Involuntary Attention to Vision in Bimodal Reaction Tasks

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INVOLUNTARY ATTENTION TO VISION IN BIMODAL REACTION TASKS

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The effects of attention on the bimodal reaction tasks were examined. Eighteen subjects were presented a series of stimuli consisting of a light, tone, and light-plus-tone in random stimulus onset asynchronies. Half of the subjects responded to the light and ignored the tone, and another half responded to the tone and ignored the light. Mean reaction time (RT) to the tone was found to be slower than to the light, even though in general RT to the tone presented alone is faster than to the light presented alone. This result shows that, even when the subjects attend to auditory stimulus, visual information processing occurs and suppresses auditory information processing.

Key words: intersensory process, bimodal reaction time, attention.

In multimodal event detection, visual input tends to be processed in preference to auditory one (Colavita, 1974; Egeth & Sager, 1979; Posner, Nissen, & Klein, 1976; Shapiro, Egerman, & Klein, 1984; Hohnsbein, Falkenstein, Hoormann, & Blanke, 1991; Takahashi & Maruyama, 1992).

Colavita (1974) found that when visual and auditory signals are presented simultaneously in the light and tone choice reaction task, subjects generally respond to the visual input and were often unaware that an auditory signal has occurred. In his study, the loudness of the tone was equated subjectively to the light intensity, and the number of tone presentation were the same as the light. This phenomenon is called visual dominance in stimulus detection (Posner, Nissen, & Klein, 1976; Posner & Rogers, 1978).

This visual dominance is robust several alterations of stimulus conditions as well as the motor reactions. It holds even when the auditory stimulus has a subjective intensity twice (Colavita, 1974) or half (Egeth & Sager, 1977) that of the visual stimulus, when peripheral vision is employed (Colavita, Tomko, & Weisberg, 1976), when subjects are required to respond to the stimulus termination instead of stimulus onset (Colavita & Weisberg, 1979) and when simple rather than choice reaction task is used (Takahashi & Maruyama, 1992).

On the other hand, the magnitude of the visual dominance effect is sensitive to the relative presentation ratio of the light, tone and light plus tone, the instructions to attend to a specific modality (Egeth & Sager, 1977), and the extent to which subjects must divide their attention between objects in space (Colavita, 1982).

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Judging from the above, it is supposed that attention rather than sensory affair is involved in the visual dominance as to the reaction task. Two attention theories have been proposed to explain the results of experiments using the bimodal reaction tasks. Egeth and Sager(1977) demonstrated that the visual dominance was influenced by the instruction and the relative presentation ratio of stimuli, and suggested that attention is important to the visual dominance. We will use the term *voluntary attention* to refer attention in Egeth et al. In contrast to this, Posner, Klein, and Nissen(1976) demonstrated that vision was inherently less alerting and suggested that relatively more attention should be allocated to vision. We will use the term *involuntary attention* to refer attention in Posner et al.

The aim of this study was to determine which attention process is involved in the visual dominance. We used the bimodal reaction task with an accessory signal as Morrel (1968). The subjects were required to respond to either a light or tone. The other stimulus was presented together as an accessory signal. Since the auditory and visual modalities differ in reaction latency, simple RTs to a tone, i.e., auditory-only RTs, are faster than that to a light (Woodworth & Scholosberg, 1965). If the inclusion of a light or tone as an accessory signal has no effect, or a similar effect, on the auditory and visual responses respectively, we would expect the auditory RTs in this experiment to be faster than the visual ones. However, if an *involuntary attention* to vision occurs, even when the subject attends to the tone, then visual information processing interferes the response to the tone, and the auditory RTs will not be faster than the visual RTs.

METHODS

Subjects: The subjects were 20 undergraduate and graduate students, all were naive to this experiment, and had normal visual acuity with no known deficits. They were divided into two groups of nine. One group was run under a "visual response condition" and another group under an "auditory response condition". The data of one male in the visual response condition and one female in the auditory response condition had to be discarded because of an excessively long response time.

Apparatus: The tasks were conducted in a dimly lit and shielded room. Each subject was seated facing a box to which a patch was attached for light presentation. The visual stimulus (light) was projected onto the inner side of the patch which was 50 cm distant from the S's eyes and subtended a visual angle of 0.7 deg. The brightness of the light was 50 cd/m^2. When the light was off, this patch's circle served as a fixation point since it let the light of the room into the box. The auditory stimulus was a 4000 Hz tone presented binaurally via headphones.

Procedure: After allowing a moderate time for adapting to the darkness, each subject was asked to matched the tone to the light which they perceived to be of equivalent intensity by the method of limits. Stevens and Marks (1965) showed that cross-modality matching between the brightness of light and the loudness of a tone is possible. The light and tone were presented simultaneously for 1 sec and the subjects were asked to compare the loudness of the tone with the brightness of the light. Six equivalent intensities were obtained by three ascending and three descending series. The average of these six was the intensity used in the subsequent reaction task.

In the visual response condition, the *S*'s task was to respond as quickly as possible to a light by depressing a key. There were thirty-nine trials in a session: in fifteen of these trials a tone was presented after the light at stimulus onset asynchronies (SOAs) of 25, 50, and 100 msec. In another fifteen trials a tone was presented before the light at SOAs of 25, 50, 100 msec. In five of the trials, the tone and light were presented simultaneously. There were five presentations of each of the seven paired trials. In the remaining two trials, the light was presented alone. In two out of thirty-nine trials, the tone stimulus was presented alone, and to this event, the Subject was instructed to withhold motor response. All of the trials were given at random order.

The auditory response condition required the Subject to respond only to trials containing a tone stimulus and withhold response to the light when it occurred alone. The experimental sequencing was identical to the visual response condition described above.

Before performing the task, the subjects were told to which stimulus they should respond. Each subject repeated the session 5 times.

Light and tone onsets were controlled by a microcomputer, and reaction times were measured to the milliseconds. In every session, the verbal instruction was followed by an auditory warning click that preceded the response stimulus by 1 to 2 sec randomized with a mean 1.5 sec. The intertrial interval was randomized with a mean of 6 sec and a range of 5 to 7 sec.

The stimulus was presented for a maximum of 1 sec, unless terminated by the keypress. When no reaction was given for 1 sec or the reaction was given within 50 msec after the stimulus onset, that trial was discarded as an error and another new trial was added.

RESULTS

Reaction times: Figure 1 shows the mean RTs for each of the five sessions. Reaction time is plotted as a function of stimulus onset asynchrony. As can be seen in this figure, visual RTs were faster than auditory RTs for the earlier sessions. However, with repetition of the tasks there was a shift, and auditory RTs became almost as fast as visual RTs. A three-way analysis of variance (2 modalities × 5 sessions × 8 stimulus presentation conditions) was performed on the mean RTs. There was significant interaction between modality and session [$F(4,64) = 7.23$, $p < .005$]. The interaction of modality with stimulus onset asynchrony was also significant [$F(7,112) = 2.00$, $p < .10$]. No other effects were close to being significant.

Errors: There were thirty-five errors in the visual response condition including seventeen errors in which the subjects falsely responded to the tone by pressing the key. However, nineteen of the total errors resulted from the same subject. On the other hand, there were thirteen errors in the auditory response condition including twelve false responses to the light. No significant bias were found between the two conditions, so no analysis was conducted.

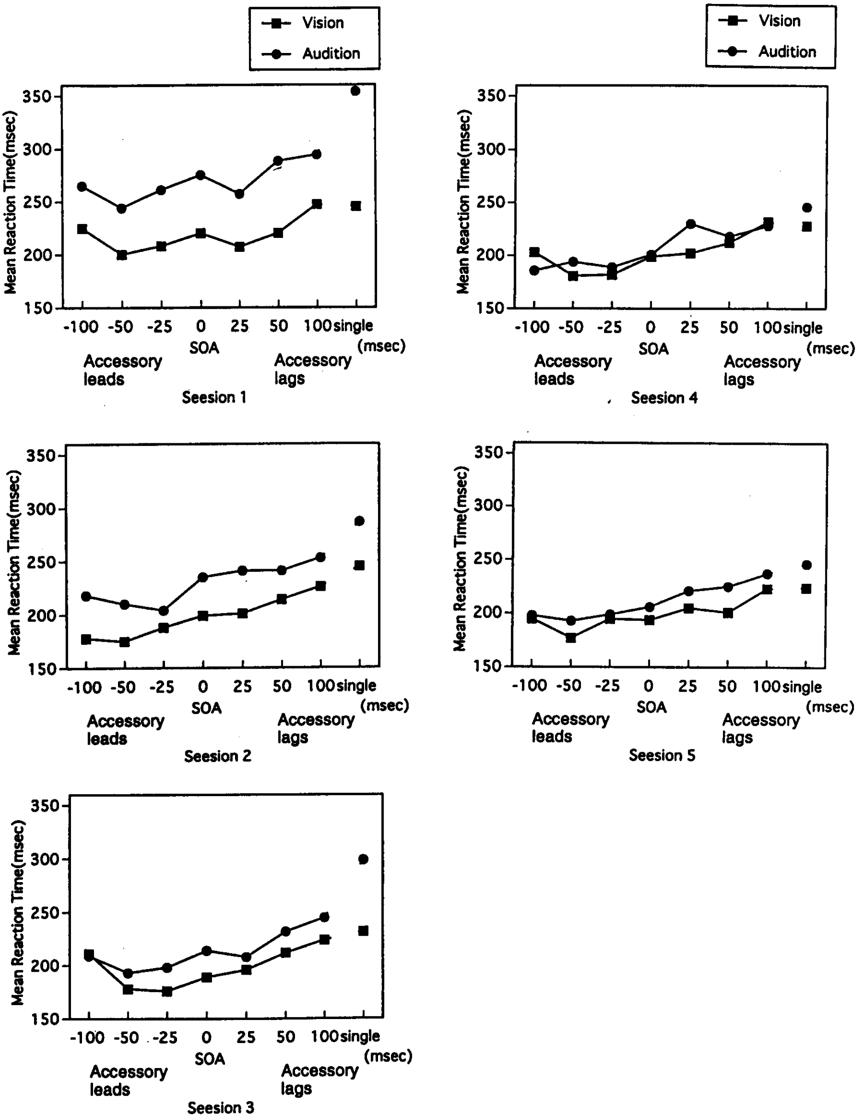

Fig. 1. Mean RT for each session as a function of light-tone or tone-light interval in both modality tasks. Squares show visual RTs and circles show auditory RTs. Each point represents mean of 40 observations. RT to single light and single tone shown at far right of each graph.

Discussion

The auditory RTs were slower than the visual RTs in the earlier sessions and the difference in RT between the visual and the auditory stimulus decreased substantially over the course of five sessions. RTs were faster when the accessory signal preceded the main signal and the RT difference caused by the inclusion of an auditory accessory signal was greater than that caused by the inclusion of a visual accessory signal.

As described in the introduction, simple auditory RT is in general faster than simple visual RT (Woodworth & Schlosberg, 1965) even when using stimuli equated subjectively in strength (Colavita, 1974; Egeth & Sager, 1977; Takahashi & Maruyama,1992). Thus, if the accessory signals had no effect, or a similar effect, on the responses, then the auditory RTs in this experiment would be faster than visual ones. However, the auditory RTs were slower than or similar to the visual ones. This result indicates that the visual and auditory accessory signals have an asymmetric effect: the visual accessory signal interferes more with the auditory response.

On the other hand, when the response stimulus was presented alone, the response was slower than all of the paired trials. In addition, RTs were faster when the accessory signal preceded the response stimulus. These results suggest that the accessory signal facilitates the response to some extent.

It follows from these facts that in the auditory response condition, even if the subjects attend to the auditory stimulus, visual information processing occurs during the task. And, although the visual accessory signal facilitates the auditory response in each trial, visual information processing generally interferes with auditory information processing.

These results support the explanation that connecting with the context of attention theory, an involuntary attention to vision is involved in the visual dominance; even when the subject responded only to the tone, involuntary visual information processing occurred. Thus, as the subjects divide their attention to more modalities, involuntary visual information processing will tend to occur and vision would dominate audition. From our experiment we conclude that, for multimodal event detection, involuntary attention is involved in visual dominance.

Morrel (1968) and Posner, Nissen, and Klein (1976) also examined the accessory signal effect in bimodal reaction tasks, however, the results they obtained were contrary to the present results. That is, auditory RTs were faster than the visual RTs and the auditory accessory signal was more effective than the visual accessory in reducing reaction time. The RTs obtained in our experiment seem to exhibit a similar tendency as the tasks were repeated. Thus, the number of task trials might cause this inconsistency in results. In fact, Morrel (1968) gave 288 response trials to a subject, which supports this argument. The involuntary visual processing involved in visual dominance might be specific to naive subjects. The visual dominance in bimodal order judgment has been observed in almost all naive subjects (Colavita, 1974; Egeth & Sager, 1977; Takahashi & Maruyama,1992). It would be of interest to see the effect of naivete on the visual dominance.

How does this change occur when repeating the task? Although the answer for this is not known at present, one explanation might be as follows: compared to the simple reaction task, the task of this study had more uncertainty, i.e., the subjects did not know which of the stimulus would appear first. Also, the subject had to choose the response, that is, key-press for the response stimulus and no-action for the accessory signal. Thus the task might force the subjects into a more complicated reaction. As the subjects repeated the task, they might obtain more knowledge of the stimulus and practice in the response. The decrease in uncertainty might account f**e**r change in RTs.

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