REM AND SREM FITTING COMPARISONS OF VENTED AND UNVENTED HEARING AIDS USING THE AUDIOSCAN VERIFIT AND VERIFIT2

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PURPOSE

To compare the output of eighty hearing aids fitted using REM on the Audioscan VF2 hearing aid fitting system to the output of the same aids when run using: a) Simulated real ear measurement (SREM) in the 0.4 cc coupler on the VF2; b) Real ear measurement (REM) on the Audioscan VF1 hearing aid fitting system and c) SREM in the 2cc coupler on the VF1 for hearing aid fittings with clinically typical venting (Figure 1). The impacts of venting and the use of alternative couplers on REM/SREM agreement within and across test systems are evaluated in this study.

METHOD

Twenty-one adult participants with mild to severe hearing losses were fitted with Unitron behind-the-ear (BTE), in-the-ear (ITE); and/or, receiver-in-the-canal (RIC) hearing aids. Most participants were fitted with more than one style (BTE: n=18, ITE: n=10, RIC: n=12). Clinically typical vent sizes were used in BTEs and RICs. Fittings were fine tuned on Audioscan VF2 (version 4.2.2) using the REAR. Fittings were re-measured (SREM VF2, REM and SREM VF1 (version 3.12.2). SREMs of the RIC aids were completed in the VF2 using the Audioscan thin-tube, receiver in canal (TRIC) adaptor with the 0.4cc wideband coupler, and puttied to the HA-1 2cc-coupler in the VF1. All SREM fittings used the patient's VF2 foamtip wRECD, transformed to the HA-1 coupler for use with the VF1, and also transformed for use with BTE hearing aids when required. [(4)]

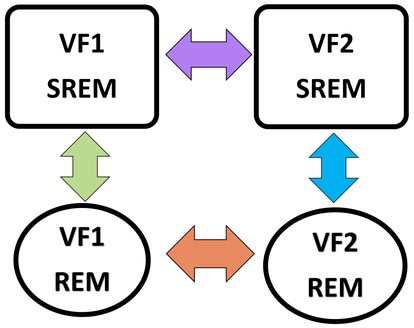

Figure 1. Conceptual illustration of comparisons made in this project, both between- and within-system. Each comparison was made for left and right ears of BTE, ITE, and RIC hearing aid styles.

ANALYSES

Repeated-measures Analysis of Variance (ANOVA, GLM SPSSv23) was used to evaluate between-measurement differences per level and across frequency. If significant differences were revealed, post-hoc paired comparisons were completed (with Bonferroni corrections) to locate any frequencies at which significant measurement differences occurred. Significant comparisons with differences greater than ±3 dB are flagged with asterisks (*) in the figures and are bolded in the tables shown to the right. This 3 dB criterion was chosen after review of 95% confidence intervals for test-retest variance and fit to targets variance for well-fitted hearing aids.[(1,2,3,5,6)]

Where differences were observed, we reviewed individual cases and product support information to develop likely explanations and to conclude whether the differences have impact for clinical practice. Interpretations are provided.

Case Example (BTE, REM and SREM verification):

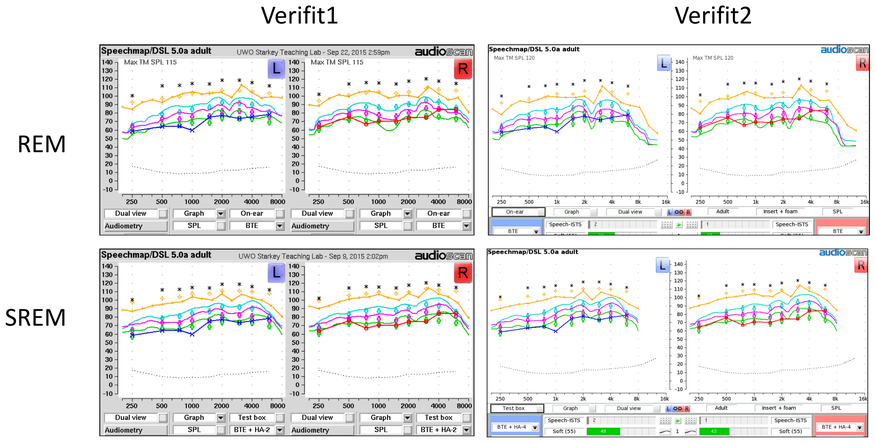

Figure 2. Verifit 1 and Verifit2 measures made with the same patient and same BTE hearing aid, using real ear measurement (REM) and simulated real ear measurement (SREM).

Mean differences across system, level, and style:

Table 1. Mean differences between measurement conditions, for the same hearing aids, patients, and hearing aid settings. Specific conditions are listed in top row of each table, and hearing aid style, test level, and sample size are shown in the leftmost column. Means that differed significantly in post hoc pairwise comparisons (Bonferroni adjusted) and that exceed ±3 dB are indicated in bold font. For BTE hearing aids, reference data from unvented BTEs [(5)] are also shown for REM/SREM comparisons.

1a. Verifit 1: REM - SREM (dB)

Frequency (Hz)		250	500	750	1000	1500	2000	3000	4000	6000	8000
ITE n=20	55 dB	**5.9**	1.55	1.46	-0.96	-1.26	1.10	0.07	**-5.65**	**-8.27**	-.03
	65 dB	**5.4**	2.11	2.00	-0.51	-.45	1.72	0.1	**-3.99**	**-6.88**	1.27
	75 dB	**6.46**	2.7	2.18	-.07	-0.73	1.38	-0.37	**-3.86**	**-6.31**	1.29
	MPO	Comparison not completed due to different test levels									
BTE n=36	55 dB	**4.34**	0.68	2.30	-0.91	-2.10	-1.67	0.31	-2.79	-2.79	**3.60**
	65 dB	**5.62**	2.67	**4.55**	0.45	-1.28	-1.15	0.20	**-3.09**	-1.85	**3.88**
	75 dB	**5.38**	**3.93**	**6.44**	1.00	0.25	-0.03	0.02	-2.76	-1.48	**4.20**
	Munro & Millward	.88	1.1	1.1	2.25	1.1	1.8	1	1.45	1.6	NR
RIC n=24	55 dB	0.60	**-6.66**	**-4.84**	-2.40	2.24	1.61	2.92	-0.32	-2.57	-1.82
	65 dB	-0.95	**-7.33**	**-4.83**	-2.86	2.38	1.74	2.52	-0.38	-2.84	-2.02
	75 dB	0.43	**-5.60**	-1.67	-0.28	**4.06**	**3.36**	**3.22**	0.18	-1.82	-1.63
	MPO	Comparison not completed due to different test levels									

1b. Verifit 1: SREM - Verifit 2 SREM (dB)

Frequency (Hz)		250	500	750	1000	1500	2000	3000	4000	6000	8000
ITE n=20	55 dB	2.52	**4.36**	2.29	0.96	1.45	2.37	2.60	**4.08**	**6.84**	**8.53**
	65 dB	1.54	**3.46**	2.78	1.87	0.46	0.79	2.54	**3.19**	**3.74**	**5.06**
	75 dB	2.25	2.83	**3.17**	0.41	-0.21	0.50	2.15	2.20	**3.12**	**4.26**
	MPO	1.17	**3.76**	2.95	1.14	-0.21	0.76	2.48	1.52	**3.05**	1.10
BTE n=36	55 dB	**3.74**	**4.14**	2.16	0.56	2.37	0.95	**-4.36**	-2.30	**3.17**	**-4.62**
	65 dB	1.95	2.22	1.53	1.41	2.01	0.16	-2.34	-1.95	1.07	**-7.22**
	75 dB	2.03	1.95	2.36	0.96	1.54	0.41	-2.02	-1.98	1.02	**-7.85**
	MPO	1.21	-0.12	0.56	3.02	1.28	0.86	-0.08	-1.04	2.28	**-5.49**
RIC n=24	55 dB	-1.58	-0.51	-1.86	-2.00	-0.58	0.21	-1.63	-0.96	-0.20	0.90
	65 dB	0.29	0.35	-0.70	-0.78	-0.55	-0.28	-0.27	-0.18	-1.47	-0.94
	75 dB	-0.05	-0.09	0.07	-1.13	-1.27	-0.84	-0.69	-0.68	-1.37	-1.43
	MPO	0.90	2.16	0.05	0.15	-0.21	-0.68	-0.23	0.29	-1.05	-2.56

1c. Verifit 2: REM - SREM (dB)

Frequency (Hz)		250	500	750	1000	1500	2000	3000	4000	6000	8000
ITE n=20	55 dB	**7.16**	**3.55**	1.5	-0.02	**-3.55**	-.02	1.09	-3.08	**-7.52**	-.29
	65 dB	**7.11**	**3.75**	1.97	.017	-2.58	.077	1.26	-1.22	**-4.83**	-.21
	75 dB	**7.72**	**5.21**	2.99	-1.1	-1.84	2.24	2.13	-.43	-2.73	2.5
	MPO	Comparison not completed due to different test levels									
BTE n=36	55 dB	**7.69**	4.09	**5.58**	0.59	-0.49	-2.64	-1.96	**-5.97**	-2.49	**-7.88**
	65 dB	**7.41**	3.94	**5.30**	0.56	-0.71	-2.35	-2.41	**-5.96**	-1.58	**-8.41**
	75 dB	**6.84**	**5.24**	**7.35**	2.00	1.34	-0.06	-1.18	**-4.49**	-0.43	**-7.44**
	Munro & Millward	.88	1.1	1.1	2.25	1.1	1.8	1	1.45	1.6	NR
RIC n=24	55 dB	-1.50	**-8.88**	**-5.87**	-2.74	0.58	0.79	2.75	**-3.62**	**-5.63**	**-5.13**
	65 dB	-1.73	**-8.92**	**-6.02**	-2.61	1.09	1.15	2.95	-2.70	**-4.48**	**-5.43**
	75 dB	-0.15	**-6.88**	**-3.44**	-0.13	2.73	2.35	**3.86**	-1.01	-2.83	**-3.61**
	MPO	Comparison not completed due to different test levels									

1d. Verifit 1: REM - Verifit 2 REM (dB)

Frequency (Hz)		250	500	750	1000	1500	2000	3000	4000	6000	8000
ITE n=20	55 dB	0.95	1.42	1.37	-0.77	2.74	2.67	0.05	0.54	**5.28**	**7.80**
	65 dB	-0.17	1.83	2.81	1.19	2.59	1.74	1.38	0.42	1.69	**6.54**
	75 dB	0.29	1.03	2.79	-0.19	1.41	0.25	0.04	-0.75	0.19	**3.58**
	MPO	**3.37**	1.26	1.06	0.81	1.79	0.99	0.43	1.39	0.02	1.72
BTE n=36	55 dB	0.40	0.72	-1.12	-0.94	0.76	1.91	-2.08	0.88	2.88	**6.86**
	65 dB	0.15	0.95	0.78	1.30	1.45	1.36	0.26	0.91	0.80	**5.07**
	75 dB	0.57	0.64	1.45	-0.04	0.46	0.44	-0.82	-0.24	-0.02	**3.79**
	MPO	**3.89**	1.10	0.80	1.49	1.88	1.97	0.47	0.91	1.23	1.00
RIC n=24	55 dB	0.52	1.71	-0.83	-1.66	1.07	1.04	-1.45	2.34	2.87	**4.21**
	65 dB	0.00	1.59	0.72	-0.78	0.75	0.27	-0.83	2.03	0.15	2.51
	75 dB	0.53	1.19	1.84	-1.29	0.06	0.17	-1.33	0.50	-0.36	0.55
	MPO	**3.12**	2.25	1.97	0.91	3.30	3.03	1.37	2.95	2.48	2.79

Mean frequency responses (BTE, REM):

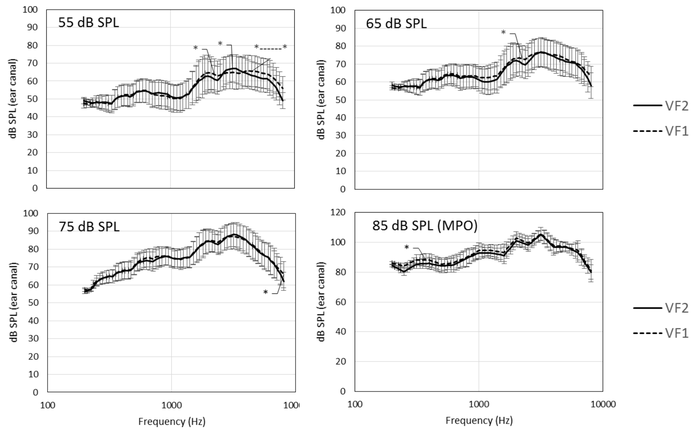

Figure 3. Mean frequency responses for VF-1 and VF-2 for the BTE group (bars show one standard deviation), across test level.

RESULTS

- Across all styles of hearing aids (BTE, ITE, RIC), results suggest good between-system agreement for REAR, within ±3 dB between 500 and 4000 Hz across levels and hearing aid styles (Table d). This is comparable to previous studies of BTE REM/SREM (Table 1a, 1c), to variation around prescriptive targets for well-fitted hearing aids, and to variation attributable to test-retest of real ear measurement [(1,2,3,5,6)]
- Some between-system differences were observed at the **test level of 55 dB**, due to a test signal spectrum difference between systems. This input difference is ≤2.3 dB, and is **removed in updated software** (VF1 3.12.12).
- At the **troughs of measurement**, the VF2 system has a lower measurement noise floor (e.g., Figure 3). This accounts for differences in individual measurement troughs, as well as between-system **differences at 8000 Hz** for non-RIC fittings that have little hearing aid output. At these frequencies, the VF1 displays higher SPL than the VF2, if the measurement fell into noise floor.
- **Vented fittings and some ITE fittings** had measurement error during coupler-based verification (SREM), with average errors in the low frequencies of up to 9 dB. Individual errors occurred in both directions, occurred even for vents of moderate size (e.g., 2 mm), and showed patterns related to (a) unaided sound entering through the vent; (b) aided sound leaking out of the vent; and (c) different noise floors present in the sealed test box versus in a quiet verification room. This pattern of results indicates that **on-ear verification** is likely the best choice for these fitting types.
- **Coupler-based fittings** showed good consistency for ITE, BTE, and RIC fittings. For RICs, this evaluates the use of the TRIC adaptor for coupler-based fitting, and is comparable to putty-based coupling.

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