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# Towards a Functional Hearing Test for Musicians: The Probe Tone Method

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# 14 Towards a Functional Hearing Test for Musicians: The Probe Tone Method

BY FRANK A. RUSSO

The relationship between hearing outcomes in the real world and hearing thresholds obtained by pure-tone audiometry has long been recognized as weak (Davis, 1947; Hirsch, 1952). This fact presents a problem for hearing aid fitting and will continue to do so as long as people wish to use hearing in their day-to-day living. Over the last few decades, the problem has been alleviated to some extent by what have come to be known as functional hearing tests. Generally, these tests assess some aspect of real-world hearing (e.g., speech perception) under simulated real-world conditions (e.g., noisy environments). Examples of such tests include the SPIN-R (Bilger, Nuetzel, Rabinowitz, & Rzeczkowski, 1984; Kalikow, Stevens, & Elliot, 1977) and HINT tests (Nilsson, Soli, & Sullivan, 1994). In both tests, the procedure involves having the participant repeat back words presented in a background of noise. Word identification accuracy can be used to differentiate individuals who would otherwise be judged equivalent on the basis of pure-tone audiometry alone (Pichora-Fuller, Schneider, & Daneman, 1995). Thresholds obtained from pure-tone audiometry may also be inadequate for predicting hearing outcomes in the real world of musicians.

Although functional aspects of hearing can and probably should be discussed informally during a fitting, there may be additional benefit obtained from the administration of formal tests that have been designed to address functional aspects of hearing for musicians. The benefit of formal tests is potentially very high when one considers the paucity of theory and evidence regarding optimization of hearing aids for music (Chasin & Russo, 2004). In short, it appears that there is a need for the development of new tests for measurement of functional hearing in musicians. These functional tests for musicians could be incorporated into the fitting protocol as a supplement to more informal methods.

**KEY POINT**

There is a need for the development of new tests for measurement of functional hearing in musicians.

## WHAT EXACTLY CONSTITUTES FUNCTIONAL HEARING FOR MUSICIANS?

A working definition of functional hearing in musicians is simply the extent to which the hearing faculty may be used to support music production. The assessment of functional hearing will thus depend in part on the type of music that will be performed. For example, for musicians performing in a multipart group (such as a string quartet), they should be able to monitor their performance while remaining aware of what the other players are doing. For musicians producing music on a non–fixed-pitch instrument (e.g., violin), they should be able to hear slight intonation problems. For musicians who play an instrument with timbre that can be shaped (such as voice), they should be able to hear as much of the spectrum as possible. These challenges are not mutually exclusive and with a suboptimal capacity for hearing, can easily add up to drain the cognitive resources of the performer. These same cognitive resources might otherwise be allocated towards expressivity and communication with the audience.

Regardless of the particular performance challenges a musician is faced with, one aspect of functional hearing that is almost always required is sensitivity to tonality. Tonality refers to the hierarchical organization of pitches around the tonic or key-note of a piece. In Western music, this organization has been described as a four-level hierarchy of stability. The highest stability is assigned to the tonic tone (do), followed by nontonic triad tones (mi, so), followed by nontriadic tones (re, fa, la, ti), and finally the nonscale tones. Although this hierarchy tends to be most evident in classical music, it can be found in all genres of Western music including folk, pop, country, and punk. Across these different genres, pitches that occupy more stable positions in the hierarchy are more likely to start and end a piece and to occur more frequently. Tonal organization is interpreted and may be clarified by the musician through performance expression (Thompson & Cuddy, 1997). Beyond clarifying the overall structure of a piece, tonality is a determinant of tension (Smith & Cuddy, 2003), which is another critical aspect of performance expression. The process of interpreting and clarifying tonal organization is particularly important for music involving improvisation and/or frequent modulations between keys.

### KEY POINT

One aspect of functional hearing that is almost always required is sensitivity to tonality.

## PROBE TONE METHOD

The probe tone method can be used to quantify the psychological representation of tonality (Krumhansl & Shepard, 1979). In this method, the listener is provided with a key-defining context (e.g., a tone sequence based on the major triad) followed by a probe tone. On separate trials, a probe tone is drawn from each of the chromatic scale steps. The listener is asked to evaluate the extent to which each probe tone fits the context, normally on a seven-point scale that ranges from “fits very poorly” to “fits very well.” The set of probe tone ratings forms the probe tone

profile, which may be compared to a standardized profile. This comparison forms the basis of the proposed functional test of hearing for musicians.

The standardized profiles were derived from average probe tone ratings obtained across musically trained listeners and across a variety of key-defining contexts (Krumhansl & Kessler, 1982). They are consistent with music-theoretic descriptions of tonal stability and they may be used as a referent against which sensitivity to tonality may be estimated (Russo, Cuddy, Galembo, & Thompson, 2007). The strength of the correlation between a listener's probe tone ratings and the standardized profile is known as the recovery score and is reflective of the listener's sensitivity to tonality under a particular set of listening conditions.

Researchers in music cognition have used the probe tone method in order to study variability in sensitivity to tonality due to age (Halpern, Kwak, Bartlett, & Dowling, 1996; Minghella, Russo, & Pichora-Fuller, 2007), frequency range (Russo et al., 2007), and timbre (Cuddy, Russo & Galembo, 2007; Minghella et al., 2007). Although most listeners with healthy hearing will show sensitivity to the hierarchy of pitches implied by a key-defining sequence presented under ideal listening conditions, minor perturbations in the fine temporal structure of tones (e.g., inharmonicity) can lead to a significant loss in sensitivity to the tonal hierarchy—that is, lower recovery scores (Cuddy et al., 2007; Minghella et al., 2007). These perturbations are introduced naturally in tones produced by stringed instruments due to deviations from ideal elasticity (Galembo, Askenfelt, Cuddy, & Russo, 2001; Russo et al., 2007). Similar perturbations may be introduced by an impaired auditory system (Schneider & Pichora-Fuller, 2001) or theoretically by the hearing aid itself.

### KEY POINT

Researchers in music cognition have used the probe tone method in order to study variability in sensitivity to tonality due to age, frequency range, and timbre, and it may have some applicability to the assessment of musicians.

## HOW TO ASSESS FUNCTIONAL HEARING IN MUSICIANS

In order to implement the proposed test in a hearing clinic, it is advisable to have MIDI software that will allow you to encode and play back melodies. The playback feature should allow for specification of the playback instrument so that the test tones can be customized in accord with your client's principal instrument. There are free software programs available that have this capability.[1]

The test should be administered in blocks of trials, where each block involves a particular configuration of hearing aid settings. The ideal playback level should be adjusted so that the test tones are equivalent to the unaided threshold.[2]

[1] e.g., Anvil

[2] The tones are presented at the unaided threshold so as to present a challenging listening situation. In this test, musicians are not responsible for performance and are thus able to recruit relatively more resources than would be possible in a performance situation.

Each block includes 12 trials, consisting of one presentation each of all of the chromatic scale steps (in random order of presentation). Each trial consists of a key-defining melodic context (do-mi-do-so) followed by a probe tone after a 1-second rest. The exact transposition of the key-defining context does not matter, so long as it is major (which results in more consistent responding than the minor) and within the normal pitch range of the musician's instrument. Notation of example probe tone trials is provided in Figure 14–1 and Figure 14–2. The probe tone in Figure 14–1 fits reasonably well with the key-defining context, whereas the probe tone in Figure 14–2 does not.

**KEY POINT**

In the probe tone method the recovery score is reflective of the listener's sensitivity to tonality under a particular set of listening conditions.

## Interpreting the Results

The recovery score for a particular block is simply the correlation between the ratings and the standardized profile.[3] An example has been depicted in Table 14–1. Higher recovery scores indicate more sensitivity to tonality. The minimum recovery score is –1 and the maximum recovery score is +1. An acceptable recovery score for a musician would be .6 or greater.

The recovery scores for the example provided in Table 14–1 are .57 and .89 for the first and second settings, respectively. Further insights may be obtained by examining the pattern of probe tone ratings. In the example, the level of differentiation in stability ratings between tones for the first setting is quite poor and there seems to be a strong influence of pitch proximity from the tonic (i.e., stability ratings decreasing with greater pitch distance from tonic). Similar patterns of probe tone ratings have been observed in ratings obtained with pure

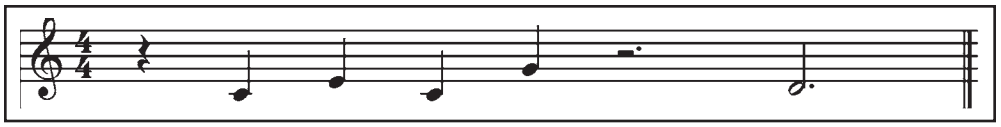

**Figure 14–1.** In this example of a probe tone trial, the key-defining context (do-mi-do-so) is followed by a probe tone (re) that fits reasonably well (i.e., a nontriadic scale tone).

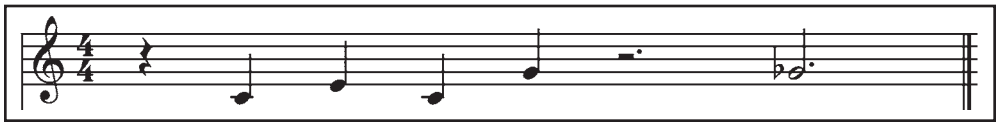

**Figure 14–2.** In this example of a probe tone trial, the key-defining context (do-mi-do-so) is followed by a probe tone (so-flat) that does not fit well (i.e., a nonscale tone).

[3]The standardized ratings are for the major mode and may thus be assigned to any major scale. For example, the standardized rating for G in G major would be equivalent to the standardized rating for C in C major (6.35).

**Table 14–1.** An example worksheet for a functional test of hearing for musicians based on the probe tone method

**Client:** Miles Davis

**Playback instrument:** Trumpet

**Key/Tonic (do):** C Major / C3

**Hearing Aid Setting I:** Parameter A: XX, Parameter B: XX, Parameter C: XX

**Hearing Aid Setting II:** Parameter A: XX, Parameter B: XX, Parameter C: XX

| *Scale Step* | *Ratings First Setting* | *Ratings Second Setting* | *Standardized Profile* |
|---|---|---|---|
| C | 5 | 7 | 6.35 |
| C# | 4 | 2 | 2.23 |
| D | 4 | 4 | 3.48 |
| D# | 3 | 3 | 2.33 |
| E | 3 | 5 | 4.38 |
| F | 3 | 4 | 4.09 |
| F# | 3 | 2 | 2.52 |
| G | 4 | 4 | 5.19 |
| G# | 3 | 2 | 2.39 |
| A | 3 | 5 | 3.66 |
| A# | 2 | 3 | 2.29 |
| B | 1 | 3 | 2.88 |
| **Recovery** | **.57** | **.89** | |

tones or with complex musical tones presented under adverse acoustic conditions (Cuddy et al., 2007).

## Test Materials and Considerations for Testing

Blocked stimuli files (MIDI, WAVE, MP3), response keys, and additional instructions are available from the author's Web site (http://www.ryerson.ca/smart/functional.html). As mentioned above, MIDI has the advantage of enabling customization (instrument and range). Nonetheless, the WAVE and MP3 files (realized with midrange piano tones) will give a reasonable indication of functional hearing and can be played using any media player.

If the performer is not a soloist, it may be advisable to perform the procedure with a background of pink noise. The spectral envelope of the pink noise is comparable to the long-term average spectrum

of music, and may be useful in simulating the streaming demands placed upon the performing musician. Regardless of whether the pink noise manipulation is used, measurement error can be reduced by using multiple blocks for a setting (ratings across blocks can be averaged) and by providing a few practice trials in anticipation of any block.

## GOING FORWARD: FORMALIZING THE PROPOSED TEST AND DEVELOPING OTHERS

An important aspect in the development of functional tests of hearing for speech has been the standardization process. In developing a functional hearing test for musicians, it would be ideal to aim for a similar level of rigor.

First, there is a need to demonstrate psychometric equivalence across different blocks (i.e., probe tone orderings) of the same test. This first issue may be broken down into a number of sub goals: (a) ensuring that different blocks of the same test are of equal difficulty; (b) ensuring that different blocks of the same test lead to homogeneity of variance; and (c) ensuring that the test is reliable such that measurements across multiple blocks of the same condition (e.g., same instrument and same settings) lead to comparable outcomes. In addition to the issue of equivalence across blocks, it would also be useful to establish test norms using representative samples so that an individual's hearing ability may be evaluated with respect to a particular population (compared with other people who play the same instrument).

Finally, as mentioned above, tonality is only one aspect of functional hearing in musicians, albeit ubiquitous in most genres of music. It would be useful to develop other functional tests that measure hearing skills that may be required for successful performance in specific genres of music (e.g., intonation tests for singers).

## SUMMARY

A framework has been presented for administering a functional test of hearing for musicians. The test provides a measure of tonal sensitivity, which is an essential component of most music that is performed today. The framework can and should be customized to suit the needs of the individual performer. Although the functional test described has not been subjected to a standardization process, it seems reasonable to expect that it can be used on multiple occasions with the same client, thus providing a source of objective comparison of functional hearing obtained with different hearing aid settings.

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