Matching real-ear targets for adult hearing aid fittings: NAL-NL1 and DSL v5.0 prescriptive formulae

La correspondance des cibles in situ pour l'ajustement des appareils auditifs chez les adultes : formules prescriptives NAL-NL1 vs DSL v5.0

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KEY WORDS

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Abstract

The value of using real-ear measures when fitting hearing aids has been well researched and the information is readily available in the literature. However, a review of recent research showed that there is limited evidence to determine whether real-ear targets for gain and output can be achieved with current technology. Seven experienced clinicians fitted hearing aids to real-ear targets using one of two prescriptive methods: National Acoustic Laboratories, Non-Linear, version 1 (NAL-NL1) and Desired Sensation Level, version 5 (DSL v5.0, adult targets). One hundred ears were assessed for DSL v5.0 and 134 ears were assessed for NAL-NL1 to determine how closely the fittings matched real ear targets. The results indicate that a hearing aid can be matched to target within ±5 dB regardless of the number of gain adjustment handles, the manufacturer, or the style; with the exception of severe/profound hearing loss, particularly in the high frequencies.

Abrégé

L'utilité des mesures in situ pour l'ajustement des appareils auditifs a fait l'objet de plusieurs recherches. L'information à ce sujet est par ailleurs facilement accessible dans la littérature. Néanmoins, une récente recension des écrits a montré qu'il y a peu de données à savoir s'il est possible d'atteindre des cibles in situ pour le gain et le niveau de sortie avec la technologie actuelle. Afin de déterminer à quel point les ajustements correspondaient aux cibles in situ, sept cliniciens ont ajusté 100 appareils auditifs avec la méthode DSL v5.0 *Desired Sensation Level, version 5* (DSL v5.0, adult targets) et 134 avec la méthode *National Acoustic Laboratories, Non-Linear, version 1* (NAL-NL1). Les résultats indiquent qu'un appareil auditif peut être ajusté à ±5 dB de la cible quel que soit le nombre de bandes réglables, le fabricant ou le style à l'exception des cas de pertes auditives sévères ou profondes, particulièrement pour les pertes en hautes fréquences.

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Objective verification using probe microphone measures and the use of targets from a validated prescriptive method is the recommended best practice for fitting hearing aids (Valente et al., 2006). In Canada, both the College of Speech and Hearing Health Professionals of British Columbia (CSHHP-BC, 2014) and the College of Audiologists and Speech-Language Pathologists of Ontario (2016) have guidelines for hearing aid fitting that require the use of real-ear measures to ensure that hearing aid gain and output levels meet prescriptive targets for the individual hearing aid user. Two of the most used prescriptive methods in North America are National Acoustic Laboratories, Non-Linear, version 1 (NAL-NL1) and Desired Sensation Level, version 5.0 (DSL v5.0) (Mueller & Picou, 2010). The aim of the NAL-NL1 prescriptive method is to maximize speech intelligibility and maintain overall loudness at a level similar to, but not exceeding that of a listener with normal hearing (Dillon, 1999). The aim of DSL v5.0 prescriptive method is to ensure loudness comfort and audibility of a wide frequency range across multiple input levels (Scollie et al., 2005). Depending on the degree, configuration, and type of hearing loss, as well as input level, these two approaches may lead to very similar targets (within 1 dB) or very different targets (15 dB or more difference between prescriptive methods) (Johnson & Dillon, 2011).

The goal of this study was to assess hearing aid fittings on adults using real-ear measures and either NAL-NL1 or DSL v5.0 to determine whether current hearing aid technology was able to achieve the recommended prescriptive targets. Recent research regarding match to targets[1] often cite a ±10 dB criterion (Aazh & Moore, 2007). This is consistent with the work of Jenstad et al. (2007) who demonstrated that there is a ±10 dB range that can be considered acceptable for adult hearing aid users when listening to average input levels of speech. However, other studies have shown that it is possible to achieve a better match to targets than ±10 dB. Polonenko et al. (2010) found that the majority of real-ear measures were within 5.8 to 8.4 dB of the DSL v5.0 targets for adults. Similarly, the Modernization of Hearing Aid Services (MHAS) in the United Kingdom adopted recommendations from Gatehouse, Stephens, Davis, and Bamford (2001) for matching within 5 dB of targets up to 2000 Hz and within 8 dB of targets above 2000 Hz. Taken together, these studies suggest that real-ear measures within 5-10 dB of targets would be acceptable. In the current study, registered audiologists at the Western Institute for the Deaf and Hard of Hearing (WIDHH) conducted a quality assurance/quality improvement review of their clinical files to determine how closely real-ear targets were matched for two commonly-used prescriptive methods, NAL-NL1 and DSL v5.0, and whether there were any factors that predicted inability to meet targets. We adopted a criterion of ±5 dB of targets as the gold standard, based on the previous research.

Method

Participants

Seven experienced clinicians at three different clinical sites submitted hearing aid real-ear measurements from sequential clients who attended their scheduled appointment to be fitted with new hearing aids. The clinicians were aware that their fittings would be reviewed for determining how well they matched targets. Participants in this study were adults with sensorineural hearing loss ranging from mild to profound and included both new and experienced hearing aid users. Target calculation and fitting procedures were the same regardless of previous experience with hearing aids. One hundred and thirty-four ears were assessed with NAL-NL1 and 100 ears were assessed with DSL v5.0. For data collection, on the day of the initial hearing aid evaluation, the clinician selected the prescriptive method by even dates (NAL-NL1) or odd dates (DSL v5.0)[2]. The clinician used adult prescriptive targets for the DSL v5.0 fittings.

Materials

Clinicians made real-ear measurements with the Audioscan Verifit® VF1 Speechmap™, software version 3.4.18, and standard probe tubes. They used foam inserts (ER3a) for measuring real-ear-to-coupler differences (RECDs) prior to fitting. The clinician used the Verifit® to generate targets for NAL-NL1 and DSL v5.0 at three input levels, as well as maximum power output (MPO). For the purposes of this study, soft speech was tested at 55 dB SPL (G55), average speech was tested at 65 dB SPL (G65), and loud speech was tested at 75 dB SPL (G75).

The clients' own hearing aids were used in this study. The clinician and client together selected the hearing aids at the hearing assessment appointment based on the client's audiometric and lifestyle needs, dexterity, esthetic concerns, and budget. The devices ranged from 3-20 gain adjustment handles and were selected from seven different manufacturers. Styles included completely-in-the-canal, in-the-canal, half-shell, in-the-ear, behind-the-ear, receiver-in-the-aid (with slim tube), and receiver-in-the ear. This selection represents the majority of hearing aid manufacturers, all technology levels, and all styles.

Procedures

All procedures followed the standard clinical protocol at WIDHH for the initial hearing aid fitting, which follows the recommendations of the American Academy of Audiology (Valente et al., 2006) and the CSHHP-BC (2014). The clinician fitted the hearing aids according to the WIDHH protocol. The clinician noted potential reasons for the inability to achieve target within 5 dB (i.e., feedback, frequency response of hearing aid, tolerance, insufficient gain, or other). They printed the real-ear measures for the client file, along with the Verifit® calculated speech intelligibility index (SII) at each input level. The clinician may then have adjusted the hearing aids further for the client's preferences or tolerance where necessary. Measures made after these adjustments were not included in this study.

The WIDHH fitting protocol is as follows:

1) *Calibration.* Regular maintenance of the clinic equipment includes annual calibration by an accredited instrumentation company; a biologic listening check of the soundbooth equipment each morning; and a weekly calibration check of the Audioscan® Verifit test box reference microphone, on-ear probe microphone, and RECD transducer.

2) *Audiometric assessment.* The standard audiometric assessment includes case history, otoscopy, air and bone conduction thresholds (including inter-octaves where possible), speech audiometry, loudness discomfort levels (LDLs), immittance audiometry, binaural speech-in-noise testing, discussion of results, and rehabilitation recommendations.

3) *Hearing aid selection.* In consultation with the client, the clinician selects appropriate technology. The clinician takes impressions where necessary, and for open fittings, he or she measures the client's ear for receiver or slim tube length. The client is then booked to return for a hearing aid evaluation appointment within a two week period.

4) *Quality control and initial fitting.* The clinician conducts a quality control check of the hearing aid prior to the fitting. At this time, he or she uses the manufacturer's software to estimate the initial fitting. If there is a gain adaptation manager in the software, whereby gain is reduced from targets for new hearing aid users, the clinician sets the level to maximum (i.e., 100 % of target gain). In preparation for real-ear verification, if frequency lowering is available in the hearing aid, the clinician disables this feature.

5) *Feedback test.* Prior to inserting the probe tubes, the clinician inserts the hearing aids into the ears and, if required, a feedback test is completed.

6) *RECD.* On the day of the initial hearing aid evaluation, the clinician measures a real ear to coupler difference (RECD) on each ear.

7) *Real ear verification.*

   a. On the Audioscan Verifit® VF1 fitting and verification system, the clinician selects the Speechmap™ (calibrated speech) test, then selects the prescriptive formula (NAL-NL1 or DSL v5.0) for the client. Using Speech-std (1) and selecting G65 dB SPL input /average speech presentation level, the hearing aid frequency response is adjusted such that the average of the long term average speech spectrum (LTASS) matches average speech targets.

   b. Using Speech-std (1) and selecting G55 dB SPL input/soft speech presentation level, the clinician adjusts the soft gain handles until the average of the LTASS matches soft speech targets. It is important to monitor changes in the compression ratios. While higher compression ratios may be necessary to address tolerance issues, compression ratios greater than 2:1 may impact intelligibility (Souza, 2007).

   c. If time allows, using Speech-std (1) and selecting G75 dB SPL input/loud speech presentation level, the clinician adjusts the loud gain handles until the average of the LTASS matches loud speech targets, while continuing to monitor changes in the compression ratio.

   d. If soft and loud gain handles have been adjusted, the clinician retests the G65 input level.

   e. The clinician tests the hearing aid's maximum power output (MPO) using swept pure tones. This measured output should be at or below the DSL or NAL prescriptive targets or, if available, the client's loudness discomfort levels (LDLs).

Match to targets data were obtained at this point. The steps below were part of the full clinical protocol, but data from these steps are not included in the present study. These steps often include an adjustment away from target. Because

our purpose was to determine whether prescriptive targets could be matched, not whether they could be tolerated, we gathered data at the point of closest ideal match to targets.

8) *Hearing aid fine-tuning.* Following real-ear verification, through discussion with the client, the clinician may adjust the hearing aids to ensure the client is comfortable with the amplified sound (e.g., lower the gain to a tolerable level). If adjustments are made, a final real-ear measure is required before the client is discharged from the hearing aid evaluation. The clinican counsels the client on realistic expectations, particularly if settings need to be reduced significantly from target gain.

9) *Directional microphones.* The clinician assesses the directional microphones by completing a listening check, a directional microphone test in the Verifit® test box, or an on-ear measure to confirm directional microphones are working properly.

10) *Telecoil program.* If a telecoil program is added during the initial fitting, the hearing aid is tested in the telecoil program using the live speech protocol on the Verifit® with speech presented via telephone.

11) *Streaming programs.* If streaming programs are added, the clinician performs a listening check to confirm their performance.

12) *Manual programs.* The clinician performs real-ear verification on any manual programs. One hour is allotted for fitting two hearing aids, or ½ hour for one hearing aid. An additional ½ hour hearing instrument orientation session is booked directly following this appointment to show the client how to use and maintain the hearing aid(s).

Table 1. DSL v5.0 95% Confidence Intervals (in dB) by Frequency, Input Level, and Degree of Hearing Loss

Degree of Loss	Input Level	250 Hz	500 Hz	750 Hz	1000 Hz	1500 Hz	2000 Hz	3000 Hz	4000 Hz	6000 Hz
Mild										
	G55	2.4	0.8	0.9	0.5	0.8	0.6	0.8	1.4	3.2
	G65	1.7	0.8	1.5	0.7	0.7	0.4	0.4	1.4	3.5
	G75	4.8	1.7	1.6	1.6	0.9	1.2	2.9	1.6	3.6
	MPO	1.4	2.3	2.2	2.7	1.3	2	1.3	1.4	4.2
Mod										
	G55	1	0.6	1	0.7	0.8	0.5	0.6	0.7	1.5
	G65	0.8	0.6	0.8	0.7	0.6	0.4	0.5	0.8	1.7
	G75	2.2	1.6	2.1	1.4	1.4	1.2	1.6	2	3.6
	MPO	2.5	2.8	2.7	2.7	0.8	2.8	1.1	2.6	2.9
Mod-Sev										
	G55	1.7	0.5	0.8	0.8	0.7	0.8	1.1	3.1	4.9
	G65	1.4	0.7	0.8	0.7	0.5	0.5	0.9	2.1	4.9
	G75	2.7	1.7	2.3	1.7	1.3	1.9	2.4	2.5	2.8
	MPO	2.2	2.1	2.2	1.2	1.8	1.5	1.8	3.7	4.3
Sev/Prof										
	G55	1.3	1.4	2	1.1	2.2	1.5	4.1	5.4	7.7
	G65	0.9	0.9	1.9	1.1	1.6	3.2	3.5	5.3	6.7
	G75		4.9		6.9	5.9	6.9	14.7	3.9	
	MPO	1.9	2.4	2.8	1.4	1.4	0.9	3.9	3.5	8.1

Note: Empty cells reflect insufficient data at these input levels and frequencies

Results

DSL v5.0 results are shown in Table 1. NAL-NL1 results are shown in Table 2. Data were categorized by hearing loss as defined by the 3-frequency (.5, 1, and 2 kHz) pure tone average (PTA): Mild, Moderate, Moderately-Severe, and Severe/Profound.[3] These tables show the 95% confidence intervals for input levels at G65 (average speech), G55 (soft speech), G75 (loud speech), and maximum power output (MPO). With respect to this study, a 95% confidence interval means that there is a 95% probablility that the individual fitting was within the stated dB range (Lane, n.d.). Results show that in most instances current technology can match both NAL-NL1 and DSL v5.0 targets across hearing losses, with some exceptions in severe and profound losses, particularly in the high frequencies. Note that for NAL-NL1, prescriptive targets are not always generated at 3 kHz and above for severe/profound losses, with the rationale that the amplified signal will provide minimal benefit to the predicted Speech Intelligibility Index (SII) (Byrne, Dillon, Ching, Katsch, & Keidser, 2001).

The percentage of real-ear measures that were within ±5 dB of the target are presented in Table 3 for DSL v.5.0 and Table 4 for NAL-NL1. At most frequencies and for both prescriptive methods, the hearing aids matched target within ±5 dB at least 80% of the time. Exceptions occurred mainly for 250 Hz targets, the loud speech input level (G75), 3000 Hz and above for severe to profound losses, and MPO targets. The 250 Hz variance from targets occurred mostly for mild losses for the DSL prescriptive method only. As explained by Dillon (2012), this is likely due to the direct pathway for the unaided signal through the vent or open fitting. In this study, consistent with WIDHH clinical protocol,

Table 2. NAL-NL1 95% Confidence Intervals (in dB) by Frequency, Input Level, and Degree of Hearing Loss

Degree of Loss	Input Level	250 Hz	500 Hz	750 Hz	1000 Hz	1500 Hz	2000 Hz	3000 Hz	4000 Hz	6000 Hz
Mild										
	G55	0.8	0.7	1.4	0.9	1.6	1.1	0.8	2.4	3
	G65	0.5	0.6	1.5	1	1	0.5	0.5	0.8	2
	G75	0.9	0.7	3.6	3.1	2.9	2.1	1.4	1.9	3.2
	MPO	0.9	2.7	3.2	3.2	3.7	2.5	2.6	2.8	
Mod										
	G55	0.6	0.6	1.3	0.8	0.9	0.5	1.7	1.2	3
	G65	0.6	0.6	0.7	0.5	1.2	0.5	1.2	0.7	1.8
	G75	1.7	1.5	1.4	1.6	3.6	1.3	3.5	1.7	4.4
	MPO	1	1.9	3.9	1.7	1.7	1.5	2.2	1.7	
Mod-Sev										
	G55	1	0.5	1.1	0.8	1.7	0.6	4.7	1.7	5.1
	G65	0.8	0.4	0.4	0.6	0.6	0.5	0.7	0.6	3.6
	G75	2.4	1	1.8	2.2	1.7	1.6	0.8	1.2	1.7
	MPO	2.1	2.1	2.4	1.5	2.6	1.5	3.4	2.6	
Sev/Prof										
	G55	2.4	0.9	0.9	1.5	1.1	1.3	1.9	1.1	21.5
	G65	1.4	0.6	0.8	0.9	0.6	0.9	2.4	1.1	7.6
	G75	2.3	1.6	1.7	4.8	4.1	6.3	10.2	15.9	3.9
	MPO	2.8	2.3	2.3	2.3	3.2	1.8	2.3	3.3	

Note: Empty cells reflect insufficient data at these input levels and frequencies

Table 3. Percent of Fittings Within ±5 dB of Targets DSL v5.0 by Frequency, Input Level, and Degree of Hearing Loss

Degree of Loss	Input Level	250 Hz	500 Hz	750 Hz	1000 Hz	1500 Hz	2000 Hz	3000 Hz	4000 Hz	6000 Hz
Mild										
	G55	45	86	100	100	100	100	89	91	75
	G65	59	91	88	91	100	100	100	86	55
	G75	58	83	100	83	100	100	83	100	100
	MPO	70	62	71	76	86	76	94	67	61
Mod										
	G55	80	95	82	90	86	100	95	88	56
	G65	88	95	91	93	93	100	97	83	51
	G75	94	100	92	100	100	100	100	88	94
	MPO	73	50	33	48	90	68	74	60	48
Mod-Sev										
	G55	68	96	95	92	89	88	91	85	39
	G65	76	96	95	88	100	100	82	69	43
	G75	100	100	78	80	100	100	100	80	100
	MPO	50	42	50	69	87	54	72	62	26
Sev/Prof										
	G55	91	73	83	100	67	82	13	27	
	G65	100	71	71	92	90	100	75	33	
	G75	100	100	100	100	100	100	100	100	100
	MPO	73	75	83	83	89	92	57	8	

Note: Empty cells reflect insufficient data at these input levels and frequencies

the G65 and G55 real-ear measures were prioritized during fittings. The clinicians completed the G75 real-ear measures if time permitted and deemed necessary. As such, there were fewer available G75 data points to assess. The seemingly poor match to targets for MPO measures is due to the conservative approach taken by WIDHH clinicians that MPO targets do not necessarily need to be matched, but are provided as a reference point that should not be exceeded by a high level input signal. As well, as can be seen in Table 4, the hearing aids met 100% of the targets at some frequencies. However, in many cases, the prescriptive method did not generate targets at all frequencies for severe to profound losses. In cases where targets were available, they were matched, but the data pool is small and therefore this percentage may not reflect what can be achieved in all fittings.

The Speech Intelligibility Index (SII) is calculated based on the amount of audible signal provided by the hearing aid to make speech information available and useable for the hard of hearing listener (Byrne et al., 2001). The SII, a variant of the Articulation Index (AI), scores between 0.0 and 1.0. A greater proportion of the speech signal is available to the listener as the score approaches 1.0, which in turn suggests the individual's speech understanding will be greater (Abrams & McArdle, 2006). The Verifit® provides the SII for each speech test conducted. These results are shown in Table 5. We conducted an analysis of variance (ANOVA) for each input level to determine whether there were differences between the prescriptive methods with regards to calculated audibility. First, we compared SII values for the unaided condition to determine whether there were differences in audibility between the groups prior to amplification. An ANOVA with two independent variables:

Table 4. Percent of Fittings Within ±5 dB of Targets for NAL-NL1 by Frequency, Input Level, and Degree of Hearing Loss

Degree of Loss	Input Level	250 Hz	500 Hz	750 Hz	1000 Hz	1500 Hz	2000 Hz	3000 Hz	4000 Hz	6000 Hz
Mild										
	G55	92	93	78	85	93	93	94	91	100
	G65	96	96	89	89	93	100	100	92	82
	G75	78	100	57	44	57	89	88	71	38
	MPO		15		37	27	44	50	38	
Mod										
	G55	91	92	87	86	100	100	73	100	90
	G65	94	97	100	100	92	100	74	91	67
	G75	38	88	100	75	60	88	60	88	14
	MPO		3	10	19	33	33	36	8	
Mod-Sev										
	G55	71	97	83	90	91	94	80	89	50
	G65	84	100	100	94	100	97	100	96	83
	G75	64	91	75	73	86	91	100	100	100
	MPO		12	25	36	40	48	13	27	
Sev/Prof										
	G55	86	94	100	82	90	78	33	100	33
	G65	79	97	100	96	100	88	55	100	20
	G75	50	88	100	63	75	83	50	33	
	MPO	23	33	29	33	54	53	17	7	

Note: Empty cells reflect insufficient data at these input levels and frequencies

Table 5. Comparison of SII Between DSL v5.0 and NAL-NL1

	DSL v5.0			NAL-NL1		
Input level (dB SPL)	55	65	75	55	65	75
Mild						
	63 (12)	79 (12)	81 (10)	65 (10)	77 (10)	76 (5)
Moderate						
	42 (8)	63 (7)	75 (5)	57 (10)	71 (9)	75 (7)
Moderately- severe						
	31 (6)	47 (9)	67 (3)	35 (8)	50 (8)	62 (8)
Severe/ profound						
	11 (9)	30 (11)	39 (22)	15 (8)	26 (11)	37 (11)

The listed value is the mean SII and the standard deviation is in brackets

Prescriptive Method (2 levels: NAL and DSL) and Hearing Loss (4 levels: Mild, Moderate, Moderately-Severe, and Severe/Profound) revealed that there was a difference in unaided SII between the two groups ($F(1,221) = 6.526$, $p = .011$, $\eta^2 = .029$), with the group set to DSL targets having higher SII values without amplification than the group set to NAL targets. Thus, unaided SII was used as a covariate in subsequent analyses. There was a main effect of hearing loss, as expected ($F(3,221) = 330.959$, $p < .001$, $\eta^2 = .818$), and no interaction between hearing loss and prescriptive method ($F(3,221) = .502$, $p = .681$, $\eta^2 = .007$). The main effects of degree of loss are not reported further, as they are not central to the main questions of this paper.

For G55, the ANOVA revealed a significant difference between prescriptive methods ($F(1,216) = 35.023$, $p < .01$, $\eta^2 = .14$) such that the fittings with NAL targets had higher SII values than DSL. There was no interaction between prescriptive method and degree of hearing loss ($F(3,216) = 2.139$, $p = .096$, $\eta^2 = .029$).

For G65, the ANOVA revealed a significant difference between prescriptive methods, ($F(1,220) = 4.990$, $p = .026$, $\eta^2 = .022$), such that the fittings with NAL targets had higher SII values than DSL. There was no interaction between prescriptive method and degree of hearing loss ($F(3,220) = 2.453$, $p = .064$, $\eta^2 = .032$).

For G75, the ANOVA revealed no significant difference between prescriptive methods, ($F(1,68) = .578$, $p = .450$, $\eta^2 = .008$) and no interaction between prescriptive method and degree of hearing loss ($F(3,68) = .207$, $p = .891$, $\eta^2 = .009$).

In instances where the real-ear measures were not within ±5 dB of targets the clinicians noted the reasons, from the following list: insufficient gain at that frequency, feedback, frequency response of the hearing aid (i.e., a peak or dip in the frequency response of the aid that could not be resolved with the available gain handles), listener tolerance, and other. Within the "other" category, clinicians noted additional issues that prevented ability to achieve targets, including: a) adjustment at one frequency created an issue at another frequency; b) occlusion; c) MPO already at maximum; and d) for mild losses, in particular, the gain at 250 Hz was the same whether the aid was on or off (less gain could not be achieved and the gain exceeded the target regardless of whether the aid was on or off). There did not appear to be a pattern or predominant cause for the inability to match targets. Additionally, it was not possible to perform statistical analysis to determine if these issues were related to degree of hearing loss, hearing aid style, or level of hearing aid technology as there were insufficient instances of a poor match to targets.

Discussion

Real-ear measures are the standard tool to determine how well a hearing aid matches prescriptive targets (Mueller, 2005). Our results indicate that for all hearing loss ranges and at most frequencies, current hearing aid technology matched both NAL-NL1 and DSL v5.0 targets for soft (55 dB SPL), average (65 dB SPL), and loud (75 dB SPL) speech input levels within ±5 dB.

Adjusting hearing aids to match prescribed real-ear targets provides a consistent, well-researched starting point upon which clinicians may base the hearing aid fitting. In order for the client to accept and wear the hearing aid initially, the clinician may need to adjust the setting away from these targets (Aazh & Moore, 2007; British Society of Audiology and British Academy of Audiology, 2007). However, it is important to ensure the selected hearing aid is able to meet prescriptive targets for the individual even if adjustments need to be made based on hearing needs, tolerances, and preferences.

The tables provided in this study may be used as a general clinical reference tool to assess 'goodness of fit' of a clinician's hearing aid fittings with real-ear measures. It is not expected that every hearing aid fitting will result in all targets being matched within ±5 dB. However, a clinician should be able to conduct a file review and see that across clients the match to targets is at least as good as the percentages reported in the provided tables.

For each hearing aid fitting, it is important to assess the current performance of the aid as well as the reserve gain to accommodate future issues that may arise. In cases where there is a poor match to targets, the clinician may either reconsider the aid or address other physical fitting issues (e.g., poorly fitting mold or custom tip, venting leading to feedback issues, occlusion, etc.) to meet the client's needs. Alternatively, once the aid has been set to targets, if the client reports loudness tolerance issues and the gain is reduced, the clinician should counsel the client on the rationale, the impact it will have on hearing speech sounds, and future plans to adjust the aid as necessary for an optimal fitting.

The data reported in this study do not directly assess whether one prescriptive method is better than the other. Analysis of the aided audibility (speech intelligibility index; SII) values showed that the hearing aids set to NAL targets provided higher audibility (when corrected for unaided audibility) than the hearing aids set to DSL targets, for both 55 and 65 dB SPL input levels. The effect size was large for G55 and small for G65 (using Cohen's 1988 effect

size guidelines). It may be worth further investigation to determine whether these differences in audibility have an impact upon user benefit and satisfaction.

Further research is necessary to determine if there are differences among basic, mid-range, and advanced technology with regards to being able to match targets. It is also necessary to assess the ability to match targets for the newer version of NAL: NAL-NL2. Finally, research is necessary to assess whether one fitting protocol is ultimately more beneficial than another in terms of clarity, satisfaction, and benefit.

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End Notes

[1]The phrase *match to targets* is used in this study, however, *fit to targets* is also commonly used in other studies.

[2]Note: the file review was conducted just as NAL-NL2 was being released. To ensure consistency in the data, fittings using NAL-NL2 were not analyzed.

[3]Note: due to a small n in each of the severe and profound categories, these were combined.

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