Preference for One or Two Hearing Aids among Adult Patients

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Objectives: Most practitioners believe that use of two hearing aids is the ideal fitting for adults with bilateral symmetrical hearing loss. However, previous research has consistently shown that a substantial proportion of these patients actually prefer to use only one hearing aid. This study explored whether this pattern of preferences is seen with technologically advanced hearing aids. In addition, a selection of variables that were available prefitting were used to attempt to predict which patients will prefer one hearing aid rather than two.

Design: The study was designed as a 12-week field trial including structured and unstructured use of one and two hearing aids. Ninety-four subjects with mild to moderate bilaterally symmetrical hearing loss were bilaterally fit with 2005–2007 era hearing aids. Potential predictors included demographic, audiometric, auditory lifestyle, personality, and binaural processing variables. After the field trial, each subject stated his/her preference for one or two hearing aids and completed three self-report outcome questionnaires for their preferred fitting.

Results: Previous research was confirmed with modern technology hearing aids: after the field trial, 46% of the subjects preferred to use one hearing aid rather than two. Subjects who preferred two hearing aids tended to report better real-world outcomes than those who preferred one. Subjects who reported more hearing problems in daily life, who experienced more binaural loudness summation, and whose ears were more equivalent in dichotic listening were more likely to prefer to use two hearing aids. Contrary to conventional wisdom (ideas that are generally accepted as true), audiometric hearing loss and auditory lifestyle were not predictive of aiding preference. However, the best predictive approach from these data yielded accurate predictions for only two-thirds of the subjects.

Conclusions: Evidence-based practice calls for a conscientious melding of current evidence, clinical judgment, and patient preferences. The results of this research challenge practitioners to recognize that many patients who seem to be ideal candidates for bilateral aiding will actually prefer to wear only one hearing aid. Furthermore, at this time, there is no accurate method that will predict which patients will prefer one hearing aid rather than two. Currently, the most effective approach open to practitioners would be to conduct a candid unbiased systematic field trial allowing each patient to compare unilateral and bilateral fittings in daily life. This might necessitate more fitting sessions and could perhaps add to the practitioner's burden. This downside should be weighed against the additional patient satisfaction that can be anticipated as a result of transparency in the fitting protocol, collaboration with the patient in the treatment decisions, and the knowledge of selecting the most cost-effective patient-centered solution.

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INTRODUCTION

The advantages of binaural hearing over monaural hearing were reported more than half a century ago (Koenig 1950) and have been extensively studied for many years. For recent reviews, see Akeroyd (2006) and ~~Steven~~ Colburn et al. (2006). These advantages include reduced head shadow effect as well as benefits of binaural processing such as improved speech understanding, especially in spatially separated noise (binaural squelch); binaural loudness summation; and improved localization. There have been numerous studies attempting to determine whether these binaural processing advantages are demonstrable in laboratory testing for bilaterally hearing-impaired persons wearing two hearing aids. Although the results have not been unanimous, many investigations report demonstrable binaural advantages for subjects wearing two hearing aids (e.g. Hawkins & Yacullo 1984; Day et al. 1988; Byrne et al. 1992; Freyaldenhoven et al. 2006). Because data demonstrating the availability of binaural advantages seem to establish the efficacy of bilateral hearing aid fittings, it might seem logical to assume that individuals with bilateral hearing impairment will prefer to wear two hearing aids rather than one in daily life. However, efficacy established in a laboratory setting does not ensure effectiveness in daily life. Thus, there also has been interest in scientifically establishing a preference for wearing two hearing aids, rather than one, in daily life. There have been two types of research designs that have explored advantages of bilateral hearing aid fittings in everyday life: field trials and retrospective surveys.

Several field trials addressing this topic have been reported in which patients were fitted with one or two devices and asked, after an acclimatization period, to report which arrangement they preferred. In a study of hearing-impaired military personnel, Erdman and Sedge (1981) fitted 30 subjects with two hearing aids and conducted a 2-week field trial to systematically compare unilateral and bilateral fittings. Although most of the subjects reported a preference for two hearing aids, 20% of the subjects declared a preference for wearing only one hearing aid at the end of the trial. In a similar study, Schreurs and Olsen (1985) fitted 30 subjects with two hearing aids followed by a 4-week field trial with systematic comparison of unilateral and bilateral fittings. At the end of the trial, most subjects preferred the bilateral fitting for listening in quiet and the unilateral fitting for listening in noise. Ultimately, 57% of the subjects purchased one hearing aid and 27% purchased two. Day et al. (1988) reported a field trial with 51 subjects fitted with two hearing aids and reassessed after a period of several months of unsupervised use of one or two devices. At the end of the trial, 22% of the group declared a preference for wearing only one hearing aid. Stephens et al. (1991) conducted a crossover trial with 29 subjects, comparing fitting of one or two hearing aids. Each segment of the trial was 4 to 6 weeks in length. Forty-five percent of the subjects elected to adopt the unilateral fitting at the end of the trial. Finally, Vaughan-Jones et al. (1993) completed a crossover trial comparing unilateral and bilateral fittings in which the length of each arm was 10

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weeks. Of the 64 subjects, 61% eventually chose the unilateral aided condition.

Another approach to explore the benefits of bilateral versus unilateral hearing aid fittings in daily life is the retrospective survey. In this type of study, patients who previously have been fit with two hearing aids are queried about whether, and when, they actually use both devices or only one (or neither). Many of the published retrospective surveys were conducted in countries where hearing aids are provided under a public health umbrella. In these systems, it is typical that some selection process is used to determine which patients will receive two hearing aids, although the criteria for recommending two hearing aids rather than one are not always explicit. Therefore, the subject groups in these studies are not necessarily a random selection of typical hearing aid wearers.

Brooks and Bulmer (1981) surveyed 204 patients who had received two hearing aids through the British National Health Service at least 3 months earlier. Twenty-five percent of the respondents reported that they did not regularly use both hearing aids, but only 3% stated a definite preference for only one device. Chung and Stephens (1986) surveyed 200 patients who had chosen to be fitted with two hearing aids at least 6 months earlier. The goal was to explore factors that influenced hearing aid use. Nineteen percent of these individuals reported that they now used only one hearing aid. Dillon et al. (1999) reported a wide-ranging study of hearing aid fitting outcomes in which they surveyed 4421 patients around Australia. Of those patients who had originally received two hearing aids, 20% reported wearing only one when surveyed 3 months later. Kobler et al. (2001) assessed the outcomes for 144 Swedish patients who had been provided with two hearing aids at least 8 months previously. They determined that 33% of the group actually used only one hearing aid.

Finally, a somewhat different but still illuminating retrospective study was reported by Boymans et al. (2009). This work described the results of a clinical program in The Netherlands in which the fitting of one or two hearing aids was decided collaboratively between the practitioner and the patient. The protocol encompassed several fitting sessions, trial periods, counseling, real ear measures, and speech testing. Results accumulated across 1000 patients sampled from eight centers indicated that about 40% of patients who experienced this protocol were ultimately fitted with one hearing aid rather than two. However, after the subject group was pared down to 689 who were thought most likely to benefit from bilateral fitting (by excluding individuals with asymmetric hearing loss and those with better-ear hearing loss less than 35 dB), the proportion of subjects choosing one hearing aid rather than two was 31%.

The consensus of these studies over at least 25 years is that the majority of bilaterally impaired persons who are provided with two hearing aids do ultimately decide that the advantages of wearing two hearing aids outweigh the advantages of wearing only one. Nevertheless, it is striking that in every reported field trial and retrospective survey, a substantial percent of subjects reported a preference for wearing only one hearing aid rather than two. Despite the generally positive outcomes of bilateral hearing aid fittings, there is always a substantial minority of individuals in any studied group who ultimately prefer and choose to wear only one hearing aid. The reported prevalence of this result is surprisingly high. If we assume that each of the controlled field trials produced a valid estimate of the preference for wearing one hearing aid, an average of those estimates indicates that 41% of patients preferred to wear one hearing aid rather than two. If we likewise assume that each of the retrospective surveys produced a valid estimate of the preference for wearing one hearing aid, the average of those estimates suggests that the preference occurred in 21% of patients.

Given the existence of this body of literature, it is surprising that current practitioners seem to believe strongly that bilateral fitting is the best treatment for essentially all bilaterally hearing-impaired adults (Kiessling et al. 2006). The proportion of bilateral hearing aid fittings in the United States has grown steadily over the past 20 years to 90% (Kochkin 2009). The assertion of superiority for bilateral fittings is typically supported by extrapolations from the laboratory data cited earlier. Sometimes, the assertion is bolstered by self-report data showing that patients wearing two hearing aids tend to have better subjective outcomes than patients who wear only one hearing aid (Kochkin & Kuk 1997). However, this argument is not convincing unless it can be demonstrated that patients who choose to wear one hearing aid are willing and able to improve their fitting outcomes by switching to two hearing aids.

Some practitioners are aware that not all their bilaterally impaired adult patients prefer to use two hearing aids, but they do not have a method of prospectively identifying which bilaterally impaired individuals will prefer only one hearing aid. Typical audiometric and demographic data (age, audiogram, speech recognition score, etc.) have not been useful in predicting unsuccessful bilateral fittings (Day et al. 1988; Swan 1989; Vaughan-Jones et al. 1993; Boymans et al. 2009). The most fully explored potential predictor of unsuccessful bilateral hearing aid fitting is the presence of binaural interference. In normal binaural functioning, cues from the two ears are integrated to produce superior performance over either ear alone. When binaural interference is present, the two ears do not work together to take advantage of interaural differences: there is obstruction rather than integration. As a result, bilateral performance is poorer than that with the better unilateral ear. Binaural interference and accompanying abnormalities in dichotic listening skills have been studied extensively by Jerger and coworkers (Jerger et al. 1990, 1993, 1995; Chmiel & Jerger, 1996; Chmiel et al. 1997). Taken as a whole, this work presents a convincing case for the presence of binaural interference and abnormally poor dichotic listening abilities in at least 10% of elderly hearing-impaired persons, and it demonstrates that bilateral amplification might be unsuccessful in these cases.

Based on existing estimates, it is unlikely that binaural interference accounts for all the one-quarter or more of bilateral fittings in which one instrument is ultimately rejected (41% in field trials and 21% in retrospective surveys). Several investigators suggest that other indicators for fitting only two hearing aids might include a lack of binaural advantages such as binaural loudness summation and/or binaural release from masking (Haggard & Hall 1982; Swan 1989; Stephens et al. 1991; Kobler et al. 2001). In addition, it seems plausible that self-report variables AQ: 2 measurable before the fitting (e.g., subjective assessment of hearing loss or personality attributes) might play a role in determining acceptance of a bilateral fitting in the long term.

In summary, existing research including both clinical trials and descriptive studies has repeatedly shown that a substantial proportion of adults who have bilateral hearing impairment opt to wear only one hearing aid even when two devices are readily available. The implication is that a sizeable minority of hearing-impaired listeners either do not perceive the anticipated benefits of bilateral hearing aids or find that the benefits do not outweigh the drawbacks. These individuals might be better served with a unilateral fitting. It is also noteworthy that most of the reviewed studies were conducted in an era when hearing aids were technologically far inferior to current devices. Thus, it is possible that the proportional preference for two hearing aids has increased with technology improvement.

An accurate and practical method for prospectively identifying individuals who will prefer to wear one hearing aid despite their bilateral hearing impairment could be expected to result in more appropriate resource allocation, more cost-effective treatments, and more satisfied patients. Although (as reviewed above) some potential predictors of preference for one or two hearing aids have been mentioned in the literature, little effort has been made to compare prefitting indicators with postfitting long-term outcomes of hearing aid fitting.

The research described here was directed toward answering two questions:

1. Are previous results about preference for one or two hearing aids replicated when subjects are fitted with modern high-tech devices?
2. How accurately can long-term preference for one or two hearing aids be predicted using a combination of prefitting psychoacoustic, self-report, and demographic data?

~~PATIENTS AND~~ METHODS

Subjects who met the inclusion criteria were administered a test battery to explore their binaural functioning and to accumulate self-report data regarding personality and auditory lifestyle. This was followed by hearing aid fitting and verification. Then, subjects began a structured 3-wk unilateral/bilateral device wearing schedule to ensure significant experience with both amplification choices. Next, they used both hearing aids as desired in daily life for about 9 wks, exploring the effectiveness of unilateral and bilateral fittings. Finally, they participated in an exit interview and provided subjective outcome data on the effectiveness of their preferred fitting of one or two hearing aids.

Participants

Subjects were recruited from the Mountain Home Veterans Affairs Medical Center (VAMC) and the University of Memphis Hearing Aid Research Laboratory (HARL). The VAMC recruited male patients seeking amplification. The HARL used advertisements, word of mouth, brochures, and personal letters to recruit both men and women who were interested in new hearing aids. Subjects were paid for their participation.

Inclusion criteria were symmetrical bilateral stable sensorineural hearing impairment, better ear pure-tone average (0.5, 1.0, 2.0 kHz) of 30 to 80 dB HL, normal immittance test results, age between 50 and 85 yrs, a report of typically active lifestyle, self-rated good or excellent physical and mental health, adequate literacy and cognitive competence (by informal testing and researcher report) to respond to questionnaires, and willingness to wear hearing aids at least 4 hrs a day during the trial. In addition, potential subjects were required to be open-minded about whether they would prefer to wear one or two hearing aids in daily life. Exclusion criteria included an existing preference for either one or two hearing aids, observed or reported neurologic or psychiatric disorder, fluctuating hearing impairment, and chronic middle or outer ear pathology.

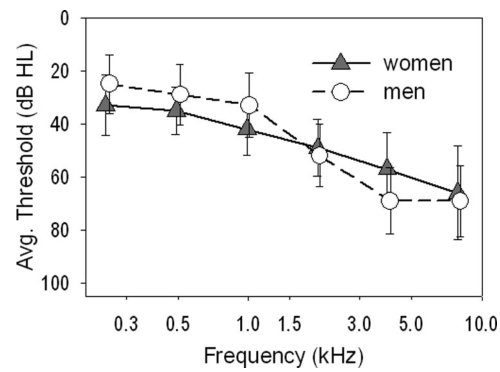

Fig. 1. Mean audiograms for men and women enrolled in the study. Bars show 1SD.

A priori computation of power for the study was based on pilot data using the dichotic digits test and results from Carter et al. (2001). It was assumed that 80% of subjects whose dichotic digits score was 3SD below the mean would prefer to use one hearing aid rather than two. In this case, 100 subjects yielded about 80% power to reject the null hypothesis (α = 0.05) that hearing aid preference was unrelated to the dichotic digits score. Thus, the targeted number of subjects was 100.

Of 98 potential subjects at the VAMC, 49 met all inclusion criteria and were enrolled in the study. Of 71 potential subjects at the HARL, 51 met all inclusion criteria and were enrolled in the study. Subsequently, six individuals withdrew for personal reasons not related to the study. A total of 94 individuals, 57 men and 37 women (47 at each site), completed the experiment. Mean ages were 69 yrs (range: 51 to 83 yrs) for women and 71 yrs (range: 58 to 83 yrs) for men. Seventy-six subjects were classified as new hearing aid users. Of these, 10 had tried amplification briefly in the past but did not pursue it. The remaining 18 subjects owned and used (at least part time) one or two hearing aids but did not know whether they would actually prefer to wear one or two hearing aids in daily life. Figure 1 depicts the mean audiograms of men and women F1
subjects. Mean word recognition scores for women and men were 82% (range: 42 to 100%) and 76% (range: 42 to 96%), respectively.

Prefitting Questionnaires

The Auditory Lifestyle and Demand Questionnaire (ALDQ) was developed by Gatehouse et al. (1999). The goal of the ALDQ is to describe the range of listening environments that are experienced by the individual in daily life and to assess the extent to which auditory requirements play a role in daily functioning. This 24-item questionnaire yields scores in two subscales: Lifestyle and Demand.

Lifestyle represents the diversity of listening situations experienced. Each Lifestyle item queries the regularity with which a given situation occurs in everyday life. It is scored on a 3-point scale: 0 = very rarely, 1 = sometimes, 2 = often. The Lifestyle score was computed by summing the 24-item responses in the subscale, thus the potential raw scores ranged from 0 to 48. Demand is a combination of Lifestyle and the importance of each situation to that subject. The second set of responses provides an importance weighting for each item in the Lifestyle subscale. It includes responses on a 3-point scale: 0 = very little, 1 = some importance, 2 = very important. The Demand score was computed as follows: each item response in the Lifestyle subscale was multiplied by its corresponding importance weighting and the 24 products were summed to create the Demand score for the subject. The potential raw scores ranged from 0 to 96. Both Lifestyle and Demand subscales were converted to percentage scores.

Two dominant dimensions of personality were assessed using the Positive and Negative Affect Schedule (PANAS). The PANAS was developed by Watson et al. (1988). Positive affect is the extent to which an individual feels engaged, animated, attentive, etc., whereas negative affect reflects unpleasant states such as fearfulness, irritability, pessimism, etc. The two dimensions are independent: they should not be thought of as opposite ends of the same continuum. The results of the PANAS offer a condensed view of the "big five" personality traits described by many psychology researchers (e.g., McCrae & Costa 1997). Unpublished data from our laboratory has shown that the Negative Affect score is significantly positively correlated with the personality dimension typically labeled Neuroticism, whereas the Positive Affect score is significantly positively correlated with each of the four personality dimensions typically labeled Extraversion, Openness, Agreeableness, and Conscientiousness (Kelly & Cox, Reference Note 1). The PANAS is a 20-item scale that yields scores for Positive Affect (PA) and Negative Affect (NA). Each affect state is measured using 10 items. Each item is a word describing a mood or emotion (interested, ashamed, etc.) and the subjects indicate the extent to which they generally feel this way on a 5-point scale: from 1 = very slightly to 5 = extremely. A higher score represents a stronger level of affect. The Negative Affect score was calculated by summing the 10 scores for the negative affect items. The Positive Affect score was calculated by summing the 10 scores for the positive affect items. Thus, each score could range from 10 to 50.

Binaural Test Battery

Three types of binaural interaction were tested for this research: binaural loudness summation, binaural squelch, and binaural interference. Each test feasibly could be used as part of a prefit assessment in a clinical setting. The tests were chosen because they have the following characteristics that were desirable for this experiment with older hearing-impaired listeners: (1) all three involve binaural processing of speech, (2) the speech material is familiar without being too easy, (3) pilot testing [illegible] that all three tests result in clearly measurable binaural effects for a typical older hearing-impaired listener, (4) for symmetrical high-frequency cochlear hearing loss, they are resistant to confounding due to audibility effects (Strouse & Wilson 1999), (5) based on published work and pilot work in our laboratory, all three tests have been shown to be reliable (Humes et al. 1996; Cox et al. 1997), and (6) all three tests are readily administered in a clinical environment. Each test used speech stimuli delivered from CD recordings routed through an audiometer and presented to the subject via ER-3A insert earphones coupled to the ears with compressible foam plugs. AQ: 3

TABLE 1. Loudness categories used in the binaural loudness summation test

Category No.	Category Description
7	Uncomfortably loud
6	Loud but OK
5	Comfortable but slightly loud
4	Comfortable
3	Comfortable but slightly soft
2	Soft
1	Very soft

Binaural Loudness Summation • The binaural loudness summation test determined the extent to which binaural listening affected the level at which speech was deemed to be comfortably loud, compared with monaural listening. Binaural summation was measured as the difference in decibels between comfortable loudness levels for each ear separately and for both ears together. It is a common clinical observation that preferred hearing aid gain is less for bilateral fittings than for unilateral fittings. This is usually assumed to be the result of binaural loudness summation (Dermody & Byrne 1975). It is plausible that individual differences in the size of this effect are proportional to binaural integration ability in general and possibly associated with the acceptance of bilateral amplification.

The stimuli were successive sentences from a passage of the Connected Speech Test (Cox et al. 1987) presented without competing noise. The subject was given a list of the seven loudness categories as depicted in Table 1 and instructed to verbally respond to indicate the appropriate loudness category when a sentence was presented. The goal was to determine the level judged to be "comfortable but slightly loud" (category 5). First, a practice trial was run with the stimuli presented bilaterally. Sentences were presented in ascending 5-dB steps until a category 7 level was reached. The level was then lowered 20 to 30 dB and the ascending 5 dB method began again and continued until a category 7 was again attained. This practice was continued until the subject responded consistently. Once the investigator was satisfied, the subject understood the task, and the binaural summation test began. T1

The sentences were presented to one ear with 10 dB ascending increments until a category 5 response was given. The stimulus was then decreased 10 to 15 dB and presented again in 2 dB ascending steps until a category 5 value was given. The test continued in this manner until two category 5 responses were given at the same dial setting. This level was the "comfortable but slightly loud" (CSL) level for that ear. The test was repeated for the other ear. After monaural CSL level had been determined for each ear, the audiometer tracking was engaged so the level in the two ears would increase/decrease together, preserving any interaural difference in monaural CSL levels. Then, the binaural CSL test was conducted in the same manner as the monaural CSL test. The binaural summation score for the test was the difference between the binaural CSL level and the monaural CSL level.

The binaural CSL level was used as the stimulus level for the remaining tests in the binaural test battery. This ensured both equal loudness and appropriate audibility for both ears. In addition, using a CSL level presentation ensured that the binaural interaction and binaural interference tests were presented at a level close to that which would be chosen by the subject in daily life when listening to amplified sounds using hearing aids.

Binaural Squelch • A test of binaural release from masking for speech (binaural squelch) was chosen because it was postulated that the extent to which the two ears are able to work together to improve speech intelligibility in noise would be predictive of the advantage bestowed by bilateral hearing aids in real-world listening. The phenomenon of binaural squelch has been extensively studied in normal-hearing listeners but less fully explored in listeners with hearing impairme[illegible]lished research has shown that older listeners yield smaller binaural squelch effects than do younger listeners (Grose et al. 1994). In addition, studi[illegible] indicated that hearing-impaired individuals often have smaller binaural squelch than normal-hearing persons (Noffsinger 1982; Jerger et al. 19[illegible]urthermore, it is generally observed that binaural squelch for speech varies to some extent with stimulus details (Wilson et al. 1994; Johansson & Arlinger 2002).

Binaural squelch was quantified as the difference between two binaural SNR-50 scores (SNR-50 is the signal-to-noise ratio [SNR] that yields a speech recognition score of 50% correct). The first SNR-50 was measured with speech and noise, both in-phase at the two ears. The second SNR-50 was measured with speech 180° out of phase but noise in-phase at the two ears. The stimuli were spondee words presented from the Department of Veterans Affairs compact disc entitled "Tonal & Speech Materials for Auditory Perception Assessment Disc 2.0." Using the same test with young normal-hearing adults, Wilson et al. (1994) reported mean binaural squelch values of about 8 to 9 dB. In a pilot study in our laboratory, we found the mean binaural squelch value for older adults with hearing loss to be about 4 dB, which is consistent with previous research showing smaller release from masking effects for hearing-impaired and older listeners.

The test comprises 10 spondee words (Wilson et al. 1982). To minimize word learning effects, the subject was given a list of the 10 words before the test began. Each spondee word was embedded in a burst of broadband noise (duration 2000 msecs). Stimuli were recorded at 16 SNRs ranging from 0 to −30 dB. Four words were presented at each SNR. The test began with four words presented at 0 dB SNR. For each consecutive four-word set, the SNR on the CD changed by 2 dB, making the words increasingly difficult to understand. The test continued until the subject missed all four words in a single SNR condition. The test was stopped at this point. The test score was the poorest SNR at which 50% of the spondee words were correctly repeated. The entire test was performed twice. The binaural squelch score was the difference between the average in-phase SNR and the average out-of-phase SNR.

Binaural Interference • Binaural interference was estimated using a dichotic digits test. The test materials were provided on the Department of Veterans Affairs compact disc entitled "Tonal & Speech Materials for Auditory Perception Assessment Disc 2.0." The test presented sets of three different one-syllable digits simultaneously to the two ears, without background noise. For example, the right ear might receive "2, 10, 4" while the left ear receives "1, 8, 6." The recorded digits were synchronized so that the onsets were simultaneous for the two digits of each right-left pair. Subjects were instructed to recall and repeat all digits from both ears (free recall) or only those from left or right ear (directed recall). They were given practice trials until they were comfortable with the tasks (usually about five trials). There were 25 trials in each test condition (directed right, directed left, and free recall). In all three conditions, the listener was presented with stimuli to both ears but instructed to repeat only the digits heard in the right ear (Directed Right condition), digits heard in the left ear (Directed Left condition), or all the digits heard in both ears (Free Recall condition).

Results may be interpreted in terms of the score differences between (1) free and directed recall and (2) left and right ears. In general, it is expected that the free recall task will be more difficult than the directed recall task because of the greater cognitive, attention, and memory resources called on when both ears are simultaneously monitored. In addition, it is expected that there will be a right ear advantage so that right ear scores are better than left ear scores. Published normative data for the dichotic digits confirm these expectations and show that performance declines with age (Strouse & Wilson 1999). Furthermore, data from this test have been reported (Carter et al. 2001) to be associated with binaural interference and unsuccessful bilateral amplification in four individual cases.

Initially, scores were computed for the free recall condition for each ear (free-right and free-left) and for the directed recall condition for each ear (direct-right and direct-left). Each score was based on the number correctly recalled from 75 digits. Four additional scores were computed to analyze the results of the test as follows:

1. Right Ear Advantage free recall (REA_{free}) = free-right − free-left.
2. Right Ear Advantage directed recall (REA_{dir}) = direct-right − direct-left.
3. Cognitive effect right ear (Cog_{re}) = direct-right − free-right.
4. Cognitive effect left ear (Cog_{le}) = direct-left − free-left.

Hearing Aid Fitting

The hearing aids used this in this study were required to meet the following criteria to be consistent with the subject audiograms and with current practice in hearing aid fitting: (1) appropriate for a 30 to 80 dB HL three-frequency average sensorineural hearing loss with a flat or sloping configuration, (2) good quality digital programmable device, (3) some form of compression, (4) a directional microphone (either fixed or adaptive technology), and (5) at least two programs (program 1 set for omni-directional and program 2 set for directional). In addition, user volume controls were required to allow subjects to adjust gain as needed for using one or two hearing aids. Also, because of the length of the experiment, it was essential that the hearing aids be acceptable to the subject for long-term use. Other allowed features were feedback management (as long as it did not degrade the high frequency-response), digital noise reduction, and telecoil. Table 2 gives the distribution of hearing aid make/model used in the study. T2 The hearing aids styles were chosen as appropriate for the subject and were distributed across subject ears as follows: BTE = 73, ITE = 18, ITC = 2, CIC = 1. Hearing aid features in addition to volume control and directional microphone were chosen as appropriate for the subject as follows: telecoil = 158, feedback

TABLE 2. Distribution of hearing aid models for 94 subjects

Manufacturer	Model	Pairs
Siemens	Centra	1
Siemens	Cielo	10
Unitron	Conversa	5
Starkey	Destiny	1
Phonak	Valeo	44
Phonak	Eleva	8
Oticon	Tego Pro	25

manager = 20, digital noise reduction = 85, low level expansion = 8.

For all 47 of the HARL subjects and 15 of the VAMC subjects, hearing aids were loaned to them for this investigation with the understanding that they would be returned at the end of the study. The remaining 32 VAMC subjects were fit with hearing aids purchased by the VA. It was emphasized with these 32 veterans that they would keep both hearing aids regardless of their wearing preference at the end of the study.

Hearing Aid Fitting and Verification Protocol • Hearing aids were initially programmed using the manufacturer's proprietary method and then modified based on the fitting targets. Modifications of performance and verification were completed under the guidance of probe microphone real ear measurements using a Fonix 7000 Hearing Aid Test System. The target for average speech was to amplify speech-like noise (labeled DGSP-ICRA noise) at 65 dB SPL to match the displayed NAL-R prescription within ±3 dB in the frequency range from 500 to 3000 Hz. The target for loud sounds was to amplify tone bursts at 85 dB SPL to a level close to but not exceeding the displayed MPO targets. The target for soft sounds was to amplify speech-like noise at 45 dB SPL so that the 1/3 octave band levels of speech were similar to the listener's thresholds. For the Fonix test box, which analyzes speech-like noise in 79 bands each 100-Hz wide, the soft-sound target was operationalized as no more than 5 dB below displayed thresholds between 250 and 1000 Hz and no more than 15 dB below displayed thresholds at 2000 and 3000 Hz. After initial adjustment of the hearing aid to match real ear targets, the fitting was fine-tuned using subjective assessments in four areas: quality of own voice, bilateral loudness balance, quality of other voices, and general loudness comfort. Adjustments were made if necessary. Program 1 and program 2 were identical except for the directional microphone.

F2–4 The final fittings (after all adjustments) are summarized in Figures 2 to 4. Average speech is shown in Figure 2 where the mean NAL-R target is compared with the mean real ear aided response (REAR) across frequencies. Figure 2 gives the result for the right ear. The left ear result was essentially identical. Maximum output levels are summarized in Figure 3 where the average OSPL90 value prescribed using the NAL procedure (Dillon & Storey 1998) is compared with the mean three-frequency average Real Ear Saturation Response. The audibility of soft sounds was assessed by computing the difference between displayed pure-tone thresholds (similar to 1/3 octave band levels) and the measured REAR for 45 dB input (corrected to approximate 1/3 octave band levels). The soft-sound results in low-, mid-, and high-frequency bands are given in Figure 4. For some subjects, it was not possible to visualize

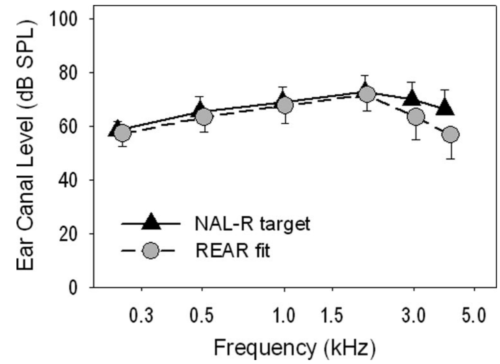

Fig. 2. Mean NAL-R target for average speech compared with the mean real ear aided response (REAR) across frequencies. Bars show 1SD. Data are for the right ear.

target and ear canal levels for both MPO and soft sounds on the Fonix output. Consequently, some data are missing for these two variables.

After the fittings were complete, verbal instructions were provided about using the hearing aids, and a hearing aid orientation booklet containing the same material was given to each subject to take home. The booklet reviewed topics such as adjusting to a hearing aid, replacing batteries, inserting and removing a hearing aid, adjusting hearing aids in noise, telephone use, and hearing aid care and maintenance. Hearing aid insertion, removal, and volume and program manipulation were practiced with each subject. The subjects were reminded to wear the hearing aid(s) at least 4 hrs a day.

Field Trial and Wearing Schedule

After the fitting and orientation to the hearing aids, each subject was given a 3-wk wearing schedule to ensure that both unilateral and bilateral amplification were experienced in a variety of daily life settings. The wearing schedule encompassed three 1-wk periods during which each aid was worn unilaterally for 1 wk and both were worn bilaterally for 1 wk. There were six possible orders of the three conditions (left, right, and both). Each block of six consecutive subjects was randomized to the six orders so that all orders were used equally often. During each 1-wk trial, the subject completed a daily checklist to record the hours of device use and the type of listening situations encountered. The checklists were returned to the researcher at each postfitting visit.

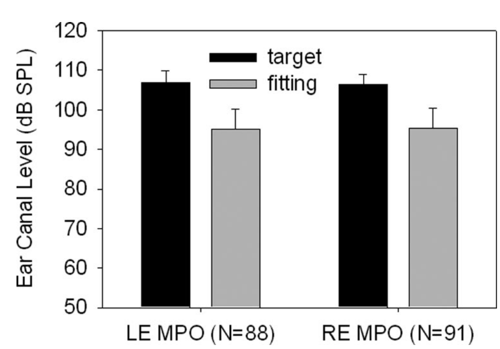

Fig. 3. The average OSPL90 value prescribed using the NAL procedure compared with the mean three-frequency average real ear saturation response (RESR) for each ear. Bars show 1SD. N = number of subjects.

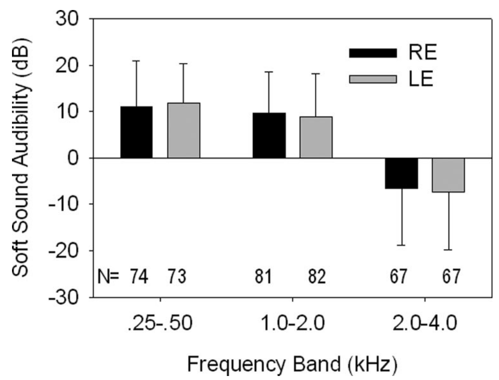

Fig. 4. Audibility of soft sounds assessed by computing the difference between pure-tone thresholds (similar to 1/3 octave band levels) and the measured REAR for 45 dB speech (in approximate 1/3 octave band levels). Results are given in each ear for low-, mid-, and high-frequency bands. Bars show 1SD. N = number of subjects.

Postfit visits were scheduled at the end of weeks 1, 2, and 3. During these visits, the seven daily checklists for the corresponding week were reviewed to ensure that the procedures for the trial had been observed. Also, the appropriate hearing aid(s) were issued for the following week. If the hearing aids needed to be adjusted or repaired during the trial period, the length of the trial was extended to ensure that the intent of the trial was achieved. At the end of the 3-wk prescribed wearing schedule, the subject was given both hearing aids and instructed to continue to experiment using the aids in different configurations (right ear, left ear, or both ears) and to continue wearing the aid(s) for at least 4 hrs a day for the next 9 wks until the final postfit visit.

Final Session

At the end of the trial, subjects returned to the laboratory to declare their preference for wearing one or two hearing aids in daily life and to complete outcome questionnaires. For the average subject, the total length of the study from fitting to end was 94 days. Ninety percent of the subjects completed the study in the time period of 79 to 126 days. The shortest length was 74 days and the longest was 161 days. The time variations across subjects occurred due to personal schedules of the subjects and/or problems with the fittings that caused the trial to be extended.

The exit interview included 10 verbally delivered questions covering wearing preference in different listening situations. These included understanding speech in quiet, understanding speech in noise, hearing best over long distances, best sound of own voice, best sound quality, best loudness, best for general use, best localization, least tiring, and most comfortable sound. After these questions, the subject declared whether s/he preferred to wear one or two hearing aids overall and his/her level of certainty about that preference on a 4-point scale from "very uncertain" to "very certain." The subject was then asked to provide (in his/her own words) the three most important reasons for their choice of one or two hearing aids. Finally, those who preferred to wear one hearing aid completed an additional survey in which they selected from a list of 24 potential reasons derived from literature and experience to indicate any that contributed to their choice (Appendix).

Outcome Questionnaires • These questionnaires were completed after the exit interview. Subjects were instructed to complete the questionnaires to reflect performance with ~~of~~ their preferred fitting of one or two hearing aids.

***International Outcome Inventory for Hearing Aids* •** The International Outcome Inventory for Hearing Aids (IOI-HA) is a seven-item instrument used to provide a broad perspective of fitting outcome by sampling different outcome domains such as benefit, quality of life, etc. (Cox et al. 2000). An eighth item was included to permit allocation of subjects into two groups based on the severity of subjective hearing problems as recommended by Cox et al. (2003). To encourage the subject to consider the outcome "big picture," this was the first questionnaire administered. Each item is given a rating of 1 to 5, with higher ratings indicating a better outcome. Scoring was based on two factors recommended by Cox and Alexander (2002). Factor 1 ("Advantages") was calculated by summing the scores on four items (use, benefit, satisfaction, and quality of life) and thus had possible scores of 4 to 20. Factor 2 ("Limitations") was calculated by summing scores on three items (residual activity limitations, residual participation restrictions, and impact on others) and thus had possible scores of 3 to 15.

***Abbreviated Profile of Hearing Aid Benefit* •** The Abbreviated Profile of Hearing Aid Benefit (APHAB) (Cox & Alexander 1995) is a 24-item questionnaire that measures unaided and aided performance in four six-item subscales: ease of communication, reverberation, background noise, and aversiveness of sounds. In addition, the three subscales that deal with speech communication (ease of communication, reverberation, and background noise) are averaged to produce a global score. The subscales are scored using reported frequency of problems. Scores are computed for unaided and aided listening in each subscale. A higher score is a poorer outcome. In addition, benefit scores are calculated by subtracting the aided subscale score from the corresponding unaided subscale score. For benefit, a higher score is a better outcome. Subjects completed the questionnaire for both unaided and aided listening at the same time.

***Device Oriented Subjective Outcome Scale* •** The Device Oriented Subjective Outcome (DOSO) (Cox et al., Reference Note 2) is composed of six subscales: speech cues, listening effort, pleasantness, quietness, convenience, and use. Two of the subscales (speech cues and listening effort) have two equivalent forms that were combined in this study to yield a total length of 40 items. The first 37 items focus on how well the hearing aid performs under specific conditions or with certain stimuli. The final three items evaluate hearing aid use. The six subscale scores are calculated by averaging the item responses in each subscale. The possible range of scores is 1 to 7 for the first five subscales and 1 to 5 for the use subscale. A higher score is a better outcome.

At the end of this session, the 62 subjects with loaner hearing aids returned the aids to the researchers, as planned. Subjects who were using hearing aids purchased by the VA did not return them regardless of their preference.

Follow-Up Survey of Hearing Aid Ownership Decisions

Three months after the final research session, the 62 subjects who used loaner hearing aids for the study were contacted via telephone or mail regarding subsequent decisions and actions about obtaining hearing aids. They had not been told to expect this contact. Four subjects could not be reached. The remaining 58 subjects responded to a five-item survey: (1)

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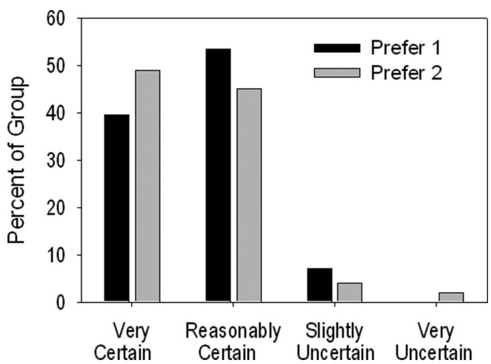

Fig. 5. Subject preference for one hearing versus two and the level of certainty of that decision.

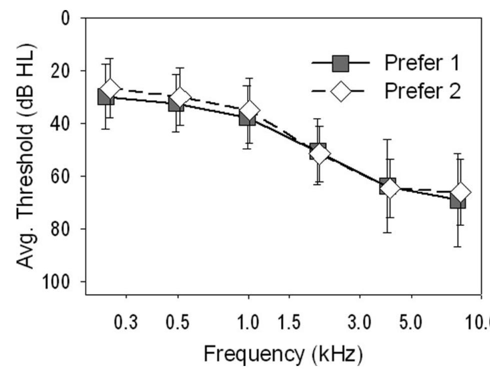

Fig. 6. Mean audiogram depicting subjects who selected one hearing aid versus two. Bars show 1SD.

Have you purchased hearing aids? (2) If yes, how many hearing aids did you purchase (one or two)? (3) If you bought two hearing aids, what percentage of the time do you wear both hearing aids together? (4) If you did not purchase hearing aids, do you plan on obtaining them in the future? (5) If you plan on getting hearing aids, do you plan to get one or two?

RESULTS

This study included open-ended questions, standardized questionnaires, and objective tests. Several different types of analyses were used in the attempt to understand the behavior and motivations of the subjects. In assessing the results, we visually inspected the data for potential trends; computed effect sizes, where appropriate, to evaluate differences in treatment outcomes in a manner that is independent of sample size; and performed null hypothesis significance tests to evaluate the likelihood that observed differences between means would occur if the null hypothesis were true. Most of the analyses involved mixed-model analysis of variance (ANOVA) in which preference for one or two hearing aids served as the categorical factor and the examined experimental variable was the within-subject factor. If the likelihood of the observed difference was less than 5% ($p < 0.05$), we call that "significant." If the likelihood was between 5 and 10% ($p = 0.1$ to 0.05), we consider that finding to be worthy of mention. All statistical tests were run with SPSS version 14.

Preference for One or Two Hearing Aids

Of the 94 subjects enrolled in the study, 46% (43 subjects) expressed an overall preference for wearing one hearing aid rather than two hearing aids in the final interview. Subjects were asked how certain they were of their hearing aid choice.
F5 Their answers are summarized in Figure 5. More than 90% of each group (those who preferred one hearing aid and those who preferred two) was very or reasonably certain about their preference decision. Only one person was very uncertain. Of the subjects who preferred one hearing aid, 29% preferred the right ear, 40% preferred the left ear, and 31% did not have an ear preference (these data were missing for one subject). Mean reported daily hearing aid use was 7.7 hrs for subjects who preferred one hearing aid and 8.1 hrs for subjects who preferred two. This difference in daily use was not statistically signifi-
F6 cant. Figure 6 depicts the average audiograms for subjects who preferred one hearing aid and subjects who preferred two. There were no observable or significant differences between these audiograms. Both groups had mean unaided word recognition scores of 78.2%. Within the group that preferred one hearing aid, the mean age was 70.4 yrs (SD = 7.4), 86% were new hearing aid users, and 49% were women. Within the group that preferred two hearing aids, the mean age was 69.8 yrs (SD = 6.9), 76.5% were new hearing aid users, and 31% were women. Testing for the significance of difference between proportions determined that the proportions of new and experienced hearing aid users preferring one versus two hearing aids was not significantly different ($p = 0.24$, two tailed), suggesting that previous experience was not an influential variable in the preference decision. Additional corresponding tests determined that the difference in the proportions of women and men who chose one versus two hearing aids approached significance ($p = 0.084$, two tailed), suggesting that gender might be an influential variable in the preference decision.

Potential Predictors of Preference for One or Two Hearing Aids

In addition to the variables summarized above, the battery of potential predictors of preference for one or two hearing aids comprised three standardized questionnaires measuring lifestyle (ALDQ), personality (PANAS), and subjective hearing problems (unaided APHAB) and three tests of binaural interaction (binaural loudness summation, binaural squelch, and binaural interference). To initially assess the potential leverage of each of these variables as a lone predictor of fitting preference, the performance of each preference group was compared for each predictor.

Auditory Lifestyle and Demand Questionnaire • Subjects who preferred a unilateral fitting (N = 43) reported mean percentages for Lifestyle and Demand of 58.5% (SD = 13.6%) and 48.9% (SD = 17.1%), respectively. Subjects who preferred a bilateral fitting (N = 51) reported mean percentages for Lifestyle and Demand of 55.5% (SD = 11.3%) and 46.9% (SD = 13.5%), respectively. ANOVA revealed no significant differences between the two preference groups in mean scores for Lifestyle and Demand ($p = 0.723$).

Positive and Negative Affect Schedule • Subjects who preferred one hearing aid reported a mean PA score of 35.5 (SD = 5.4) and a mean NA score of 15.2 (SD = 4.7). Subjects who preferred two hearing aids reported a mean PA score of

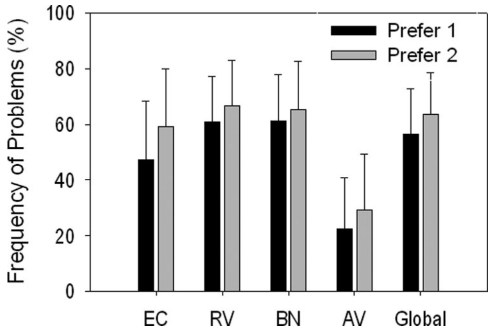

Fig. 7. Mean scores for each subscale of the APHAB (Ease of Communication, Reverberation, Background Noise, and Aversiveness to Sounds) and the Global score for subjects who preferred one hearing aid and those who preferred two. Data are given for unaided listening. Bars show 1SD.

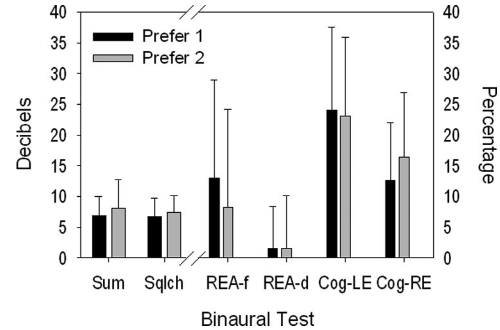

Fig. 8. Results from the Binaural Test Battery for each preference group. Means (in dB) for binaural summation (SUM) and binaural squelch (SQLCH) are referenced to the left axis. Means (in %) for four scores from the dichotic digit battery are referenced to the right axis (REA-f = right ear advantage, free recall; REA-d = right ear advantage, direct recall; Cog-LE = cognitive effect, left ear; Cog-RE = cognitive effect, right ear). Bars show 1SD.

35.2 (SD = 6.2) and a mean NA score of 17.3 (SD = 6.1). ANOVA revealed no significant differences between preference groups in mean scores for PA and NA ($p = 0.289$).

APHAB—Unaided • The unaided scores for the four subscales of the APHAB and the Global score (comprising Ease of Communication, Reverberation, and Background Noise, ~~and Aversiveness to Sounds~~ subscales) are reported in Figure 7 for subjects who preferred one hearing aid and for those who preferred two hearing aids. The subscales Ease of Communication, Reverberation, and Background Noise are reported for descriptive purposes, but statistical analyses were completed using the Global score and the Aversiveness score. As Figure 7 reveals, there was a consistent pattern in which a lower frequency of problems was reported by subjects who preferred one hearing aid compared with those who preferred two hearing aids. Using ANOVA, it was determined that there was a statistically significant interaction between APHAB score and preference group ($F[1,92] = 4.028$, $p = 0.048$). Exploration of this interaction revealed that the mean Global score was significantly higher for the group that preferred two hearing aids ($F[1,92] = 5.073$, $p = 0.027$). The same pattern of mean differences between groups was seen for the AV score, with statistical results approaching significance ($F[1,92] = 3.24$, $p = 0.075$). These results indicate that patients who report fewer unaided problems, especially in speech communication, are more likely to choose one hearing aid rather than two.

F7 F8

Tests of Binaural Interaction • Figure 8 summarizes the results of all tests run in the binaural test battery. The results for binaural summation and binaural squelch, scored in decibels, are displayed relative to the left axis. The scores derived from the dichotic digits test, scored in percentage, are displayed relative to the right axis. The average scores revealed more binaural summation and greater binaural squelch for the subjects who preferred two hearing aids, suggesting that these listeners experienced somewhat more effective binaural interaction than those who preferred one hearing aid. The statistical significance of these results was explored using ANOVA. There were no significant main effects or interactions, but the main effect of hearing aid preference approached significance ($F[1,92] = 3.008$, $p = 0.086$), which lends some support to the hypothesis that more effective binaural interaction might be one factor that contributes to the preference for wearing one or two hearing aids.

As described earlier, four scores were computed from the data obtained in the dichotic digits test. Right ear advantage (REA) was assessed for both the free recall and the direct recall conditions. The mean data in Figure 8 show that the REA in the direct recall condition was only 1 to 2% and very similar for both preference groups. In the free recall condition, the REA was approximately 10% and a larger REA was seen for subjects who preferred one hearing aid. The statistical significance of these observations was explored using ANOVA. Results indicated that, overall, REA scores were greater for the free recall condition ($F[1,92] = 32.8$, $p < 0.001$). However, there was no significant main effect for preference groups, and the interaction was not significant. The other type of score derived from the dichotic digits test was a measure of cognitive effect. The computation of this score is based on the premise that cognitive overload can limit the score in the free recall condition, and this limitation can be reduced in the direct recall condition. The difference between the scores from the free and direct recall conditions in one ear is a measure of the cognitive overload effect in that ear. As Figure 8 shows, the mean cognitive effect (Cog) was between 12 and 25%, and a larger Cog was seen in the left ear than in the right ear. The statistical significance of these observations was explored using ANOVA. Results indicated that, overall, Cog scores were greater for the left ear than for the right ear ($F[1,92] = 32.8$, $p < 0.001$). However, there was no significant main effect for preference groups, and the interaction was not significant.

Optimizing the Prediction of Preference for One or Two Hearing Aids

In the absence of any specific predictors of unilateral/bilateral preference, we could achieve a maximum accuracy of 54% in predicting this preference by simply predicting that all subjects prefer to wear two hearing aids. A major goal of this investigation was to improve the accuracy of this prediction. The topic was explored by determining how accurately the preference for two hearing aids could be predicted based on a combination of variables that would be available in advance of the hearing aid fitting. Although only one of the potential predictor variables discussed above (subjective hearing problems unaided) was independently significantly related to the preference for one or two hearing aids, several other variables revealed trends in the predicted direction that did not reach a

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TABLE 3. Linear correlations between potential predictor variables and preference for one or two hearing aids

Variable	Correlation Coefficient
Pure-tone average	−0.082
Age	−0.048
Hearing aid experience	0.121
Gender	−0.178
Lifestyle	−0.021
Demand	−0.048
Positive affect	−0.031
Negative affect	0.185
APHAB unaided global	0.229*
APHAB unaided AV	0.173
Binaural summation	0.145
Binaural squelch	0.111
REA_{free}	−0.150
REA_{dir}	−0.003
Cognitive effect LE	−0.035
Cognitive effect RE	0.189

* $p < 0.05$ (two tailed).

significance level of $p = 0.05$. It seemed plausible that a combination of predictor variables might be successful in improving the accuracy with which a preference for bilateral fitting could be predicted in advance. Logistic regression analysis was used to examine this possibility.

Logistic regression analysis is a method for finding an optimum combination of variables to predict a dichotomous outcome (preference for one or two hearing aids). In this investigation, there were 16 potential predictor variables. Each one of them arguably could be useful in predicting preference for one or two hearing aids. However, based on the data shown above, some of them seemed more likely to be useful predictors than others. The number of predictor variables was reduced for the analysis by eliminating those that did not explain at least 1% of the variance in hearing aid preference. In other words, to be retained for the logistic regression, a variable was required to have a minimum
T3 correlation of 0.1 with hearing aid preference. Table 3 gives the correlation coefficient between each potential predictor variable and preference for one or two hearing aids.

There were nine variables with correlations of at least 0.1 with hearing aid preference. They included two demographic variables (gender and previous hearing aid experience), three subjective assessments (Negative Affect, Unaided AV, and Unaided Global), and four psychoacoustic test scores (binaural summation, binaural squelch, right ear advantage-free, and cognitive effect-right ear). These nine variables were entered into a backward stepwise logistic regression. This procedure systematically discarded variables that did not significantly improve the outcome prediction (p to remove = 0.1). After the process of eliminating variables that did not produce a significant improvement in the prediction, four variables remained. The logistic regression analysis determined that subject preference for two hearing aids could be predicted with 66% accuracy using these four variables: unaided AV score, unaided global score, binaural summation, and right ear advantage for the free recall portion of the dichotic digits test. Results of the
T4, AQ:4 logistic regression are summarized in Table 4.

When these four predictor variables were combined, they accurately predicted preference for one or two hearing aids for

TABLE 4. Logistic regression results

	Beta (SE)	Sig.	Odds Ratio
Unaided AV	0.027 (0.013)	0.035	1.027
Unaided global	0.048 (0.018)	0.007	1.049
Binaural summation	0.109 (0.06)	0.068	1.115
REA free recall	−0.041 (0.017)	0.016	.960
Constant	−3.782 (1.253)	0.003	.023

When the odds ratio is greater than one, the odds of a preference for two hearing aids increases as the predictor increases. When the odds ratio is less than one, the odds of a preference for two hearing aids decreases as the predictor increases. $R^2 = 0.17$ *(Cox & Snell), 0.27 (Nagelkerke),* $\chi^2(4) = 17.39$, $p = 0.002$.

two-thirds of the 94 subjects in the study. For one-third of the subjects, the preference prediction was wrong. Figure 9 illustrates F9
the results for each subject. In this figure, the probability score determined from the logistic regression is given on the horizontal axis. Each symbol corresponds to a subject. Subjects who preferred two hearing aids are depicted with squares. Subjects who preferred one hearing aid are depicted with circles. Correct predictions are shown using black symbols. Wrong predictions are shown using gray symbols. Among the 32 wrong predictions, 14 represent subjects who preferred two hearing aids and 18 represent subjects who preferred one hearing aid.

Self-Report Outcomes of Preferred Fittings

Three outcome questionnaires were completed to quantify subjective performance with the preferred fitting of one or two hearing aids.

International Outcome Inventory for Hearing Aids • Responses to the IOI-HA were partitioned into two factors called Advantages and Limitations. In addition, the data were compiled separately for subjective hearing loss reports of mild to moderate (MM) problems (51 subjects) and moderately severe or severe (MS+) problems (43 subjects) as recommended by Cox et al. (2003). Figure 10 summarizes the data for both F10
preference groups. A higher score is a better outcome. It can be seen that for both categories of subjective hearing loss (MM and MS+), the mean Advantages outcome score was higher for the subjects who preferred two hearing aids. The effect sizes (Cohen's *d*) were 0.39 and 0.48 for MM and MS+ categories, respectively. For the Limitations outcomes, the result was

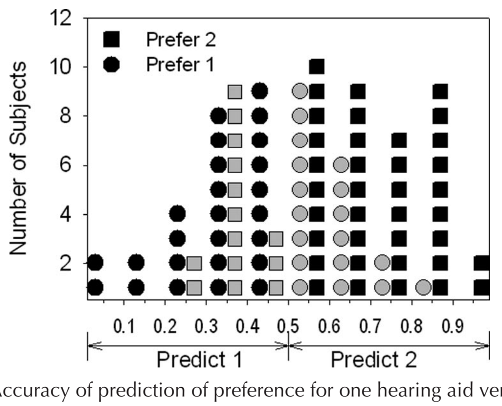

Fig. 9. Accuracy of prediction of preference for one hearing aid versus two from the logistic regression model. Subjects who preferred one hearing aid are indicated by circles and subjects who preferred two hearing aids are indicated by squares. Correct predictions are shown with black symbols and incorrect predictions are shown with gray symbols.

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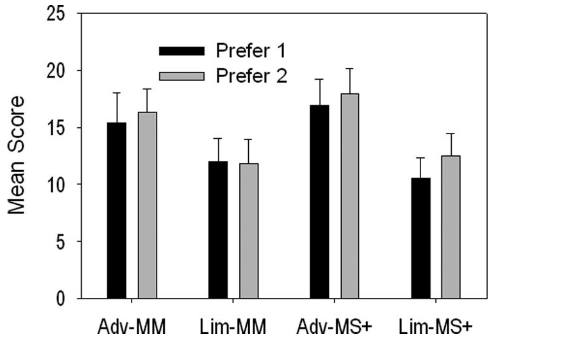

Fig. 10. Mean IOI-HA results for subjects who preferred one hearing aid and subjects who preferred two hearing aids. MM = mild to moderate; MS+ = moderately severe to severe; Adv = advantages; Lim = limitations. Bars show 1SD.

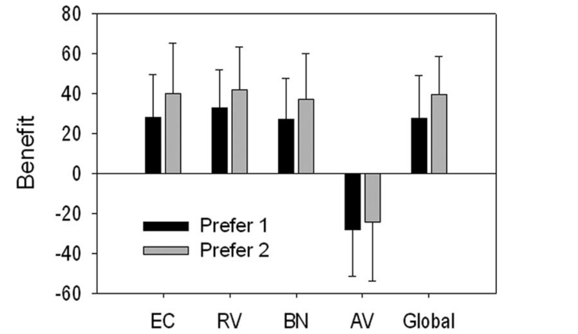

Fig. 12. Mean benefit on the APHAB for each hearing aid preference group for each subscale (Ease of Communication, Reverberation, Background Noise, and Aversiveness to Sounds) and the Global score. Bars show 1SD.

different across the two subjective hearing loss categories. For the MS+ category, the mean score was higher for the subjects who preferred two hearing aids (Cohen's $d = 1.07$); however, for the MM category, the scores were essentially equal for subjects who preferred one and two hearing aids (Cohen's $d = -0.06$). The statistical significance of these results was explored using ANOVA. For the subjects in the MM category, there were no significant differences between the preference groups in either Advantages or Limitations. For the subjects in the MS+ category, there were no significant differences between the preference groups in the Advantages scores; however, subjects who preferred two hearing aids reported a significantly higher mean score ($F[1,41] = 10.98$, $p = 0.002$) for the Limitations factor.

Device Oriented Subjective Outcome • Responses to the DOSO, scored for each of six subscales, are illustrated in
F11 Figure 11 for each hearing aid preference group. A higher score is better. Three subjects accidentally omitted several items on this questionnaire, so the analysis is based on N = 91. There is an overall trend suggesting that subjects who preferred two hearing aids reported better average outcomes on five of the six subscales: Speech Cues (Cohen's $d = 0.32$), Listening Effort (Cohen's $d = 0.24$), Pleasantness (Cohen's $d = 0.44$), Quietness (Cohen's $d = 0.38$), and Use (Cohen's $d = 0.31$). Subjects who preferred one aid reported better average outcomes on the Convenience subscale (Cohen's $d = 0.39$). The statistical significance of these observations was explored using ANOVA. The results revealed a significant interaction between preference and subscale score ($F[5,445] = 4.88$, $p = 0.001$, $\epsilon = 0.82$, df have been adjusted using the Greenhouse-Geisser correction). Exploration of the interaction using univariate tests indicated that subjects who preferred two hearing aids scored significantly higher on the Pleasantness subscale ($F[1,89] = 4.30$, $p = 0.041$). Also, the differences between preference groups approached significance for two other subscales: Quietness ($F[1,89] = 3.29$, $p = 0.073$) and Convenience ($F[1,89] = 3.32$, $p = 0.072$). On the Convenience subscale, the mean difference favored the subjects who preferred one hearing aid.

Abbreviated Profile of Hearing Aid Benefit • Figure 12 F12
illustrates the benefit measured using the APHAB for each hearing aid preference group. A higher score is better. For descriptive purposes, the results are displayed for all subscales and for the Global score. The overall trend suggests that subjects who preferred two hearing aids reported greater benefit for speech communication (Cohen's $d = 0.6$) and fewer issues with sounds that may be perceived as averse (Cohen's $d = 0.15$). The statistical significance of these observations was explored using ANOVA including only the Global and Aversiveness scores. The results revealed a significant overall difference in which subjects who preferred two hearing aids reported more benefit than those who preferred one ($F[1,92] = 6.58$, $p = 0.012$). The interaction between APHAB score and hearing aid preference was not significant.

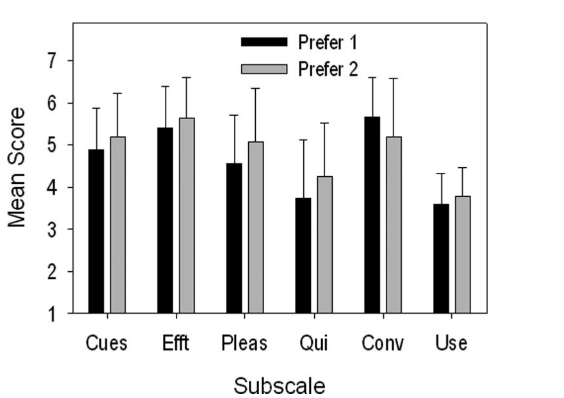

Fig. 11. Mean scores on the DOSO for each hearing aid preference group for each subscale: speech cues (Cues), listening effort (Efft), pleasantness (Pleas), quietness (Qui), convenience (Conv), and use (Use). Bars show 1SD.

Why Did Some Subjects Prefer One Hearing Aid?

Three types of data were collected to explore the reasons for subjects' preferences for one or two hearing aids.

1. They were asked for their preference for one or two hearing aids in each of 10 listening situations. These data are not further analyzed because subjects tended to give the same preference (for one or two hearing aids) in each situation as their declared overall preference.
2. They were asked to provide up to three reasons for their preference in their own words. These data were subjected to a content analysis to derive overall themes (Krippendorf 2004). The results are shown in Figure 13 ordered by F13 reasons most used for preferring one hearing aid.
3. If they preferred one hearing aid, they were asked to select contributing reasons for the choice from a list of 24 potential reasons (see Appendix). Five of the reasons were

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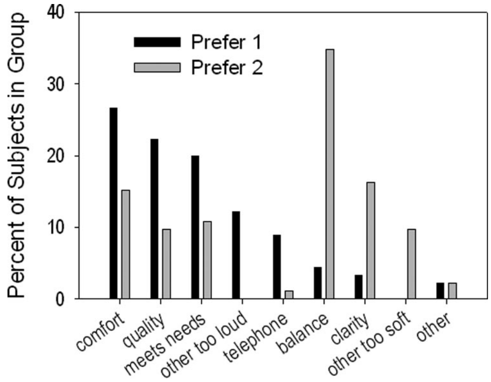

Fig. 13. Summary of unstructured reasons given for preferring one or two hearing aids.

endorsed by at least 50% of the subjects who preferred one hearing aid. These reasons are listed in Table 5.

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Were Fitting Preferences Stable Over Time?

Three months after the study concluded, 58 of the 62 subjects who used loaner hearing aids responded to a short mail or telephone survey about their subsequent purchase decisions. The results are summarized in Table 6. Eight of the subjects had not made any purchase decision. Of the 50 subjects who had made a purchase decision, some had not actually purchased the hearing aids but stated their intention to do so. Among the subjects who had made a purchase decision, 80% reaffirmed their initial preference for one or two hearing aids. Of the remaining 20%, some who preferred two hearing aids actually decided to purchase one, and some who preferred one hearing aid actually decided to purchase two.

T6

DISCUSSION

As reviewed above, past research with bilaterally hearing impaired adults has consistently shown that a substantial percentage report a preference for wearing one hearing aid rather than two, even when two are readily available to them. Most of these studies were performed in an era when hearing aids were technologically far inferior to those available now. One goal of this study was to determine whether this preference pattern continues when patients use devices that are typical of current technology. The hearing aids worn by subjects in this investigation were new in 2005–2007 and exemplified good quality advanced technology. Nevertheless, the pattern in which a large proportion of patients

TABLE 5. Five reasons for preferring one hearing aid that were endorsed by at least 50% of the subjects who preferred one hearing aid

1. In quiet, I understand speech as well or better when I wear only one hearing aid.
2. My voice sounds more natural/comfortable when I wear only one hearing aid.
3. In noisy situations, I understand speech as well or better when I wear only one hearing aid.
4. One hearing aid helps me as much as two.
5. It's inconvenient to use the telephone when I wear two hearing aids.

TABLE 6. Purchase decisions made by 58 subjects three months after the study concluded

move "Purchase Decision" to vertical

	Initial Decision	
	One Aid	Two Aids
~~Purchase decision~~		
One aid	22	4
Two aids	6	18
None	5	3

ultimately preferred to wear one hearing aid rather than two was repeated in our results. This outcome indicates that the preference observed in previous research for wearing one hearing aid was not primarily driven by technological limitations. It is also noteworthy that the percentage of subjects who ultimately preferred one hearing aid in our study, 46%, is quite similar to the average of 41% found in previous clinical trials of one versus two hearing aids.

Outcomes with Bilateral versus Unilateral Hearing Aids

The strongest argument typically used in favor of bilateral fitting is that patients who use two hearing aids tend to have better real-world outcomes than those who use one. However, this claim was not generally supported in studies predating the current technology era beginning around 2000. In particular, the most highly desired benefit of bilateral fitting, improved speech understanding in noise, could not be demonstrated consistently in everyday life (for a review, see Noble 2006). Noble and Gatehouse (2006) argued that the paucity of evidence supporting advantages of bilateral fittings in daily life was the result of an oversimplified measurement strategy. They attempted to provide a more nuanced insight into potential advantages of bilateral aiding using the Speech, Spatial, and Qualities of Hearing questionnaire. Their data suggested that even when significant binaural advantages could not be seen in conventional situations such as speech understanding in noise, they could be seen in dynamic listening situations such as identifying movement of sounds.

The results of the current investigation with more technologically advanced hearing aids tend to support conventional wisdom (ideas that are generally accepted as true) that patients who wear two hearing aids report better real-world outcomes. However, note that in our analyses, subjects were categorized based on their own preferences. It is likely that bilaterally aided subject groups in previous studies included some individuals who actually would have preferred to wear one hearing aid. We used three standardized questionnaires to quantify outcomes for subjects who preferred one or two hearing aids. The content of the questionnaires encompassed general impressions such as benefit and pleasantness of sound as well as more specific topics such as speech understanding in quiet and noise. As illustrated in Figures 10 to 12, responses to all three questionnaires reveal binaural advantages in that they show a trend for better outcomes in those subjects who preferred two hearing aids. These results are consistent with some outcomes in other recent studies. For example, Kramer et al. (2002) found that scores on the Advantages subscale of the IOI-HA were significantly better for wearers of two hearing aids than for wearers of one. Although their effect size was small ($d \cong 0.2$), the large number of subjects (N = 505) produced a statistically significant difference. We replicated this outcome in this study where the scores for the Advantages subscale were better for subjects who preferred two hearing aids, with an effect size $d \cong 0.4$. This result was statistically significant in this study when all subjects were pooled, even though it was not significant when subjects were partitioned into the two hearing loss groups (Fig. 10). Boymans et al. (2009) reported mixed results. With one set of questionnaires, significantly greater real-world benefit was seen for patients who opted for two hearing aids rather than one. However, there was not a significant advantage for bilateral fittings in the results of the IOI-HA.

The protocol followed in this investigation (as in Boymans et al. (2009)) was designed to facilitate a search by each listener to identify the amplification system that would provide him/her with the most benefit and overall satisfaction, taking into account all the complexities of the individual's life, including the many circumstances that are not explored by standardized questionnaires. The results of our investigation, and the great majority of previous comparable studies, show that when faced with this decision, a substantial proportion of bilaterally hearing-impaired persons decide that their optimal amplification system includes one hearing aid rather than two. Why do they make this choice, and can we predict it in advance of the fitting?

Predictors of Preference for a Unilateral Hearing Aid Fitting

As seen in Table 3, there were 16 a priori potential predictors of preference for bilateral aiding in this study. They were drawn from conventional wisdom as well as from research with normal-hearing and hearing-impaired groups of listeners. The statistical exploration of these data yielded a finding that the preference for one or two hearing aids could be predicted accurately for about two-thirds of patients using four variables (Table 4). The combination of useful variables reinforced several aspects of conventional wisdom and basic research.

Conventional wisdom suggests that patients who have more hearing problems are more likely to appreciate two hearing aids. In this study, scores from the unaided APHAB quantified the extent to which the subject believed that the hearing loss caused problems in daily life. A report of more problems was associated with greater likelihood of preferring two hearing aids. This trend was also reported by previous researchers (e.g., Stephens et al. 1991; Boymans et al. 2009).

Many practitioners have argued in favor of bilateral aiding based on the well-established advantages of binaural listening for normal-hearing listeners. In this study, one of those advantages (binaural summation of loudness) was found to make a positive contribution to the preference for two hearing aids: greater binaural loudness summation was predictive of a preference for two rather than one.

Several researchers have suggested that scores obtained in dichotic listening tests can reflect interference or imbalance between ears and that this might be consistent with a deficit in binaural benefits which, in turn, limits the advantages of two hearing aids. Our finding that a greater right ear advantage in dichotic listening was associated with lower preference for two hearing aids bolsters this line of reasoning. Overall, a preference for two hearing aids rather than one was predictable from a combination of more perceived daily problems, greater binaural advantage, and less binaural imbalance.

It is also noteworthy that our investigation failed to confirm the validity of two additional variables that often have been put forward as predictive of a preference for bilateral aiding: audiometric hearing loss and auditory lifestyle. It is widely claimed that individuals with more objective hearing impairment are more likely to prefer two hearing aids. However, in this study, the mean audiogram for subjects who preferred two hearing aids was essentially identical to the mean audiogram for those who preferred one (Fig. 6). In support of this, pure-tone average thresholds were not significantly correlated with aiding preference (Table 3). This finding cannot be generalized beyond the scope of the specific audiograms encompassed in this study. Although our subjects represented a wide range of audiograms typical of hearing aid users with mild to moderate hearing loss, there were no subjects with severe or profound hearing loss (the poorest three-frequency pure-tone average was 60 dB HL). In addition, there were no subjects with bilaterally asymmetrical audiograms. Other studies also have reported that hearing impairment quantified using the audiogram was n[illegible]ictive of a preference for one or two hearing aids (Schreurs & Olsen 1985; Day et al. 1988; Vaughan-Jones et al. 1993). However, some researchers have observed that more hearing loss is predictive of opting for two hearing aids (Chung & Stephens 1986; Stephens et al. 1991).

Another widely cited rationale for preferring one or two hearing aids involves the extent to which the patient's daily life calls for frequent interaction with different types of sounds (e.g., attending performances, group conversations, shopping, driving, picnics, TV, library job, and children). This variable is often called auditory lifestyle (other terms that have been used include listening needs, activity index, auditory ecology, and hearing demands). Based on conventional wisdom, an individual with a more demanding auditory lifestyle will be more likely to prefer two hearing aids. Previous studies of preference for one or two hearing aids have not directly assessed this variable, although Kobler et al. (2001) found some indirect support for the proposition. In this investigation, auditory lifestyle was quantified using the ALDQ. The ALDQ yields one score that reflects the variety of sounds in an individual's daily life and a second score that weights these sounds in terms of their importance for the listener. Neither of these scores provided significant leverage in predicting which subjects would prefer to use two hearing aids (Table 3). This finding indicates either that auditory lifestyle is not an important predictor of preference for two hearing aids or that the ALDQ does not quantify the relevant aspects of auditory lifestyle. Although the ALDQ has not been widely used, research has tended to support its construct validity. ALDQ scores have been shown to be associated with preference for linear versus nonlinear processing and with amplification subjective outcomes (Gatehouse et al. 1999, 2006; Vestergaard 2006). Taking another approach to this question, Shaughnessy and Cox (Reference Note 3) explored auditory ecology using three approaches in addition to the ALDQ for a convenience sample of 34 subjects from this study during a typical week. The three types of measures were (1) acoustical measurements to determine the distribution of levels of speech, noise, and speech-in-noise; (2) checklist of daily listening situations; and (3) checklist of language activities. None of these measures revealed a difference in auditory ecologies between the 14 subjects in this group who preferred two hearing aids and the 20 who preferred one. This is an additional indication that auditory lifestyle might not be predictive of a preference for two hearing aids.

Additional Reasons for Preferring One or Two Hearing Aids

Using four of the variables that were selected a priori as potential predictors of a preference for two hearing aids, it was possible to correctly categorize two-thirds of the subjects regarding their preference. However, 18 subjects who were predicted to prefer two hearing aids actually chose one, and 14 subjects who were predicted to prefer one hearing aid actually chose two (Fig. 9). To further explore their underlying motivations, all subjects were asked to provide in their own words up to three reasons for their choice of one or two hearing aids. Figure 13 summarizes these data and clearly demonstrates that subjects who preferred one hearing aid used very different decision criteria from those who preferred two. The three most frequently cited reasons for preferring one hearing aid were more comfort, better quality, and "it is enough to meet my needs." These subjects seemed to indicate that help provided by one hearing aid was "good enough" and they found persuasive advantages (such as easy telephone use) in having one ear left open. Amplified sound in the second ear did not yield benefits sufficient to overcome disadvantages related to quality, comfort, and loudness (even though volume controls were provided). This impression is supported by the five reasons listed in Table 5, which can be summarized as follows: two hearing aids did not help more than one and sometimes were worse.

The three most frequently cited reasons for preferring two hearing aids were feeling balanced, clarity of sounds, and comfort. These kinds of reasons are familiar and anticipated by conventional wisdom. The reference to balance is consistent with clinical anecdotes about a need for sound in both ears to achieve a sense of stability in space as well as research that points to a [illegible]or bilateral input to execute auditory scene analysis (Noble & Gatehouse 2006). Furthermore, references to clarity of sounds are consistent with expectations about binaural processing with bilateral fitting: normal-hearing listeners can achieve substantially improved effective SNRs with two-ear listening. It is interesting to note that greater comfort was among the three top reasons given for their preference by both groups of subjects. However, the components of comfort were subtly different in the two groups. Explication of comfort by subjects who preferred one hearing aid included feeling more normal and free, not closed in, plugged, or cut off. In contrast, subjects who preferred two hearing aids described comfort as feeling more capable, secure, relaxed, and safe.

Other Considerations

Hearing Aid Fittings • As described earlier, the process of hearing aid fitting was the same for all subjects. After target matching, the fittings were fine-tuned to ensure that they would be acceptable for each subject. It is reasonable to ask whether the patient-driven fine-tuning process resulted in systematic differences in the final fittings for subjects who subsequently preferred two hearing aids versus those who preferred one. Three small differences did emerge. (1) The typical subject who preferred one hearing aid chose average gain for conversational speech equal to 97% of his/her target gain, whereas the corresponding value for subjects who preferred two hearing aids was 98% of his/her target gain. This difference approached statistical significance ($t[89] = 1.97$, $p = 0.052$). (2) The average MPO was 13.6 dB below average target for subjects who preferred one hearing aid, whereas it was 10.1 dB below target for subjects who preferred two. This 3.5 dB mean difference was statistically significant ($t[84] = 3.45$, $p = 0.001$). (3) Midfrequency audibility of soft speech was 6.6 dB for the average subject who preferred one hearing aid, whereas it was 10.7 dB for the average subject who preferred two. This 4.1 dB mean difference was statistically significant ($t[77] = 2.12$, $p = 0.037$). All these subject-driven differences are consistent in suggesting that, compared with those who preferred two hearing aids, individuals who preferred one hearing aid had a lower tolerance for sound. Recall, however, that all hearing aids were provided with volume controls, which could have been used to change gain levels during the field trial.

Open Fittings • When this investigation was undertaken, open fittings were not widely used. The behind-the-ear hearing aids used in this study were coupled to the ear canal using earmolds with appropriate venting and feedback management. Given the success of open fittings in the past few years, it is natural to wonder whether the results of this study would have changed if open fittings had been used for some of the subjects, consistent with current clinical practice. It could be speculated that more openness in the ear canal coupling would have promoted greater acceptance of two hearing aids among subjects who preferred one in this study. Although we cannot resolve this matter with the current data, it is possible to consider any differences in the venting configuration between subjects who preferred one hearing aid or two. Specific information about the venting used for each person was available only for the HARL subjects. Their earmold vents were measured using length and diameter. For subjects who preferred two hearing aids, the mean length × diameter of the vents were 16.7 mm × 2.9 mm. For subjects who preferred one hearing aid, the mean length × diameter of the vents were 17.5 mm × 2.8 mm. Thus, on average, the vents were similar for both groups. Additional research will be necessary to determine the effect, if any, of open fittings on preference for one or two hearing aids.

Financial Considerations • The cost of purchasing hearing aids is often noted as one of the reasons patients choose to wear one rather than two. It should be emphasized that these sorts of concerns did not play a part in this study. There was never a question of the subjects purchasing any of the hearing aids that they wore. The only time in which financial issues could have come into play was in the subjects' decisions about whether they would purchase one or two hearing aids. These decisions were undertaken after the study was completed and did not involve anyone associated with the research. As seen in Table 6, several subjects who had preferred two hearing aids ultimately decided to purchase one. This decision could have been impacted by financial considerations, but it is not pertinent to the validity of our data.

Relevance for Clinical Practice

Evidence-based practice calls for a conscientious melding of current evidence, clinical judgment, and patient preferences. The results of this investigation reinforce and extend several decades of previous research on the preference for one or two hearing aids. The evidence in this and previous studies points to the conclusion that bilateral aiding is not necessarily the patient-centered treatment for all adults with mild to moderate bilaterally symmetrical hearing loss. It is reasonable to believe that regardless of practi-

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tioner inclination, at least 30 to 40% of these patients will ultimately decide that they prefer to wear one hearing aid.

Practitioners might be concerned about their ethical responsibilities toward patients who do not comply with a professional recommendation to wear two hearing aids. Because listeners who opt for two hearing aids tend to report better amplification outcomes on standardized questionnaires, practitioners might feel obligated to try to persuade listeners who opt for one hearing aid to change their minds and accept wearing two, in the hopes of achieving better outcomes in daily life. After all, at the very least, using two hearing aids will always give relief from head shadow effects. On the other hand, respect for patient decisions about their own treatment is a fundamental value in health care. In dealing with this kind of quandary, it is helpful to consider some theory about patient decision making and compliance with treatment recommendations. Stewart and DeMarco (2006) presented a compelling theoretical approach to this topic that makes several important points. (1) Fully informed rational patients will attempt to maximize the net benefit of treatments. (2) Net benefit is the difference between treatment benefits (such as decrease in symptoms of hearing loss) and treatment burdens (such as money, aggravation, stigma, and discomfort of using hearing aids). The benefits and burdens of treatment differ across individuals and the treatment point at which net benefit is maximized likewise differs. (3) For many individuals, net benefit is maximized at a point that is well below the ideal treatment level recommended by professionals. Application of this theory to the present situation points to the conclusion that there will be patients for whom the decision to wear one hearing aid rather than the recommended two (noncompliance) is fully rational and, therefore, should be respected. The practitioner does have the ethical responsibility to make sure that the patient has accurate and clear information to bring to the decision-making process. This can be achieved using informational counseling as well as real-life trials.

The goal of clinical practice should be to arrive at the most effective treatment that is compatible with patient preferences as expeditiously as possible and with maximum cost-effectiveness for the patient, practitioner, and any third-party payer. In current practice, it is typical to recommend two hearing aids for essentially all patients with mild to moderate symmetrical hearing loss. Then, over time, the patient determines whether he/she prefers to wear both the purchased hearing aids or only one. If a substantial percentage of patients ultimately decide to wear only one device, this practice model is not expeditious for the patient or cost-effective for the payer.

How can clinical practice with respect to fitting one or two hearing aids be made more expeditious and cost-effective? The ideal solution would be a short battery of clinical tests that could predict patient preference. The results of our study suggest that a battery of three clinical tests (unaided APHAB, binaural loudness summation, and free-recall dichotic digit test) could yield accurate prediction of aiding preference for two-thirds of patients with mild to moderate bilateral hearing loss, but this level of precision is not enough to justify a recommendation to use the battery in clinical settings. Perhaps further refinement of the predictive method can be achieved with additional research. In the meantime, however, there is no accurate way to predict in advance the aiding preference for a particular individual. At this time, the most effective approach open to practitioners would be to conduct a candid unbiased systematic field trial comparing unilateral and bilateral fittings with each patient, as has been recommended by several previous researchers (e.g., Schreurs & Olsen 1985; Vaughan-Jones et al. 1993; Boymans et al. 2009). This would necessitate more fitting sessions and perhaps add to the practitioner's burden, but this downside should be weighed against the additional patient satisfaction that can be anticipated as a result of transparency in the fitting protocol, collaboration with the patient in the treatment decisions, and the knowledge of selecting the most cost-effective patient-centered solution. A satisfied patient is an important source of positive word of mouth advertising.

Although a patient's decision about his/her own best treatment must be respected, there are some caveats associated with the choice to wear one hearing aid rather than two. Patients who prefer and wear one hearing aid are potentially vulnerable to a deprivation effect in the unaided ear. In this condition, ability to recognize words declines in the unaided ear over time, even though audiogram thresholds remain symmetrical in the patient's two ears (Silman et al. 1984). As shown by Hurley (1999), about 25% of wearers of one hearing aid developed a deprivation effect after 5 yrs of hearing aid use, with the effect more likely in patients whose hearing loss is moderate or worse. Although the real world consequences of this laboratory effect have not been reported, there is clearly some change in the processing ability of the unaided ear in these individuals. Several researchers have observed that this effect often can be reversed at least partly if amplification is subsequently applied to the deprived ear (Silverman & Silman 1990; Gelfand 1995). Another relevant issue was brought to light by Gianopoulos and Stephens (2002) who found that patients who opted for one hearing aid rather than two were more likely to reject amplification over time. They suggested that patients who opt for one hearing aid might need more ongoing professional support to promote continued use of amplification. These considerations suggest that it would be important to follow patients who opt for one hearing aid even more closely than those who opt for two.

CONCLUSIONS

When adults with mild to moderate bilaterally symmetrical hearing loss were given an opportunity to experience unilateral and bilateral hearing aid fittings in their daily lives, a substantial percentage of them decided that they preferred to use the unilateral fitting. This result with modern technology hearing aids is consistent with many previous studies using older technology devices. Several widely accepted ideas about use of two hearing aids were at least partly supported in this study: subjects who reported more hearing problems in daily life, who experienced more binaural loudness summation, and whose ears were more equivalent in dichotic listening were more likely to prefer to use two hearing aids. In addition, subjects who preferred to use two hearing aids tended to report better real-world outcomes, and the mean effect size associated with this preference averaged across outcome measures was respectable at d = 0.40 (range: 0.06 to 1.07). However, it is critical to note that this result was found when individuals who preferred to use two hearing aids were compared with individuals who preferred to use one hearing aid. Other widely believed ideas about the use of two hearing aids were not supported in this study. Hearing loss measured by the audiogram was not predictive of preference for one or two hearing aids (although none of the subjects had severe or worse hearing loss). Auditory lifestyle also was not predictive of aiding preference.

Finally, an analysis of reasons volunteered by subjects for their preference choice showed that the two groups of subjects tended to use different decision criteria.

It is self-evident and consistent with previous research that patients who develop a preference for one hearing aid will use only one hearing aid even when they have purchased (or otherwise obtained) two. The challenge for practitioners, therefore, is to recognize the existence of this tendency in many patients and to attempt to provide the most clinically effective and cost-effective hearing aid fitting that is consistent with the patient's preferences. Variables drawn from conventional wisdom and basic research were explored in this study in an attempt to develop an accurate method that could be applied prefitting to predict preference for one or two hearing aids in a given patient. Although results indicated that some of the variables provided some leverage, we were not able to devise a method with sufficient accuracy for clinical use. The prediction was wrong for one-third of the research subjects. Further research is needed to generate a more accurate predictive approach that could be clinically applicable. In the meantime, it is recommended that practitioners are candid and unbiased in exploring patient preference for one or two hearing aids before the fitting is finalized.

APPENDIX

TABLE A1. Potential reasons for preferring to wear one hearing aid rather than two

1. I did not want to spend the money to buy two hearing aids.
2. In noisy situations, I understand speech as well or better when I wear only one hearing aid.
3. One of my hearing aids feels uncomfortable in my ear (makes it sore, red, or painful).
4. Wearing both hearing aids is too tiring.
5. In quiet, I understand speech as well or better when I wear only one hearing aid.
6. Two hearing aids make me look like I am more "hard of hearing."
7. One of my hearing aids doesn't sound as good as the other one.
8. My family and/or friends don't want me to wear two hearing aids.
9. Insurance will only pay for one hearing aid.
10. One of my hearing aids is broken or often needs repairs.
11. It's inconvenient to use the telephone when I wear two hearing aids.
12. One of my hearing aids is uncomfortably loud.
13. Wearing both hearing aids is too much trouble.
14. One of the hearing aids whistles too much.
15. Wearing two hearing aids makes everything too loud.
16. One hearing aid helps me as much as two.
17. I don't like being seen wearing more than one hearing aid.
18. Batteries for two hearing aids cost too much.
19. Wearing two hearing aids makes me nervous.
20. My voice sounds more natural/comfortable when I wear only one hearing aid.
21. I use my other hearing aid as a back-up.
22. When I wear two hearing aids, I get mixed up about which one goes on which ear.
23. Wearing two hearing aids makes me feel dizzy, off-balance, or stopped up.
24. My voice is too loud when I wear two hearing aids.

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1. Kelly, R., & Cox, R. (2003). Relationship between the NEO Five-Factor Inventory (NEO-FFI) and the Positive and Negative Affect Schedule (PANAS) questionnaires. Unpublished Report, Hearing Aid Research Laboratory. University of Memphis.
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AUTHOR QUERIES

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1—Kindly check whether all section heads are OK as given.

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4—Kindly check whether the footnote of Table 4 is OK as given.

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AUTHOR QUERIES RESPONSES

1---- Please change section head "Patients and Methods" to "Methods" (please see note in text)

2---- Citation is correct. Reference: Haggard, M. P., & Hall, J. W. (1982). Forms of binaural summation and the implications of individual variability for binaural hearing aids. Scandinavian Audiology, 15, 47-63.

3----- Citation is correct. Reference: Strouse, A., & Wilson, R. (1999). Recognition of one-, two-, and three-pair dichotic digits under free and directed recall. Journal of the American Academy of Audiology, 10, 557-571.

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1. Please provide "e.g." in front of citations where indicated in the text.
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Additional Requests

1. Under the Reference section, please change the author's name from **Steven Colburn, H.** to **Colburn, S.H.** in the reference Steven Colburn, H., Shinn-Cunningham, B., Kidd, G., Jr., et al. (2006). The perceptual consequences of binaural hearing. *Int J Audiol*, *45(suppl 1)*, S34–S44. Please alphabetize in reference.
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