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Original Article

Hearing-aid assembly management among adults from culturally and linguistically diverse backgrounds: Toward the feasibility of self-fitting hearing aids

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Abstract

Objective: The purpose of the study was twofold: (1) to assess the ability of hearing-impaired adults in the developing world to independently and accurately assemble a pair of hearing aids by following instructions that were written and illustrated according to best-practice health literacy principles; and (2) to determine which factors influence independent and accurate task completion. *Design:* Correlational study. *Study sample:* Forty South African and 40 Chinese adults with a hearing loss and their partners. The participant group included 42 females and 38 males ranging in age from 32 to 92 years. *Results:* Ninety-five percent of South African and 60% of Chinese participants completed the assembly task, either on their own or with assistance from their partners. Better health literacy, younger age, and a more prestigious occupation were significantly associated with independent task completion for the South African and Chinese participants. Task accuracy was significantly linked to higher levels of cognitive function among South African participants, while a paucity of valid data prevented an analysis of accuracy from being conducted with the Chinese data. *Conclusion:* Individuals of diverse backgrounds can manage the self-fitting hearing-aid assembly task as long as health literacy levels and cultural differences are considered.

Key Words: Amplification; developing countries; health literacy; hearing aids; self-fitting hearing aids

The World Health Organization (WHO) estimates that 278 million people worldwide have a permanent, moderate to profound hearing loss, along with a further 361 million who have milder degrees of loss (Mathers et al, 2008). The distribution of hearing-impaired people worldwide is highly skewed: 80% of individuals with a hearing loss live in low- and middle-income nations. Even after adjusting for differences in age distribution across different countries, adult-onset hearing loss remains more prevalent in the developing world, particularly in sub-Saharan Africa and South Asia (Stevens et al, 2011).

Despite the wide-ranging consequences of untreated hearing loss—which include impaired speech and language acquisition, poor educational and vocational prospects, and detrimental effects on family and social life—it remains an "invisible" disability that ranks low on the list of global health priorities. Hearing loss, however, is currently the third leading cause of years lost to disability worldwide, outranking diabetes, chronic obstructive pulmonary disease, and osteoarthritis (Mathers et al, 2008), and the 13th highest contributor to the global burden of disease (Mathers & Loncar, 2006). Lack of access to hearing rehabilitation compounds the problem. Fewer than 3% of hearing-impaired individuals in the developing world have access to hearing aids, with the annual manufacture of such devices falling drastically short of global need (WHO, 2004). More than 32 million hearing aids are required annually in developing countries, but in 2001, only 750,000 were provided (Tucci et al, 2009). When global rankings of the impact of disabling conditions are adjusted for the availability of treatment, these shortfalls propel hearing loss into the number one spot, ahead of such potentially life-threatening conditions as ischemic heart disease and asthma (Mathers et al, 2008).

One of the major barriers preventing access to hearing rehabilitation in developing countries is the scarcity of audiologists, technicians, and other hearing health-care professionals that comprise an audiological infrastructure (Brouillette, 2008). A large, geographically far-flung population may be serviced by a single clinician, or, in many cases, there may be no qualified personnel available at all (Goulios & Patuzzi, 2008). In the absence of reliable, accessible hearing health care, a solution may be required in which the client, rather than the clinician, is responsible for driving the hearing rehabilitation process.

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Abbreviations

4FA	Four-frequency average (average of pure tone air-conduction thresholds at 0.5, 1, 2, and 4 kHz)
AU	Australia
BTE	Behind-the-ear hearing aid
GPT	Grooved Pegboard Test
HK	Hong Kong
MoCA	Montreal Cognitive Assessment
NAL	National Acoustic Laboratories
SA	South Africa
S-TOFHLA	Short Test of Functional Health Literacy in Adults
WHO	World Health Organization

One proposed solution is a self-fitting hearing aid, a self-contained, “do-it-yourself” amplification device that is designed to be managed entirely by the user without the need for professional support, specialized add-on equipment, or computer access (Convery et al, 2011a). The ultimate aim of research into this concept is to ensure that a self-fitting hearing aid provides outcomes that are at least on par with those achieved with traditionally fitted hearing aids. According to the self-fitting concept currently being evaluated by the National Acoustic Laboratories (NAL), the user first assembles the device from a selection of basic hearing-aid parts, then self-administers an automatic, in situ hearing test. The self-fitting hearing aid applies a prescriptive fitting rationale to the results of the hearing test to yield an appropriate gain/frequency response and compression parameters. Users may further fine-tune and train the settings to their individual preferences using an onboard button or associated remote control.

The first step in this process, management of the assembly task, has been evaluated and reported on for a pilot group of older, urban-dwelling adults in a developed country (Convery et al, 2011b). Seventy-nine of the 80 participants were able to follow a set of written, illustrated instructions to build a pair of slim-fit behind-the-ear (BTE) hearing aids, insert batteries into the completed devices, insert the hearing aids into their ears, and press an onboard button to “activate” the devices, either on their own or with the assistance of a layperson. A significant predictor of both independent and accurate task completion was health literacy, which is defined by the WHO as “the cognitive and social skills [that] determine the motivation and ability of individuals to gain access to, understand, and use information in ways [that] promote and maintain good health” (Nutbeam, 1998). Study participants with higher levels of health literacy, as measured by a standardized test, were more likely to complete the assembly task independently and accurately.

Worldwide health literacy rates are unknown, but 98% of the world’s 876 million illiterate people live in developing countries (Kickbusch, 2001). Health literacy levels, which require a more advanced application of a person’s fundamental literacy skills, are typically lower than general literacy levels (Nutbeam, 2000), indicating that the number of people worldwide with low health literacy is greater than published general literacy figures would suggest. Other known factors associated with low health literacy are age and disability. Older adults—the primary clinical population for many audiologists—are significantly more likely than their younger counterparts to have lower levels of general literacy (ABS, 2007; Baer et al, 2009) and health literacy (Baker et al, 2000), particularly in developing countries that have low overall literacy levels (UNESCO, 2005). A hearing impairment further complicates the picture, making it more difficult for clients receiving health care services to understand, synthesize, and use the information presented to them by the clinician. In the developing world, literacy rates for adults with physical, intellectual, or sensory disabilities are estimated to be as low as 3% (Groce & Bakshi, 2009).

Low levels of health literacy have consistently been associated with poorer health outcomes, management of chronic conditions, and use of health-care services (Williams et al, 1998; Berkman et al, 2011). However, little attention has been paid to its effects on the ability of individuals to interact specifically with the hearing health-care system. Nair and Cienkowski (2010) transcribed dialogues between audiologists and clients and found the clients’ estimated health literacy levels were significantly lower than those of the audiologists, suggesting that audiologists may be pitching instructional material at a level that is too difficult for their clients to fully understand. Hearing-aid instruction guides were subjected to the same analysis, with the finding that these materials not only contained uncommon words and technical jargon, but were, on average, written at a reading level higher than the average predicted reading level of the study participants (Nair & Cienkowski, 2012; Caposecco et al, 2012) and far above the grade 3–6 level recommended for health-related instructional materials (Doak et al, 1996; Osborne, 2005).

While the participants in the Convery et al (2011b) study were, overall, successful in assembling the two hearing aids, the group was not very diverse. All participants were residents of an urban area, and the majority of participants belonged to the highest socioeconomic status decile in a developed country. The study group included a preponderance of individuals with high levels of health literacy, formal education, and cognitive function. The objective of the current study was therefore to assess the ability of a culturally, linguistically, and socioeconomically diverse group of hearing-impaired adults and their lay partners to assemble, insert, and activate a pair of BTE hearing aids according to a set of written, illustrated instructions. The effect of a range of personal and demographic variables, including health literacy, on accurate and independent task completion was investigated.

Method

Participants

Forty adults from Pretoria, South Africa and 40 adults from Hong Kong, China participated in the study. Participants at both sites were screened to ensure they had a measurable hearing loss, which we defined as a four-frequency average (4FA; average of pure-tone thresholds at 0.5, 1, 2, and 4 kHz) greater than 25 dB HL in at least one ear. Forty participants, 18 male and 22 female, were drawn from a public health-care audiology clinic in South Africa (SA). Thirty percent of participants spoke English as their first language. Participants were required to attend the study appointment with a partner, friend, or relative. However, only 21 participants in the SA group did so. A staff member at the test site, who had neither clinical training nor further involvement with the study, was assigned to act as the partner for seven of the 19 participants who did not bring a partner. The staff member was unavailable to assist the remaining 12 participants on the days they attended their study appointment. Of the 22 unique partners who assisted the SA participants, four were male and 18 were female.

The Hong Kong (HK) group included 40 attendees of local senior citizens’ activity centres and was evenly divided according to gender. Chinese was the primary language of all HK participants. In HK, six staff members at the senior citizens' day centres acted as partners for 25 of the participants, with two partners each assisting eight participants, one partner assisting three participants, and three partners each assisting two participants. A total of 21 unique partners took part in the HK study, seven male and 14 female.

The treatment of participants in this study was approved by the Australian Hearing Ethics Committee, the Research Ethics Committee of the Faculty of Humanities at the University of Pretoria, and the Human Research Ethics Committee for Non-Clinical Faculties of Hong Kong University.

Procedure

Both the participants and their partners completed a demographic questionnaire about their age, gender, level of formal education, occupation, type of housing, general literacy, visual acuity, and hearing status. The participants were also asked about their previous and/or current hearing-aid experience and the partners about the nature of their relationship to the participant. The SA questionnaires were in English, while the HK versions were in Chinese. For the HK participants, the questionnaires were translated in a three-step process, with the resulting Chinese text back-translated into English twice to ensure consistency in semantic content and syntactic structure. The translation procedure also ensured the Chinese questionnaire would capture the nuances of the original English questionnaire. All translation activities were undertaken by three bilingual individuals, none of whom were hearing health-care professionals. The semantic content of the questions was identical in the SA and HK versions of the questionnaires, but the response choices varied for some items (e.g. public housing was added as a response choice for types of accommodation) to better reflect cultural differences. These differences are not expected to affect the outcomes of the study. A copy of the participant questionnaire, including the response choices available to participants from each test site, is shown in the Supplementary Appendix to be found online at http://informahealthcare.com/doi/abs/10.3109/14992027.2013.773407.

The primary task of the study appointment was the assembly of two slim-fit BTE hearing aids. Participants were given two sets of components, one for each ear: three pieces of slim tubing in three lengths (short, medium, and long), three open dome tips in three sizes (small, medium, and large), a Siemens Life hearing-aid body, and a size 312 zinc-air battery. An ear-specific instruction booklet outlined a step-by-step procedure for selecting the appropriate part sizes, assembling the components, inserting the battery into the assembled device, placing the hearing aid into the ear, troubleshooting the physical fit, and pressing a button on the body of the hearing aid to "activate" the device. The instructions were designed to adhere to best-practice health literacy principles (Caposecco et al, 2011), and as such, were written at a grade 3.5 reading level; illustrated with black-and-white line drawings; and printed in large, high-contrast type. The instructions were modelled on those used in the Australian (AU) pilot investigation described in Convery et al (2011b), but were modified in response to the three main difficulties the AU participants experienced with the assembly task: selection of the appropriate tube length, insertion of the concha lock, and troubleshooting the physical fit. First, the tubing was marked with white, yellow, and black stickers to better distinguish between the short, medium, and long lengths, respectively. The corresponding illustration in the instruction booklet was altered both to reflect this change and to more accurately show the relative differences in length between the three tubing sizes. Second, the step that dealt with the insertion of the concha lock, referred to in the instructions as the *anchor*, was reworded to improve clarity and was illustrated with two new drawings. Third, the troubleshooting section was expanded into separate steps that required the participants to perform physical actions to check that the appropriate tubing and dome sizes had been selected. An example of the differences between the original and revised instructions is shown in Figure 1.

The instructions were presented to the SA participants in English. For the HK participants, the instructions were translated following the same three-step process as the demographic questionnaires.

The participants were instructed to attempt each step of the assembly task on their own before asking for help from their partners, and were advised that requests for help could be initiated only by the participants, not by the partners. The experimenter did not answer any questions specific to the task or assist the participant in any way. Rather, the role of the experimenter was to observe and evaluate the performance of the participant. A worksheet was used to record the time taken to complete each step and to rate each step to indicate whether the step was completed correctly and/or whether assistance was provided. For steps on which partners provided assistance, the nature of the help was recorded.

Health literacy was measured with the Short Test of Functional Health Literacy in Adults (S-TOFHLA; Parker et al, 1995), in which the participant is asked to choose the correct word from a list of four to complete one or two blanks in a sentence. The test is composed of several paragraphs of health-related text. An Australian version of the S-TOFHLA (Barber et al, 2009) was used with the SA participant group, while the HK experimenter employed a Chinese version (Tang et al, 2007). As per the published norms for the original version of the S-TOFHLA, the maximum attainable score was 36. A score of ≥ 23 indicated adequate levels of health literacy, while scores of 17–22 and ≤ 16 indicated marginal and inadequate health literacy, respectively.

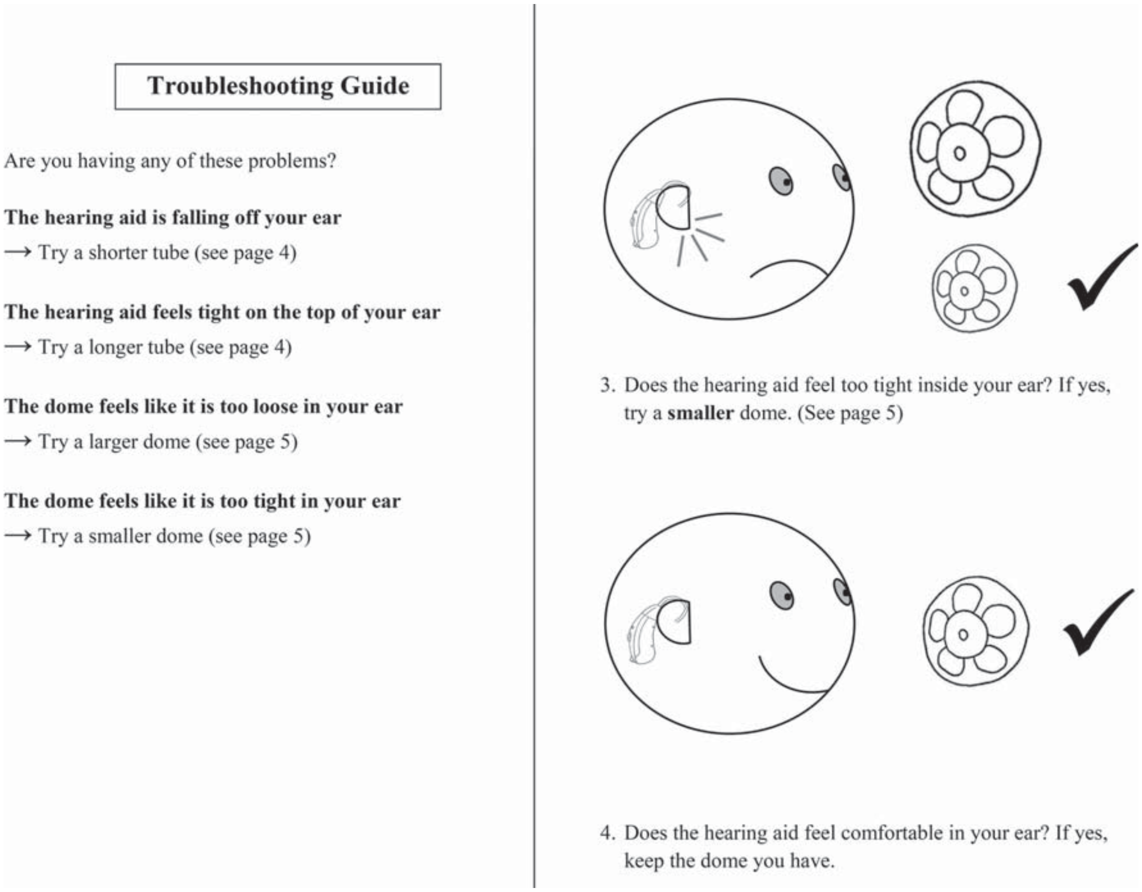
The Grooved Pegboard Test (GPT; Trites, 1977) was used to assess the participants' manual dexterity. Participants place small, keyhole-shaped metal pegs into a square 25-hole pegboard, first for the dominant hand and again for the non-dominant hand. The GPT is scored on the basis of the time taken, in seconds, to complete the task for each hand, with lower scores associated with better manual dexterity.

Cognitive function was assessed with the Montreal Cognitive Assessment (MoCA; Nasreddine et al, 2004), which measures visuospatial and executive function, abstraction, attention, delayed recall, language, and orientation to time and place. Validated versions are available for both English and Hong Kong Chinese. The maximum attainable score on the MoCA is 30 for test participants with more than 12 years of formal education. An extra point is awarded to those with 12 or fewer years of formal education, giving this population a maximum potential score of 31. Scores ≥ 26 indicate normal cognitive function, while scores < 26 suggest some degree of cognitive impairment.

Experimenters in HK and SA received data collection training via videoconferencing from one of the experimenters who conducted the Convery et al (2011b) study. All study tasks were completed in a single appointment. Participants were paid a small cash gratuity to offset their travel costs.

Data management

Numerical values were assigned to the response choices on the participant and partner questionnaires. Higher values were associated with higher degrees of perceived disability for questions pertaining to general literacy, visual acuity, and unaided hearing. In contrast,



Troubleshooting Guide

Are you having any of these problems?

The hearing aid is falling off your ear
→ Try a shorter tube (see page 4)

The hearing aid feels tight on the top of your ear
→ Try a longer tube (see page 4)

The dome feels like it is too loose in your ear
→ Try a larger dome (see page 5)

The dome feels like it is too tight in your ear
→ Try a smaller dome (see page 5)

3. Does the hearing aid feel too tight inside your ear? If yes, try a **smaller** dome. (See page 5)

4. Does the hearing aid feel comfortable in your ear? If yes, keep the dome you have.

Figure 1. The original troubleshooting section of the instructions used in Convery et al (2011b) on the left and a page of the English-language revised version used in the current study on the right.

higher values represented answers of higher rank for questions about education, occupation, and hours of daily hearing-aid use. The question about housing status was the only item that could not be directly compared across sites, as the two versions of the questionnaire each had a different number of response choices.

As the Pearson's product-moment correlation analysis demonstrated that the dominant and non-dominant hand scores on the GPT were significantly correlated for both sites (SA: $r = 0.81$, $p < 0.05$; HK: $r = 0.74$, $p < 0.0001$), a single average score was calculated for each participant.

Results

Participant characteristics

An overview of participant data is shown in Table 1. With the exception of the housing parameter, which was not measured in the AU sample, corresponding data from Convery et al (2011b) are shown in the last column for comparison purposes. On average, the SA participants were younger than those in the HK and AU groups. Both the SA and HK groups had less formal education and poorer self-assessed visual acuity and reading skills than did the AU participants. With respect to years of hearing-aid experience, the three groups differed markedly. Sixty percent of the SA participants had experience with amplification prior to this study, while only 7% of the HK group had previously worn or were currently wearing hearing aids. In comparison, 77% of the AU participants reported prior hearing-aid experience. The SA and HK participants achieved lower scores on the MoCA, GPT, and S-TOFHLA relative to the AU participants and displayed greater inter-subject variation across all three measures.

Partner characteristics

Table 2 shows partner data for the SA and HK groups. As the partner questionnaire was greatly expanded for the current study, comparative data from the AU sample are available only for age and gender. Compared to the participant group, the SA and HK partner groups were, on average, younger, with greater variation in age. Female partners were more common than male partners, comprising 82% of SA, 67% of HK, and 76% of AU partners. Partners at both test sites were, on average, similar to the participants in terms of their education level and type of housing. In HK, however, partners were more likely to work in more prestigious occupations and to report better visual acuity and reading skills. A similar proportion of partners at both sites reported previous experience handling the hearing aid(s) of a friend or family member, with 41% in SA and 43% in HK answering this question in the affirmative.

Hearing-aid assembly

The hearing-aid assembly task was performed twice, once for each ear, and included eight steps: tube selection, dome selection, dome and tube assembly, tube and hearing-aid body assembly, battery insertion, ear insertion, troubleshooting, and device activation. Among the SA participants, the total time taken to fully assemble

Table 1. An overview of participant characteristics. With the exception of the binary variable gender, for which percentages are shown, values are the mean or median, with standard deviations in parentheses. Australian data from Convery et al (2011b) are included for comparison purposes.

	South Africa (N = 40)	*Hong Kong (N = 40)*	*Australia (N = 80)*
Age (years)	67 (12.2)	74 (8.2)	73 (10.9)
Gender (%)	45 M, 55 F	50 M, 50 F	65 M, 35 F
Education	2, high school (1.1)	1, < high school (0.4)	3, trade qualification (1.3)
Occupation	1, unemployed (2.0)	2, labourer/driver (1.8)	5, manager (1.3)
Housing	1, formal (0.3)	1, private permanent (1.7)	N/A
Vision	2, good (0.8)	2, good (0.6)	1.3, good/excellent (0.6)
Reading	2, good (1.6)	3, moderate (1.2)	1, excellent (0.6)
Hearing	4, poor (1.0)	3, fair (0.8)	3, fair (0.8)
Hearing-aid experience (years)	3.8 (7.8)	0.2 (0.9)	11.0 (12.9)
MoCA	22 (6.3)	22 (4.2)	26 (3.1)
GPT (seconds)	116 (53.2)	108 (38.5)	101 (37.6)
S-TOFHLA	27 (11.6)	26 (7.9)	34 (4.6)

MoCA, Montreal Cognitive Assessment; GPT, Grooved Pegboard Test; S-TOFHLA, Short Test of Functional Health Literacy in Adults.

each hearing aid ranged from 4.1 to 12.9 minutes for the first ear and 1.4 to 9.6 minutes for the second ear, with average times of 8.4 and 5.1 minutes, respectively. The HK participants took an average of 14.9 minutes to assemble the first hearing aid and 5.5 minutes to assemble the second hearing aid. Assembly times ranged from 1.4 to 43.7 minutes for the first ear and 1.3 to 21.5 minutes for the second ear. A t-test for dependent samples revealed that the time spent per step was significantly shorter for the second hearing aid for both data sets (SA: $t_{39} = 11.7$, $p < 0.0000001$; HK: $t_{39} = 6.9$, $p < 0.0000001$). The SA participants spent significantly less time per step than did the HK participants when assembling the first hearing aid according to a t-test for independent samples ($t_{78} = -3.9$, $p = 0.0002$). The two groups did not differ significantly for the second hearing aid ($t_{78} = -0.59$, $p = 0.56$).

In addition to time, completion of the assembly procedure was evaluated according to independence (whether participants requested assistance from their partners) and accuracy (whether participants made errors). As shown in Figure 2, participants were classified into four groups based on their performance on the eight-step assembly task for each ear: independent/accurate (Group 1), independent/error (Group 2), help/accurate (Group 3), and help/error (Group 4). Using the same categories described above, participants were then assigned a single overall rating that encompassed their performance on both hearing aids. Logistic regression analysis showed that there was no significant difference between the SA and HK groups in terms of independent task completion ($p = 0.15$), but that there was a significant site effect on accuracy ($p = 0.0001$). Data from each test site are therefore examined together in subsequent analyses pertaining to independence, and separately in analyses related to accuracy.

Independence

The percentage of participants requesting help was calculated for each step and each ear and is shown in Table 3. Overall, the troubleshooting step attracted the least number of requests for help. Among the SA group, both the proportion of participants requesting assistance and the decrease in requests for assistance from the first to the second ear were similar for all other steps. Comparatively, 45–50% of HK participants requested assistance with tube selection, dome selection, and battery insertion when assembling the device for the first ear. The proportion of requests for assistance decreased considerably (by 30–37%) for the second assembly attempt. For both test sites, the number of requests for assistance was significantly higher for the first hearing aid according to a mixed-effects logistic regression analysis (SA: $z = -5.54$, $p < 0.001$; HK: $z = -7.63$, $p < 0.001$).

A Spearman's rank order correlation analysis was conducted on the combined demographic data to consolidate highly correlated parameters for a discriminant analysis. Significant correlations were found between S-TOFHLA score, MoCA score, self-assessed

Table 2. An overview of partner characteristics. Values for age, education, occupation, housing (HK), vision, and reading are the mean or median, with standard deviations in parentheses. Percentages are shown for gender and hearing-aid experience as these questions had binary response choices.

	South Africa (N = 22)	*Hong Kong (N = 21)*	*Australia (N = 80)*
Age (years)	55 (18.4)	60 (18.4)	71 (16.1)
Gender (%)	18 M, 82 F	33 M, 67 F	19 M, 61 F
Education	2, high school (1.2)	1, < high school (0.7)	N/A
Occupation	1, unemployed (1.8)	3, technician/trade worker (1.7)	N/A
Housing	1, formal (0.4)	1, private permanent (1.9)	N/A
Vision	2, good (0.6)	2, good (0.9)	N/A
Reading	2, good (1.6)	2, good (1.1)	N/A
Hearing-aid experience (%)	41 Y, 59 N	43 Y, 57 N	N/A

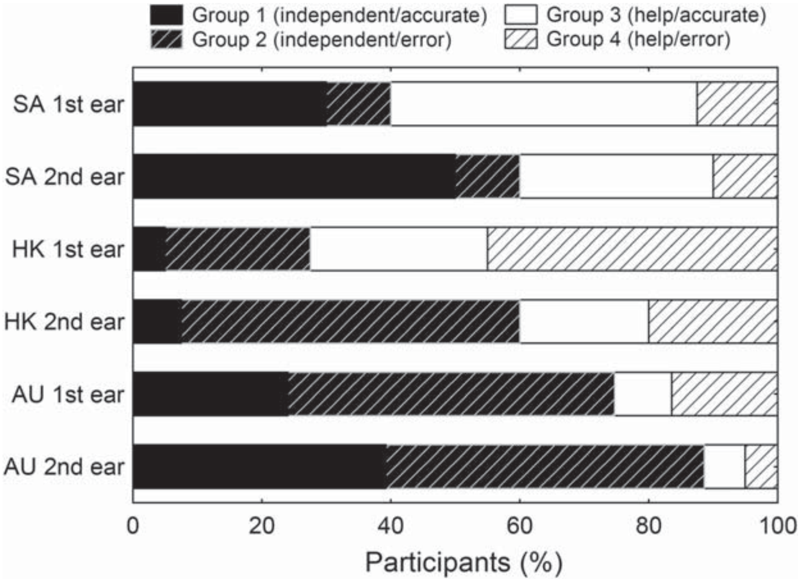


Figure 2. The proportion of participants in each group when classified according to task independence and accuracy. The AU data from Convery et al (2011b) are shown for comparison purposes.

confidence with filling out forms, and education level ($\rho > |0.41|$, $p < 0.05$). The S-TOFHLA score was selected as the representative parameter as it is a direct, validated measure of an individual's health literacy level and was also correlated with dexterity ($\rho = -0.50$, $p < 0.05$). Years of hearing-aid experience and daily hearing-aid use were highly and significantly correlated ($\rho = 0.95$, $p < 0.05$). Years of hearing-aid experience was chosen as the representative parameter as it is less susceptible to random variation over time and is more likely to be reported accurately. The remaining parameters did not show strong correlations with other parameters. Consequently, S-TOFHLA score, years of hearing-aid experience, gender, age, occupation, self-assessed hearing, and self-assessed visual acuity were selected as independent variables for a forward stepwise discriminant analysis that used task independence as the grouping variable. The analysis produced a significant model that included S-TOFHLA score, age, and occupation ($F[3,73] = 6.83$, $p < 0.0004$). Of these parameters, S-TOFHLA score and age were significant. When all three parameters were combined, the model correctly classified 78% of participants as either able or unable to complete the assembly task independently. Participants who performed the task independently were more likely to be younger, to have higher levels of health literacy, and to have worked in a more prestigious occupation. Health literacy contributed the most to the model, while occupation contributed the least (Table 4).

Table 3. The percentage of participants who requested assistance with the assembly task for each step, site, and ear.

	SA (1st ear)	*SA (2nd ear)*	*HK (1st ear)*	*HK (2nd ear)*
Tube selection	35	23	45	8
Dome selection	35	23	45	15
Dome + tube	35	20	38	20
Tube + device	40	23	40	18
Battery	33	23	50	20
Insertion	40	23	38	23
Troubleshooting	25	23	20	5
Activation	35	25	20	5

Accuracy

Table 5 shows the percentage of participants who made mistakes on the assembly task for each step and each ear, as well as the percentage of participants who omitted the step outright. For the SA group, mistakes were recorded less than 10% of the time for all steps and both ears. Omissions were observed for only the activation step on the second attempt, and the percentage was low (5%). When mistakes and omissions are combined to yield a single total error value, there was no significant difference in the proportion of SA participants making errors between the first and second hearing aids according to a mixed-effects logistic regression analysis ($z = -0.20$, $p = 0.84$). In contrast, a large percentage of HK participants omitted the final steps of the assembly procedure on both attempts. Ear insertion of both the first and second devices was omitted by 30% of HK participants. The troubleshooting step was omitted by 63% of participants for the first ear and 70% of participants for the second ear, while device activation was omitted by 45% and 58% of participants, respectively. Of the participants who attempted the troubleshooting and device activation steps, fewer than 5% made a mistake. For the other steps, the proportion of participants making mistakes varied from 5% to

Table 4. The independent variables that correctly classified 78% of SA and HK participants according to independent task completion, with their associated contribution weights (raw and standardized β coefficients), significance levels (p values), and proportions of variance (tolerance).

Variable	*Raw β*	*Standardized β*	*p value*	*Tolerance*
Health literacy	− 0.07	− 0.70	0.006	0.95
Age	0.06	0.64	0.009	0.98
Occupation	− 0.21	− 0.38	0.13	0.96

Table 5. The percentage of participants who made errors and omissions on the assembly task for each step, site, and ear.

	SA 1st ear		*SA 2nd ear*		*HK 1st ear*		*HK 2nd ear*	
	Errors	*Omissions*	*Errors*	*Omissions*	*Errors*	*Omissions*	*Errors*	*Omissions*
Tube selection	5	0	3	0	33	0	48	0
Dome selection	5	0	3	0	18	0	30	3
Dome + tube	3	0	8	0	5	0	5	5
Tube + device	5	0	3	0	20	0	33	3
Battery	10	0	0	0	18	3	25	0
Insertion	3	0	8	0	23	30	38	30
Troubleshooting	0	0	0	0	5	63	3	70
Activation	0	0	0	5	3	45	5	58

48% across ears. When both mistakes and omissions are combined, HK participants made significantly more errors on the second hearing aid compared with the first ($z = 3.91$, $p < 0.001$).

To determine whether any factors predicted which participants would complete the assembly task accurately, participants who had received assistance on one or more steps were excluded, as it was not known whether the participant or the partner was responsible for any errors made. Sixteen valid observations were available from the SA group. A Mann-Whitney U test performed on the independent variables listed in Table 1 revealed that only the MoCA score significantly discriminated between the two groups ($Z = 2.26$, $p = 0.02$). Among participants who performed the assembly task independently, those with better cognitive function were more likely to do so accurately. A comparable analysis could not be performed on the HK data due to the small number of participants who completed the assembly task without errors.

Discussion

Overall, 95% of SA participants and 60% of HK participants completed the hearing-aid assembly task, compared to 99% of the participants in the AU pilot investigation who did the same (Convery et al, 2011b). Performance on the assembly task was examined for accuracy and independence. Sixty-three percent of SA and 18% of HK participants assembled both hearing aids without errors, compared to 25% of AU participants. Forty percent of SA and 25% of HK participants performed the assembly task without assistance from their partners, compared to 72% of the AU group. The performance differences observed between the SA and HK groups underscore the fact that although both South Africa and China are considered developing countries (IMF, 2012), the “developing world” is not a homogeneous term. Despite having many characteristics in common, such as low levels of health literacy, formal education, and cognitive function, the participants in both groups demonstrated different success rates on the hearing-aid assembly task. More marked differences were observed between participants in the current study and the AU group from Convery et al (2011b), both in terms of performance on the assembly task and the characteristics of the participants. The AU participants were more likely to perform the assembly task independently and had higher levels of health literacy, formal education, cognitive function, and manual dexterity than did the SA and HK participants, highlighting the even larger discrepancy between developing and developed countries.

The assembly instructions used in Convery et al (2011b) were modified for use in this study to reduce or eliminate the major sources of error observed among the AU participants. Of the AU participants, 30% selected the wrong tube length, 38% were unable to insert the concha lock, and 50% did not troubleshoot the fit of the hearing aid. In contrast, the error rates for the SA participants on these steps were 4% for tube selection, 5% for ear insertion, and 1% for troubleshooting. The SA group did not introduce any new significant sources of error, with the error rates for the other steps ranging from 3–5%. Significantly, SA participants had lower levels of health literacy than did the AU participants, with SA participants achieving a mean S-TOFHLA score of 27/36 compared to the AU mean of 34/36. This outcome suggests that when health instructional materials are designed to adhere to best-practice health literacy principles, low levels of health literacy are not necessarily a barrier to their successful use.

Both the rate and pattern of errors differed for the HK participants. With 82% of HK participants making errors, this was not only higher than the 37% of SA and 75% of AU participants who did the same, but also included a significantly larger proportion of omissions than those observed in the SA and AU groups. The error rates for individual steps were also higher than those found among the SA and AU participants, ranging from 8% for dome and tube assembly to 70% for troubleshooting. As shown in Table 5, the first five steps were dominated by errors and the final three by omissions. While the performance differences between the AU and HK groups may be traced to poorer levels of education, health literacy, manual dexterity, and cognitive function among the HK participants, the differences between the HK and SA groups cannot be explained in this way. Both the HK and SA participants had similar overall levels of health literacy, education, and cognitive function, and the HK participants had, on average, better manual dexterity. Although the HK participants were older and had less hearing-aid experience than the SA participants, neither age nor hearing-aid experience were found to be significant predictors of task accuracy. We note that while the proportion of errors made is the same for both ears among AU and SA participants, HK participants make more errors the second time they performed the assembly task. Thus, the variables we have measured did not provide an explanation for this behaviour.

One possible reason for the poor performance of the HK participants is the fact that 58% of the group did not read the instructions fully, or at all. When we examined the participants who did not make full use of the instructions more closely, we found that this group was responsible for the majority of omissions. Of this group, only 9% completed the assembly task accurately, whereas 30% of the participants who did read the instructions did so. The finding that health literacy did not influence accuracy in the HK group is understandable in light of these observations, as health literacy skills would not play a role if the written instructions were not used.

The observation that the majority of HK participants did not make full use of the instructions, despite being instructed to do so, came as a surprise to the local experimenter. Respect for authority and compliance with directions are considered to be important values in Chinese culture, particularly among older adults. In a health-care setting, the professional is typically viewed as the “authoritative expert” (Williams et al, 2006), with the expectation that he or she will be responsible both for directing the encounter and proposing solutions to any difficulties that arise (Yip, 2005). The low levels of compliance observed in the current study may be the result of an external locus of control, a psychological construct that describes the extent to which individuals believe they can personally control events that affect them (Rotter, 1966). Those with an external locus of control believe that chance, fate, or the actions of others control the events in their lives, whereas those with an internal locus of control believe that outcomes result primarily from their own behaviour or actions. Although locus of control was not directly measured in this study, research has suggested that Chinese adults tend to have external loci of control independent of age, gender, occupation, or level of formal education (Stocks et al, 2012), and are more likely to believe that luck or fate is responsible for situational outcomes (Wu et al, 2004). A self-fitting hearing aid, in which the user, rather than a clinician, is the driving force behind it, may not be readily received by externally oriented individuals, nor those who are not accustomed, whether they be for personal or cultural reasons, to taking an active role in their health care. The effect of locus of control and the cultural context are two issues that should be investigated in future studies.

At both test sites, some individuals acted as partners for multiple participants. We do not consider this to have affected the results of the study, as the assembly task was participant-driven; partners became involved only at the direct request of the participant. If participants made an error on a step but did not recognize it as such (or if the error did not prevent them from independently proceeding to the next step, such as selecting an incorrect dome size), they would be unlikely to request assistance. The partners may have recognized the error, but were not permitted to intervene on their own initiative. Therefore, the partner only had the opportunity to influence the outcome of the assembly task if the participant specifically asked for the partner’s involvement. Similarly, the partner would be able to apply prior knowledge of the assembly task to subsequent participants only if subsequent participants did the following: (1) made an error or became unable to progress in the task, (2) recognized the error, and (3) requested help. The partner would lose the opportunity to improve the outcome of the task if any one of these three steps did not occur. To illustrate this, seven SA participants received help from the same partner, yet demonstrated different and random independence and accuracy patterns. One participant requested help on every step because she was illiterate, yet still made errors on three steps when assembling the second device. Chronologically, she was the third participant assisted by this partner. Two participants (the fourth and seventh assisted by the partner) displayed a mix of ratings across steps, and the steps for which errors were made and assistance was provided were different for each participant. The remaining four participants (the first, second, fifth, and sixth to receive assistance from the partner) each requested help on a single different step, and made no errors at all.

Participants’ performance was scored on the basis of whether they performed each step independently, and whether they did so accurately. However, the rating scale was such that there was no individual category for steps that were performed both with assistance and with errors. In other words, there was no definitive way of determining whether it was the participant or the partner who was responsible for any errors that may have arisen. It is unfortunate that we cannot be sure about the degree to which the partner contributed to the outcome, as 60% of SA and 75% of HK partners became involved in the assembly task. The importance of a close friend or family member’s involvement in the management of chronic health conditions should not be overlooked; several studies have highlighted the critical role played by the spouse (Scarinci et al, 2008) and other family members (Schow & Nerbonne, 1982) in the audiological rehabilitation process. Given the extent of partner involvement in the current study, future research into the self-fitting hearing aid should focus on the characteristics and contributions of the partner.

Conclusion

The data suggest that the self-fitting hearing-aid assembly task can be managed by a wide cross-section of the population, provided that the instructions are simple and clear, and take health literacy and cultural differences into account.

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Supplementary materials available online

Supplementary Appendix to be found online at http://informahealthcare.com/doi/abs/10.3109/14992027.2013.773407.

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