Comparisons among Different Types of Hearing Aids

A Pilot Study on Ergonomic Design of Hearing Aids

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***Abstract*—Hearing aids are widely used by people with hearing loss. In the current market, various hearing aids can be selected based on the users' demands. Previous research mostly concentrated on ear anthropometry and auditory function to explore fit and comfort of hearing aids. Even though Computer-Aided Design (CAD) simulation and virtual reality methods were used to examine the fit of earphones and specific hearing aids, how to achieve a proper fit for different types of hearing aids was not sufficiently studied. This study compares sizes and shapes among existing commercial hearing aids, and further proposes guidance in ear anthropometry for ergonomic design of hearing aids. Product parameters, including width, height, length, and weight, were measured for Behind-The-Ear (BTE) aids, In-The-Ear (ITE) aids, and In-The-Canal (ITC) aids individually. Selected hearing aids were fitted on the external ear of participants while recording their fit and comfort preferences. The findings of the study revealed the differences among BTE, ITE and ITC aids, and highlighted the anthropometric data for hearing aid design. Based on the findings of the study, potential research gaps were identified for future research.**

Keywords - hearing aids; product size and shape; fit and comfort.

I. INTRODUCTION

An ergonomic design is increasingly important with the cumulative demands of customers. Human-centered designs are especially applied in everyday used products, such as devices providing protections or achieving other functionalities. Hearing aid is one of these products in the health care industry. Hearing aids amplify the collected sound for people with hearing loss. These devices normally require long-time wearing by the users. Hence, resolving any fit issues between products and users is crucial when designing hearing aids.

Nowadays, different types of hearing aids, such as Behind-The-Ear (BTE) aids, In-The-Ear (ITE) aids, In-The-Canal (ITC) aids, and Completely-In-The-Canal (CIC) aids, are available to meet the different demands of customers. BTE aid consists of a plastic case at the backside of the ear, a clear tubing, and an earplug or an earmold. The aids are usually used for young children considering that the tubing and earplug parts can be adjusted along with the children physical growth [1]. ITE aid contains a small shell which fills outside the ear canal, which is considered as a relatively easy-to-handle device [1]. ITC aid is in a small case with a partial fit in the ear canal. The comparatively invisible sizes of ITC aids provide cosmetic appearance and efficient sound transfer for the users, but the devices are difficult to handle [1]. Figure 1 presents product shapes of three different hearing aids.

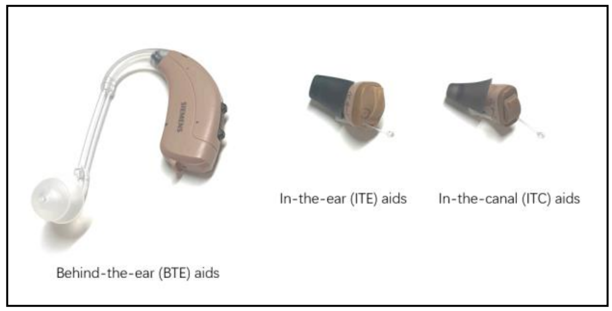

Figure 1. Different types of hearing aids

Fit evaluation has been studied for various products, such as shoes [2] and chairs [3]. For hearing aids, researchers have conducted various studies on the fit issues. Most of the previous research focused on ear anthropometry [4]-[6], auditory performance [7] [8], and cognition [9] for ear-related products, while physical fit of the product shape and size has not been systematically studied. Shapes of Bluetooth earphone were verified to influence users' comfort and fit perception [10]. However, the association between anthropometric data and design patterns has not been sufficiently evaluated. To address the design problem, there is a need to evaluate the fit for various hearing aids.

Evaluation methods, including CAD simulation and virtual reality, mock-up evaluation, and prototype evaluation, were the commonly used methods in design process [11]. CAD simulation models were applied to evaluate the product and related usability at the early designing stage. Ear-related products, such as earphone design [12] and ITC aids [13], were examined with CAD techniques. However, considering the different shapes and functionalities of ear-related products, methods to evaluate the fit of hearing aids have not been generalized comprehensively. Therefore, differences among different hearing aids should be studied for further research on ergonomic design of hearing aids.

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This paper aimed at comparing sizes and shapes among different hearing aids. As a work-in-progress study, the findings can be useful to study fit evaluation of hearing aids in future research, and it also have referential significance for other ear-related product designs. The rest of the paper is structured as follows. In Section 2, three widely used types of hearing aids were selected and different parameters, such as length, width, height and weight, were compared along with the user experience of fit and comfort. In Section 3, we present the differences of sizes and shapes among these products, and the specific ear regions and parameters are discussed for designing different hearing aids. In the last section, we conclude the differences among selected hearing aids, identified anthropometric data with application in hearing aid design, and propose future work regarding the research topic.

II. METHODS

In this paper, BTE Fun P, ITE Vibe Mini 8, and ITC Vibe Nano 8 aids (Siemens®) were measured and compared. Product parameters, including length, width, height, and weight, were measured to evaluate the product. These parameters can be compared with anthropometric data to seek proper fit. Participants were asked to wear each hearing aid for 5 minutes as shown in Figure 2. Fit and comfort perception of the participant was recorded. Contact area with the human ear was marked for further discussion on association between anthropometric data and product design.

Figure 2. Fitting hearing aids on human ear

III. RESULTS AND DISCUSSION

Despite the functionalities of different hearing aids, this study focused on the sizes and shapes of hearing aids from the fit and comfort perspective. The section showed the differences among BTE, ITE, and ITC aids based on the product shapes and sizes. While fitting different hearing aids with the human ear, reference ear regions were highlight for hearing aid design, and anthropometric dimensions were selected accordingly.

A. Differences among commericial hearing aids

Hearing aids normally require long-time usage, so the components with directly contacting external ear are vital for hearing-aid comfort and fit. Other product parameters, including size and weight, were investigated in the study. Comparison of sizes, weights, and components directly contacting the external ear are demonstrated in Table 1.

TABLE I. HEARING AIDS

Type	*Hearing aids*	*Components contacting with human ear*	*Size*	*Weight*
BTE		Round earplug in soft plastic material; Tubing contacting the ear root.	Earplugs were designed with selectable sizes.	7.16g
ITE		Special shape in direct contact with ear concha.	Width:8.71mm Height:12.97mm Length:19.88mm	1.42g
ITC		Special shape in direct contact with ear canal.	Width:5.72mmg Height:12.52mm Length:17.28mm	0.97g

Among the investigated hearing aids, BTE aids have the largest weight and size, followed by ITE and ITC aids sequentially. In the meanwhile, participants gave best scores on fit and comfort perception for BTE, followed by ITE and ITC aids in decreasing order. The parameters were difficult to compare directly, considering different aids need to fit with distinct ear region. Hence, there is a need to associate the product dimensions with anthropometric data to examine the comfort and fit. As for the product weight, load analysis can be conducted in specific ear region for the specific type of hearing aids.

B. Anthropometry for hearing aid design

Considering the fit issues, BTE, ITE, and ITC aids should be designed to match with specific ear regions individually, as presented in Figure 3. For BTE aids, tube and earplug were adjustable part, so the most important part in product design was the main body rested behind the ear. BTE should be designed considering ear root area and the back part of the ear, same as the support location of the aid. Ear root was also mentioned for earphone design in previous study [12]. ITE aids tightly fit with the ear concha, so the aid shape should be designed based on the concha shape in the contacted area. ITC aids fit with the entrance area of ear canal including part of the first bend of the canal, which was consistent with previous study [13]. Proper product size and shape can improve the comfort and fit perception during the usage of the hearing aids.

Thus, future research should focus on these areas to define the shape and size when designing different hearing aids.

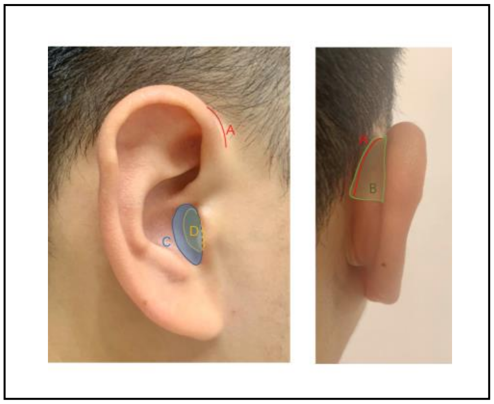

Figure 3. Ear reference area for designing hearing aids: Ear root (A) and back part of the ear (B) asscoiated with BTE aids; Ear concha (C) associated with ITE aids; Ear canal (D) associated with ITC aids.

To seek proper fit, anthropometric data were essential for designing distinct types of hearing aids. Related anthropometric dimensions can be used to define the product sizes. As the reference ear areas mentioned above, anthropometric dimensions were selected for hearing aid design. According to definitions of ear dimensions in the literature [14], different dimensions were chosen for specific hearing aids. Specifically, ear protrusion and pinna flare angle can be used for designing BTE aids; cavum concha length, center of concha to incisura intertragica length, and ear canal entrance circumference can be valuable for designing ITE aids; and ear canal entrance height, ear canal entrance width, ear canal entrance to 1st bend length, and ear canal 1st bend circumference can be applied in ITC aid design. To design the hearing aids products for different markets, these anthropometric dimensions can be applied to examine the product sizes.

IV. CONCLUSION AND FUTURE WORK

This pilot study tried to compare the shapes and sizes of different hearing aids, and examined the application of ear anthropometry in hearing aid design from comfort and fit perspective. Generally, BTE aids have the largest size and weight but the highest fit and comfort perception, while ITC have the smallest size and weight but has the lowest fit and comfort perception. Different contact areas on the external ear were recorded with diverse types of hearing aids. Accordingly, anthropometric dimensions were selected for different hearing aids based on the literature. Based on the findings in the study, potential research gaps were identified for future research. With the preliminary findings in the study, next step is to apply CAD simulation to examine the fit of different hearing aids, and use prototypes to explore the users' experience. Future research can be conducted with larger sample size and more hearing aids in different markets to improve the fit of ear-related products with the use of CAD simulation technique.

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