RogerDirect FM Transparency: A Comparison of Phonak Belong and Marvel Instruments

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ABSTRACT

This study assessed FM transparency for the Phonak RogerDirect remote-microphone receiver as a function of Phonak Marvel and Phonak Belong hearing instruments. Four electroacoustic assessments resulting in three offset measures (FM Ready, FM Muted, and FM Offset) were completed. An examination of the FM Offset data (AAA, 2011) revealed a significant effect of hearing aid (Marvel vs Belong), with no significant effect of receiver and no hearing-instrument by receiver interaction. Implications of these findings for remote-microphone system selection and FM-offset protocols are discussed.

INTRODUCTION

American National Standards Institute standards state that unoccupied classrooms should not exceed 35 dBA or a reverberation time of 0.6 to 0.7 seconds (ANSI, 2010). However, in the United States these standards are often not met and classrooms have been shown to be noisy environments that generally have a poor signal-to-noise ratio (SNR), high reverberation time, and excessive speaker-to-listener distance (Crandell & Smaldino, 2000; Knecht et al., 2002; Pugh et al., 2006). Distance, noise, and reverberation all negatively impact students' access to content delivered by their teacher. This is especially true for students with hearing loss, who have been shown to need a greater SNR to perform at their best, as compared to their typically-hearing peers (Neuman et al., 2010). Current clinical guidelines recommend that students with hearing impairment experience a classroom SNR of +15 dB to + 20 dB, a condition rarely achieved by way of hearing instruments alone (American Academy of Audiology [AAA], 2011; American Speech-Language-Hearing Association [ASHA], 2002, 2005; Hawkins, 1984; Nelson & Soli, 2000).

Remote-microphone systems, where a microphone that is distant from the hearing instrument wirelessly delivers a target signal to the listener, provide a solution to overcoming the problems of classroom noise, reverberation, and listening distance (Lewis et al., 2005; Schafer et al., 2007; Mehrkian et al., 2019; Lewis et al., 2022). Wireless signal transmission can include frequency-modulated (FM, 216-217 MHz) radio, digitally-modulated (DM, 2.4 GHz) radio, Bluetooth (BT), infrared, and induction-loop technologies. Remote-microphone systems include those designed for individual listeners (i.e., personal systems) and those designed for multiple listeners (i.e., group systems). Personal remote-microphones systems include those that can be coupled to hearing aids, cochlear implants, and osseointegrated devices (Thibodeau, 2010; Schafer et al., 2020; DeConde Johnson & Seaton, 2021).

Personal remote-microphone systems that couple to hearing aids include a microphone-transmitter and one or more receivers and receiver-adaptors, depending on the configuration of the student's personal-listening device(s). Commonly, the teacher wears the microphone-transmitter and the student wears a receiver plus receiver-adapter (i.e., audioshoe) with each hearing aid. The earliest systems of this kind used FM signal transmission and although many now utilize DM signals instead, the convention of referring to personal remote-microphone systems that couple directly to hearing aids as "FM systems" remains (and will be used in this paper).

Recently Phonak, Inc has released a new remote-microphone system receiver, RogerDirect, that can be directly uploaded into a specially-designed (e.g., Marvel platform) hearing aid or, alternatively, coupled via an audioshoe to an older platform instrument. When uploaded into a compatible instrument, RogerDirect does not require that the student attach an FM receiver and audioshoe to their hearing aid, thus reducing the size and weight of what is worn on the ear. In addition, the elimination of the need to attach an FM receiver and audioshoe to the student's instruments reduces the number of connections and signal transformations in the hearing aid/FM system coupling, thus representing a more desirable FM fitting (AAA, 2011).

Current guidelines call for educational audiologists to verify the performance of FM systems used with student hearing aids via a test of "transparency" (AAA, 2011; Jacob et al., 2021; Qi & Thibodeau, 2023). Per the AAA protocol, transparency is assessed by way of three consecutive test box measures and a single, three-frequency average determination of "FM offset." The three measures are: 1) electroacoustic response of the hearing instrument (alone) for a 65 dB SPL speech input; 2) electroacoustic response of the hearing instrument when coupled to the FM system, while the FM transmitter-microphone is on but muted and the hearing aid is in the test box (65 dB SPL speech input); and 3) electroacoustic response of the hearing instrument when coupled to the FM system, while the FM transmitter-microphone is not muted and the FM transmitter-microphone is in the test box (65 dB SPL speech input). The FM offset calculation is completed by subtracting the hearing instrument output for the second assessment from the third for 750, 1000, and 2000 Hz. The average of these three difference scores is the FM offset. FM transparency is achieved when inputs of 65 dB SPL to a wireless microphone and to a hearing aid microphone (while coupled to a muted FM transmitter-microphone) produce equal hearing-instrument outputs (AAA, 2011).

As noted above, RogerDirect FM receivers have the option of either being physically connected to an older platform hearing aid via an audioshoe (coupled mode) or being installed directly into a RogerDirect-compatible hearing aid (uploaded mode). This backwards-compatibility is important because it allows schools to have greater flexibility in the use of these units across a larger number of children and hearing instruments. Despite the benefits and flexibility of the new RogerDirect design, little is known about the relative performance of this device in the uploaded mode as compared to the traditional audioshoe coupling.

PURPOSE

The purpose of this study is to comparatively assess FM transparency, as quantified by FM offset, for the RogerDirect FM receiver under two conditions: 1) physically connected to a hearing instrument that does not allow a RogerDirect upload and 2) uploaded into a RogerDirect-compatible instrument. These data are important because they can help inform the FM-system selections educational audiologists make for students who use these instruments.

METHOD

Equipment

The following devices were used for the purposes of this study. Phonak Sky hearing aids were chosen as they included both RogerDirect and non-RogerDirect instruments.

1) Four RogerDirect receivers.

2) Four Sky B90 P ("Belong") Phonak non-RogerDirect hearing instruments.

3) Four AS18 audioshoes.

4) Four Sky M90 M ("Marvel") Phonak RogerDirect-compatible hearing aids.

5) One Phonak Roger Touchscreen FM transmitter-microphone.

Hearing aids were confirmed to meet ANSI S3.22-2009 specifications through electroacoustic analysis completed in the Audioscan Verifit 2 (American National Standards Institute [ANSI], 2009). For the purposes of the present study, each hearing aid was programmed as follows.

1) Hearing loss = 40 dB (250-8000 Hz) as measured via inserts.

2) Fitting formula = DSL v5a Pediatric.

3) Adaptation = 100%.

4) Acoustic coupling = standard earmold, 0.6-0.8 mm vent; standard tubing; damped tonehook.

Additionally, and per the AAA (2011) protocol, each RogerDirect receiver was assessed while in the factory default setting of a +10 dB FM advantage. The Belong hearing instruments were set to "Roger-Ready Roger/DAI + mic" and operated under factory default settings for directionality. The Marvel hearing aids were set to auto-detect "RogerDirect + mic" and operated under factory default settings for directionality. All toggles, switches, and buttons were deactivated on all instruments. All other settings were left at factory default positioning/levels.

A Quest sound level meter (model 2100) was used to measure ambient noise levels during instrument testing. Tests of transparency were conducted using an Audioscan Verifit 2 test box, which included a binaural coupler microphone, two testbox reference microphones, two 0.4cc wideband couplers for

BTE hearing aids, two hearing instrument stabilizers, two TRIC adaptors with earmold substitutes, and a microphone extension cable. A new Roger Installer was utilized to install/uninstall the RogerDirect into the Marvel hearing aids.

Procedure for FM Transparency Testing

Tests of FM transparency were completed using an electroacoustic assessment protocol based on the AAA (2011) guidelines, with an additional assessment of hearing aid performance following the attachment of an audioshoe (Belong) or the uploading of the RogerDirect receiver (Marvel; i.e., Assessment #2). Assessment #2 allowed for an opportunity to examine any effects of readying the hearing aids for FM (e.g., potential offset associated with adding a physical adaptor or FM receiver to the hearing aid). Specifically, for each instrument/FM system coupling, a total of four electroacoustic assessments were completed. All assessments were completed via the Verifit 2 startup menu under "test box" and "speechmap" measures. For the Belong hearing aids, they were completed as follows.

1) Assessment #1: Hearing Aid Alone[1]. The hearing aid was attached to the 0.4 cc TRIC BTE coupler and placed inside the test box adjacent to the reference mic using the holsters. The test box was closed. In the field for "Test 1" a signal level of 65 dB SPL was selected for "Speech-std(F)" and the response was captured.

2) Assessment #2: FM Ready[2]. The audioshoe (only) was attached to the hearing aid. The hearing aid was returned to the test box and placed as above. The test box was closed. In the field for "Test 2" a signal level of 65 dB SPL was selected for Speech-std(F) and the response was captured.

3) Assessment #3: FM Muted[3]. The FM receiver was attached to the audioshoe (on the hearing aid). The hearing aid was returned to the test box and placed as above. The microphone-transmitter was turned on, set to verification mode, confirmed to be paired with the FM receiver, muted, and set to the side. The test box was closed. In the field for "Test 3" a signal level of 65 dB SPL was selected for Speech-std(F) and the response was captured.

4) Assessment #4: FM[4]. The hearing aid was removed from the test box with the FM receiver, audioshoe, and 0.4 cc TRIC BTE coupler still attached. It was placed to the side on a foam pad. The FM microphone-transmitter was unmuted and placed in the test box adjacent to the reference mic and oriented to the center speaker. The test box was closed. In the field for "Test 4" a signal level of 65 dB SPL for Speech-std(F) was selected and the response was captured.

For the Marvel hearing aids, the four electroacoustic assessments were completed as follows.

1) Assessment #1: Hearing Aid Alone[5]. The hearing aid was confirmed to not have RogerDirect installed (via the Phonak Roger Installer) and was then attached to the 0.4 cc TRIC BTE coupler and placed inside the test box adjacent to the reference mic using the holsters. The test box was closed. In the field for "Test 1" a signal level of 65 dB SPL for Speech-std(F) was selected and the response was captured.

2) Assessment #2: FM Ready[6]. The hearing instrument was removed from the test box and placed in position on top of the Roger Installer. The RogerDirect receiver was plugged into the Roger Installer and installed into the hearing aid per Phonak RogerDirect installation procedures (Phonak, n.d.). The hearing aid was returned to the test box and placed as above. The test box was closed. In the field for "Test 2" a signal level of 65 dB SPL was selected for Speech-std(F) and the response was captured.

3) Assessment #3: FM Muted. The microphone-transmitter was turned on, set to verification mode, confirmed to be paired with the hearing aid, muted, and set to the side. The test box was closed. In the field for "Test 3" a signal level of 65 dB SPL for Speech-std(F) was selected and the response was captured.

4) Assessment #4: FM. The hearing aid was removed from the test box with the 0.4 cc TRIC BTE coupler still attached. It was placed to the side on a foam pad. The FM microphone-transmitter was unmuted and placed in the test box adjacent to the reference mic and oriented to the center speaker. The test box was closed. In the field for "Test 4" a signal level of 65 dB SPL for Speech-std(F) was selected and the response was captured.

All assessments were completed using the Verifit 2 in the simultaneous binaural mode, with like-models of hearing instruments comprising the pairs (i.e., Marvel and Marvel, Belong and Belong). Each of the four RogerDirect receivers was coupled to each of the four Belong and each of the four Marvel hearing aids resulting in a total of 32 hearing aid + FM receiver couplings. Each of the 32 hearing aid + FM receiver couplings was assessed twice (counter-balanced for right/left Verifit position). As noted above, these 64 assessments were completed in the simultaneous binaural mode, resulting in 32 simultaneous binaural assessments. The order of assessment (i.e., hearing instrument 1-4 coupled to FM receiver 1-4) was randomized.

Test box reference-microphone calibration and sound-level measurements of ambient room noise were completed prior to each set of transparency measures and a new hearing aid battery was used for each instrument in each transparency assessment. A listening check was performed prior to both the FM-muted and FM

[1]Equivalent to the AAA (2011) EHA65SPL assessment.
[2]Equivalent to the AAA (2011) EHA65SPL assessment, but with audioshoe attached to the hearing instrument.
[3]Equivalent to the AAA (2011) EHA/FM65SPL assessment.
[4]Equivalent to the AAA (2011) EFM/HA65SPL assessment.
[5]Equivalent to the AAA (2011) EHA65SPL assessment.
[6]Equivalent to the AAA (2011) EHA65SPL assessment, but with RogerDirect installed in the hearing instrument.

assessments to ensure that the hearing aids and FM systems were connected.

For both Marvel and Belong hearing instruments, three FM offset values were calculated for each instrument in each condition using a modified AAA (2011) protocol. As outlined below, hearing instrument output was compared between assessments #1 and #2, #2 and #3, and #3 and #4 at 750, 1000, and 2000 Hz. Mean difference score data were used for analysis.

1) FM Ready Offset. Hearing instrument output for assessment #1 (HA Alone) was subtracted from hearing instrument output for assessment #2 (FM Ready).

2) FM Muted Offset. Hearing instrument output for assessment #2 (FM Ready) was subtracted from hearing instrument output for assessment #3 (FM Muted).

3) FM Offset. Hearing instrument output for assessment #3 (FM Muted) was subtracted from hearing instrument output for assessment #4 (FM).

A summary of the four electroacoustic assessments and three offset measures is provided in Table 1.

RESULTS

Reliability

A second trained individual completed one assessment of FM transparency for each of 5 pairs of randomly-selected hearing instrument/receiver combinations (15% of the primary data set). The difference between the original and second-examiner FM offset values ranged from -0.33 to 2.0 dB. A Wilcoxon signed-rank test performed on the paired data was not significant ($p > .05$).

Offset Data

An analysis of variance (ANOVA) was performed for each of three data sets: 1) FM Ready Offset, 2) FM Muted Offset, and 3) FM Offset. The assessment of the FM Ready Offset data indicated no significant effect of hearing instrument ($F_{1,56} = 1.45$, $p > .05$) or receiver (i.e., Roger Direct 1-4; $F_{3,56} = 0.50$, $p > .05$), and no significant hearing instrument by receiver interaction ($F_{3,56} = 0.10.$, $p > .05$). An examination of the hearing instrument means revealed FM Ready Offset values of -0.01 dB and -0.11 dB for the Belong and Marvel instruments, respectively. These data suggest that readying a hearing instrument to couple to an FM system, either by attaching an audioshoe or uploading a Roger receiver, does not differentially impact hearing aid output.

The analysis of the FM Muted Offset data indicated a significant effect of hearing instrument ($F_{1,56} = 24.6$, $p < .001$), no significant effect of receiver (i.e., Roger Direct 1-4; $F_{3,56} = 0.69$, $p > .05$, and no significant hearing instrument by receiver interaction ($F_{3,56} = 0.35.$, $p > .05$). An examination of the hearing instrument means revealed FM Muted Offset values of -0.31 dB and 0.07 dB for the Belong and Marvel instruments, respectively. These data suggest that the FM coupling mode (physical connection or

Table 1

Summary of electroacoustic assessments and offset measures.

Assessment	HAT Receiver	HAT Transmitter-Mic	Input	Offset Measure
1. HA Alone	(n/a)	off	HA, 65 dB SPL	(n/a)
2. FM Ready	*Belong* audioshoe attached to HA; *Marvel:* Roger installed	off	HA, 65 dB SPL	FM Ready Offset = (FM Ready) - (HA Alone)
3. FM Muted	*Belong:* receiver attached to audioshoe; *Marvel:* Roger installed	on, muted	HA, 65 dB SPL	FM Muted Offset = (FM Muted) - (FM Ready)
4. FM	*Belong:* receiver attached to audioshoe *Marvel:* Roger installed	on, unmuted	FM, 65 dB SPL	FM Offset = (FM) - (FM Muted)

upload) affects hearing aid output when the Roger FM system is on and the FM microphone is muted, with less impact for Marvel than Belong instruments.

Finally, an analysis of variance of the FM Offset data indicated a significant effect of hearing instrument (i.e., Belong vs Marvel; $F_{1,56} = 11.43$, $p < .01$), no significant effect of receiver (i.e., RogerDirect 1-4; $F_{3,56} = 0.08$, $p > .05$), and no significant hearing instrument by receiver interaction ($F_{3,56} = 0.16.$, $p > .05$). An examination of the hearing instrument means revealed FM Offset values of 3.74 dB and 2.98 dB for the Belong and Marvel instruments, respectively. These data suggest that the mode of FM coupling affects hearing instrument output when the FM system is on and the FM microphone is unmuted (i.e., active), with a greater impact on Belong than Marvel instruments. A summary of instrument (Belong, Marvel) means by offset measure (FM ready, FM Muted, FM) is provided in Figure 1.

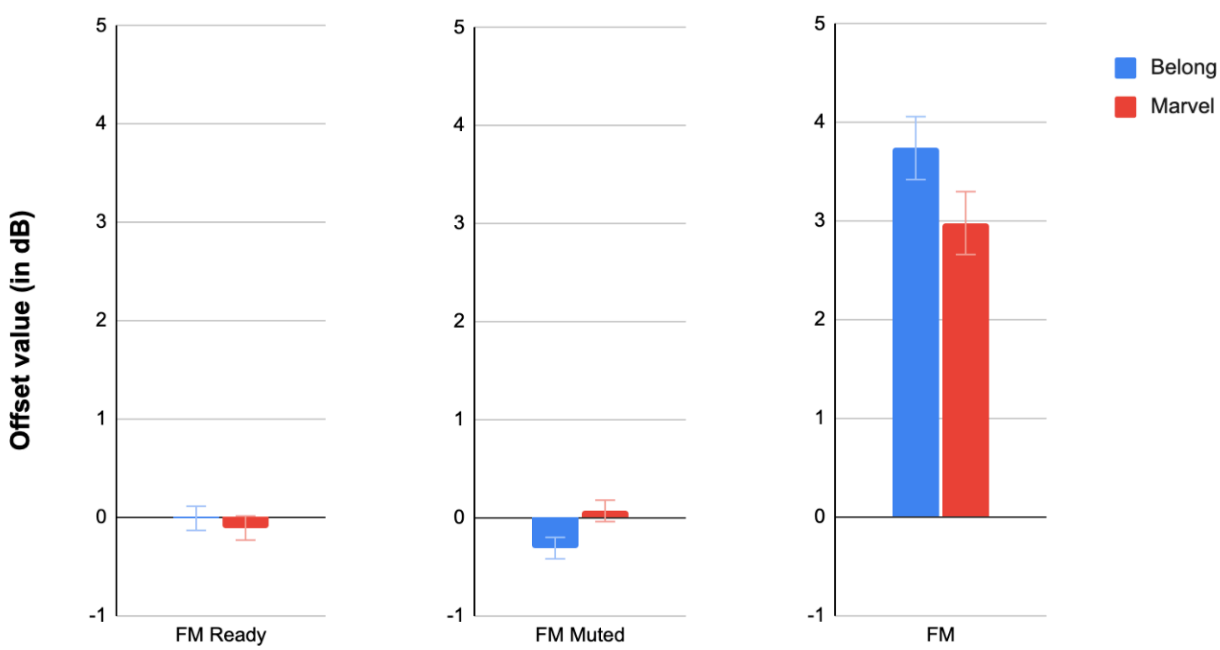
DISCUSSION

The findings of the present study indicate that hearing aid output was not affected by readying Belong and Marvel hearing instruments for Roger FM, either by attaching an audioshoe or uploading a Roger receiver into a Roger-ready instrument. This is important because students who use Belong instruments may wear an audioshoe, without a receiver attached, on their hearing aid when outside the classroom. Similarly, Roger can be expected to remain installed in a Marvel hearing instrument when the hearing aid is worn outside of school and without using the FM system. In either case, hearing instrument output is not affected by the instrument's readiness to use Roger FM.

In contrast, a physical vs uploaded Roger connection does affect hearing instrument output when coupled to an active FM system, with better outcomes (statistically less offset) for the uploaded (Marvel) mode – both when the FM microphone is muted (FM Muted Offset) and when it is active (FM Offset). In terms of clinical decision-making, the FM Muted Offset values found for the present study would not have resulted in different actions, and thus although statistically significant, are of low clinical importance. For both instruments, the offset was < +/- 1 dB and thus unlikely to result in a clinician rejecting the FM system in favor of an alternative. In addition, as FM Muted Offset reflects hearing instrument performance when teachers interrupt their FM broadcast, the data of the present study suggest that student listening via personal hearing instruments, either Belong or Marvel, would not be affected by the microphone of a coupled FM system being muted. This is important because students may

Figure 1

Offset value (in dB) for Belong and Marvel instruments as a function of offset measure (FM ready, FM Muted, FM). Error bars represent 95% Confidence Intervals, by ANOVA.



be expected to rely on hearing aid listening alone when their teacher mutes the microphone of a coupled FM system. Unlike the FM Muted findings, the FM Offset values observed by instrument type in the present study could result in different clinical actions. Specially, assuming a goal of minimizing FM Offset and that positive residual offset is more desirable than negative, an FM Offset of 3.74 dB (Belong) would lead to a 4 dB reduction in FM gain, while 2.98 dB of FM Offset (Marvel) would lead to the FM gain being reduced by 2 dB.

Overall, the findings of the present study suggest that the number of connections between an FM transmitter-microphone and a coupled hearing instrument impacts FM Offset, with fewer connections resulting in better performance. Compared to an uploaded RogerDirect receiver, using an audioshoe results in two additional connections (the receiver to the audioshoe and the audioshoe to the hearing aid) over the same receiver uploaded into a compatible hearing instrument. Although this offset may be corrected by adjusting the receiver's FM gain, the present study's finding provides empirical support for selecting FM systems that allow for the fewest possible connections and signal transformations when coupling to hearing instruments (AAA, 2011).

The present study's findings also highlight the importance of assessing FM transparency for each hearing instrument/FM system coupling. Regardless of the manner in which a receiver is coupled, assessing FM Offset is important for effective clinical decision making when fitting an FM system. The data of the present study also suggest the potential utility of expanding the AAA (2011) protocol to include FM Ready and FM Muted measures. These additional offset measures could support clinical confirmation of the appropriateness of an FM system under all student listing conditions – when using a personal instruments that is FM ready (only), when using their instruments when the FM system is active but then teacher microphone is muted, and when the FM system is active and the microphone is in use.

As other comparative FM Offset data for the RogerDirect have not been published to date, the current findings must be interpreted with caution. The present study examined a limited number of devices, each set to specific parameters. Further study expanding the number, type, and settings of instruments is warranted and would expand our understanding of the effect of hearing-instrument coupling on FM system performance.

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