Hearing Aid Use and Mild Hearing Impairment: Learnings from Big Data

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Abstract

Background: Previous research, mostly reliant on self-reports, has indicated that hearing aid (HA) use is related to the degree of hearing impairment (HI). No large-scale investigation of the relationship between data-logged HA use and HI has been conducted to date.

Purpose: This study aimed to investigate if objective measures of overall daily HA use and HA use in various listening environments are different for adults with mild HI compared to adults with moderate HI.

Research Design: This retrospective study used data extracted from a database of fitting appointments from an international group of HA providers. Only data from the participants' most recent fitting appointment were included in the final dataset.

Study Sample: A total of 8,489 bilateral HA fittings of adults over the age of 18 yr, conducted between January 2013 and June 2014, were included. Participants were subsequently allocated to HI groups, based on British Society of Audiology and American Speech-Language-Hearing Association audiometric descriptors.

Data Collection and Analysis: Fitting data from participating HA providers were regularly transferred to a central server. The data, with all personal information except age and gender removed, contained participants' four-frequency average (at 500, 1000, 2000, and 4000 Hz) as well as information on HA characteristics and usage. Following data cleaning, bivariate and post hoc statistical analyses were conducted.

Results: The total sample of adults' average daily HA use was 8.52 hr (interquartile range [IQR] = 5.49–11.77) in the left ear and 8.51 hr (IQR = 5.49–11.72) in the right ear. With a few exceptions, there were no statistical differences between hours of HA use for participants with mild HI compared to those with moderate impairment. Across all mild and moderate HI groups, the most common overall HA usage was between 8 and 12 hr per day. Other factors such as age, gender, and HA style also showed no relationship to hours of use. HAs were used, on average, for 7 hr (IQR = 4.27–9.96) per day in quiet and 1 hr (IQR = 0.33–1.41) per day in noisy listening situations.

Conclusions: Clinical populations with mild HI use HAs as frequently as those with a moderate HI. These findings support the recommendation of HAs for adults with milder degrees of HI.

Key Words: hearing aids, hearing impairment

Abbreviations: 4FAHL = four-frequency average hearing loss; ANOVA = analysis of variance; ASHA = American Speech-Language-Hearing Association; BSA = British Society of Audiology; BTE = behind-the-ear; CIC = completely-in-the-canal; HA = hearing aid; HI = hearing impairment; IQR = interquartile range; ITE = in-the-ear; $moderate^{ASHA}$ = average hearing thresholds between 41 and 55 dB HL; $moderate^{BSA}$ = average hearing thresholds between 41 and 70 dB HL; RIC = receiver-in-the-canal

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INTRODUCTION

Acquired hearing impairment (HI) is recognized by the World Health Organization as the third leading cause of disability, with a mild degree of HI being the most prevalent (World Health Organization, 2004). In a recent systematized review of research literature concerning adults with mild HI, we concluded that the provision of hearing aids (HAs) was the most common intervention for this population group (Timmer et al, 2015). There is some evidence, however, that the rate of HA fitting for mild HI is lower than for greater degrees of HI. Kochkin (2012) found that audiologists had suggested a "wait and retest" approach to intervention to 43% of HA nonadopters with mild HI, compared to 24% of HA nonadopters with a moderate/severe HI. This trend was similar for the participants who visited Hearing Instrument Specialists, who suggested a "wait and retest" approach to 35% of people who self-reported mild HI, compared to 15% with a self-reported moderate/severe HI. These findings could be due to a number of factors; practitioners may not feel HAs are of sufficient benefit for this clinical population, or alternatively, adults with mild HI may not perceive a need for intervention. There is, however, little data available to understand the reasons for the findings.

Population studies such as Gopinath et al (2011) and Hartley et al (2010) have shown that the prevalence of HA ownership and use increased as the severity of HI increased. This may not, however, provide an insight into how much, or how regularly, the HAs are used on a daily or weekly basis.

Measuring Hearing Aid Use

Perez and Edmonds (2012) systematically reviewed studies that measured and reported on HA usage in older adults. Of the 64 papers reviewed, only 5 reported objective usage data such as data logging or battery consumption information. The majority of studies (n = 32) measured usage by means of standardized self-report questionnaires such as the International Outcome Inventory-Hearing Aids (Cox and Alexander, 2002), Abbreviated Profile of Hearing Aid Benefit (Cox and Alexander, 1995), and the Glasgow Hearing Aid Benefit Profile (Gatehouse, 1999). Twenty-one of the 64 papers used a custom self-report questionnaire to measure HA usage. The use of self-report measures of HA usage has been criticized because of major differences that have been found between subjective and objective measures of use (Humes et al, 1996; Taubman et al, 1999; Mäki-Torkko et al, 2001; Gaffney, 2008; Laplante-Lévesque et al, 2014). Despite this, Perez and Edmonds (2012) noted that only 7 of the 64 studies had cross-validated self-reported usage with objective measures (data logging or battery consumption) or patient interviews.

Studies that have compared self-report and objective measures show that there is a tendency to overestimate daily usage by up to ≤4 hr per day (Humes et al, 1996). Taubman et al (1999) found that overestimates averaged 3.7 hr per day in the group of 12 participants who were not told that their usage would be verified by objective means and 1.1 hr per day in the group (n = 12) who were aware of this. Gaffney (2008) found self-reports were on average 1.9 hr higher than the HA usage measured by its data-logging feature (the 40 participants were not informed of the HA ability to objectively measure use). Mäki-Torkko et al (2001) also found subjective HA use was overestimated when compared to the HA data logging. This study, however, did not report absolute figures, but grouped the 84 participants' results from each reporting method (patient interview, diary, or HA data logging) into <4, 4–8, or >8 hr per day. Laplante-Lévesque et al (2014) also demonstrated that HA users overestimate their use by, on average, 1.2 hr per day. Participants who showed greater differences between self-report and objective usage measures were more likely to have irregular patterns of use (e.g., different hours of use day to day rather than the same amount of use every day) than those who showed greater agreement between subjective and objective usage measures. The Laplante-Lévesque et al (2014) study of 228 participants was the largest to date to report on objective measures of HA usage in adults. Walker et al (2015) investigated HA use with a sample size of 290 children between the ages of 5 mo and 7 yr and collected data logging from 232 children. Their study found a similar trend in overestimation of children's HA use by the parents and highlighted, as Perez and Edmonds (2012) did, the limited objective evidence of HA use in the research literature.

Hearing Aid Use in Different Listening Environments

Previous studies have indicated that reasons for HA nonuse include insufficient benefit in situations with background noise (Kochkin, 2007; Bertoli et al, 2009; Hartley et al, 2010; Gopinath et al, 2011) or a lack of situations in which an HA is necessary (Vuorialho et al, 2006). Few studies, however, have investigated the reported or measured use of HAs in different listening situations. Data logging in modern HAs that also classifies the sound environments in which HAs are used has the potential to address this gap in the research evidence. The current study used data from Phonak (Staefa, Switzerland) HAs, which have a robust automatic program selection based on the classified sound environment (Büchler et al, 2005), and data logging shows the hours of use in each automatic program. In the only other study we are aware of examining objective HA use in different environments, Gaffney (2008) reported a marked

difference between the self-reported time spent in noise and the HA's data-logged time spent in noise. The 40 participants in her study estimated they had spent, on average, 55% of time in quiet and 34% in a noisy environment, while data logging indicated 66% of time in quiet and 28% in noise. However, the degree of HI of the 40 participants in the Gaffney (2008) study was not reported, and therefore no conclusions can be drawn regarding differences in HA use in varying listening environments based on HI.

The objective of this study was to compare HA use by adults with mild HI to adults with moderate HI. Relationships between HA use and a number of client and HA characteristics were also investigated, as was the relationship between degree of HI and HA use in different listening environments.

METHODS

This study used big data from a large-scale international database, which logs client and HA details in the fitting software. The HA-fitting database used was generated from the Phonak Target™ fitting software, versions 3.0–3.3. Participating clinics in the United States, Canada, Australia, and Belgium (n = 159 clinics) enabled a database function in the programming software, which then created a data store of all subsequent client fittings. These fitting data were then regularly transferred to a central server, with all personal identifying information removed. Only data from each participant's most recent fitting appointment, conducted between January 2013 and June 2014, was included. The dataset for this study contained the following:

- Participants' age
- Gender
- Four-frequency average hearing loss (4FAHL; 500, 1000, 2000, and 4000 Hz) in both ears
- HA type (completely-in-the-canal [CIC], in-the-ear [ITE], behind-the-ear [BTE], or receiver-in-the-canal [RIC])
- HA price/performance category (premium, midlevel, or economy)
- Total hours of HA use for each ear
- Hours of HA use in quiet environments for each ear
- Hours of HA use in speech-in-noise environments for each ear

The HA price/performance category was defined by the fitted HA's wholesale price and features, and classified into the premium, midlevel, or economy levels commonly used by the HA industry (Strom, 2014). The Phonak HA sound classification system uses >50 parameters to broadly classify four main classes of sound: speech/quiet, speech in noise, noise, and music. Once a sound environment is classified, the HA then automatically selects the most appropriate listening program, imbedded into which are amplification (e.g., compression) and noise cleaning (e.g., beamforming) features. HA use in quiet environments was calculated as the average daily amount of time the HA was in an automatically chosen program designed for either quiet or speech-only situations. Similarly, use in speech-in-noise environments was calculated from the average daily amount of time the HA was in an automatically chosen program designed for speech-in-noise or noise situations. The use of manual programs was excluded from the dataset, as the average daily use for manual programs was minimal, in line with previous studies using Phonak HAs that showed the automatic mode to be the default program in 92% of >150,000 fittings (Rakita and Jones, 2015).

Participants

From the centralized database, the following inclusion criteria were used to extract participants' fitting details: ≥19 yr of age, audiogram available for both ears, 4FAHL between 25 and 70 dB HL, and bilateral fitting (to allow comparisons of use data between ears). From a total of 16,766 participants, 8,489 participants had bilateral HA use data extracted from data-logging files and were included in this study.

Participants were then divided into HI groups based on their 4FAHL. The degree of HI that could be classified as "moderate" is related to the audiometric descriptors and corresponding threshold ranges being used. For example, the British Society of Audiology (BSA, 2011) categorizes an average HI between 41 and 70 dB HL as "moderate." The American Speech-Language-Hearing Association (ASHA) recognizes audiometric descriptors recommended by Clark (1981), which define a moderate HI as between 40 and 55 dB HL and a moderately severe HI as between 56 and 70 dB HL. As both the BSA and ASHA systems of audiometric descriptors are in use around the world today, this study incorporated both. Participants were subsequently allocated to one of three BSA HI groups and to one of six ASHA HI groups, using the thresholds range shown in Table 1.

The three BSA HI groups were classified generally according to the BSA audiometric descriptors, although it is recognized that the BSA procedure uses a five-frequency threshold average (250, 500, 1000, 2000, and 4000 Hz) and defines a mild HI as an averaged threshold between 20 and 40 dB HL. As the dataset for this present study provided only a 4FAHL that did not include 250 Hz, it was not possible to adhere strictly to the BSA audiometric descriptors.

Strict adherence to the ASHA mild HI definition would result in the 4FAHL for the mild HI group starting at 26 dB HL (as 25 dB HL would be defined as a slight HI); however, 25 dB HL was chosen as the cutoff to ensure the size of the mild HI groups were identical,

Table 1. Audiometric Descriptors and Participant HI Groups

Descriptor	BSA HI Groups	ASHA HI Groups
Bilateral mild	25–40 dB HL in both ears	25–40 dB HL in both ears
Mild/moderate	25–40 dB HL in one ear; 41–70 dB HL in the other	25–40 dB HL in one ear; 41–55 dB HL in the other
Bilateral moderate	41–70 dB HL in both ears	41–55 dB HL in both ears
Mild/moderately severe	NA	25–40 dB HL in one ear; 56–70 dB HL in the other
Moderate/moderately severe	NA	41–55 dB HL in one ear; 56–70 dB HL in the other
Bilateral moderately severe	NA	56–70 dB HL in both ears

Note: NA = Not Applicable.

using either of the three BSA and six ASHA groups. As this paper uses different definitions of categories of HI, the threshold range used to define that audiometric descriptor is denoted by the use of either BSA or ASHA as superscript.

To investigate patterns in HA use, participants were grouped in average daily use groups (<0.5, ≥0.5 to <2, ≥2 to <4, ≥ 4 to <8, ≥8 to <12, ≥12 to <20, or ≥20 hr per day).

This study received ethical approval from the University of Queensland Behavioral and Social Sciences Ethical Review Committee.

Data Cleaning and Analysis

Only data from the participants' most recent fitting appointment (to exclude duplicates) between January 2013 and June 2014 were included in the final dataset. Any files with data logs of either 0 or 24 hr daily HA use were deleted, as these were considered defective data logs, as also experienced by Laplante-Lévesque et al (2014).

As the fitting software does not require practitioners to enter in a gender, there were many files (55%) for which the participants' gender was unspecified. Similarly, 26% of fitting files contained a default date of birth/age, rather than one manually entered. These files were still included but not used for any analysis examining gender or age, respectively.

All statistical analyses were conducted using Stata version 13 (StataCorp, College Station, TX). Bivariate analyses were conducted with analysis of variances (ANOVAs), with post hoc Bonferroni and Pearson's χ^2 to identify relationships between both HI and age, gender, HA type, HA price/performance level, and daily HA use in total as well as in different listening situations (significance level $p < 0.05$).

RESULTS

Table 2 shows the participant demographics of the full sample of 8,489 individuals. The mean age of participants was 72 yr, and there were more female than male participants. The 4FAHL data for both ears showed the average participant to have 0.25-dB difference between the left and right ears. Over half of the HAs provided to this sample were RIC devices, with BTEs being the second most popular device at 37%. Less than 10% of the participant sample was fitted with ITE devices and <1% with CIC devices. Just over one in five devices were in the premium price/performance category, with the rest of the HAs almost evenly divided between the midlevel and economy categories.

Table 3 shows the participant characteristics by each of the three BSA HI groups. Of the 8,489 participants with 4FAHL between 25 and 70 dB HL bilaterally, who presented to participating HA clinics and were fitted with HAs, 1,503 (18%) had a bilateral mild HI, 1,355 (16%) had a mild HI in one ear and a moderate[BSA]

Table 2. Participant and Hearing Aid Characteristics

Age (n = 6,310)	
Mean, years (SD)	72.08 (13.14)
Range, years	19–100
Median, years (25th to 75th percentile)	75 (64–82)
Gender (n = 3,815)	n (%)
Male	1,648 (43.2)
Female	2,167 (56.8)
HI (4FAHL, dB HL)	Mean (SD)
Left ear	48.23 (10.31)
Right ear	47.93 (10.32)
Difference in 4FAHL, left minus right ear	0.25 (7.53)
HA type, left ear	n (%)
CIC	56 (0.66)
ITE	752 (8.86)
RIC	4,536 (53.43)
BTE	3,145 (37.05)
HA type, right ear	n (%)
CIC	56 (0.66)
ITE	754 (8.88)
RIC	4,540 (53.48)
BTE	3,139 (36.98)
HA price/performance category, left ear	n (%)
Premium	1,890 (22.27)
Midlevel	3,409 (40.16)
Economy	3,190 (37.58)
HA price/performance category, right ear	
Premium	1,893 (22.30)
Midlevel	3,409 (40.16)
Economy	3,187 (37.54)

Notes: n = 8,489 unless otherwise indicated. SD = standard deviation.

Table 3. Participant and Hearing Aid Characteristics by BSA HI Groups

	Bilateral Mild, n = 1,503	Mild in One Ear and Moderate^{BSA} in One Ear, n = 1,355	Bilateral Moderate^{BSA}, n = 5,631
Age (n = 6,310)	n = 1,169	n = 1,009	n = 4,132
Mean, years (SD)	65.68 (12.10)	69.00 (12.66)	74.64 (12.76)
Range, years	19–92	19–95	19–100
Median, years (25th to 75th percentile)	66 (59–75)	71 (62–78)	78 (68–84)
Gender (n = 3,815)	n = 768, n (%)	n = 609, n (%)	n = 2,439, n (%)
Male	322 (41.9)	249 (40.9)	1,077 (44.2)
Female	446 (58.1)	360 (59.1)	1,361 (55.8)
4FAHL, dB HL	Mean (SD)	Mean (SD)	Mean (SD)
Left ear	34.07 (4.11)	42.35 (7.29)	53.42 (7.37)
Right ear	34.03 (4.06)	41.42 (7.33)	53.20 (7.33)
HA type, left ear	n (%)	n (%)	n (%)
CIC	1 (0.07)	5 (0.37)	50 (0.89)
ITE	96 (6.39)	97 (7.16)	559 (9.93)
RIC	968 (64.41)	856 (63.17)	2,713 (48.18)
BTE	439 (29.21)	397 (29.38)	2,309 (41.01)
HA type, right ear	n (%)	n (%)	n (%)
CIC	1 (0.07)	5 (0.37)	50 (0.89)
ITE	96 (6.39)	97 (7.16)	561 (9.96)
RIC	968 (64.41)	858 (63.33)	2,715 (48.21)
BTE	439 (29.21)	395 (29.15)	2,305 (40.93)
HA price/performance category, left ear	n (%)	n (%)	n (%)
Premium	356 (23.69)	297 (21.92)	1,237 (21.97)
Midlevel	604 (40.19)	554 (40.89)	2,251 (39.98)
Economy	543 (36.13)	504 (37.20)	2,143 (38.06)
HA price/performance category, right ear	n (%)	n (%)	n (%)
Premium	355 (23.62)	297 (21.92)	1,241 (22.04)
Midlevel	605 (40.25)	557 (41.11)	2,247 (39.90)
Economy	543 (36.13)	501 (36.98)	2,143 (38.06)

Notes: n = 8,489 unless otherwise indicated. SD = standard deviation.

(average hearing thresholds between 41 and 70 dB HL) HI in the other, and 5,630 (66%) had a moderate^{BSA} HI.

Participant age was statistically significant different among the BSA HI groups (one-way ANOVA [$F_{(2,6307)} = 265.18$, $p < 0.001$]. Bonferroni post hoc test revealed that age was statistically different in all three HI groups ($p < 0.001$), with participants with bilateral mild HI being on average 9.0 yr younger and participants in the mild/moderate^{BSA} group, on average, 5.6 yr younger than participants with bilateral moderate^{BSA} HI. There was no significant gender difference across the groups.

Of note is that while the price/performance category of the devices provided to participants did not vary significantly across the three BSA HI groups, there was a significant effect of HA type by HI [Pearson's $\chi^2(8) = 195.13$, $p < 0.001$ for the left ear; Pearson's $\chi^2(8) = 201.36$, $p < 0.001$ for the right ear]. Of the participants with a bilateral moderate^{BSA} HI, 48% were fitted with a RIC and 41% were fitted with a BTE. These percentages were 63–64% for RICs and 29% for BTEs for both the bilateral mild and mild/moderate^{BSA} HI groups.

Table 4 shows the participant characteristics by each of the six ASHA HI groups. As the classification of a mild HI is the same using BSA or ASHA definitions, the number of participants with a bilateral mild HI remained 18% of the total group. Just >33% of participants had a bilateral moderate^{ASHA} (average hearing thresholds between 41 and 55 dB HL) HI, and 17% had a moderately severe HI. The remaining 32% of the total group of participants presented with an asymmetrical HI.

Age differences were significant among the six ASHA HI groups also (one-way ANOVA [$F_{(5,6304)} = 116.07$, $p < 0.001$], with participants with bilateral mild HI on average 7.8 yr younger than those with a bilateral moderate^{ASHA} HI and 11.0 yr younger than those with a bilateral moderately severe HI (Bonferroni post hoc, $p < 0.001$). Age differences among the six groups were not statistically significant between the bilateral mild and mild/moderately severe, between the mild/moderate^{ASHA} and mild/moderately severe, and between the bilateral moderate^{ASHA} and moderate^{ASHA}/moderately severe groups respectively. Similar to the three BSA HI groups, there was a significant effect of type of HA fitted by HI group [Pearson's $\chi^2(20) = 363.31$, $p < 0.001$ for the left ear; Pearson's $\chi^2(20) = 369.57$, $p < 0.001$ for the right ear].

Table 4. Participant and Hearing Aid Characteristics by ASHA HI Groups

	Bilateral Mild (n = 1,503)	Mild/Moderate[ASHA] (n = 1,198)	Mild/Moderately Severe (n = 157)	Bilateral Moderate[ASHA] (n = 2,828)	Moderate[ASHA]/Moderately Severe (n = 1,356)	Bilateral Moderately Severe (n = 1,447)
Age (n = 6,310)	n = 1169	n = 892	n = 117	n = 2,104	n = 1,000	n = 1,028
Mean, years (SD)	65.68 (12.10)	69.24 (12.52)	67.18 (13.63)	73.52 (12.20)	74.92 (12.59)	76.66
Range, years	19–92	19–95	19–91	19–97	19–99	19–100
Median, years (25th to 75th percentile)	66 (58–74)	71 (62–78)	68 (61–77)	76 (67–82)	78 (68–83)	80 (71–86)
Gender (n = 3,815)	n = 768, n (%)	n = 547, n (%)	n = 62, n (%)	n = 1,250, n (%)	n = 579, n (%)	n = 609, n (%)
Male	322 (41.9)	228 (41.7)	21 (33.9)	560 (44.8)	237 (40.9)	280 (46.0)
Female	446 (58.1)	319 (58.3)	41 (66.1)	690 (55.2)	342 (59.1)	329 (54.0)
4FAHL, dB HL	Mean (SD)					
Left ear	33.30 (3.82)	41.44 (5.55)	49.28 (13.04)	48.01 (4.00)	55.51 (6.05)	61.89 (3.79)
Right ear	33.33 (3.80)	40.57 (5.54)	47.85 (13.55)	47.91 (3.97)	55.18 (6.08)	61.88 (3.66)
HA type, left ear	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
CIC	1 (0.07)	4 (0.33)	1 (0.64)	19 (0.67)	12 (0.88)	19 (1.31)
ITE	96 (6.39)	90 (7.51)	7 (4.46)	266 (9.41)	122 (9.00)	171 (11.82)
RIC	967 (64.34)	755 (63.02)	103 (65.61)	1,560 (55.16)	647 (47.57)	506 (34.97)
BTE	439 (29.21)	349 (29.13)	46 (29.30)	983 (34.76)	575 (42.40)	751 (51.90)
HA type, right ear	n (%)	n (%)	n (%)	n (%)	n (%)	
CIC	1 (0.07)	4 (0.33)	1 (0.64)	19 (0.67)	12 (0.88)	12 (0.88)
ITE	96 (6.39)	90 (7.51)	7 (4.46)	266 (9.41)	122 (9.00)	123 (9.07)
RIC	967 (64.34)	753 (62.77)	103 (65.61)	1,561 (55.20)	647 (47.57)	648 (47.78)
BTE	439 (29.21)	351 (29.30)	46 (29.30)	982 (34.72)	575 (42.40)	573 (42.26)
HA price/performance category, left ear	n (%)	n (%)	n (%)	n (%)	n (%)	
Premium	356 (23.69)	262 (21.87)	34 (21.66)	589 (20.83)	318 (23.45)	326 (22.53)
Midlevel	604 (40.19)	488 (40.73)	67 (42.68)	1,115 (39.43)	553 (40.78)	587 (40.57)
Economy	543 (36.13)	448 (37.40)	56 (35.67)	1,124 (39.74)	485 (35.77)	534 (36.90)
HA price/performance category, right ear	n (%)	n (%)	n (%)	n (%)	n (%)	
Premium	355 (23.62)	259 (21.61)	34 (21.66)	591 (20.90)	320 (23.60)	326 (22.53)
Midlevel	605 (40.25)	493 (40.15)	67 (42.68)	1,113 (39.36)	552 (40.70)	585 (40.43)
Economy	543 (36.13)	446 (37.23)	55 (35.03)	1,124 (39.74)	484 (35.69)	535 (36.97)

Notes: n = 8,489 unless otherwise indicated. SD = standard deviation.

Hearing Aid Use

Table 5 shows the average daily HA use for the three BSA HI groups. The data-logging results taken from 8,489 participants showed a total average daily use for both the left and right HA of 8.5 hr. One-way ANOVA showed that HA use in the left ear was significantly different across the three BSA HI groups [$F_{(2,8485)} = 4.31$, $p < 0.05$]. Bonferroni post hoc test revealed that overall daily use of the left HA was significantly lower in the bilateral mild (8.16 hr) compared to the bilateral moderate^{BSA} HI group (8.61 hr) ($p = 0.027$). There were no statistical differences in use of the right HA across the three BSA groups.

Average daily HA use by ASHA HI groups can be seen in Table 6. As for the BSA HI groups, there was a significant difference in overall daily use of the left HA among groups, as determined by one-way ANOVA [$F_{(5,8482)} = 3.11$, $p = 0.0084$]. Bonferroni post hoc test revealed that overall daily use of the left HA was significantly lower in the bilateral mild compared to the bilateral moderately severe HI group ($p = 0.006$).

To further investigate variability in HA use by degree of HI, data were analyzed according to extent of HA use (total average daily use of <0.5, ≥0.5 to <2, ≥2 to <4, ≥4 to <8, ≥8 to <12, ≥12 to <20, or ≥20 hr per day), and differences in these groups were investigated using both the BSA (Figure 1) and the ASHA (Figure 2) audiometric descriptors. Pearson's χ^2 statistical analysis showed there were no significant differences in HI categories across groups of HA use.

Statistical analysis showed no relationship between average daily HA use and participants' age, gender, HA style (e.g., ITE, BTE, RIC), or HA price/performance category.

Hearing Aid Use in Different Listening Situations

The HAs for this clinical population were worn on average just >1 hr per day in a speech-in-noise or noise program and just >7 hr per day in an environment identified as quiet or speech in quiet. The use of other programs, for example, the automatic music, noise, or manual programs, was minimal in this clinical population, accounting for <22 min on average per day. There were no statistical differences in use of the right HA in either quiet or speech-in-noise situations between the mild, moderate^{BSA} or mild/moderate^{BSA} groups. A statistically significant difference across groups in left daily HA use in quiet environments was determined by one-way ANOVA [$F_{(2,8483)} = 3.23$, $p < 0.05$]. However, Bonferroni post hoc analysis of daily use of the left HA in quiet among the three groups failed to reached significance ($p = 0.059$).

Similar to the three BSA groups, average daily use of the right HA in either quiet or noise did not differ across HI groups but did differ for the left HA in quiet environments among the six ASHA HI groups [$F_{(5,8480)} = 2.61$, $p < 0.05$]. Pairwise Bonferroni analysis showed the only significant difference to be between the bilateral mild and bilateral moderately severe groups ($p = 0.016$), with lesser use in the bilateral mild HI group.

DISCUSSION

This study suggests that clinical populations with mild HI who adopt HAs use these devices as much as those with a moderate degree of impairment. Additionally, the listening situations in which these clinical populations were using their HAs did not differ between those with a mild HI and those with a moderate HI.

This study found that average daily HA use recorded with data logging was 8.5 hr for both adults with mild HI and adults with moderate HI in both right and left ears. This was similar to the data-logging values measured by Gaffney (2008) but less than the 10.5 hr reported by Laplante-Lévesque et al (2014). Taubman et al (1999) also reported higher usage: 12 participants who were not told of the objective measurement of HA use averaged 9.28 hr use per day, while 12 who were informed of the data logging averaged 11.71 hr per day. The differences across studies could be due to methodological differences; while all three studies used only the value from one ear in the case of bilateral fittings, Gaffney (2008) used values from the right ear unless

Table 5. Hearing Aid Use by BSA HI Group

	Daily Use (Hr/Day) Mean (SD)					
	Overall		In Quiet		Speech in Noise	
	Left	Right	Left	Right	Left	Right
Bilateral mild (n = 1,273)	8.16 (4.25)	8.35 (4.29)	6.82 (3.87)	6.98 (3.95)	1.00 (1.03)	1.03 (1.13)
Mild in one ear and moderate^{BSA} in one ear (n = 1,213)	8.47 (4.17)	8.56 (4.01)	7.09 (3.75)	7.15 (3.65)	1.05 (1.29)	1.06 (1.15)
Bilateral moderate^{BSA} (n = 6,003)	8.61 (4.20)	8.53 (4.17)	7.18 (3.81)	7.10 (3.78)	1.07 (1.13)	1.07 (1.14)
Total sample (n = 8,489)	8.52 (4.21)	8.51 (4.16)	7.12 (3.81)	7.09 (3.79)	1.05 (1.12)	1.06 (1.14)

Note: SD = standard deviation.

Table 6. Hearing Aid Use by ASHA HI Groups

	Daily Use (Hr/Day) Mean (SD)					
	Overall		In Quiet		Speech in Noise	
	Left	Right	Left	Right	Left	Right
Bilateral mild (n = 1,273)	8.16 (4.25)	8.35 (4.29)	6.82 (3.87)	6.98 (3.95)	1.00 (1.03)	1.03 (1.13)
Mild/moderate^{ASHA} (n = 1,062)	8.50 (4.15	8.52 (4.02)	7.11 (3.74)	7.12 (3.66)	1.04 (1.12)	1.06 (1.18)
Mild/moderately severe (n = 151)	8.31 (4.30)	8.81 (4.00)	6.96 (3.84)	7.39 (3.56)	1.10 (1.20)	1.06 (0.98)
Bilateral moderate^{ASHA} (n = 2,857)	8.47 (4.18)	8.49 (4.24)	7.07 (3.78)	7.08 (3.82)	1.04 (1.12)	1.04 (1.10)
Moderate^{ASHA}/moderately severe (n = 1,451)	8.64 (4.23)	8.46 (4.11)	7.21 (3.84)	7.05 (3.72)	1.07 (1.14)	1.05 (1.11)
Bilateral moderately severe (n = 1,695)	8.81 (4.20)	8.66 (4.10)	7.36 (3.82)	7.16 (3.74)	1.11 (1.16)	1.13 (1.21)

Note: SD = standard deviation.

only the left was fitted, and Taubman et al (1999) randomly selected the ear used for statistical analysis. Laplante-Lévesque et al (2014) used the highest values of either the left or right ear, which would increase the average daily use overall. Additionally, the present study was purely retrospective, with no active participant recruitment. Thus the lower average HA use found here may have occurred because participants were not influenced by enrollment in a research study about HA use.

The difference in overall daily use of the left HA was significantly less for those with a bilateral mild HI when compared to those with a bilateral moderate^{BSA}. There is no clear explanation for this, and there were no significant differences between overall right and left HA use for the total sample in the present study. Therefore there was no evidence of handedness or right-ear advantage, which has been found in other studies investigating HA use differences in bilateral fittings with older adults (Jerger, 2001; Roup et al, 2006).

Although use of the left HA was statistically different between participants with a bilateral mild (8.16) and those with a bilateral moderate^{BSA} (8.61) HI (Table 5), overall daily use differed by only 0.45 hr, or an average of 27 min per day, which could not be deemed clinically relevant. Further investigation using the ASHA audiometric descriptors (Table 6), which distinguish a moderate from a moderately severe HI, showed that average daily use of the left HA was statistically lower only for participants with a mild HI, compared to those who had an average threshold of 56 dB HL or greater, in both ears. Again, the magnitude of the largest difference in overall average daily use for left and right aids was 39 min per day, so low that it may not be deemed

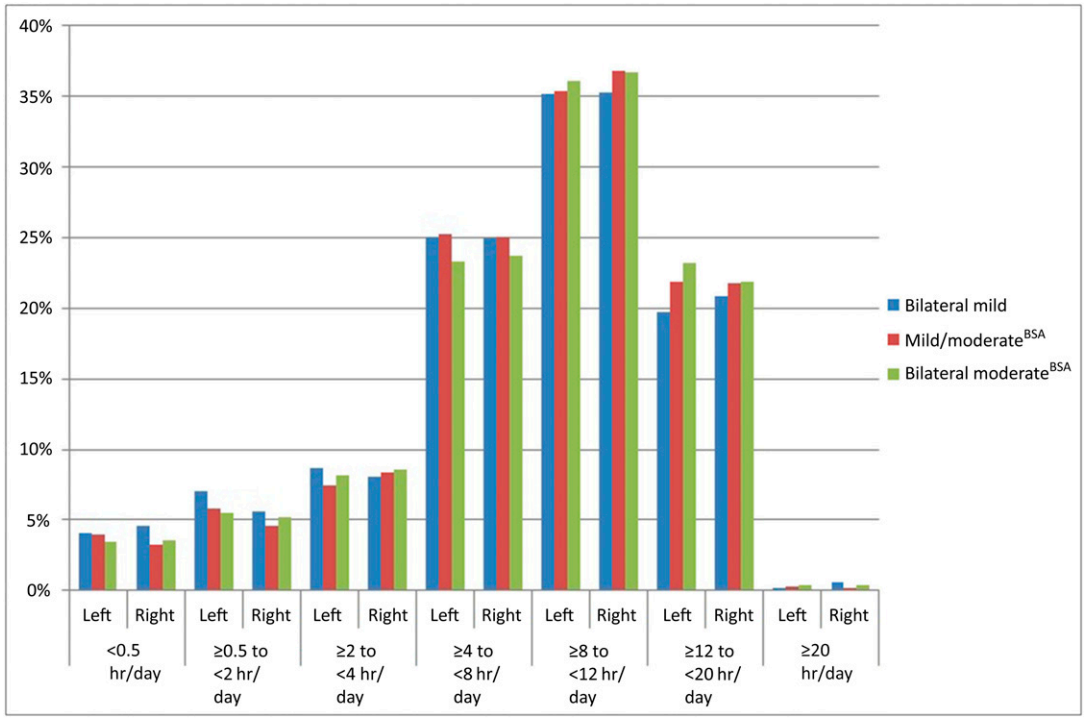

Figure 1. Grouped average overall HA use, by ear and BSA HI groups. (This figure appears in color in the online version of this article.)

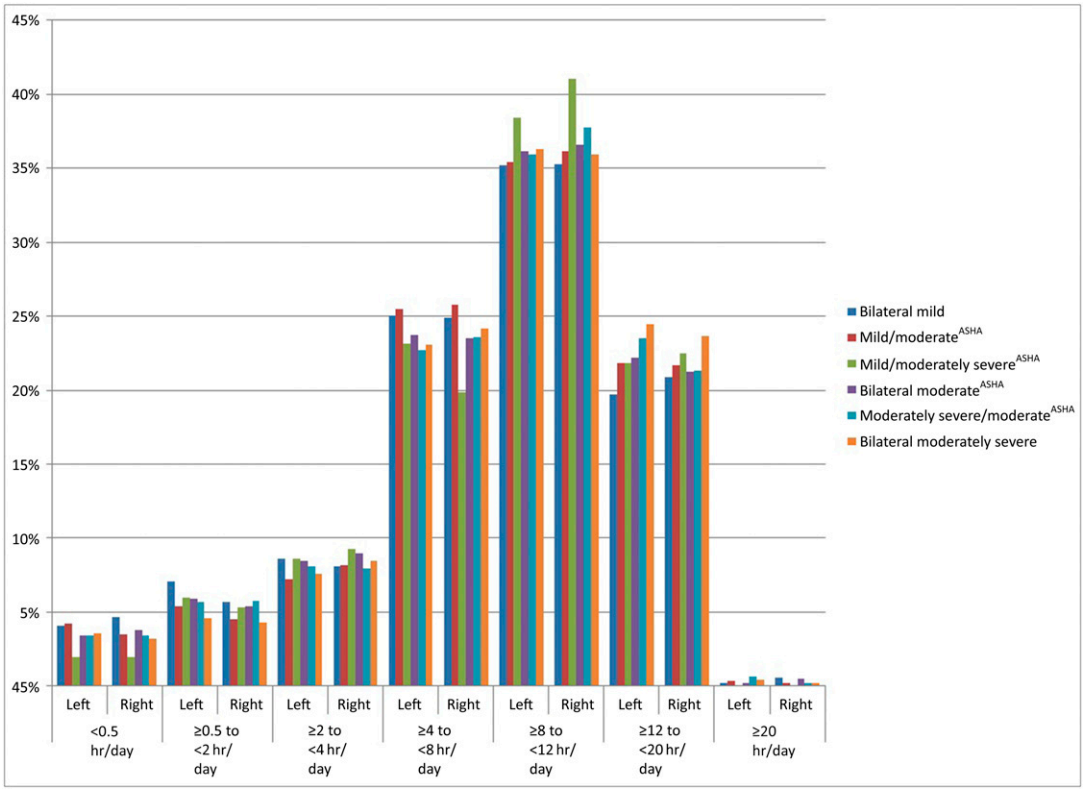

Figure 2. Grouped average overall HA use, by ear and ASHA HI groups. (This figure appears in color in the online version of this article.)

clinically relevant by most clinicians. Additionally, given that the data-logging feature saves to memory only periodically and not continuously, the precision of the logged data is ±15 min.

As seen in Figures 1 and 2, patterns of HA use did not differ across different HI groups. In general, for all HI groups, <5% of all participants wore their HAs <30 min per day, <15% of participants wore their HAs between 30 min and 4 hr per day, and >80% of all participants wore their HAs >4 hr per day. The most common length of HA use for all HI groups was between 8 and 12 hr per day. Approximately 20% of all participants wore their HAs >12 hr per day.

The overall lack of relationship between hours of HA use and degree of HI is consistent with previous research. Perez and Edmonds (2012) found HI was significantly related to usage in only 3 of 64 studies. Studies published after the Perez and Edmonds (2012) review also found no association between average daily HA usage and the measured degree of HI (Solheim et al, 2012; Laplante-Lévesque et al, 2014). These findings reiterate the notion that standard measures of HI such as pure-tone audiometry have little correlation with subjective disability and that benefit from HAs cannot be predicted by degree of HI. Adults who report activity limitations and participation restrictions, regardless of measured HI, are more likely to adopt HAs and obtain benefit from HAs (Timmer et al, 2015).

The present study found no association between HA use and age or gender. Nonsignificant findings for age and gender may have been influenced by 55% of files not having a reliable age entered and 26% of files not including gender., However, previous research has also found no association between age or gender and HA use. Indeed, the Knudsen et al (2010) and Perez and Edmonds (2012) systematic reviews conclude the aspects that influence HA use may be rather more complex and include motivational, personality, and socioeconomic factors.

This study found the participants' HAs activated the "speech in quiet/quiet" program 83.3% of the time and the "speech in noise" program 12.4% of the time on a daily basis. The remaining 4.3% of use was in situations classified either as "noise only" or "music." HA use across different listening situations could be expected to vary with age as lifestyle changes occur. However, in this sample, no evidence was found that the HAs for younger participants were used more often in noisier environments than were those of older participants. This may be because, although the sample included participants aged ≥19 yr of age, the average age was 72 yr. As Wu and Bentler (2012) report, their participants (n = 27) aged >65 yr were more often in quieter listening environments, and had less demanding auditory lifestyles, than younger participants. In future, new technology and research methodologies such as Ecological Momentary Assessment (Shiffman et al, 2008) may

better inform researchers and clinicians of the auditory lifestyle of adults with HI.

To the authors' knowledge, this study is the first to use big data to extract objective HA use values. It also investigated HA use in different listening environments. A limitation of this study is that the database does not show the classified environment, and instead reports on the program activated in the HA based on that classification. There is room for misclassification error, but such error was potentially mitigated in this study by including only modern devices with robust classification features (Büchler et al, 2005) manufactured on recent technology and classification platforms. A further limitation of this study was that by including only participants with data-logging files showing >0 hr of overall daily use, we cannot comment on how many participants may have been fitted with HAs but never used them. A final limitation is that due to the retrospective design of this study, it cannot make any conclusion on other outcomes of the fittings. Although the exact relationship among HA use, benefit, and satisfaction remains unclear, many studies have found a correlation among the three constructs (Salomon et al, 1988; Dillon et al, 1999; Joore et al, 2002; Bertoli et al, 2009; Abdellaoui and Tran Ba Huy, 2013). It is clear that benefit and satisfaction from an HA can be derived only when it is used and that it is intuitively logical that people would continue to wear HAs in everyday life only if they were obtaining some benefit from doing so. A recent systematic review by Johnson et al (2016) concluded that the limited research literature available does support the notion that HAs are of benefit to adults with mild HI.

This study compared HA use for adults with mild HI, a clinical population with a dearth of research evidence, to adults with moderate degrees of HI. This study showed that when HAs are used, they are typically used for a significant part of the day, regardless of the degree of HI. Highly situational use, which could be defined as an average of 2 or fewer hours per day, was evident in <10% of the participants in each HI group. Although this study was limited to individuals who had presented to clinicians and had been fitted with HAs, the overall use data are encouraging. It therefore can provide a benchmark for clinicians when counseling clients about HA adoption and use.

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