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RELATIONSHIP BETWEEN HRTF'S AND ANTHROPOMETRIC DATA

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ABSTRACT
The objective of the experiment is to investigate the feasibility of the technique to relate HRTF's to physical dimensions of the human subjects. For this purpose HRTF's and five physical dimensions of the pinna were measured on 7 subjects. HRTF's were measured at 12 positions in horizontal plane at the level of the subject ears in anechoic chamber. Physical dimensions were estimated from scanned images of the subject ears. Frequencies of the first predominant dip in HRTF's were estimated and correlated with measured physical dimensions. Correlation coefficients between concha breath and first predominant dip at the sound source position in front (r^2=0.81), and ear breadth and first predominant dip at the sound source position in back (r^2=0.67) were found to be statistically significant ($p<0.05$).

1 - INTRODUCTION
Sound quality evaluation requires an authentic sound recording and reproduction technique. To that end binaural technology is used. However, binaural technology does not always provide authentic sound reproduction. Due to mismatch between artificial head dimensions used for sound recording and anthropometrical dimensions of individuals who participate in listening tests localization errors occur. Experimental results show that recordings made with HRTF's (Head Related Transfer Function) of a carefully selected human gave better localization performance than recordings made with currently manufactured artificial heads (Möller et al., 1999). Anthropometrical dimensions refer to body sizes, shapes and other physical characteristics. According to Pheasant (1998) anthropometry may be simply defined as the measuring of human beings. The objective of the experiment is to investigate the feasibility of the technique to relate HRTF's to anthropometric dimensions of the human subjects.

2 - METHOD
Seven male subjects from the staff of department were selected as test persons. HRTF's were measured with small condenser microphone (Sennheisner KE-4-211-2) connected to single supply operational amplifier SSM-2135S. This setup is similar to that used by Maijala, 1997, except no earplug was used to fully block the ear canal. Microphone was positioned at ear canal entrance position. Only one microphone in the right ear was used. Measurements were made using PC equipped with Maximum-Length Sequence System Analyzer (MLSSA) from DRA Laboratories. Measurement procedure was similar to that used by Gardner (1998). The impulse response for each measurement position was obtained using Maximum Length Sequence (MLS) of 16383 samples. Therefore each measurement yielded 16383 point impulse response. As described by Gardner, most of these data are irrelevant due to samples in the beginning associated with the ear travel and delay in measurement system and samples in the end associated with reflections from the objects in the room. Therefore samples from 290 to 1213 were analyzed only and each impulse response analyzed was 926 samples (16.1 msec) long. Effective frequency range for this analysis was 80Hz − 20kHz. HRTF measurements were carried out in anechoic chamber. Subjects were seated in a chair during measurement and were instructed to stay still. Small two-way loudspeaker was position 1.5 meters away from the center of the head position. HRTF's were measured in horizontal plane at the level of the entrance to the ear canal at following 12 positions: front, back, 30, 60, 90, 120, 150 deg to the

left, and 30, 60, 90, 120, 150 deg to the right of the subject. In order to perform free-field equalization of HRTF's, microphone response at the center of the subject head position (without subject present) was measured for loudspeaker positioned in front. Equalization was performed by dividing complex spectrum of each measured HRTF by complex spectrum of microphone free-field response.
Measurement of anthropometrical data. Five dimensions of pina were measured for each subjects right ear as shown in Fig. 1.

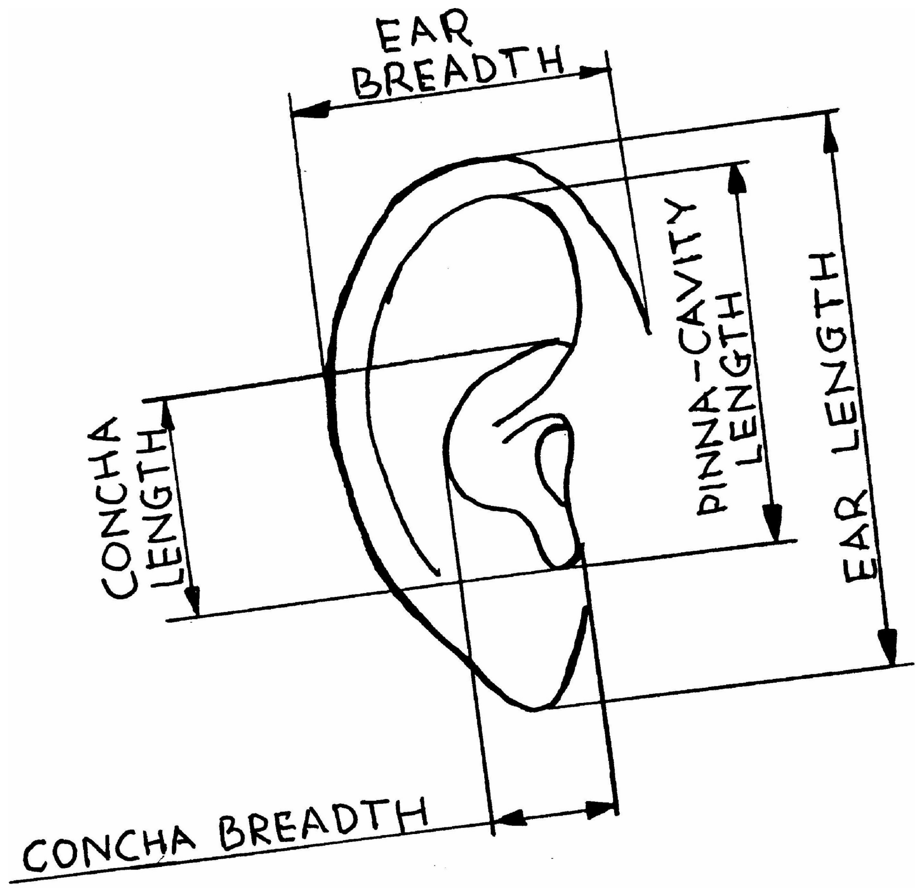

Figure 1: Measured anthropometrical dimensions.

Each subjects face and ears were scanned using laser scanner. During scanning subjects were seated on a chair with a headrest in order to keep the head as still as possible. It is not possible to scan the areas of the head covered by hear, therefore only face and ears of each subject were scanned. The dimensions of the ears were measured on scanned images. This procedure allows to zoom in the view of the ear and does not require the presence of the subject.

3 - RESULTS

The summary of measured ear dimensions is shown in Table 1. In order to relate the anthropometrical data of the pinnas to the HRTF's there was a need to extract certain features of transfer functions. For this purpose the frequency of the first predominant dip of each subjects HRTF's for positions in front, back and to the right were estimated. Example of measured transfer functions with indication of the position of predominant dip is shown in Fig. 2. Two statistically significant ($p<0.05$) correlations of five dimensions of the pinna with extracted frequencies of first predominant dip for 7 sound source positions were found. Namely between concha breath and first predominant dip at the sound source position in front ($r^2=0.81$), and ear breadth and first predominant dip at the sound source position in back ($r^2=0.67$).
Correlation coefficients between these pinna dimensions and first predominant dip for 7 sound source positions are shown in Fig 3. It is interesting to note decreasing correlation between concha breadth and first dip frequency when sound source moves from front to back of the subject. The pattern for the other correlation is not smooth (the significant correlation is much larger than correlation coefficients for nearby positions). Similar pattern was observed for correlation coefficients between ear length and

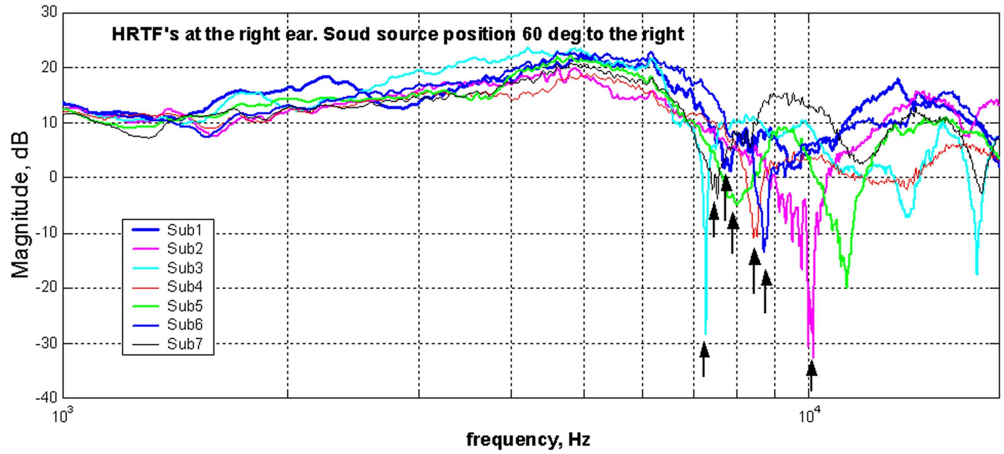

Figure 2: Free field equalized HRTF's at the right ear for sound source position of 60 deg to the right; arrows indicate the frequency of the predominant dip.

first predominant dip frequency and concha length and first predominant dip frequency. However, none of these correlation coefficients were statistically significant.

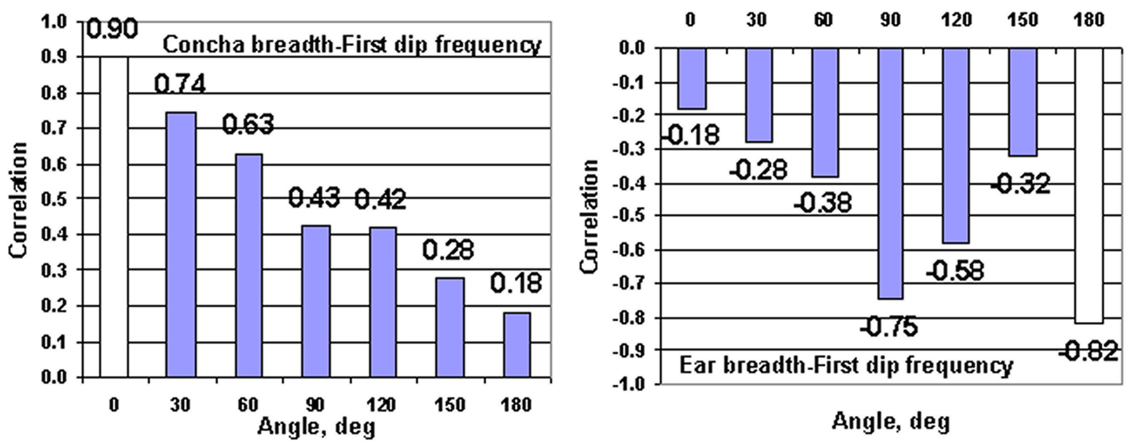

Figure 3: Correlation coefficients between concha breadth and predominant dip frequency (left); ear breadth and first predominant dip frequency (right) for azimuth angles to the right of the listener; white bars indicate statistically significant results.

Fig. 4 displays the data for the statistically significant correlation coefficients. It is observed that there might be non-linear relationship between the variables, however more subjects need to be measured to establish this fact.

	Mean	Min	Max	S.D.
Ear length (mm)	64.4	56.1	75.7	6.2
Ear breadth (mm)	31.8	28.6	35.3	2.5
Concha length (mm)	28.0	23.6	33.0	3.2
Concha breadth (mm)	18.5	16.4	20.9	2.0
Pinna-cavity length (mm)	43.9	38.1	49.3	4.7

Table 1: Summary of measured ear dimensions for 7 subjects.

4 - DISCUSSION

Due to the small sample size the results obtained in this experiment should be accepted with caution. However the focus of this investigation was to test the method for investigating relationships between the features of HRTF's and andthropometric data of subjects. Laser scanning procedure to obtain physical

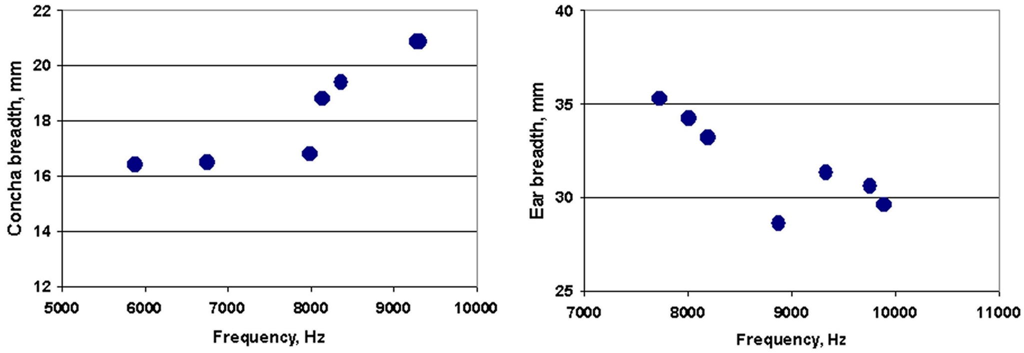

Figure 4: Concha breadth (left) and ear breadth (right) versus frequency of first predominant dip in HRTF for statistically significant correlation coefficients.

dimensions of the subjects showed advantages and limitations. The biggest advantage is the availability of the data for future investigations, i.e. there is no need to find the same subjects if additional physical measurements are required. Limitation is the inability to scan in the data for subjects upper body, i.e. it is not possible to scan over the hear. In this investigation only the linear dimensions were considered, however there is a need to consider angles and shapes. This sets the path for further research.

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