Fit and comfort perception on hearing aids: a pilot study

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Abstract. Fit and comfort issues in ergonomic designs contain both physical fit and users' comfort perception, which are important for products with increasing requirements based on user experience, such as hearing aids. In this study, 3D ear was modelled as a reference to determine the size and shape of in-the-ear hearing aids. Four models and twelves sizes of hearing aids were customized designed based on the anthropometric reference model. The prototypes were 3D printed with Acrylonitrile Butadiene Styrene (ABS), Polylactic Acid (PLA), and Nylon materials. The study revealed the differences of user experience with the changes of product parameters, including size, shape and material, which suggested scaling range and proportion for research in customized design of hearing aids. The study contributed to a better understanding of the relationship between anthropometry and hearing aid design for further research on generalizing comprehension of users' perception.

Keywords: Fit and Comfort· User Perception · Hearing Aid Design · 3D Printing

1 Introduction

As science of design, ergonomics was highlighted when designing workplace, product, or system to fulfill human's demands on fit and comfort [1]. Researchers have investigated users' fit and comfort perception on different products, such as bra [2], footwear [3] and mask [4]. However, related studies on ear-related products mostly focused on audition performances [5, 6], while fit and comfort issues have not been sufficiently studies. Hence, there is a need to study users' fit and comfort perception on ear-related products, especially for long-wearing hearing aids.

Nowadays, ear-related products with various appearances and functionalities have been developed to meet customers' demands. With exploration of ear anthropometry, Lee et al. [7] applied the anthropometric data into ear-tip design with virtual fitting method, while Chiu et al. [8] investigated comfort perception on different models of

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Bluetooth earphones. Nevertheless, these findings cannot be directly utilized to guide hearing aids design considering the different types of hearing aids, including completely-in-the-canal (CIC), in-the-canal (ITC), in-the-ear (ITE), behind-the-ear (BTE), etc. As one of the main concerns in current hearing aids market [9], fit and comfort issues need to be addressed for related design use.

Modern techniques can assist related research efficiently and effectively. 3D scanning technology has been widely used to provide accurate and detailed information of ear anthropometry, and ear molding gives a solution to obtain the anthropometric data of the canal and some part of the concha. Ear anthropometry was conducted with a combination of ear molding and 3D scanning techniques [7, 10-12], as a theoretical reference for related product design. However, its application in product design needs to be explored with scientifically bridging the anthropometry with users' perception.

The main aim of the study is to test the influences of size and shape of hearing aids in fit and comfort perception, as a pilot study for further comprehensive investigation on users' preferences. In the study, 3D scanning was used to acquire the size and shape of external ear to seek for a proper physical fit, and prototypes in different sizes and shapes were 3D printed for user testing to understand users' fit and comfort perception.

2 Method

Prototypes of hearing aids were customized designed based on the ear anthropometric data of individuals. To acquire the anthropometric data related to hearing aid design, ear canal and concha were molded with ear impression silicone (®ABR), and the earmolds were scanned by a 3D scanner (®RangVision). The 3D model was then used as a reference to determine the original size and shape of the hearing aids.

Different types of hearing aids were designed including both full-shell and half-shell hearing aids, with and without the 1st bend of ear canal. Twelve sizes were generated with scaling the original size for each individual, with scaling proportions of 70%, 75%, 80%, 85%, 90%, 95%, 100%, 105%, 110%, 115%, 120% and 125%. Different materials, Polylactic Acid (PLA), Acrylonitrile Butadiene Styrene (ABS), and Nylon 12, were then 3D printed for further testing. Fig 1 presents the different shapes and sizes of hearing aid prototypes.

Fig. 1. Examples of prototypes: ***Model 1***: full-shell hearing aid without ear canal fitting; ***Model 2***: full-shell hearing aid with ear canal fitting; ***Model 3***: half-shell hearing aid with ear canal fitting; and ***Model 4***: half-shell hearing aid without ear canal fitting.

During the prototype test, the participant was asked to wear each prototype for 1 minute, and then filled a 7-point satisfaction Likert scale questionnaire on fit and comfort perception. There was a one-minute break between two tests. In the study, fit referred to the physical condition on the use of the prototype, for example, too lose or to tight was considered as dissatisfaction on fit, while comfort highlighted the cognitive preferences regarding comfort perception. Fig 2 shows an example of experiment setting.

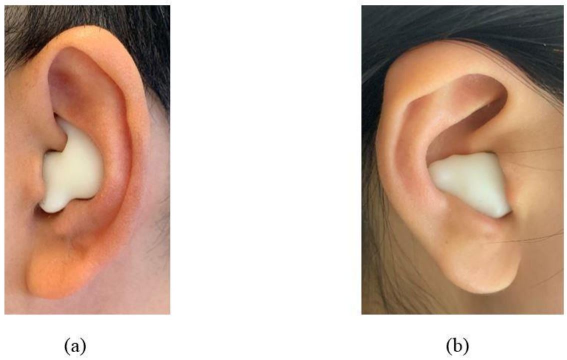

Fig. 2. Examples of experimental setting: (a) testing full-shell hearing aid; (b) testing half-shell hearing aid.

3 Results

Different material was used to 3D print the prototypes of hearing aids. Among the three materials, ABS provided best printing quality with smooth surface, while the thickness of the printing layer using PLA was non-negligible regarding the product size, and Nylon powder kept falling off from the surface slightly.

Within-subject analysis was conducted to survey the influence of product shape on fit and comfort perception. According to the user experience, Model 1 and Model 4 were more preferable than Model 2 and Model 3. Certain sizes of selected hearing aids can provide certain degree of fit and comfort, and the tolerance range of product size decreased from Model 4, Model 1, Model 3, to Model 2. Under the same condition, the most satisfactory size varied upon different model, which decreased from Model 4, Model 1, Model 3 to Model 2. Particularly, participant felt anxious when the prototype contained part fitting with the 1st bend of ear canal.

Between-subject analysis was used to examine the influence of product size on users' fit and comfort perception. Model 1 was selected for prototype testing in the study. Generally, participants feel relatively bad fit and comfort perception when the scaling proportion is below 80% or above 110%. Among all the scaling proportions, 90% and 100% mostly meet the most satisfaction on fit and comfort perception.

4 Discussion

The study revealed the differences of user experience with the changes of product parameters, including material, shape and size of hearing aids. Application of these findings needs to be discussed with addressing the limitations and future application.

Differences among ABS, PLA, and Nylon to 3D print the hearing aid prototypes were intuitively observed. In the study, Fused Deposition Modelling (FDM) was used to print PLA, the accuracy of which was determined with the printing layer thickness (0.4mm). Since the size of hearing aids is relatively small, the accuracy of PLA model obviously affected the prototype quality. Specifically, the prototype surface was rough which may influence uses' comfort perception, and even some surface cannot be printed fully. Using Selective Laser Sintering (SLS), Nylon material can provide higher accuracy (0.1-0.2mm), but the principle of the technique brought same challenge of rough surface. ABS was 3D printed with Stereo Lithography Apparatus (SLA) technique with accuracy of 0.1mm, which provided smooth surface of the complete hearing aids model. Therefore, ABS is more suitable for future hearing aid prototype test use.

Shape of hearing aids has noteworthy influence on users' fit and comfort perception. Model 2 and 3 provides fit on 1st bend of ear canal, while Model 1 and 4 deleted related part fitting with 1st bend of ear canal. Even though Model 2 and 3 can provide a better fit with the cavum concha and ear canal, Model 1 and 4 are more preferable than Model 2 and 3, which can be explained with the human sensitivity on ear canal. The tolerance size range of half-shell hearing aid is wider than the full-shell design, and the most satisfactory size of half-shell hearing aids is bigger than full-shell ones, which suggested different scales need to be explored for specific product shape.

Users' fit and comfort perception varied upon the product sizes. In the study, when the scaling proportion is below 80%, the prototypes were excessively loose to fall off from the external ear. With scaling proportion of 110% or above, the prototypes were extremely tight to congest the concha, and some of them even cannot be wear on the external ear. These findings suggested that proper fit can be further investigated within the scaling range of 80% ~110% for full-shell hearing aids.

One of the limitations in the study was restricted material and equipment for 3D printing. With relatively less time-consuming and easy-to-use characteristics, ABS, PLA, and Nylon were selected in the study to create the hearing aids prototypes. The paper only discussed the application of 3D printing for hearing aids design use. Further study can be conducted on more types of hearing aids to generalize a more comprehensive understanding between anthropometry and user preferences.

5 Conclusion

The study provided a primary understanding of user's perception on hearing aids with influences of size and shape. With bridging the product parameters with fit and comfort perception in this study, future research can be conducted to generalize users' fit and comfort perception for designing ear-related products. In addition, these findings also can be considered as a validation of 3D anthropometry of external ear with 3D scanning techniques.

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