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LOCALIZATION OF SOUND IN ROOMS-THE EFFECT OF VISUAL FIXATION

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Introduction

It is well established that visual cues can significantly bias the localization of auditory stimuli. This is especially true if the observer expects that the sources of visual and auditory sensations are one and the same, in which case the bias is termed a ventriloquism effect [1].

We have recently performed a study of human localization of sound sources in a concert hall situation [2]. Noting that previous studies of visual bias on auditory localization have been confined to small test beds or anechoic rooms we thought it worthwhile to search for visual bias in the larger scale geometry.

Experiment

Subjects: The subjects for these experiments, lettered A-J, were 10 subjects from the experiments of ref. 2, numbers 2, 3, 4, 5, 6, 7, 8, 9, 10 and 13 respectively. They ranged in age from 8 to 42. Subjects E and F were female. Subject D was left handed; subjects B and F had been switched from left handed to right handed in childhood. All subjects reported normal hearing and normal or completely corrected vision. Before participating in the experiments described here subjects had performed at least five runs of the auditory localization task.

Method: The auditory stimulus and experimental geometry were identical to those of ref. 2. The signal was an 80 dB 500 Hz sine tone pulse gated on and off with a hard edge. The pulse had a duration of 50 ms. The sine pulse was sent to one of 8 small loudspeakers located on an arc 12 meters from the subject and spaced 4 degrees apart. The speakers were 1 meter from the floor. The experiments were performed in the Espace de Projection at IRCAM, a variable acoustics concert hall with dimensions 24x15.5 m by 11.5 m high. The wall and ceiling surfaces of the room were chosen to be highly absorbing, providing a reverberation time of 1 s at 500 Hz. The subject's task was to decide which loudspeaker had sounded. An experimental run consisted of 10 pulses from each of the speakers, presented in random order, requiring a total of 80 judgments.

The new feature of the experiments described here is that the subject's gaze was directed. This was done by placing two small pilot lamps at the center of loudspeaker number 1, the leftmost, or at the center of loudspeaker number 8, the rightmost. Prior to the acoustic pulse either one or both of the pilot lamps was illuminated for about ½ second. The subject was required to declare first how many lamps had been lit and then which speaker had sounded the pulse.

The two lamps were separated by 0.4 degrees. When the lamps were on speaker number 1, for example, it was easy for the subject to count the illuminated lamps if he was looking at speaker 1, but impossible to count them if he was looking to the right of speaker 4. If on a given trial a subject incorrectly reported the number of lamps his localization judgement for that trial was not accepted as data. No record was kept of the incorrect responses to the lamps; we noted only that the number was almost nil. The purpose of the visual task was merely to fix the subject's gaze near speaker 1 or near speaker 8.

Although the visual task directed the subject's gaze, we did not want the subject's head to be oriented towards the extreme left or right. The subject was required to maintain his head in a forward orientation, along the line which passed between speakers 4 and 5, and to move only his eyes to left or right to observe the lamps on speakers 1 or 8. In order to monitor the head position we placed a television camera directly in front of the subject, well below his line of sight to the speakers. If a subject's head was not oriented properly the experimenter halted the experiment briefly to remind the subject to correct his head position.

Each subject completed three runs, one with his gaze directed to the left, one with his gaze directed to the right, and a control run with no visual requirement.

Results

The most important statistical measure of performance is E(k), the average localization error in degrees given that the sound source was speaker k ($1 \leq k \leq 8$). It is defined as $4[r(k)-k]$, where r(k) is the subject's numerical response given source number k, averaged over the 10 trials of a run. Figure 1 shows $\langle E(k) \rangle$, averaged over the 10 subjects for the three conditions: leftward gaze (1), rightward gaze (8) and undirected gaze, the control (c). The figure shows that there is a significant bias of auditory localization towards the direction of the subject's gaze. The amount of the bias can be determined by subtracting $\langle E(k) \rangle$ in the control condition from $\langle E(k) \rangle$ in the directed gaze conditions 1 and 8. It shows no particular dependence upon the angular discrepancy between the visual target and the sound source, which ranged from -28 to +28 degrees. The errors, averaged over subjects, trials and source location are $\langle E_c(k) \rangle = -0.6(\pm 1.3)$ degrees, $\langle E_1(k) \rangle = -2.3(\pm 1.3)$ degrees, $\langle E_8(k) \rangle = 1.5(\pm 1.6)$ degrees. The average bias then is 1.9 degrees towards the gaze.

Figure 2 shows the standard deviation of subject judgements. There is a small effect supporting the conclusions of Platt and Warren [3] and Berman and Welch [4] that the variability in auditory localization is reduced when the eyes are directed towards the target.

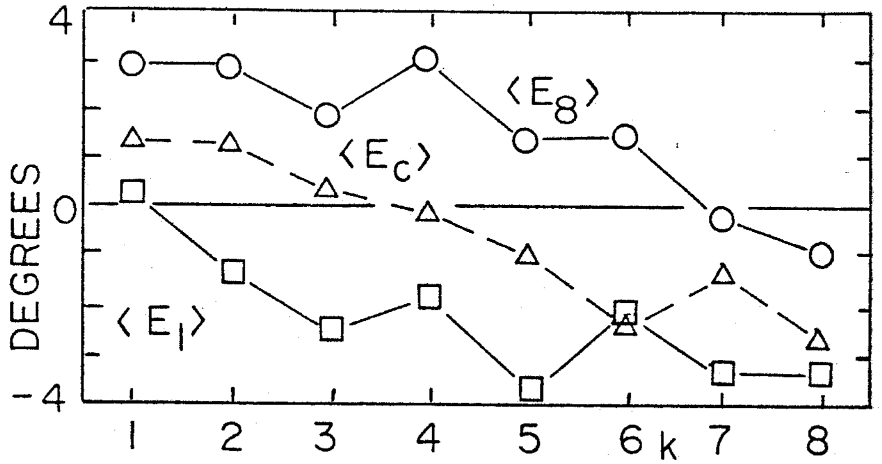

Fig. 1 Localization error, averaged over subjects, vs correct source number, k.

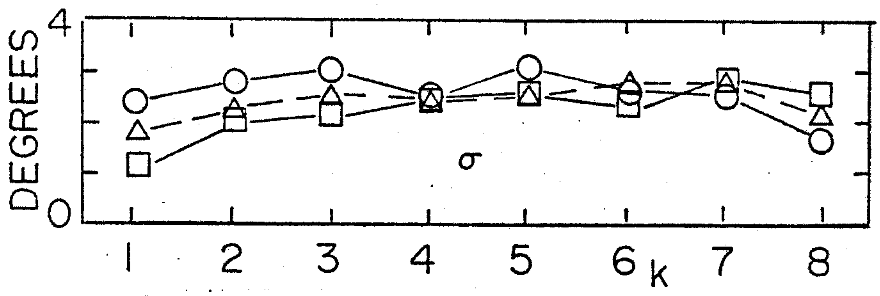

Fig. 2 Standard deviation of the localization judgements, averaged over subjects, vs correct source number, k. Symbols are the same as in Fig. 1.

Discussion

Besides the large-scale geometry, our experiment differed in several other ways from other work on visual bias. Unlike most previous studies our visual cue was not synchronous with the auditory stimulus. There was a gap of approximately 250 ms between the offset of the lamp(s) and the onset of the acoustic signal. Although previous workers have tried to separate ventriloquism from bias by using lamps (not normally associated with auditory cues) it appears that mere synchrony may lead to the perception of a unified source [5]. In this respect our experiment was similar to one by Weerts and Thurlow [6] who also obtained a visual bias of 2 degrees. We note also that when Bertelson and Radeau [7] counted only trials in which subjects reported no source unity the bias effect was independent of the visual-auditory angular discrepancy, a result similar to ours. By contrast their bias increased with increasing discrepancy for those trials in which subjects reported source unity.

Further, most previous work has employed pointing responses. Given the effects of visual bias on proprioception [8] one might suspect pointing responses to include an unwanted bias. Such an effect was avoided by our source identification procedure.

Conclusion

Visual bias effects on auditory localization, previously found in the laboratory, occur as well in concert hall environments. Bias effects of directed gaze agree in sign, magnitude and in their independence of visual-acoustical discrepancy angle with those of previous experiments which have excluded ventriloquism effects.

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