Audio-visual Spatial Coherence Judgments in the Peripheral Visual Fields

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ABSTRACT

Auditory and visual stimuli presented in the peripheral visual field were perceived as spatially coincident when the auditory stimulus was presented five to seven degrees outwards from the direction of the visual stimulus. Furthermore, judgments of the perceived distance between auditory and visual stimuli presented in the periphery did not increase when an auditory stimulus was presented in the peripheral side of the visual stimulus. As to the origin of this phenomenon, there would seem to be two possibilities. One is that the participants could not perceptually distinguish the distance on the peripheral side because of the limitation of accuracy perception. The other is that the participants could distinguish the distances, but could not evaluate them because of the insufficient experimental setup of auditory stimuli. In order to confirm which of these two alternative explanations is valid, we conducted an experiment similar to that of our previous study using a sufficient number of loudspeakers for the presentation of auditory stimuli. Results revealed that judgments of perceived distance increased on the peripheral side. This indicates that we can perceive discrimination between audio and visual stimuli on the peripheral side.

Keywords : Auditory and Visual Stimuli, Peripheral Visual Field, Sound Localization, Visual Localization, Spatial Perception, Spatial localization

Ⅰ. Introduction

Human beings are capable of perceiving events in their external environment through multiple modalities. Under certain conditions, the information acquired from several senses is unified. In particular, audio-visual integration has long been studied by various researchers. The most famous finding in this area is the ventriloquism effect[1-3]. When auditory and visual stimuli are simultaneously presented, the perceived location of the auditory stimulus is shifted toward the location of the visual stimulus. Welch and Warren[4] postulated the modality appropriateness hypothesis. This hypothesis asserts that the modality that is most appropriate or reliable with respect to a given task dominates the perception in the context of that task. They claimed, for example, that vision dominates in spatial tasks because of its higher spatial resolution, whereas audition dominates in temporal tasks because of its higher temporal resolution. However, findings of more recent studies have contradicted this hypothesis. Alais and Burr[5] found that the perception of spatial location by observers relied more on auditory cues when the visual cue was progressively blurred. Their results showed that vision does not usually dominate in spatial tasks.

While many studies of audio-visual integration have been carried out, most of them have focused primarily on stimuli presented in the central visual field. In the periphery, the accuracy of spatial localization is lower than that in the central field. This tendency is greater in vision than in audition[6]. Therefore, it is possible that the auditory modality becomes dominant in audio-visual integration in the periphery. In such a case, we expect that stimuli presented in the periphery give rise to a behavior different than that observed in the central visual field. In order to investigate this phenomenon we searched for any differences in the perception of spatial disparity between auditory and visual stimuli presented from the central visual field and those presented in the periphery.

In our previous experiment[7], we found an audio-visual interrelationship for spatial localization judgment in the peripheral visual field, and compared it with the behavior in the central visual field. A method of psychophysical scaling was employed in combination with simple audio-visual stimuli(1 kHz pure tone bursts and flashing light spots) that were presented with various spatial

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disparities. Participants were required to look straight ahead while visual and auditory stimuli were presented simultaneously and were instructed to judge the spatial coherence between the perceptual location of the visual stimulus and that of the auditory stimulus using an integer scale from 1 to 5, "1" meaning 'completely coincident' and "5" meaning that the distance between the auditory and visual stimuli was the greatest, the participants had participated in training sessions and knew the greatest distance. From this experiment, when the visual stimulus was presented in the peripheral visual field, the auditory and visual stimuli were perceived as if they originated from the same position when the auditory stimulus was presented outwards by about five to seven degrees from the physical direction of the visual stimulus source(see Fig. 1(b)). Meanwhile, such shifts could not be observed when the visual stimulus was presented in the central visual field(see Fig. 1(a)).

However, when the visual stimulus was presented in the periphery and the auditory stimulus was presented farther from the front than the position of the presented visual stimulus, the perceived inconsistency did not increase when the physical position of vision became further outside(see Fig. 1(b)). In the previous experimental set up, however, the number of loudspeakers outside of the visual stimuli might have been insufficient in the case of the peripheral visual field. With these angles, the participants could not give their judgments properly. Therefore, we conducted an experiment by adding three loudspeakers in the outwards direction of each visual stimulus.

II. Experiment

2.1 Participants and apparatus

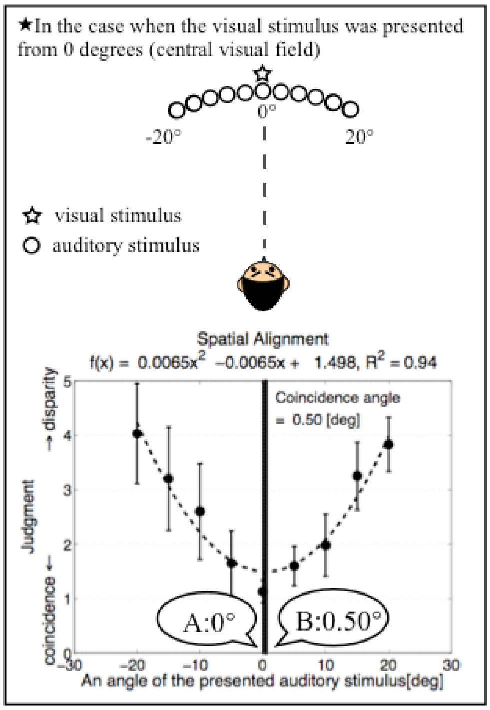
Four males, 20 to 30 years of age without vision and audition impairments participated in the experiment. The experiment was conducted in a completely dark anechoic room. The participants sat on a chair located in the center of an apparatus for audio-visual stimulation. A participant's head was restrained in a straightforward position with a custom-made restraining device. With the apparatus, an auditory stimulus was presented from one of the 37 loudspeakers, which spanned ± 90° of a circle with a radius of 1.2 m at five degree intervals. Loudspeakers (Hoshiden, 30 mm) were installed in small cylindrical boxes(114 cm^3) covered with acoustic absorbing material. A visual stimulus was presented using white light emitting diodes(LEDs), placed at the top front of the loudspeakers at 0 degrees, ± 20 degrees, and ± 40 degrees. Fig. 1 shows previous experimental results[7]. The error bars show the standard error. The abscissa shows the angle at which the auditory stimulus was presented, while the ordinate displays the values on the psychophysical scale corresponding to the participant''s judgment of spatial disparity between the two stimuli. The dotted lines in the figures show quadratic fitting of the data. The thick vertical lines (A) show the directions corresponding to physical coincidence in the visual and auditory stimuli. The bold vertical lines (B) in the figures mark the directions of the minimum values for the fittings, that is, the directions for which the participants perceived the two stimuli as coming from the same direction. We call this the "coincidence angle"; its value is shown in the upper right corner of the graphs.

2.2 Stimuli

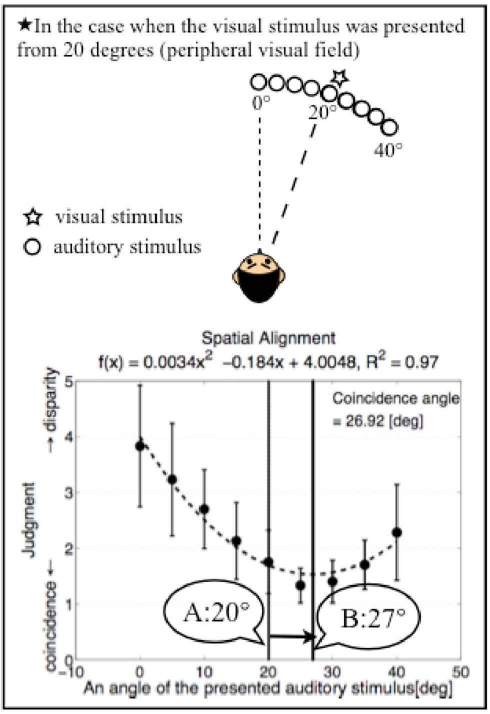
An auditory stimulus consisted of five 20 ms pulses, using a 1 kHz pure tone with a sound pressure level of 75 dB, followed by 180 ms of silence (for a total duration of 1 second). A visual stimulus was synchronized with the auditory stimulus and presented from one of the five directions, such as ± 40, ± 20 or 0 degrees. As mentioned above, three loudspeakers were added to investigate outward behavior of the perceived distance. In this experiment, an auditory stimulus was presented from one of the twelve loudspeakers, which were arranged as follows: One was at a position of similar to that of the visual stimulus, four speakers were inwards from the visual stimulus position, and seven speakers were outwards from the visual stimulus position. For example, if the visual stimulus was presented from the direction of 40 degrees, the auditory stimulus was presented from one of the speakers in the directions from 20 to 75 degrees. One exception was the case when the visual stimulus was presented from 0 degrees, in which case only nine loudspeakers were used (-20 degrees to +20 degrees). Hence, this experiment spanned a total of 4 (peripheral visual stimuli) × 12 (auditory stimuli)
+ 1 (central visual stimulus) × 9 (auditory stimuli) = 57 audio-visual stimuli.

2.3 Task and Procedure

Participants were required to fix their sight straight ahead and were instructed to judge the distance between the perceptual locations of the sound and the flash using an integer scale from 1 to 5. Where "1" indicates "complete coincidence" of the perceptual locations of auditory and visual stimuli, and "5" indicates that the spatial disparity between the auditory and visual stimuli was the largest. Participants' responses were recorded by a microphone placed inside the anechoic room. One



(a) Presented visual stimulus : 0°



(b) Presented visual stimulus : 20°

Fig. 1. Experimental results

session consisted of a ten-trial warm-up period to allow adaptation to the dark room, followed by 57 trials comprising all stimuli in random order. Each participant completed one practice session followed by four sessions for actual data gathering. The experiment took place as follows:

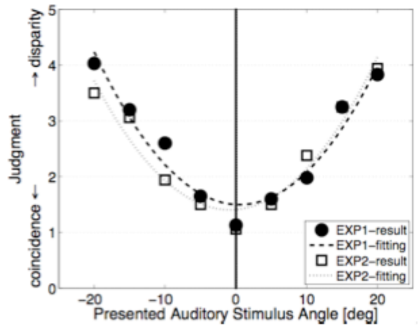
1. Participants were instructed to sit on a chair at the center of the speaker array and to fix their heads and sight straight ahead.
2. Subjects held a push button and pressed it to start each trial.
3. A fixation point was presented from the front LED for two seconds so that the participants could focus on it.
4. Audio-visual stimuli were presented after a one-to two-seconds (randomly chosen) waiting period after the fixation point was turn off.
5. Participants verbally responded their estimation of the spatial disparity between the visual and auditory stimuli using the aforementioned scale, and an experimenter recorded the responses.
6. Steps 2 through 5 were repeated for all trials.

2.4 Result

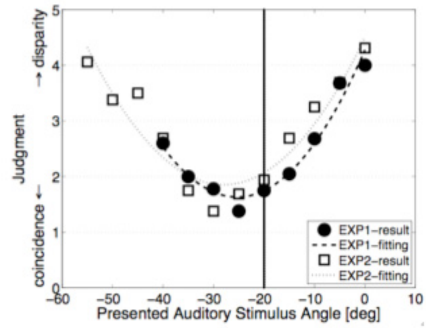
The experimental results are shown in Fig. 2 together with the results of the previous experiment. The data of the previous experiment and this experiment are labeled with filled circles and open squares, respectively. Plotted curves correspond to quadratic fittings of the data. The dashed line shows a fitting to the results of the previous experiment; the dotted line shows a fitting to the results of this experiment. When the visual stimulus was presented from 0 degrees (Fig. 2(a)), the results show that the participants made similar judgments in both experiments. When the visual stimulus was presented from 20 degrees (Fig. 2(c)), both experiments resulted in a coincidence angle of approximately 27 degrees; that is, the participants perceived both stimuli as originating at the same location when the auditory stimulus was presented outwards by about seven degrees from the physical direction of the visual source. However, when the visual stimulus was presented from 40 degrees (Fig. 4(e)), the psychophysical scale evaluated by the participants showed lower values for the outwards angles than those for the inwards ones. The difference between the 20 and 40 degree scenarios might be explained with reference to the results of Mills[8], according to which the minimum audible angle(MAA) increases drastically for angles greater than 60 degrees; that is, the auditory resolution for these angles suffers a significant drop.

Ⅲ. Discussion

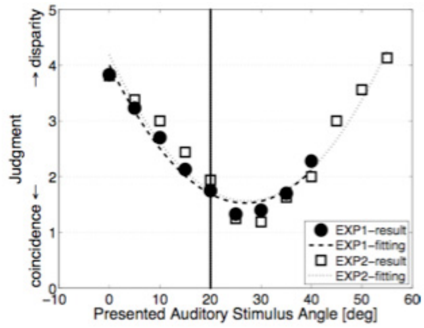
Through this experiment, we found that the participants were able to properly perceive an increase of the distance between the location of the auditory source and that of the visual source, even when the auditory stimulus was presented from the peripheral side of the visual stimulus. Therefore, the phenomenon that the coincidence angle shifts toward the periphery is not attributable to the ambiguity of the distance between auditory and visual source on the peripheral side of the visual source An explanation is needed for this shift for the auditory stimuli of approximately five to seven degrees outwards from the direction of visual stimuli. To consider the reason for this shift, we have to examine the possibility that this shift originated from a simple disparity between the perceived and physical locations for either the visual or the auditory stimulus without performing multimodal integration. If subjects perceived a visual stimulus from seven degrees outward from physical position or vice versa, perceived an auditory stimulus seven degrees inward, the coincidence angle should shift toward the periphery. Mateeff et al.[9] found that the perceived direction for a visual target presented in the periphery was shifted inwards from its actual physical location while Mapp et al. [10] did not found any consistent discrepancy between the perceived and actual positions of visual stimuli presented from angles up to 20 degrees away from the front. For auditory stimuli, Suzuki et al.[11] found that a 1 kHz pure tone could be accurately located when presented within an angle of 30 degrees away from the front if no interference sound was simultaneously given. These results imply that the shift of the coincidence angle cannot be explained by the mislocalization in unimodal(either visual or auditory) spatial perception. Distortion in the perception of audiovisual spatial integration may exist in the peripheral field. The reason behind this difference is not currently understood and we deem available data to be insufficient to properly characterize this phenomenon. Further experiments seem necessary to characterize this perceptual distortion in greater detail and more quantitatively.



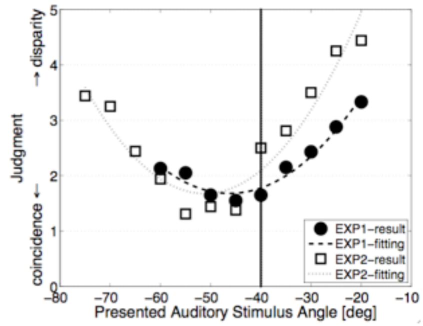
(a) Presented visual stimulus at 0°



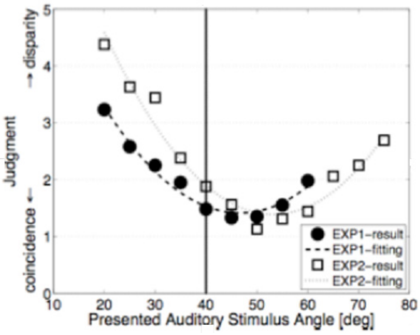
(b) Presented visual stimulus at -20°



(c) Presented visual stimulus at 20°



(d) Presented visual stimulus at -40°



(e) Presented visual stimulus at 40°

Fig. 2. Comparing the results between the previous experiment and present experiment

Ⅳ. Conclusions

Our results show that perceptual coincidence between audio and visual stimuli in peripheral visual field can be lead when the auditory stimulus is presented outwards by about five to seven degrees from the position of the visual stimulus. Nevertheless, participants could distinguish the difference as the distance increased in the periphery. This indicates that the phenomenon is summarized by a outward shifting of the coincidence angle. In contrast, no such shifts were observed when the visual stimulus was presented in the central visual field.

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