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Interference of an Auditory Intervening Task on the Accuracy of Temporal Judgment

Satoru KAWAMURA

1. Introduction

A number of studies have reported that there is no difference in perception of time among sensory modalities. In other words, these studies claimed that the characteristics of the processing of temporal information within a stimulus did not differ, regardless of the modality to which the stimulus was given. Warm, Foulke and Leob (1966) reported that time reproduction did not differ between the interval provided auditorily and that provided visually and that there is no difference in the tendency of the change of the time reproduction over trials between the two modalities. Using the method of adjustment, Craig (1973) compared the filled-duration illusions, which refer to the phenomenon that intervals filled with stimuli are perceived as being longer than empty intervals of equal physical duration, and obtained findings that suggested that there was no significant difference among visual, auditory and tactual stimuli. Buffardi (1971) obtained results similar to those of Craig (1973) by the method of paired comparison. Using the method of bisection, Warm, Stutz and Vassalo (1975) showed that there was no difference in temporal judgment between visual and auditory stimuli and that the effect of training of bisections was symmetrical both from visual training to auditory test and from auditory training to visual test. Using the methods of magnitude estimation and verbal estimation, Bobko, Thompson and Schiffman (1977) investigated the relationship between judged and physical duration for auditory and visual modalities and showed that the stimulus modality exerted little influence on the obtained power functions between judged and physical duration.

Based on the findings that time perception did not differ between sensory modalities, Warm *et al.* (1975) indicated the existence of a specific mechanism for temporal processing independent of modalities. However, the absence of any difference between modalities does not necessarily imply the existence of a specific mechanism for temporal processing that does not depend on the processing of any sensory modalities. In other words, it is possible to explain these findings even if temporal processing depends on the mechanism of a certain modality. It is more likely that temporal processing is included in some sensory systems rather than that there is a mechanism that specifically processes temporal information, because time itself is not a physical substance but is one of the attributes of stimuli presented to sensory systems. If this speculation is valid, it would be necessary to clarify what sensory modality or modalities actually serve as the basis of temporal processing.

This question cannot be answered only by studies that merely compare temporal judgment such as time reproduction and magnitude estimation of the stimuli given to different sensory modalities, because the implications of the findings of the studies described above are ambiguous. To clarify this issue, the present study combined and compared a pair of experiments. The first experiment aimed to replicate the findings of previous studies by showing that time perception did not differ between the different modalities to which the temporal interval was given if the stimulus required the processing of only one modality. The second experiment aimed to examine the possibility that temporal processing depends on the processing of some specific sensory modality. For this purpose, the experiment investigated how a nontemporal task inserted in a temporal interval interferes with the temporal judgment of the interval. The interference stimulus was visual for an auditory interval and auditory for a visual interval.

2. Experiment 1

The aim of Experiment 1 was to compare the accuracies of reproduction of temporal intervals presented visually and auditorily.

2.1 Method

Apparatus. Stimulus control and the recording of the participants' responses were executed using an NEC PC-9821As personal computer with a PC-TV455 color monitor having a 26.4 cm × 16.5 cm screen.

Participants. Five undergraduate or graduate students (all males) participated in the auditory interval condition (referred to as AU-condition hereafter) and visual interval condition (referred to as VS-condition hereafter). Each individual participated in these two conditions on different days to avoid the adaptation effect that might occur because of the continuity of the conditions. Further, to check the order effect precisely, two participants first attended to the AU-condition and the remainder first attended to the VS-condition.

Stimulus. The visual stimulus in the VS-condition was a filled white circle with a diameter of 12 mm displayed at the center of the screen. The auditory stimulus in the AU-condition was a beep tone of 880 Hz generated by the sound source of the computer and presented from the computer's built-in speakers. Participants were seated at a distance of 80 cm from the computer and the screen. The temporal intervals that the participants were required to reproduce were defined by the interval between two presentations of a circle on the screen in the VS-condition or two presentations of a beep tone in the AU-condition. In both conditions, the first and second presentations of the circle or tone lasted for 150 msec each. The interval between the onset of the first presentation and that of the second presentation varied from 2,300 msec to 5,000 msec with increments of 300 msec. Therefore, ten different intervals were used as stimuli in both conditions.

Procedure. The participants were instructed to fix their gaze on the center of the screen throughout the experiment. At the beginning of each trial, a "ready" signal (written in Japanese) was presented for two seconds at the center of the screen. Three seconds after the disappearance of the "ready" signal, one of the stimuli composed of two presentations of a circle or a tone was presented. Immediately after the presentation of the stimulus ended, the participants were required to reproduce the interval between the onsets of the two presentations by pressing the "2" key on the keyboard twice such that the interval of the key presses is subjectively identical to their perceived interval. After their reproduction ended, the "ready" signal for the next stimulus was presented. In each condition, the participants performed six blocks of trials. Each block contained twenty trials: two sets of all ten types of intervals. The participants were permitted to rest for a period of time between blocks.

2.2 Results

The first of the six blocks was regarded as a practice session and the data obtained for this block were excluded from the analysis. Therefore, the ten data sets of the remaining five blocks were used for analysis for each type of the interval. In addition, data in which the participants reproduced an interval greater than ten seconds or less than one second were also excluded because they were thought to be generated not by the participants' temporal judgment itself but by some failure of the participants' ability for response. For each participant, correlation coefficients between the presented intervals and the reproduced intervals across the ten types of intervals were calculated for the AU- and VS-conditions as indices of the accuracy of time reproduction. Table 1 shows the correlation coefficients of the two conditions and the regression lines of the reproduced interval as a function of the actual interval for each participant. This

Table 1

Correlation coefficients between actual intervals and reproduced intervals and regression lines for each subject in Experiment 1

Participant	Interval	*r*	Regression line
A	Auditory	.95318	y = 464.10 + .92541 x
	Visual	.94519	y = 966.36 + .90357 x
B	Auditory	.96232	y = -282.4 + .97364 x
	Visual	.92834	y = -116.4 + .87083 x
C	Auditory	.87709	y = 687.26 + .86583 x
	Visual	.87805	y = -316.2 + 1.0876 x
D	Auditory	.93324	y = -570.9 + 1.0820 x
	Visual	.93687	y = -442.9 + .98883 x
E	Auditory	.92253	y = 709.53 + .84464 x
	Visual	.92131	y = 249.81 + .83283 x

Note) *'r',* 'y', and 'x' indicate the correlation coefficient, the reproduced interval and the actual interval, respectively.

illustrates extremely high correlation coefficients between the presented interval and the reproduced interval both in the AU- and VS-conditions for all participants. Statistical analysis showed no significant differences in correlation coefficients between the AU- and the VS- conditions for any of the participants ($p > .1$). This finding indicates that the accuracy of time reproduction did not differ regardless of whether the interval was presented visually or auditorily. This corresponded to the findings of Craig (1973) and the other studies described above, which claimed that temporal judgment does not differ according to the sensory modality to which the stimulus is presented.

3. Experiment 2

Experiment 1 showed that the accuracy of time reproduction did not differ between the case in which the stimulus was visually presented and the case in which it was auditorily presented. As discussed in the Introduction, however, this does not necessarily verify that there exists a mechanism operating entirely for temporal processing without depending on the processing of some modalities. There remains the possibility that the mechanism for a certain sensory modality serves as a processor of temporal information regardless of the modality to which the stimulus is presented. If so, when a non-temporal task is required to be processed by the modality that is also in charge of temporal processing, the time perception of the interval including that nontemporal task will be interfered with. In Experiment 2, visual or auditory interference was inserted between the intervals used in Experiment 1 and how that interference affects the accuracy of time reproduction was investigated.

3.1 Method

Apparatus. The apparatus in Experiment 2 was completely identical to that in Experiment 1.

Participants. The same five individuals who participated in Experiment 1 participated in the audition-with-the-visual-interference condition (referred to as AU-VSI-condition hereafter) and vision-with-auditory-interference condition (referred to as VS-AUI-condition hereafter). Each individual participated in two conditions on different days. Two participants first attended to the AU-VSI-condition and the remainder first attended to the VS-AUI-condition.

Stimuli. In the AU-VSI-condition, a visual stimulus for an interference task — a blue or yellow circle with a diameter of 12 mm — was presented at the center of the screen for 150 msec during the auditorily presented interval for time reproduction, which was identical to that in the AU-condition of Experiment 1. In the VS-AUI-condition, an auditory stimulus for an interference task — a 440 Hz or 1,760 Hz beep tone — was presented for 150 msec during the visually presented interval, which was identical to that in the VS-condition of Experiment 1. In both conditions, the intervals to be reproduced by the participants were varied from 2,300 msec to 5,000 msec with increments of 300 msec, resulting in ten types of intervals for both conditions, identical to Experiment 1. The temporal position of the interference stimulus was randomly varied within a range from trial to trial; the earliest one started 600 msec after the beginning of the tested interval and the last one started 1,000 msec before the end of the interval.

Procedure. The participants were instructed to fix their gaze on the center of the screen throughout the experiment. At the beginning of each trial, a "ready" signal (written in Japanese) was presented for two seconds at the center of the screen. Three seconds after the disappearance of the "ready" signal, one of the stimuli was presented. The participants were first required to respond to the interference stimulus immediately after it was presented. In the AU-VSI-condition, they were required to press the "1" key if the stimulus was blue and the "3" key if it was yellow as fast and accurately as possible. In the VS-AUI-condition, they were required to press the "1" key if the tone was low (400 Hz) and the "3" key if the tone was high (1,760 Hz) as fast and accurately as possible. After the interval ended, the participants were required to reproduce the interval of the two presentations of visual stimuli in the VS-AUI-condition and of auditory stimuli in the AU-VSI-condition by pressing the "2" key of the keyboard twice, as in Experiment 1. In each condition, the participants performed six blocks of trials. Each block contained twenty trials: two sets of all ten types of intervals. The participants were permitted to rest for a period of time between blocks.

3.2 Result

As in Experiment 1, the data for the first block and the time reproductions greater than 10 seconds or less than one second were excluded from the analysis. Furthermore, the data for trials in which the participants made an incorrect response to the interference stimulus, i.e., when the participant erred in the judgment of the tone height in the VS-AUI-condition or of the color of the circle in the AU-VSI-condition, were also excluded. For each participant, the correlation coefficients of the two conditions between the presented intervals and the reproduced intervals were calculated as indices of the accuracy of time reproduction. Table 2 shows the correlation coefficients of the VS-AUI- and AU-VSI-conditions between the presented interval and the reproduced interval and the regression line for the reproduced interval as a function of the presented interval for all five participants. This illustrates that the correlation coefficients in the VS-AUI-condition were lower than those in the AU-VSI-condition for all participants. Statistical analysis also indicated that these differences were significant for all partici-

Table 2

Correlation coefficients between actual intervals and reproduced intervals and regression lines for each subject in Experiment 2

Participant	Interval	Interference	*r*	Regression line
A	Auditory	Visual	.94199	y = 635.45 + .86536 x
	Visual	Auditory	.86184	y = 940.40 + .85909 x
B	Auditory	Visual	.94682	y = -331.8 + .92513 x
	Visual	Auditory	.86436	y = -212.7 + .73040 x
C	Auditory	Visual	.87529	y = 833.21 + .74094 x
	Visual	Auditory	.80057	y = 584.08 + .90634 x
D	Auditory	Visual	.92267	y = -372.4 + .91403 x
	Visual	Auditory	.86364	y = -107.1 + .81239 x
E	Auditory	Visual	.91417	y = 819.12 + .81985 x
	Visual	Auditory	.83114	y = 397.01 + .92264 x

Note) '*r*', 'y', and 'x' indicate the correlation coefficient, the reproduced interval and the actual interval, respectively.

pants ($p < .01$). A comparison of the correlation coefficients of the VS-condition in Experiment 1and those of the VS-AUI-condition in Experiment 2 reveals that the auditory interference significantly reduced the accuracy of the reproduction of the visual interval ($p < .01$). On the other hand, a comparison of the correlation coefficients of the AU-condition in Experiment 1 and those of AU-VSI-condition in Experiment 2 revealed that the visual interference did not affect the accuracy of the reproduction of the auditory interval ($p > .1$). These findings indicate that the auditory interference reduced the accuracy of the temporal processing while the visual interference did not.

4. Discussion

The present study was designed based on the speculation that temporal processing might be mediated by a mechanism of a specific modality and, if so, the processing demand of nontemporal information of this modality would affect concurrent temporal processing. As expected, the findings obtained in Experiment 2 suggested that as compared with visual nontemporal processing, auditory nontemporal processing interfered selectively with temporal processing. This finding indicates the possibility that temporal processing is at least partially mediated by an auditory mechanism.

In general, auditory information is conveyed to a human as a temporal pattern of air vibrations. Therefore, it is expected that the auditory processing system should have a mechanism to represent temporal elements of the stimulus. Such a mechanism would be manifested by the close relationship between temporal processing and auditory processing, as is found in the present study. In an auditory mechanism, one hypothetical "operator" that is applied to the processing of the temporal duration of the stimulus given to that modality as well as another modality is an internal or imaginary sound like inner speech. In other words, when a stimulus, whether auditory or non-auditory, is presented, some imaginary sound is generated in the participants' brains, just like inner speech. This internal sound, which is expected to be represented in the auditory system, starts at the onset of the stimulus and stops at its offset. Thus, the representation of this internal sound is referred to in temporal judgments such as time reproduction.

In vision, on the other hand, the processing demand for temporal information appears to be relatively small as compared with audition because the greater part of visual information is conveyed to perceivers as spatial variables. Accordingly, it is expected that vision is inferior to audition as a mechanism for representing temporal information. Although visual phenomena are characterized by the dominance of spatial elements, temporal elements are also included in visual stimulus. This is because visual objects are not always static but are possibly varied in terms of their position, size, color, brightness, and so on, and perceivers often have to handle that temporal information in order to adapt themselves to such changes over time. Therefore, it is unlikely that a visual mechanism cannot operate as the basis of time perception. It would be reasonable to expect that visual processing can also serve as the mechanism for temporal processing and interferes with concurrent temporal judgment, even if the degree of contribution and interference are different from, and perhaps smaller than, those of the auditory mechanism. In fact, Macar, Grondin and Casini (1994) found that temporal judgment was affected by the interpolating task that required the perceiver to discriminate the intensity of the visual stimulus.

As discussed above, the finding that temporal judgment does not differ regardless of the modality to which the temporal interval is given can be explained by supposing that there exists a specific mechanism for temporal processing independent of any sensory modalities as well as by supposing that the mechanism of a specific modality performs temporal processing. Based on the fact that information from the environment enters perceivers via some sensory modalities such as audition or vision, it seems more likely that temporal processing is involved in such sensory mechanisms than that there is a specific temporal mechanism independent of any sensory modality. Mach (1883) stated that "time is an abstraction, at which we arrive by means of the changes of things" (p. 273). This implies that time is not the frame wherein events occur but a by-product of our processing of information in our environment. The relationship between temporal processing and sensory modalities should be investigated further because the present study only indicated the possibility that a certain modality mechanism might serve as temporal processing, by using limited conditions.

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A number of studies have reported that there is no difference in perception of time among sensory modalities, i.e., visual, auditory, tactual, and so on. In other words, these studies claimed that the characteristics of the processing of temporal information within a stimulus did not differ, regardless of the modality to which the stimulus was given. The evidences were obtained by using various kinds of methods such as time reproduction, the method of adjustment, the method of paired comparison, the method of bisection, the method of magnitude estimation, and the method of verbal estimation. Based on the findings that time perception did not differ between sensory modalities, Warm et al. (1975) indicated the existence of a specific mechanism for temporal processing independent of modalities. However, the absence of any difference between modalities does not necessarily imply the existence of a specific mechanism for temporal processing that does not depend on the processing of any sensory modalities. It is possible to explain these findings even if temporal processing depends on the mechanism of a certain modality.

The present study was designed to investigate whether temporal processing is executed by some specific temporal mechanism or is involved in the processing of some sensory modality. In Experiment 1, five participants were required to reproduce a temporal interval presented via auditory and visual modalities. The accuracies of reproduction of the two kinds of intervals were not significantly different from each other. This finding corresponds to those of the previous studies, based on which researchers claimed that a specific mechanism independent of sensory modalities performs temporal processing. In Experiment 2, a visual interference task was inserted during the auditory interval and an auditory interference task was inserted during the visual interval. This experiment revealed that the auditory interference reduced the accuracy of reproduction of the visual interval, while the visual interference did not affect the reproduction of the auditory interval. These findings indicate a close relationship between temporal processing and auditory processing, i.e., the possibility that certain sensory modalities operate as the mechanism for temporal processing.