4aPPb11. Effects of targeted pinna occlusion on pinna/spectral cues to localization in the median plane

Alan Musicant* and Robert R. Baudo

*Corresponding author's address: psychology, Mid. Tenn. St. Univ., Murfreesboro, TN 37132, Alan.Musicant@mtsu.edu

Auditory localization accuracy (in humans) in the median sagittal plane has been attributed, by some authors, to an effect of "spectral notches" that occurs in the frequency region of 4-8kHz. Another possibility for decrements in vertical plane localization accuracy has been overlooked. Roffler and Butler (1967) and Hebrank and Wright (1974) both demonstrated that removal or absence of sound frequencies above about 8 to 10kHz led to decrements in vertical plane localization accuracy. They did this by using carefully selected types of band pass or band limited noise. A reduction in accuracy of auditory vertical localization by occluding all or part of the pinna has been known for many years (Gardner and Gardner, 1973). We have previously reported results that demonstrate disruption in accuracy with various partial pinna occlusions (ARO, 2012) that differs from results reported by Gardner and Gardner. We now have data that seems to indicate that the reduction in localization accuracy occurs, in part, because of disturbances in high frequency regions (above about 8 to 10kHz) and that disruptions in "spectral notches" (4-8kHz) has little to no effect upon vertical plane localization.
Introduction

Localization of sound in the median sagittal plane (MSP) has been the subject of study for many years, perhaps starting with Bloch (1893, cited by Butler, 1975). Roffler and Butler (1968), Blauert (1969/1970), Gardner and Gardner (1973) and Hebrank and Wright (1974) all examined this problem and attempted to explicate the nature of how such localization took place in the absence of the well-studied interaural cues of time and level. These authors all dealt with the problem under free field listening conditions. More recently, Langendijk and Bronkhorst (2002) as well as Zhang and Hartmann (2010), utilizing virtual auditory techniques, have also contributed information to our understanding. Most of these authors sought to determine the effect upon localization of various regions of the audible sound spectrum by employing techniques that presented sounds that had been manipulated in a variety of ways. Sounds that were band passed, band limited or more specifically filtered by adding notches, peaks or flattening the spectral features have been utilized. We have chosen a somewhat different route in an attempt to determine cues for localization in the MSP. That is, we have chosen to examine the disruption in the sound spectral pattern when various pinna cavities have been occluded. A somewhat similar, but less extensive examination of such disruptions has previously been reported by Iida, Yairi and Morimoto (1998).

Localization Experiment

Behavioral localization tests (partial results of which were presented at the ARO Midwinter meeting of 2012), were conducted with seven participants whose hearing levels were better than 20 dB HL for frequencies between 250 and 8000 Hz. Tests of localization were conducted in an IAC single wall audiometric chamber (9’ L x 9’ W x 10’ H) that was lined with 4” acoustic foam (Aurelex). Subjects were asked to indicate from which loudspeaker a stimulus originated. Stimuli consisted of 5 repetitions of a 200ms noise (200Hz to 15kHz), shaped to provide ± 2dB flat spectrum with no identifiable peaks or valleys. Each repetition was filtered from a different broad band, digitally generated noise. Rise-fall times were 10ms and were cos² shaped. Loudspeakers were arranged and spaced with 5° of separation (+ 45° range) along a vertical arc placed at 0° azimuth. Loudspeakers were numbered, from 1 to 19 (#1 was the lowest positioned at -45° elevation).

We, with our extended loudspeaker range, replicated the pinna occlusion experiment of Gardner and Gardner (1973). That is we occluded, progressively, more and more of the pinna, from scapha only to occlusion of the complete pinna (with the exception of an opening to the ear canal). Additionally, we occluded only individual parts of the pinna (scapha only, fossa only, upper and lower concha only and also whole concha occlusion). Results varied from those reported by the Gardner’s. We concluded that the differences between what we found and what they reported in the progressive occlusion conditions were likely a result of two issues: 1) the use of a restricted range of loudspeakers in the original experiment and 2) the use of only two subjects who likely did not represent the general population.

We also reported, in contrast to the Gardner and Gardner (1973) report, that occlusion of the scapha of the pinna did cause disruption of MSP localization ability for two subjects out of a total of seven. In this current report we have sought, through the use of small electret
microphones, placed in an occluded auditory canal, to correlate changes in the spectral pattern of sound, caused by occlusion of various parts of the pinna, to the behavioral pattern of localization responses to noise bursts originating from free field loudspeakers.

**Spectral measurements from pinna open and occluded conditions**

Subjects were seated in a chair, placed the middle of the audiometric chamber. The chair was equipped with a headrest. The chair was positioned so that the midpoint of each subjects head was at the center point of the arc holding the loudspeakers. A small Knowles electret microphone (model FG-3329C) was fixed into position at the entrance of the occluded ear canal of both pinnae. Subjects were instructed to keep their head steady and placed against the headrest. The experimenter left the chamber and 30 separate presentations of short duration (50 msec) stimuli were played through each loudspeaker along the MSP. These stimuli were recorded and averaged with a 96kHz sampling rate. This was done for the open pinna condition the scapha occluded, the fossa occluded and the upper concha occluded conditions. Additionally, the response of the microphones and the associated electronics were also determined using the same technique, but, with the microphones placed in the same relative position in the chamber without the presence of a subject. Spectral patterns were then determined by processing the time information and subtracting the characteristics of the loudspeaker/microphone/electronic characteristics from that measurement made with the microphones at the entrance of the ear canal.

**Results**

**Figures 1 a-c** indicate the spectral pattern (left pinna only) for subject R for both the open pinna condition (solid line) and the scapha occluded condition (dashed line) and three loudspeaker locations (40, 20 and 0 deg. elevation). Subject R showed very little change to localization ability for the scapha occluded condition compared to the open pinna condition (overall accuracy across the 19 loudspeakers went from 3.8 deg. to 4.9 deg. for the scapha occluded condition). Subject R did show a disruption in the spectral pattern for the scapha occluded condition relative to the open pinna condition. Specifically, there were changes, either shifts in frequency or disappearance of a notch located in the 9-10kHz frequency range. However, little change in the localization behavior occurred. For the most part there was little disruption of the 10kHz and above spectral pattern. **Figures 2 a-c** indicate the spectral pattern for subject D for the same conditions as for subject R. However, there were profound disruptions in the localization performance for this subject when comparing pinna open to scapha occluded conditions (overall accuracy across the 19 loudspeakers went from 6.7 deg. to 16.3 deg. for the scapha occluded condition). Examination of the spectral patterns for these conditions does not show any consistent patterns. Examination of three other subjects, none of whom showed the same disruption in localization performance as subject D, indicate spectral changes that are more consistent with those of subject R.
Figure 1 a-c. Measured pinna spectral patterns for subject R for two pinna conditions, pinna open (solid lines) and scapha occluded (dashed lines) for three elevations. a. 40 deg. elevation, b. 20 deg. elevation and c. 0 deg. elevation.
Figure 2 a-c. Measured pinna spectral patterns for subject D for two pinna conditions, pinna open (solid lines) and scapha occluded (dashed lines) for three elevations. a. 40 deg. elevation, b. 20 deg. elevation and c. 0 deg. elevation.
Conclusions

We have demonstrated that substantial changes in MSP localization performance occur, for some subjects, with occlusion of the scapha, a result that has not previously been reported. The performance difficulties are accompanied by inconsistent changes to the spectral patterns of the pinna transform function. In contrast, several subjects did not show changes in their behavioral performance with the scapha occluded. These subjects often maintained much of the spectral pattern of the pinna transform function, especially in the frequency region of 10-14kHz.

References


