An Auditory Illusion of Distance

WE have previously described experiments showing that the apparent position of a sound source in space can be moved about the horizontal plane if sound is additionally fed by a single headphone to one ear[1]; the magnitude of this apparent movement depends largely on the frequency and intensity relations between the loudspeaker and headphone sounds. As we investigated this phenomenon, which we regard as an example of binaural interaction, we noticed that if two headphones were used instead of one a single sound image was perceived the apparent distance of which from the listener could be controlled by changing loudspeaker-to-headphone loudness relations. The work recorded here examines this illusion of distance more closely.

A diagram of the experimental situation is shown in Fig. 1. A listener, wearing headphones, sat in a semi-reclining position facing a loudspeaker 320 cm away at the end of a cloth-covered arc 26 cm wide. Four red lights were spaced along the arc at a distance of 320, 250, 150 and 50 cm from the listener's head. Ten msec bursts of band-pass filtered noise (1·5–6 kc/s) were delivered at a repetition rate of 6 per sec to both loudspeaker and headphones. The headphone stimulus was delayed electronically so that the speaker and headphone pulses would reach the listener simultaneously.

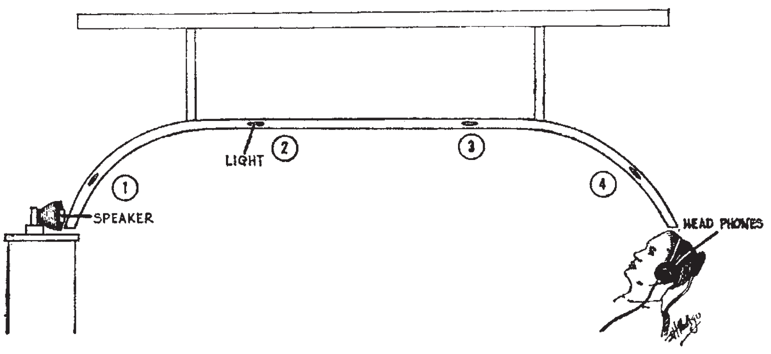

Fig. 1. Diagram of listening situation showing relation between loud-speaker, light positions Nos. 1–4 and listener

Six listeners participated. The tests were conducted in a sound-treated room the only illumination of which was that provided by the lights mounted on the arc. Headphones were placed on the listener and thresholds were then determined for the speaker and for the headphone stimuli. Next, with the speaker stimulus presented at 15, 20 or 25 db above threshold, the listener was instructed to adjust an attenuator controlling the headphone stimulus (2 db steps) until the perceived auditory image was coincident with a previously specified light. As soon as the listener had accomplished this, his attenuator reading was recorded. The listener was then asked to bring the sound image to coincide with a different light and the new attenuator reading was recorded. This scaling procedure was repeated six times, and median attenuator settings were calculated for each of the four lights at each of the three sensation-levels of the speaker stimulus.

To recapitulate: in this first or scaling session the listener was given control over one of the attenuators and was asked to adjust it so as to move the sound image to particular locations. In the next five sessions the listener had no control over the stimuli; the attenuator settings he had previously arrived at were reproduced and he was asked to identify the light positions from which the sounds appeared to be originating. As soon as he responded the 'correct light' was brightened briefly to tell him whether his choice was consistent with judgements made during his scaling session. Listeners were given six trials per session with each of the twelve possible combinations of speaker/headphone sensation-levels. Order of presentation was varied from day to day.

Table 1. MEDIAN PER CENT CORRECT IDENTIFICATIONS OF ILLUSORY AND REAL DISTANCES

	Light positions			
Distances	1	2	3	4
Illusory	84	77	85	97
Real	48	55	81	88

Table 1 shows the median per cent 'correct' identifications for all test sessions. No significant improvement in performance could be detected as testing progressed, suggesting that listeners were not learning to recognize apparent sound sources on the basis of any qualitative differences between sounds. Several persons who took no part in these formal tests nevertheless listened to the stimulus combinations; nearly all volunteered that the distance illusion was striking.

We were interested in finding out how well a listener would perform if the sound was actually emanating from one or the other light position; in other words, using 'real' rather than 'illusory' distance. Five additional sessions were conducted with a small loudspeaker placed next to each light. No headphones were worn on these occasions. Thresholds were taken for the loudspeaker at light position No. 1 and the auditory stimuli delivered by each of the speakers was set to 15, 20, or 25 db above this threshold. Median per cent 'correct' identifications for this condition are also shown in Table 1. A comparison of these figures with those obtained earlier clearly shows that over-all performances were superior when listeners were asked to judge illusory rather than real distances.

When other cues for distance are minimal, a listener judges the distance of a sound primarily by its loudness; that which is louder appears nearer[2]. Our listeners performed poorly in judging real distances presumably because there was an overlap of loudness between adjacent speakers and hence the loudness cues were ambiguous. There was also loudness overlap between many of the combination stimuli used in the illusory distance test; but listeners performed reliably and were able, in the majority of instances, to identify illusory distance correctly. In fact, the illusion of distance can be compelling even when the normal loudness cues are reversed; thus we have observed that as the intensity of the loudspeaker is increased (increasing the total perceived loudness) a sound image previously located in the head can be moved away. These observations indicate that whatever the basis for this illusion of distance it certainly concerns more than loudness. In the experiments so far described the intensities at the two ears have been equal; however, if a right–left intensity differential is introduced and suitably varied, the apparent sound source in space now moves laterally.

In these types of listening situations, the two auditory inputs (loudspeaker and headphones) each acting alone produce an auditory image; one is externalized while the other appears to be in the head. When the two inputs are presented simultaneously only a single image is perceived. Our results suggest that the apparent location of this fused image is determined by the relative dominance of the two separate images.

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