Comments

Comment by Moore:

It is well known that reaction times depend on a speed-accuracy tradeoff. Thus, to interpret differences in reaction time across frequencies for which the hearing loss differed, it is important to know whether and how misses and false positives differed across frequencies, especially for levels at and just above absolute threshold. Can you provide this information?

Two aspects of your data seem problematic for your hypothesis that loudness is closely related to reaction times and, therefore, for a given subject, equal reaction times imply equal loudness. The first aspect stems from your finding that, within a given hearing-impaired subject, the reaction times for the frequency where absolute threshold was higher generally remained below those for the frequency where absolute threshold was lower, even when the stimuli were well above absolute threshold. Assuming that these subjects had loudness recruitment (in the sense that, at high sound levels, equal levels lead to approximately equal loudness), one would have expected the reaction times to reach roughly equal asymptotic values for the two frequencies tested for each listener. This was clearly not the case for most subjects. Even if loudness recruitment was incomplete, one would expect the reaction times to reach roughly equal asymptotic values for the two frequencies tested in cases where the asymptote was reached at moderate sensation levels in the better ear, as was the case for HI-3 and HI-4.

The second aspect of your data that seems problematic comes from the consequences of assuming that, for a given ear, equal reaction times imply equal loudness. For subject HI-2, this leads to the prediction that a 4-kHz signal at about 8 dB SL (77 dB SPL) would be as loud as a 1-kHz signal at about 53 dB SL (56 dB SPL). For subject HI-5, a 2-kHz signal at about 8 dB SL (75 dB SPL) should be as loud as a 0.5-kHz signal at about 60 dB SL (98 dB SPL). Loudness matches across ears for subjects with unilateral or highly asymmetric hearing loss show that a sound presented to an impaired ear at a level of 8 dB SL would typically be matched to a sound in the normal (or better) ear with a level between 15 and 40 dB SL (Miskolczy-Fodor, 1960; Moore, Glasberg, Hess and Birchall, 1985; Moore and Glasberg, 1997). Your assumption appears to lead to loudness estimates that are higher than empirically measured for tones that are just above absolute threshold in an impaired ear.

Miskolczy-Fodor, F. (1960) Relation between loudness and duration of tonal pulses. III. Response in cases of abnormal loudness function. J. Acoust. Soc. Am. 32, 486-492.

Moore, B. C. J. and Glasberg, B. R. (1997) A model of loudness perception applied to cochlear hearing loss. Auditory Neurosci. 3, 289-311.

Moore, B. C. J., Glasberg, B. R., Hess, R. F. and Birchall, J. P. (1985) Effects of flanking noise bands on the rate of growth of loudness of tones in normal and recruiting ears. J. Acoust. Soc. Am. 77, 1505-1515.

Reply:

Regarding the speed-accuracy tradeoff, an analysis shows that the false-alarm rates were low—ranging from zero in over 900 trials to seven in just over 800 trials. Therefore, they were counted across all levels. To assess the precision of trials at threshold, the hit rate was also quite low—ranging from 0.055 to 0.9. Across all listeners, d’ at their normal frequency was 3.3, whereas the average d’ across the impaired frequency was 3.9. Because calculating d’ for listeners with false-alarm rates of zero is somewhat arbitrary, we did the same analysis for listeners with false-alarm rates greater than zero. The results showed the same trends. The average d’ was 2.8 at the normal frequency and 3.4 at the impaired frequency. Both analyses indicate that the listeners performed with greater precision at the impaired frequency. Therefore, the speed-accuracy tradeoff cannot explain the faster reaction time observed with elevated thresholds at the impaired frequency.

We do not find the two aspects of the data you refer to particularly problematic. Your first comment is that “the reaction times for the frequency where absolute threshold was higher generally remained below those for the frequency where absolute threshold was lower, even when the stimuli were well above absolute threshold.” This is true because the data are plotted in terms of SL so that a moderate SL would be a considerably higher SPL than a moderate SL at a normal frequency. Therefore, we would not necessarily expect the curves to meet.

Your second comment concerns the assumption that equal reaction times imply equal loudness. Whereas it is true that the equal reaction-time contours at moderate and high SLs do not always conform to our knowledge of typical loudness matches between normal and impaired frequencies, we have obtained data from several listeners in which we see an excellent agreement between reaction-time contours and loudness matches throughout the entire dynamic range. The deviations that are apparent in the data shown in the proceedings most likely can be ascribed to difficulty in determining slowly changing reaction times with sufficient precision. The important finding for the present data is that reaction times change rapidly with level near threshold. It seems quite clear that at and near threshold, reaction times are faster at the impaired frequency than at the normal frequency. These data—together with previous data cited in the proceedings—lend further support to the concept of Softness Imperception.

Moore:

It is curious that your analyses show that the value of d’ for the threshold stimuli was over 3 both for the “normal” frequency and for the “impaired” frequency, since your threshold estimation procedure should have led to d’ values much lower than 3. The high d’ values that you got imply that your “threshold” stimuli were not really at threshold – rather, they were nearly perfectly detectable, which means that they were, in fact, several decibels above threshold. Given this, your data cannot be taken as providing direct support for the claim that, at threshold, loudness is greater for an “impaired” frequency than for a “normal” frequency.

Turning to the second point, it still seems to me problematic that the reaction times for the “impaired” frequency generally remained below those for the “normal” frequency, even at high SLs, If the data were re-plotted in terms of SPL rather than SL, they would suggest over-recruitment at high levels, i.e., at equal high SPLs, the loudness should be greater at the “impaired” frequency than at the “normal” frequency. Since over-recruitment is only rarely observed, this suggests that there is a problem with the assumption that reaction time is a direct indicator of loudness.

Florentine:

In regard to d’ at threshold, we believe that the values are likely to be inflated by the low false-alarm rates, especially those that were estimated to be zero. Threshold was measured very carefully using our adaptive 2AFC procedure at the beginning of each session with RT measurements and these thresholds were used to set the SLs at each frequency. Accordingly, we see no reason to believe that the 0-dB SL stimuli were substantially above threshold for the RT measurements. The important point of the d’s extracted from the RT data is that they do not support the idea that the faster RTs at the elevated thresholds are due to a speed-accuracy tradeoff.

In regard to the RTs at high levels, we believe that imprecision is likely to explain the discrepancies you note. Because RTs change slowly at high levels and the RT estimates are somewhat variable, the discrepancies appear to be well within the uncertainty of the data. In fact, as stated in the reply to your first question, additional data indicate excellent agreement between equal-RT contours and loudness matches, when experienced listeners are used.