How do Head-Related Transfer Functions of Children depend on Growth?

Janina Fels
Institute of Technical Acoustics, RWTH Aachen University, 52056 Aachen, Germany,
Email: jfe@akustik.rwth-aachen.de

Introduction

Standards for development and measurement of hearing aids (for example DIN EN 60 118) refer to an artificial head. This artificial head (KEMAR), however, is based on anthropometrical data of adult heads.

A first investigation [1] showed that the head-related transfer functions (HRTF) of children differ very much from adult HRTF. Even a scaled adult head yields big differences in the HRTF in comparison to an infant or child. Consequently, there are still uncertainties in the development of dummy heads and proper hearing aids for children.

Determination of HRTF of children

For obtaining HRTFs, the Boundary Element Method (BEM) [2] is used in a reciprocal arrangement [3]. In order to compute the HRTF using BEM, a CAD model is needed. The CAD model is created with the geometrical data measured from 3D stereo photographs by using a digital photogrammetric system. The modelling of a detailed head using this method [1] is precise but very time-consuming. Serious problems are on the one hand the creation of a closed model on the other hand the meshing of this very detailed surface [4]. A disadvantage is that a database of anthropometrical data of heads can only be created with a re-measuring of the head dimensions. Genuit [5] developed a fundamental geometric parameter model for an adult head which is quite easy to build as a CAD model. Originally, this model was intended to be the basis for analytic calculations of diffraction theory. In this study, it serves as parameter set for the abstract CAD model.

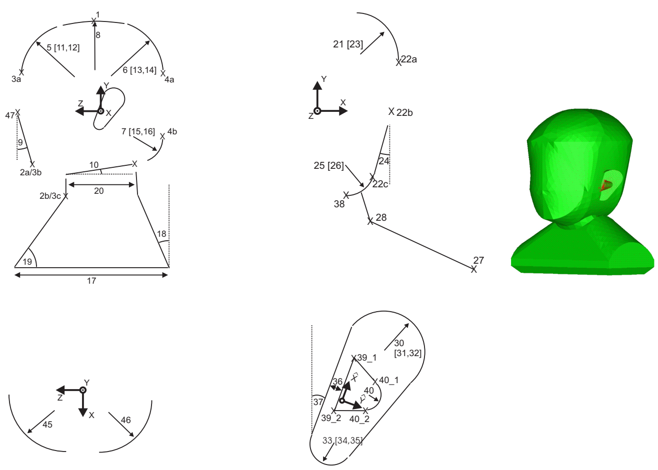

Figure 1: Left: Geometrical data for an abstract parametric child model. Right: Parametric child model as a CAD model.

In this model, however, many simplifications have been made which are appropriate for an adult head. A child's head could not be created without making a lot of changes in the model. Thus, the characteristic dimensions to be taken as parameters were modified and extended (see Figure 1). The radii of the front and back of the head for instance are now measured separately. A child's head is rounder than an adult's head. Little children do not have a distinctively long neck like adults.

A detailed model of a six-month-old child and an abstract parametric model using the optimised dimensions taken from the same child were created. If the detailed and the optimised parametric models are overlaid, only very small differences in the geometry are left. Figure 2 shows the HRTF magnitude for frontal incidence. After the modifications, a good concordance could be achieved.

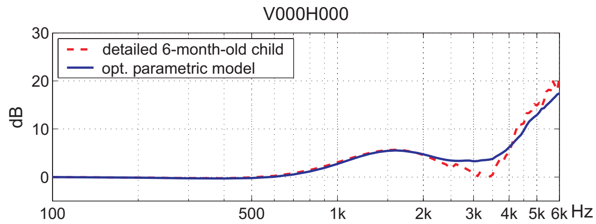

Figure 2: HRTF magnitude for frontal incidence of the abstract parametric model in comparison to the HRTF of a detailed child head.

Data Collection and Results

So far, the geometrical data according to Figure 1 have been gained from stereo photographs of 64 children with ages ranging from six months to seventeen years. 25 of the children are male – 39 female. The various geometrical data are independent from each other. Some values show a big growth-dependency – others do not. For example, the depth of the head seems to reach the final value very early (in kindergarten age) compared with the development of the height of the head. This value rises continuously up to adolescence.

24 of the measured children are between 4 and 6 years old. 31 children are kindergarteners. Thus, an initial statistical evaluation could be made at least on this latter group of kindergarten age (see [4]). The standard deviations are in the same order of magnitude as reported by other authors for adult data. Finally, the median values are chosen to build a head representing children of kindergarten age.

Figure 3 shows the HRTF magnitude in the horizontal and median plane for the six-month-old head, the median kindergarten head and the adult head. The HRTF is calculated from the parametric models using BEM. The colorbar indicates the magnitude in decibel. Figure 4 shows the HRTF from the three heads for frontal incidence. The curves for the sound incidence from the front show a more or less distinctive first minimum. For each head, this minimum is located at different frequencies and shifts towards lower ones with increasing age.

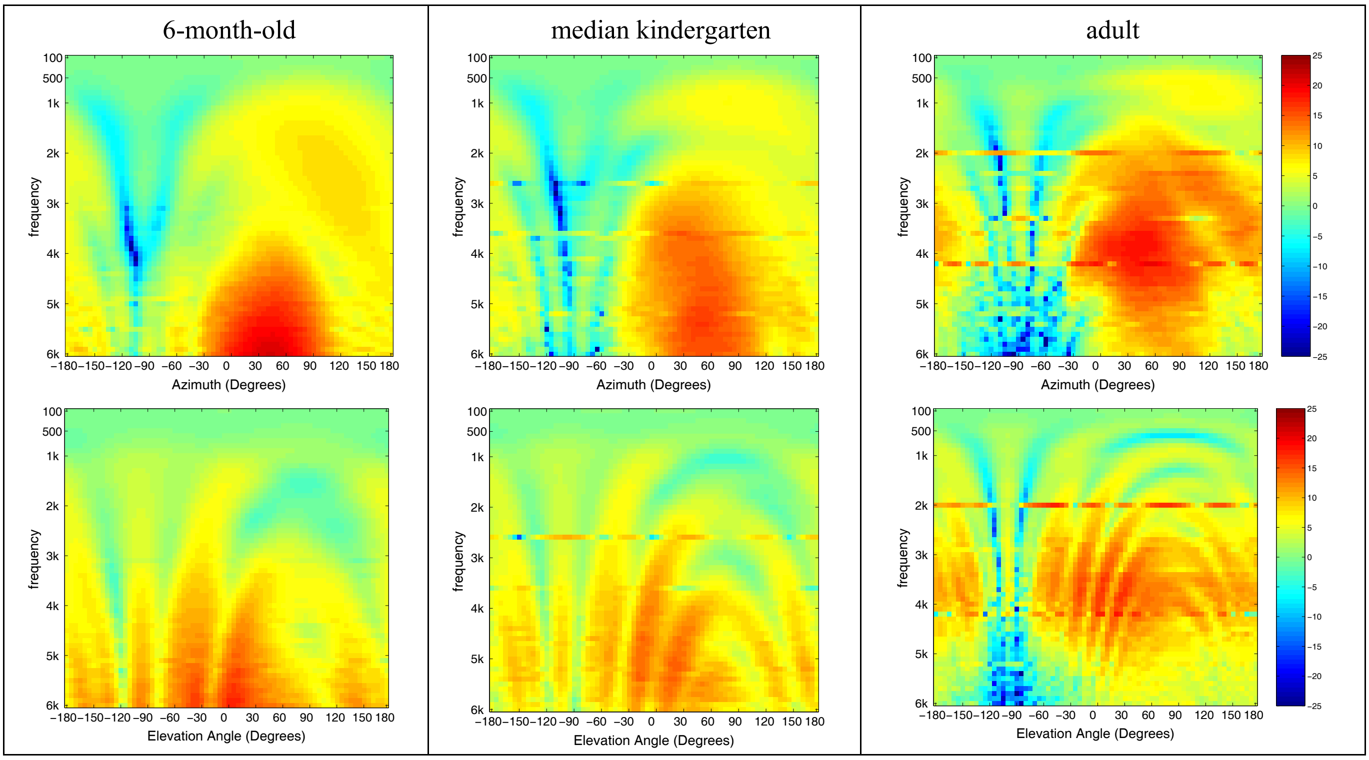

Figure 3: HRTF magnitude in the horizontal and median plane for a 6-month-old child, the median kindergarten, and the adult.

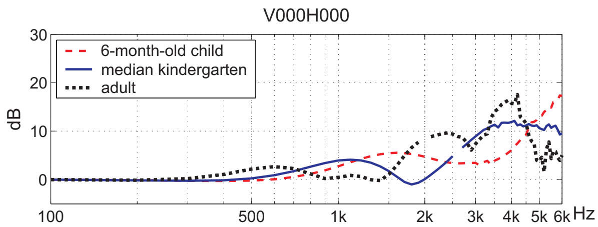

Figure 4: HRTF magnitude for frontal incidence of six-month-old child, median kindergarten, and adult (all parametric models).

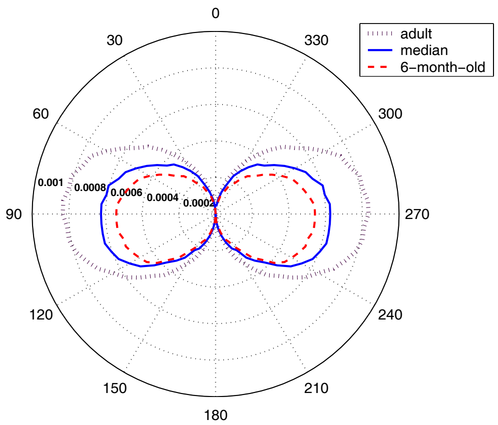

Figure 5: ITD of the six-month-old, the median kindergarten, and the adult head.

Furthermore, other cues of spatial hearing can be deduced from the HRTF. The interaural time difference (ITD) (Figure 5) is computed as the time shift of the maximum of the cross-correlation function of the left and right ear impulse responses. The impulses were low-pass filtered at 1500 Hz edge before cross correlation. It can be observed that a head with a larger diameter yields a larger ITD.

Conclusion

With a photogrammetric system it is possible to measure any dimension of a head very precisely. This system enables data collection even for very young children. Using some basic geometrical data, an abstract parametric CAD model of heads can be built, easily meshed and numerically evaluated by using BEM.

Genuit's parametric model has been expanded with the necessary anthropometric measurements for children. Thus, a parametric head for children, which reproduces a detailed child head very well, can be created and computed.

This first investigation of HRTFs of children shows that it is necessary to investigate further HRTFs of various ages until the best gradual transition into an adult HRTF is found. The data can also be used for the construction of artificial heads representing children. For a wide range of children, geometrical data are still to be collected.

References

[1] Fels, J., Ermittlung von geometrischen Daten für die Entwicklung von Kinderkunstköpfen. Proc. DAGA '03, Aachen, 100.

[2] Kahana, Y., Nelson, P. A., Petyt, M., Choi, S. Numerical modelling of the transfer functions of a dummy-head and of the external ear. Proceedings of AES 16th International Conference, Rovaniemi, 1999.

[3] Fahy, F. J., The vibro-acoustic reciprocity principle and applications to noise control. ACUSTICA **81** (1995), 544.

[4] Fels, J., Buthmann, P., Vorländer, M., Head-related transfer functions of children, Acta Acustica united with Acustica (subm.)

[5] Genuit, K., Ein Modell zur Beschreibung von Aussenohrübertragungseigenschaften, Dissertation, Aachen University, 1984.