms, where positive and negative SOAs indicate that the visual and auditory stimulus presented first, respectively. We performed each attention test separately and presented the auditory and visual test stimuli with the nine SOAs in random order. After each presentation, we asked the subject to answer the following question: “Which stimulus was perceived first, the sound or light?”

Subjects and trials

Four males in their early 20's participated in the experiments as the subjects. All subjects had normal hearing acuity and normal or corrected-to-normal vision.

We conducted 45 trials (9 SOAs $\times$ 5 iterations) per one session and performed 16 sessions in each attention test, where the presentation order was different in every session. We conducted $11,520$ trials (4 attention tests $\times$ 45 trials $\times$ 16 sessions $\times$ 4 subjects) in total.

RESULTS

Figure 3 shows the experimental results. The white and gray bars indicate the answer rates that the sound was perceived first (sound precedence) and the light was perceived first (light precedence), respectively. The horizontal axis denotes the SOA, where positive and negative values mean that the light and sound was presented first, respectively. (a), (b), (c), and (d) correspond to the results of the sound attention, light attention, sound-light synchronous attention, and sound-light random attention tests, respectively.

The answer rates of the sound precedence decrease and those of the light precedence increase as the SOA becomes large in all cases. In the result of the sound attention test (Fig. 3 (a)), the rate of the sound precedence is almost equal to that of the light precedence at a SOA of 0 ms, i.e., the point of subjective simultaneity (PSS) is almost equal to the timing of presentation of the auditory and visual stimulus. On the other hand, in the light attention, sound-light synchronous attention, and sound-light random attention test (Fig. 3 (b) – (d)), the rate of the sound precedence is smaller (around 20%) than that of the light precedence at a SOA of 0 ms in each result. This means that the PSS could be shifted a little to negative side of the SOA.

ANALYSIS

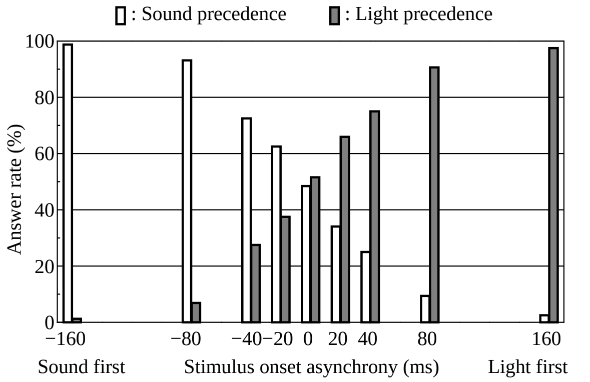
To quantitatively evaluate the PSS, we fitted the results in Fig. 3 to the following sigmoid logistic function (Fig. 4):

$$f(x) = \frac{a}{1 + e^{-k(x-x_c)}}, \quad (1)$$

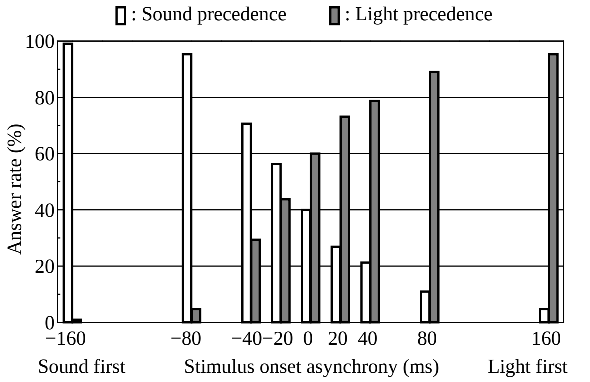
where $f(x)$ is the answer rate of the sound precedence ($k < 0$) or the light precedence ($k > 0$), x corresponds with the SOA, k is the slope coefficient related to the sharpness of the judgment between "the sound was perceived first" and "the light was perceived first," and x_c is the value of x at $f(x) = a/2$, i.e., x_c shows the PSS. $a = 100$ (%) corresponds to the maximum value of the answer rate.

Table 1 shows the PSS in each attention test. A negative value indicates that the PSS shifted toward the sound precedence. In Table 1, the PSS shifted toward the sound precedence by 2 ms at the sound attention, by about 10 ms at the light attention, by about 9 ms at the sound-light synchronous attention, and by about 15 ms at the sound-light random attention.

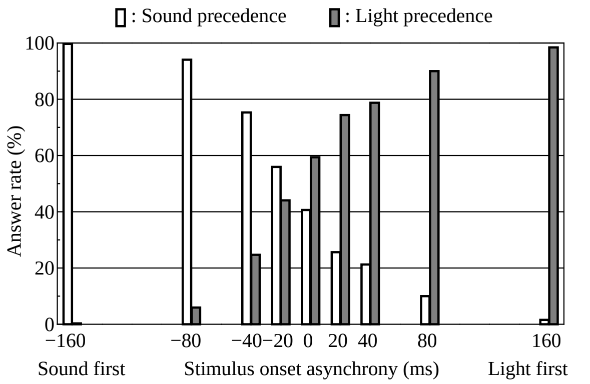
Zampini et al. investigated audio-visual prior entry effects using an audio-visual simultaneity judgment task under conditions of the attention was to be directed either to the auditory or to the visual modality, or else to divided their attention equally between the two modalities (Zampini, Shore, and Spence 2005). They then reported that the visual stimulus had to lead auditory stimulus by 46 ms at attend-audition condition, by 39 ms at divided attention condition, and by 32 ms at attend-vision condition. Comparing our results with their results, the PSS shift shows the opposite direction, i.e., the PSS shifted toward the auditory precedence in our results while it shifted toward the visual precedence in their results. However,



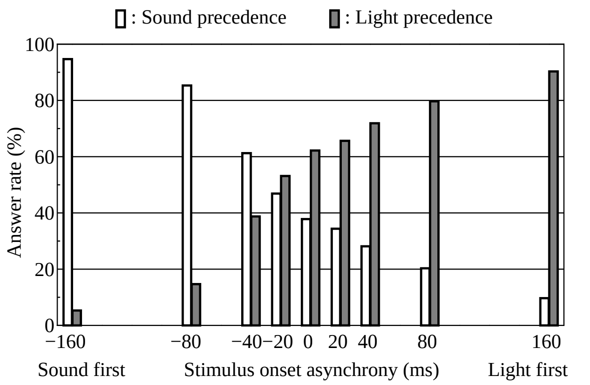
(a) Sound attention test.



(b) Light attention test.



(c) Sound-light synchronous attention test.



(d) Sound-light random attention test.

Figure 3: Experimental results. The white and gray bars indicate the answer rates that the sound was perceived first (sound precedence) and the light was perceived first (light precedence), respectively. The horizontal axis denotes the stimulus onset asynchrony (SOA) between the sound and light.

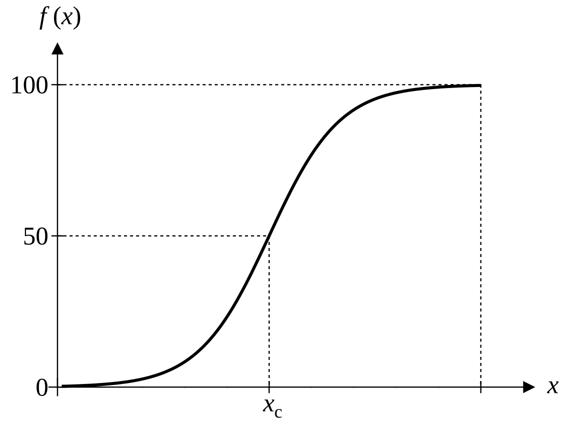


Figure 4: Sigmoid logistic function $f(x)$ in Eq. (1) when $k > 0$ and $a = 100$. In this case, $f(x)$ and x correspond with the answer rate of the light precedence and the SOA, respectively. Here, x_c correspond to the PSS.

when considering the PSS shift in the case of the auditory attention based on the case of the visual attention, the PSS shifted in the same direction, i.e., the PSS shifted toward the visual precedence by about 8 ms in our results and by 14 ms in their results. A further consideration is still necessary because some conditions were different between our and their experiments such as how to present the stimuli, how to give attention, and so on.

On the other hand, in our experiments, the range of the PSS shift at the light attention was almost the same as that at the sound-light synchronous attention. The reason is considered that the perceptual intensity of the sound was weaker than that of the light. We, therefore, have to consider subjective equivalence of the intensity between the auditory and visual stimulus in future.

Table 1: PSSs obtained using the sigmoid logistic function Eq. (1). A negative value indicates that the PSS shifted toward the sound precedence.

Sound (ms)	Light (ms)	Sound-light sync. (ms)	Sound-light random (ms)
−2.0	−10.2	−9.2	−14.8

CONCLUSION

In this paper, we carried out experiments for evaluating the simultaneity perception between an auditory and visual stimulus when auditory or/and visual preceding stimuli were presented in order to direct the attention of the experimental subjects to the auditory, visual, or both auditory-visual modalities. There were four presentation patterns of the preceding stimuli of only sound stimuli (sound attention test), only light stimuli (light attention test), synchronous sound and light stimuli (sound-light synchronous attention test), and random sound or light stimuli (sound-light random attention test). After presenting the preceding stimuli, followed by the auditory and visual test stimulus at varying stimulus onset asynchronies (SOAs), then we made the subjects to judge which of the sound or light stimulus was perceived first. We evaluated the point of subjective simultaneity (PSS) and obtained that the PSS shifted toward the sound precedence by 2 ms at the sound attention test, by 10 ms at the light attention test, by 9 ms at the sound-light synchronous attention test, and by 15 ms at the sound-light random attention test.

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