Categorical loudness perception in normal and hearing impaired subjects

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Abstract: This study compared categorical loudness perception in three subject groups with 11 subjects in each group: young (22 and 24 years) normal, older (43-60 years) normal, older (60 to 80 years) hearing impaired (thresholds in the range of 50 to 70 dB SPL at the test frequencies of 2 and 4 kHz). The subjects were asked to judge the loudness of warbled tones presented at various sound pressure levels in the following categories: 'Not audible', 'very soft', 'soft', 'comfortable', 'loud' and 'very loud'. The Multivariate analyses of variance on the thresholds, and the very soft, soft, comfortable and loud categories revealed significant differences in loudness perception among the normal and the hearing impaired subjects.

INTRODUCTION

The knowledge of loudness perception by hearing impaired subjects is important in fitting hearing aids. Conventional pure tone audiometry provides information on thresholds, but loudness scaling can provide valuable information over the entire audible range which is important for fitting non-linear (dynamic range compression) hearing aids. The differences in the loudness perception among normal and hearing impaired subjects allow us to estimate the amplification that will be necessary for a variety of input levels (1). This study was designed to investigate the differences in the loudness growth functions of normal and moderately hearing impaired subjects using a categorical loudness scaling procedure.

METHOD

Subjects:

Three subject groups with 11 subjects in each group participated in the study. The first group comprised of young subjects with normal hearing (below 20 dB HL) within the age range of 22 to 24 years. The second group consisted of older subjects with normal hearing within the age-range of 43 to 60 years. The third group included older (60 to 80 years) subjects with sensori-neural hearing impairment in the range of 50 to 70 dB SPL at 2 and 4 kHz. The tympanicometric results of all the subjects indicated normal middle ear function.

Loudness judgements:

The commercially available Auricle AudioDiagnostic system (Madsen Electronics) was used for the presentation of warble tones and loudness scaling. The Auricle system allows calibration of sound pressure levels (SPLs) for each individual ear. The subject responds through a responder which has 7 labeled responses varying from 'Not audible' to 'Too loud'. In addition, there are two (green and yellow) light indicators. The green light blinks 1 second in advance and during the stimulus presentation. Following the presentation of stimuli it stays lit till the client responds. When a response button is pressed, the yellow indicator lights up to inform the subject that the response has been accepted by the computer. The subject is expected to respond within 10 secs following the presentation.

The subjects were provided with written instructions that are included within the Auricle audiometer during all the phases of loudness testing. The written instructions minimized any differences in test instructions across subjects. The instructions are known to affect the results of loudness scaling.

The test frequencies were 2 and 4 kHz. Three bursts of warble tones with 0.5 sec duration and 0.5 sec pause were presented through insert earphones, for loudness scaling. Initially, the 'Very soft' and the 'Too loud' SPLs were determined by presenting stimuli at increasing SPLs in 5 dB steps and asking the subjects to press the appropriate button on the responder to determine the dynamic range (DR). In the absence of this initial measurement of dynamic range, the subjects tend to avoid the highest level categories to leave headroom for extremely loud stimuli, as they have no information about the highest presentation levels. The lowest value presented during the loudness scaling procedure is 5 dB below the level judged as 'Very soft' and the highest level is 5 dB above the level judged as 'Too loud'. The LGOB (2) II algorithm was used for loudness scaling. Step size in this algorithm is DR/7 or if DR is less than 50 dB, it is DR/3. The SPLs are randomly presented at each frequency. The subjects judged the SPLs in the following categories: Not audible, Very soft, Soft, Comfortable, Loud, Very loud and Too loud.

Analyses:

Only those SPLs judged twice with the same loudness judgements were included in the analyses. All the SPLs
judged in the same loudness category were averaged to generate a single SPL value in each category. Multivariate Analyses of variance (MANOVA) were performed on the 'threshold', 'very soft', 'soft', 'comfortable', and 'loud' variables. The MANOVA were performed separately for each frequency. Further analyses was planned with the Scheffe test.

RESULTS

The mean SPLs for each loudness category for the three subject groups are presented in Table 1.

Table 1. The mean SPLs and standard deviations (in parentheses) for the three subject groups.

<table>
<thead>
<tr>
<th>Subject group</th>
<th>Threshold</th>
<th>Very soft</th>
<th>Soft</th>
<th>Comfort</th>
<th>Loud</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 kHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young Normal</td>
<td>16.4 (5.0)</td>
<td>34.8 (5.5)</td>
<td>64.2 (10.5)</td>
<td>84.9 (8.8)</td>
<td>98.2 (9.4)</td>
</tr>
<tr>
<td>Older Normal</td>
<td>18.2 (4.6)</td>
<td>32.5 (8.6)</td>
<td>61.6 (15.3)</td>
<td>80.7 (13.6)</td>
<td>95.9 (11.0)</td>
</tr>
<tr>
<td>Older Hearing Impaired</td>
<td>61.8 (7.2)</td>
<td>66.2 (6.5)</td>
<td>80.2 (5.3)</td>
<td>93.7 (8.1)</td>
<td>103.5 (9.3)</td>
</tr>
<tr>
<td></td>
<td>4 kHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young Normal</td>
<td>9.6 (6.5)</td>
<td>25.7 (7.8)</td>
<td>54.2 (9.6)</td>
<td>75.5 (7.0)</td>
<td>87.0 (12.2)</td>
</tr>
<tr>
<td>Older Normal</td>
<td>14.6 (4.2)</td>
<td>32.3 (11.7)</td>
<td>60.0 (14.1)</td>
<td>80.1 (10.1)</td>
<td>92.2 (9.4)</td>
</tr>
<tr>
<td>Older Hearing Impaired</td>
<td>62.7 (6.5)</td>
<td>68.6 (7.8)</td>
<td>81.1 (7.8)</td>
<td>92.8 (9.1)</td>
<td>101.9 (11.8)</td>
</tr>
</tbody>
</table>

The results were similar for both the test frequencies (2 and 4 kHz). The MANOVA revealed significant main effects for the loudness categories and the subject groups (p < .0000). In addition, a significant interaction was also apparent (p = .0000). Further analyses with the Scheffe test revealed no significant differences in loudness perception across the young normal and the older normal subjects. The older hearing impaired subjects differed significantly from the young normal subjects across all the loudness categories. The older hearing impaired subjects also differed significantly from the older normal subjects across all the loudness categories with the exception of the 'loud' category for 4 kHz where the difference was not significant. As can be seen in Table 1, the interaction was created by the fact that the perceptual differences in the normal and hearing impaired groups were largest for the 'very soft' category. A slow reduction in this difference was apparent for higher loudness categories with minimal differences noted for the 'loud' category. Observation of the data showed considerable variability in loudness perception, especially for the judgement of 'loud' sounds.

DISCUSSION

These results agree with other studies of loudness perception, conducted using different techniques (3). The results suggest that for individuals with a hearing impairment in the 50 to 70 dB SPL range, amplification will be required for low and high level sounds. However the required gain for high level sounds will be less than that required for low level sounds to restore normal loudness. The results also suggest that measurement of individual loudness functions may be beneficial.

REFERENCES