

Role of Pinna Cavities in Median Plane Localization

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Abstract: Sound localization tests and HRTFs measurements in the median plane were carried out under the conditions of progressively occluding three pinna cavities: scapha, fossa, and concha. The results show that the spectral cue in median plane localization is mainly formed by concha.

INTRODUCTION

Gardner and Gardner(1) showed that the pinna cavities play an important role in median plane localization. However, it was not clear whether the decrease of the localization accuracy under the occluded pinna conditions depends on the source elevation or not. In addition, little is known about an individual difference. This paper investigates the role of each pinna cavity in median plane localization by sound localization tests and HRTFs measurements under the conditions of progressively occluding three pinna cavities.

LOCALIZATION TESTS

Sound localization tests were carried out under the following five pinna conditions; condition O(normal pinna), condition S(scapha occluded), condition SF(scapha and fossa occluded), condition SFC(scapha, fossa, and concha occluded), and condition C(concha occluded). A molding clay was used to occlude the cavities. Under the pinna conditions SFC and C, however, each ear canal was connected to the outside by a through hole in the clay with the same diameter as that of the ear canal. Thus, the subjects received sound signals with both ears and perceived a sound image outside the head. The source signal was a white noise(280 - 11200Hz). The sound pressure level of all the stimuli was constant at 50 ± 0.5 dBA slow, peak, at the center of the subject's head in an anechoic chamber without any subjects. Seven loudspeakers were located in the median plane at every 30° from the front (at 0°) to the back (at 180°). Two females and seven males between 21 and 35 years of age with normal ability of median plane localization under the condition O acted as subjects. Seventy of the stimuli (10 times per direction \times 7 directions) were presented to the subjects in random order for each pinna condition. The duration of stimulus was 2s. The interval between stimuli was 5s. Each subject was tested individually, while seated, with the head fixed in a darkened anechoic chamber. The task of the subjects was to mark down the direction of the sound image on a circle on the recording sheet for each stimulus. After the tests, the marks were read to 1° using a protractor. **Table 1** shows the number of directions in which the Welch's test showed that the localization error with the occluded pinna was significantly higher than that with the normal pinna($p < 0.01$).

Under the pinna condition S, the results of six of the nine subjects showed no significant differences at any of the directions. Each of other three subjects showed significant difference at only one direction out of the seven directions. Therefore, it is proper to conclude that the accuracy of the sound localization with the occluded scapha is almost the same as that with the normal pinna.

Under the pinna condition SF, three of the nine subjects showed no significant differences at any of the seven directions. Another three subjects, M, Y, and F, showed significant difference at only one direction. It is proper to conclude that the accuracy of the sound localization of these six subjects with the occluded scapha and fossa is almost the same as that with the normal pinna. Subject Z showed significant difference at two directions, subject I at four directions, and subject K at three directions. Both subjects I and K had a tendency to perceive a sound image only around one specific elevation, regardless of the sound source elevation, as follows; subject I around 75°, subject K around 0°.

Under the pinna condition SFC, seven of the nine subjects showed significant differences at more than four

directions. Subject I perceived sound images only around 75°, subjects M, K, Z, and U only around 0°, and subject Y only around 180°. On the other hand, both subjects H and N did not show any significant differences at any of the directions. Their accuracy of sound localization in the median plane with the occluded scapha, fossa, and concha is almost the same as that with the normal pinna.

Under the pinna condition C, the accuracy of localization in seven subjects decreases, same as the pinna condition SFC. Two subjects, H and N, localized a sound image with nearly the same accuracy as the normal pinna even when their concha was occluded.

MEASUREMENTS OF HEAD-RELATED TRANSFER FUNCTIONS(HRTFs)

The HRTFs were measured using a small electret condenser microphone. The sampling frequency was 48kHz and the response length was about 5.3ms. The subjects, the sound source elevations, and the pinna conditions were the same ones that were used in the localization tests. Since it is known that the sound characteristics of the ear canal resonance are independent of the sound source direction(2), the HRTFs measurements were carried out occluding the subjects' ear canals with absorbent cotton to reduce the resonance.

Figure 1 indicates the examples of the amplitude spectrum of the HRTFs(at 0° of subject M). The behaviors of the amplitude spectrum of the HRTFs below 3kHz, under all the occluded pinna conditions, are very similar to that of the normal pinna condition. On the other hand, those above 3kHz change by occluding pinna cavities, as follows. The behaviors of the amplitude spectrum of the HRTFs under the pinna conditions S and SF are similar to that of the normal pinna condition. Contrary to this, the behaviors of the amplitude spectrum of the HRTFs under the pinna conditions SFC and C are different from that of the normal pinna condition. The gentle peak around 4kHz and the sharp dips around 8kHz and 9kHz disappeared.

The same results as mentioned above were obtained at any other elevation. This suggests that the amplitude spectrum of the HRTFs is greatly influenced by occluding concha. No remarkable individual differences were occurred. The similar changes were observed in the HRTFs of subjects H and N, whose localization accuracy did not change by occluding concha.

TABLE 1. The number of directions where significant differences occurred comparing with normal pinna($p < 0.01$).

Pinna Condition	Subject									
	H	N	U	M	Z	Y	F	I	K	
S	0	0	0	0	1	0	1	0	1	
SF	0	0	0	1	2	1	1	4	3	
SFC	0	0	4	4	5	4	4	5	5	
C	2	1	5	4	3	3	5	4	6	

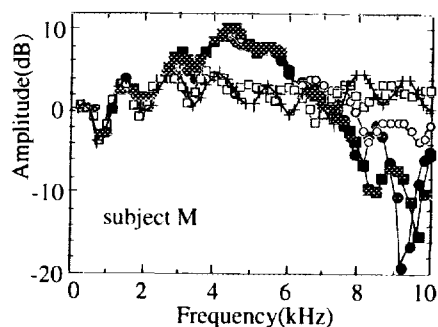


FIGURE 1. Measured HRTFs at 0° elevation under the pinna condition O(●), S(○), SF(■), SFC(□), and C(+).

CONCLUSIONS

The results of the localization tests and the HRTFs measurements show: (1) Concha plays a great role in median plane localization regardless of the sound source elevation. (2) The amplitude spectrum of HRTFs shows a significant change under the conditions of concha occlusion. The comparisons of these results suggest that (3) the spectral cue in median plane localization is mainly formed by concha. (4) However, the degree of localization error which is caused by the occlusion of the pinna cavities depends on the subjects.

REFERENCES

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