Disabilities and Handicaps Associated with Impaired Auditory Localization

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Abstract
A questionnaire on (1) difficulties in everyday sound localization (localization disabilities), (2) limitations and disadvantages related to such disabilities (localization handicaps), and (3) everyday speech hearing disabilities was completed by 104 people with symmetrical hearing losses. Respondents considered situations when listening with and without their usual hearing aid fittings. The hearing-impaired group rated their unaided localization ability as significantly poorer than a sample with no reported hearing loss, particularly discrimination of distance. Only slight limitations on everyday activity due to localization disability were found, but disadvantage was reported in the form of experiences of confusion of sounds, of resultant loss of concentration, and of a wish to escape settings where this occurred. There was a moderate correlation between localization and speech hearing, even when hearing level was controlled for. Aided listening, whether with one or with two hearing aids, was reported as enabling significant improvements in both functions.

Key Words: Handicaps, self-assessment, sound localization, speech hearing

The subject of this study is the ability of people whose hearing is impaired to localize sound and to discriminate distance of sound. In particular, we examined self-assessed everyday disabilities resulting from or associated with impaired localization capacity. The concept of disability that we use is that of the World Health Organization’s International Classification of Impairments, Disabilities and Handicaps (WHO, 1980). In that scheme, “disability” refers to auditory consequences of impairments; in the present context, this means limitations in the everyday exercise of distinguishing the whereabouts of sounds due to impairment of that aspect of hearing.

Free-field localization and related functions (e.g., interaural discrimination) in people with impaired hearing have been the subject of study using various performance measures. Durlach et al (1981) reviewed research to that date; subsequent studies are reviewed by Noble et al (1994). Localization depends mainly on detection of interaural time and level differences for sounds displaced horizontally from the median sagittal plane of the body (Mills, 1972), and on spectral alterations, brought about primarily by the pinnae, for elevation and front-rear discrimination (Blauert, 1969/70; Weinrich, 1982; Musicant and Butler, 1984; Asano et al, 1990). Almost everyone who has a hearing loss suffers impairment of this ability, the most notable ill-effect being on median vertical plane localization (Butler, 1970; Noble et al, 1994), which depends on pinna resonance effects above 4 kHz, a frequency region showing reduced sensitivity in most cases of hearing loss. A further effect observed by Noble et al was that listeners with poorer hearing in the 4- to 6-kHz region confused rearward and frontward locations.

Hausler et al (1983) noted that little or nothing is known about everyday disabilities or handicapping effects arising from impaired localization function. There is reason to expect that impairment of this ability should affect the experience of hearing in the everyday environment. Evidence from comparative studies suggests that localization has a major role in the evolutionary trajectory of the mammalian
auditory system (Masterton et al, 1968). A moment's reflection allows one to recognize the importance of this function for personal safety and for effective orientation to events in the environment, not least in following conversation in a group setting where the location of the current speaker switches continually and unpredictably. The problem of disabled localization has featured in some studies of everyday hearing disabilities. It emerged as a significant factor in the formation (Noble and Atherley, 1970) and analysis (Thomas and Ring, 1981) of the Hearing Measurement Scale (HMS). Lutman et al (1987) found it to be an independent factor in self-assessed profiles of hearing disability. In a 25-item form of the HMS (Eriksson-Mangold et al, 1992), six of the seven items on localization disability from the original 41-item form were retained in the short version, confirming that this factor has significance in people's reports of everyday hearing difficulties.

While specific localization disabilities have been reported by people with impaired hearing, a further point has not been previously explored, namely, the extent to which those who describe themselves as having such difficulties also experience handicaps as a result. The WHO (1980) scheme defines handicaps as nonauditory consequences due to impairments and disabilities. In this context, such handicaps might occur in the form of experiences of personal insecurity or confusion in environmental settings that are unfamiliar or that induce localization problems, thus reducing general well-being. Furthermore, they may give rise to limitations on one's independent actions — for example, avoidance of certain areas or everyday activities. We sought to identify possible handicaps that may be directly attributable to localization disabilities.

Besides a direct impact on the ability to discriminate the whereabouts of events, it is possible that impaired localization could be related to problems with speech perception. There are two ways this might occur. Plomp and Mimpen (1981) showed, in normal-hearing listeners, that increasing the spatial separation of a speech signal from competing noise assists in effective reception of the speech. Where a listener's ability to discriminate spatial whereabouts is diminished, it could be hypothesized that there is less advantage resulting from spatial separation of speech and noise. There are suggestive reports in the literature. Platte et al (1978) and Pröschel and Döring (1990) observed that some people with normal hearing sensitivity yet difficulty understanding speech in noise also had reduced localization ability. Another type of link may be hypothesized from some results of Häusler et al (1983), who reported that, in people with bilateral sensorineural hearing loss yet good speech discrimination scores in quiet, there was also good localization ability, as reflected in near normal minimum audible angles (MAA) in frontal vertical and lateral horizontal planes. By contrast, listeners with low speech scores had large MAAs. These authors suggested that impaired ability to discriminate spectral variations in complex sounds might account for the parallel decrements in both functions. Thus, there might be connections between experienced difficulties in both localization and speech discrimination, and the present study offered an opportunity to explore that possibility.

The principal aims of the present investigation were, therefore, to inquire about (1) everyday disabilities in sound localization among hearing-impaired listeners; (2) possible handicaps, in the form of disadvantages in everyday life, associated with localization disability; and (3) everyday disabilities in speech discrimination and their correlation with localization disability. In pursuing the third aim, attention was given to representing speech hearing situations that involved variation in the number of sounds and the extent of competing sounds. As most of the participants in this study were people fitted with hearing aids to one or both ears, a secondary aim was to examine the effect on self-assessed disabilities in both localization and speech discrimination for unaided listening versus either unilateral or bilateral aided listening.

The present study forms part of a larger investigation of speech discrimination and localization among hearing-impaired people. The purpose of this part was to uncover features of everyday experience, including that of handicap, through questions designed to tap such experience. Our aims did not include the development of a scale of self-assessed localization, tested in terms of its general psychometric properties. Such a project could of course be pursued, and results reported here may provide some useful background. We note that Nobie (1969) found test–retest reliabilities of 0.82 and 0.84, respectively, for the speech and localization sections of the HMS, and that Thomas and Ring (1981) found the factor structure of the HMS to be generally very sound.
Thus, previous investigation of self-reported speech and localization disability indicates that these can be expected to be psychometrically well behaved.

**METHOD**

**Questionnaire Design**

A preliminary set of questions about localization and speech hearing was drafted, based in part on those in the HMS and in part on our own intuitions. Questions about handicapping consequences of localization disability were drawn exclusively from our intuitions, and we were conscious that respondents might report handicaps due to factors other than localization impairment. Tape-recorded group discussions were arranged with nine people whose hearing threshold and localization performance we already had records of, from a study of localization function and hearing aid fitting (Byrne et al, 1992). They were invited to the discussion as representatives of a wide range of abilities, at least as expressed through experimental testing. Using the draft questions as a guide, discussion covered the three areas of (1) localization disabilities, (2) handicaps associated with localization, and (3) speech hearing disabilities. From notes made at the time or from listening to the audio recordings, the set of items was amended by (a) excluding any that had evoked no real recognition from the participants and (b) altering the wording, and adding items, to better fit the nature of reported experiences. A common four-point response scale ("almost always," "often," "sometimes," and "almost never") was applied to each item; for localization and speech hearing disability items, response options of "not applicable" and "wouldn't hear it" were added.

The resulting questionnaire was tried on a sample of 10 people with no reported hearing difficulties, partly to gain feedback about its intelligibility in written form and partly to provide baseline data. Further alterations to the item set and wording were made in the light of comments from this sample. Several items assume disabled localization function and/or hearing aid use and hence were not meaningful for the sample with no reported problems. As the final questionnaire form was designed for self-administration among people fitted with hearing aids, each localization and speech hearing disability item had two response modes: listening aided and unaided.

One or two localization items were framed as straight questions ("In the street, can you judge how far away someone is, from the sound of their voice or footsteps?"); most were worded as "scene setting," as were all the speech hearing items ("You are outdoors in an unfamiliar place. You can hear the sound of someone mowing the lawn. You can't see where they are. Do you know where the sound is coming from?"). The items on handicap were more varied in their phrasing, reflecting the different kind of issues that they were designed to inquire about ("Does difficulty telling where sounds are coming from lead you to avoid busy shops or streets?"); "You are in a place where sounds seem mixed up and confused. You are by yourself. Do you feel a need to leave that place quickly to go to a place where you will feel more comfortable?"). Most disability items were positively worded ("Can you..."); some were expressed in negative terms ("Do you find it hard to..."). This was done to try to avoid response bias, but it may have confounded the measurement, as noted later. The items forming the three sections of the inventory (localization, handicap, speech hearing) are given in the Appendix.

**Participants**

Besides the normal-hearing group, participants comprised a subset of the sample of people previously studied by Byrne et al (1992) together with a number of new clinic clients, each of whom, like those of the previous group, was selected to have symmetrical hearing losses, defined as average hearing levels across the four frequencies of 0.5, 1, 2, and 4 kHz (4FAHLS) no greater than 15 dB different between the left and right ears. A sample of 104 people with impaired hearing forms the basis of the present analyses; almost all (92) had sensorineural hearing loss; 12 had mixed/conductive loss. They were from a sample of 125 people who had been approached by letter asking for their help in completing the questionnaire. The questionnaire was either mailed to them or completed by them when they came to the laboratory for other test purposes. All participants had been fitted previously with one or two hearing aids by Australian Hearing Services audiologists, according to the NAL prescription (Byrne and Dillon, 1986). Mean better ear hearing threshold levels are shown in Table 1 ("better" is whichever was the better HTL between left and right ears at each test frequency for a listener) as well as mean age.
Table 1  Average Better Ear HTLs*, 4FAHL, and Age for the 104 Hearing-impaired Respondents

<table>
<thead>
<tr>
<th>Frequency (kHz)</th>
<th>0.25</th>
<th>0.5</th>
<th>1</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>4FAHL</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>33.5</td>
<td>34.7</td>
<td>41.2</td>
<td>51.8</td>
<td>64.2</td>
<td>70.7</td>
<td>71.3</td>
<td>48.0</td>
<td>71.6</td>
</tr>
<tr>
<td>SD</td>
<td>20.0</td>
<td>20.6</td>
<td>18.4</td>
<td>13.6</td>
<td>16.7</td>
<td>15.8</td>
<td>18.0</td>
<td>14.1</td>
<td>8.1</td>
</tr>
</tbody>
</table>

*Better level at each frequency for each listener.

Data Processing and Analysis

In all sections of the questionnaire responses to each item were scored from 1 to 4, with 4 representing least difficulty. Responses of “not applicable” or “wouldn’t hear it” — sections I (localization) and III (speech hearing) only — were not scored. Across respondents and items, the frequency varied with which one or other of the nonscoring categories was checked; hence, the number of scorable responses varies. Given this, average scores were derived, namely (1) the average of scorable responses on each item and (2) the average of scorable responses, within each section, for each person. In the first case, only unaided listening averages have been used for analysis; in the second case, both the average for unaided listening and that for aided were computed.

The omission of nonscorable responses introduces a bias in calculating the first of the above averages. Specifically, people making this response tend to be the most disabled and would be likely, therefore, to get low scores if they had been able to respond about unaided localization or speech discrimination for the item in question. Thus, a reduction in the number of scorable responses may lead to underestimating the average disability associated with a particular item because the missing scores would have likely been low ones. The bias does not operate on averages for persons since whatever scores are available reflect each person’s self-assessed ability. Item-by-item comparisons between groups may be slightly distorted if one group has fewer scorable responses than the other. This bias seemed preferable to the problems that would occur with any other scoring procedure; its effect is taken account of in describing the results of the first analysis; remaining analyses use averages for persons.

Not all items responded to have been included in the analysis of results. To analyze the performance of each item in relation to its section, individual respondents’ section totals were computed. In Sections I and III, responses on negatively worded items, unaided (#2, 4, 7, 11, and 13 in Section I, and #26, 32, 36 and 37 in Section III), were found to be generally less correlated with section totals. This seems to have been because some respondents answered some negatively worded items as though they were positively worded. Rather than try to second guess what respondents had intended to say, a decision was made to exclude the results from negatively worded items. An item from Section I (#14) and two from Section II (#22 and 25) were also excluded due to the absence of correlation with section totals.

In the analysis to follow, differences are reported between the samples with impaired and normal hearing. The comparisons are based on a subset of items that had the same sense in terms of wording in the form presented to the two groups and that were meaningful to both. In the analysis of effects of unilateral versus bilateral hearing aid use, respondents were selected who reported both aided and unaided listening and the use of only a unilateral or bilateral aid fitting.

RESULTS

Disability and Handicap Ratings

For the hearing-impaired sample as a whole, the reported degrees of unaided localization disability, handicap, and speech hearing disability associated with each item in the questionnaire are shown in Table 2, together with equivalent data for the sample with normal hearing.

Section I Scores. For discrimination of direction (items 1 to 9), the mean responses per item, unaided, of the hearing-impaired sample are very similar for each, around 2.5. On average, people are reporting problems more than “sometimes” and less than “often”. The normal-hearing sample was also fairly uniform in responses across these items, and about one scale point higher on average. If we consider the averages for people over those items (statistics not
### Table 2 Average Scores on Each Item Included in Analyses and Number of Responses by Hearing-Impaired Sample and by Normal-hearing Sample for Any Equivalent Item

<table>
<thead>
<tr>
<th>Questionnaire Item</th>
<th>Impaired Group</th>
<th></th>
<th>Normal Group</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AV</td>
<td>SD</td>
<td>N</td>
<td>AV</td>
</tr>
<tr>
<td><strong>Section I (Localization)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Conversation, which part of own house</td>
<td>2.6</td>
<td>1.1</td>
<td>80</td>
<td>3.3</td>
</tr>
<tr>
<td>3. Lawnmower out of sight, unfamiliar place</td>
<td>2.5</td>
<td>1.2</td>
<td>91</td>
<td>3.3</td>
</tr>
<tr>
<td>5. Door slam where in unfamiliar house</td>
<td>2.5</td>
<td>1.1</td>
<td>84</td>
<td>3.4</td>
</tr>
<tr>
<td>8. Dog bark, tell where without looking?</td>
<td>2.5</td>
<td>1.1</td>
<td>90</td>
<td>3.2</td>
</tr>
<tr>
<td>10. Distance of other from voice or footsteps</td>
<td>2.6</td>
<td>1.1</td>
<td>84</td>
<td>3.6</td>
</tr>
<tr>
<td>12. Distance of bus out of sight, busy street</td>
<td>2.2</td>
<td>1.0</td>
<td>75</td>
<td>3.4</td>
</tr>
<tr>
<td><strong>Section II (Handicap)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. Confident person</td>
<td>3.3</td>
<td>0.9</td>
<td>104</td>
<td>3.0</td>
</tr>
<tr>
<td>16. Nervous, strange place, due to localization difficulty</td>
<td>3.3</td>
<td>0.9</td>
<td>104</td>
<td>—</td>
</tr>
<tr>
<td>17. Avoid busy areas, due to localization difficulty</td>
<td>3.6</td>
<td>0.6</td>
<td>104</td>
<td>—</td>
</tr>
<tr>
<td>18. Avoid shopping alone, due to localization difficulty</td>
<td>3.9</td>
<td>0.4</td>
<td>103</td>
<td>—</td>
</tr>
<tr>
<td>19. Uneasy in strange house</td>
<td>3.1</td>
<td>1.1</td>
<td>102</td>
<td>3.2</td>
</tr>
<tr>
<td>20. Sounds seem confused in busy place</td>
<td>2.5</td>
<td>1.1</td>
<td>104</td>
<td>3.1</td>
</tr>
<tr>
<td>21. Feel uncertain of own whereabouts</td>
<td>3.7</td>
<td>0.6</td>
<td>103</td>
<td>3.6</td>
</tr>
<tr>
<td>23. Lose concentration when sounds are confused</td>
<td>3.0</td>
<td>0.9</td>
<td>103</td>
<td>—</td>
</tr>
<tr>
<td>24. Leave areas where sounds are confused</td>
<td>3.1</td>
<td>1.1</td>
<td>104</td>
<td>—</td>
</tr>
<tr>
<td><strong>Section III (Speech Hearing)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27. Hear speech of one person at home, TV on</td>
<td>2.0</td>
<td>0.9</td>
<td>78</td>
<td>3.7</td>
</tr>
<tr>
<td>28. Hear one person at home in quiet</td>
<td>3.0</td>
<td>1.0</td>
<td>88</td>
<td>3.9</td>
</tr>
<tr>
<td>29. Follow group conversation, noisy club</td>
<td>1.7</td>
<td>0.9</td>
<td>80</td>
<td>3.5</td>
</tr>
<tr>
<td>30. Small group in quiet</td>
<td>2.5</td>
<td>1.1</td>
<td>85</td>
<td>3.8</td>
</tr>
<tr>
<td>31. Group meeting, everyone visible</td>
<td>2.4</td>
<td>1.0</td>
<td>82</td>
<td>3.7</td>
</tr>
<tr>
<td>32. Small group in busy restaurant</td>
<td>2.1</td>
<td>0.9</td>
<td>82</td>
<td>—</td>
</tr>
<tr>
<td>33. One person, quiet, understand what say?</td>
<td>3.1</td>
<td>1.0</td>
<td>86</td>
<td>4.0</td>
</tr>
<tr>
<td>34. Group, some not visible</td>
<td>1.7</td>
<td>0.9</td>
<td>76</td>
<td>—</td>
</tr>
<tr>
<td>38. Quiet, rapid switches in conversation</td>
<td>2.3</td>
<td>1.0</td>
<td>82</td>
<td>—</td>
</tr>
</tbody>
</table>

*Minimum score = 1, maximum score = 4, *maximum N = 104, `maximum N = 10.

Sections I and III are answered as when not wearing a hearing aid(s). See Appendix for full text of each item.

subject to the overestimation due to nonscoring responses), the values are 2.35 (SD = 0.99) and 3.37 (SD = 0.51) for the impaired and normal-hearing groups, respectively.

Discrimination of distance (items 10 and 12) was reported by the group with impaired hearing as more severely affected than directional ability, the average per-item scores indicating that they are "often" having difficulty in this matter (average for the two items over persons = 2.08, SD = 1.02). The difference in response to item 9 — telling the direction of a vehicle in the street — and item 12 — telling how far away it is — is small (2.6 vs. 2.1, by either form of averaging) but highly significant (number of pairs of scoring responses = 77, F = 85.34, p = .0001, R^2 = .59). The group with normal hearing had averages on the distance items within the range of their other scores (average for the two items over persons = 3.35, SD = 0.47). The normal-hearing sample's scores on individual items are all significantly higher than those of the hearing-impaired sample, particularly in the case of the two distance items.

As seen in the "N" column, there were between 13 and 29 nonscoring responses from the impaired group on most Section I and III items, typically because people said that they would not hear, unaided, in the context described. The setting in item 6 (high-rise building), in addition, was reported to be not applicable for many respondents. The localization results are also shown in Figure 1, in which the hearing-impaired listeners have been divided into two groups, depending on whether the 4FAHL was less than or greater than 50 dB. Within both impaired groups, there is a wide range of scores for all items, but the mean scores for both are consistently below the means for the group with normal hearing, and the means for the more
impaired group are consistently below the means for the less impaired group. These data highlight the general relationship between reported localization difficulties and hearing level.

**Section II Scores.** In general, the respondents with impaired hearing reported few signs of handicap directly attributable to localization disability. Because nonscoring responses are not applicable to this section, the per-item values more truly reflect the average for the group. Problems of disorientation and confusion (#16, 21) were typically experienced between “sometimes” and “almost never” (i.e., were relatively rare). Limitations on independent activity (#17 and 18) were “almost never” experienced. Items inquiring about confidence (#15 and 19) also provided average responses greater than 3. The slightly lower score for item 19 (feeling ill at ease in a stranger’s home) was commented upon by some respondents as due to the fear of not being able to communicate successfully when interacting with people unfamiliar to them. The exceptional handicapping effect appears to be in reports of experiencing confusion of sounds in busy places (#20, average [AV] = 2.5), losing concentration as a result (#23, AV = 3.0), and feeling the need to escape from such contexts (#24, AV = 3.1).

There is not much scope for comparison with the normal hearing group since most items in Section II were not seen as meaningful for them. There are no differences to speak of between the two samples on the confidence items (#15 and 19).

**Section III Scores.** The unaided speech hearing scores of the impaired-hearing group show considerable inter-item variability. The most notable effects are in the transition from quiet to even a single source of interfering noise (item 28, [AV = 3.0] vs. item 27 [AV = 2.0]). Group conversation, if it occurs in quiet (#30, AV = 2.5) or if everyone in the group is visible (#31, AV = 2.4), affords moderate difficulty. Group conversation with some background noise (#33, AV = 2.1) or where not everyone can be seen (#35, AV = 1.7) proves more substantially troublesome. Only marginally worse than the latter is the situation with a group in a definitely noisy place (#29, AV = 1.7). All normal versus hearing-impaired Section III scores are significantly different, but the divergence between the impaired and unimpaired respondents is most distinctive with respect to the group conversation and competing noise contexts.
In the group with impaired hearing, the average score over persons for Section III was 2.24 (0.74). Only six items in Section III were in common between groups with impaired and normal hearing. On this subset, the averages over persons were 2.38 (0.78) and 3.77 (0.34) for the two groups, respectively. On Section I as a whole, the averages over persons were 2.25 (0.96) and 3.37 (0.44) for the two groups, respectively.

Relations among Section Scores, Taking Account of HTL and Age

The relations among scores on the three sections of the questionnaire are examined for the hearing-impaired sample under unaided conditions. Table 3 shows the correlation matrix for the questionnaire sections (averages of scorable responses), as well as the variables of hearing level (4FAHL) and age. As expected, negative correlations were found between questionnaire and 4FAHL, indicating that increased hearing loss is associated with greater self-reported disability (lower questionnaire score). There appear to be no relationships between age and either 4FAHL or Section III scores, and modest positive correlations with Sections I and II. The latter correlations were due mainly to the spurious effect of three younger (aged 32, 33, and 42) but more disabled and handicapped respondents and reduced virtually to zero when their data were excluded.

The interest in this analysis is between localization disability and handicap and between localization and speech hearing disability. As the matrix in Table 3 shows, the correlations between localization and handicap and between localization and speech hearing are moderately high, while that between handicap and speech hearing is notably lower (though all are significantly greater than 0, p < .05). Stepwise regression analysis of localization, speech hearing, FAHL, and age on the handicap score showed that only the localization score accounted for an appreciable component (30%, r = .548) of variability in the handicap score. A similar analysis on the speech hearing score showed that localization and 4FAHL accounted for some 48 percent of variability (r = .696). When 4FAHL was partialled out, the localization score accounted for 31 percent (partial r = .557) of the variance in speech hearing. This pattern of results is maintained whether or not the data from the three younger respondents are included.

Comparing Unaided and Aided Responses

To compare unaided and aided listening, cases were selected where respondents had answered questions in Sections I and III under both listening conditions. To make the comparison as a function of type of fitting, people were selected who were fitted bilaterally and who reported that, when listening aided, they always used both aids. (One exception was made, a person who reported bilateral use about 85% of the time.) Of these, 17 were able to be matched in terms of threshold level with 17 exclusively
unilateral cases (4FAHL of unilateral group = 44.7 dB, bilateral = 44.8; SD = 9.6 for both groups). Average unaided and aided scores are shown in Table 4.

For both Sections I and III, two-way ANOVA showed significant main effects for aided over unaided listening, no effect for type of fitting, and no interactions. In both listening conditions, there were no significant main effects either for section or type of fitting, although aided speech hearing tended to be greater than aided localization. The results in Table 4 show consistently but nonsignificantly higher scores among the unilateral than the bilateral group, an outcome that approaches significance (p = .08) for aided speech hearing (3.1 vs. 2.7). The average handicap scores of the two groups were 3.3 (unilateral) and 3.1 (bilateral).

DISCUSSION

Normal versus Impaired Samples

Our results show clear evidence that people with interaurally symmetrical loss of hearing report localization problems, when listening unaided, that are significantly greater than those reported by people with no apparent abnormality. For reasons explained in the Method section, per-item averages can be subject to bias; hence, average outcomes over individuals are used to comment on these and other differences. For each directional hearing situation described, and these covered indoor and exterior settings, there was a generally similar degree of disability reported by the hearing-impaired respondents. There was a significantly greater decrement in unaided distance discrimination reported by the hearing-impaired group, compared even with their directional responses. This may reflect a reduction in the "auditory horizon" and/or the possibility that distance hearing depends on detecting changes in high-frequency energy (Blauert, 1983). Many hearing-impaired people may be unable to detect such changes because the high frequencies may be audible only at short distances, if at all.

The normal sample report a broadly uniform small degree of difficulty in everyday localization, be it direction or distance; by contrast, they assess themselves as having almost no difficulty in everyday speech hearing. The hearing-impaired group report a similar average level of difficulty with unaided speech hearing as with unaided localization. There is thus a relatively greater difference between normal and hearing-impaired groups in everyday speech and hearing-impaired groups in everyday spatial hearing. There were substantial differences among different speech hearing situations; for example, the presence of noise seriously increases the problem. Demorest and Erdman (1987, p. 135) reported a similarly distinctive difference between hearing speech in quiet versus noisy settings, as reflected in self-ratings among respondents on the Communication Profile for the Hearing Impaired.

There appear to be only small signs of handicap associated with localization disability. In fact, the results on this dimension are comparable for our hearing-impaired and normal-hearing groups, although the possibilities for comparison were limited. There are some signs of uneasiness experienced in strange places; the experience of sounds being confused in busy places was more commonly reported, with loss of concentration and a desire to escape such situations acknowledged as due to this experience of confusion. There are almost no signs that independent everyday activity is actually curtailed, at least in the great majority of cases. We note that the average confidence rating of the hearing-impaired sample (item 15) was no different from that of the normal-hearing sample and recognize that our participants, having opted to use hearing aids and take part in this study, could be a somewhat more confident subset of the older hearing-impaired population.

Relations among Questionnaire Sections

A closer correlation was found between localization and handicap than between speech hearing and handicap. This was expected: the handicap section was largely designed to inquire about handicaps specifically linked to localization disability. The stepwise regression analysis shows that, overall, whatever relation does obtain between handicap and speech hearing is contingent upon the relation between handicap and localization. That latter relation is in turn independent of other features such as age or hearing level. While there must be factors that we have not measured that mediate handicap score, the indication is that we have indeed identified features of handicap that flow from localization disability. The extent of such handicaps is generally slight (with some exceptions, such as experiences of confusion and of desire to escape) but they reveal a connection with localization.
difficulties. Stepwise regression analyses on each item in the handicap section showed that the localization score only was related, though not strongly, to all but one item, including general ones such as confidence (#15, R = .45) and feeling ill at ease in a stranger’s home (#19, R = .34). The exception was item #18 (avoiding shopping alone), which was weakly related only to speech hearing (R = .32).

Standing in contrast to the association between localization and handicap is the pattern of speech hearing correlations. This factor is evidently associated with 4FAHL whilst being independently correlated with localization (partial r = .557) and much less directly related with handicap or age. We examined the correlations between localization and individual speech hearing items. Given the co-correlation between Section III and hearing level, we considered the coefficients when 4FAHL is partialled out. No single speech item relates strongly to the localization variable, though all partial correlations are significantly greater than zero. The two highest partial correlations (.51 and .49) were with items 30 and 31, which concern listening in a group setting, followed by those with items 27 and 29, which emphasize listening against a background of noise. The smallest partial correlation (.32) was with item 34 (understanding a single speaker in quiet conditions). The general result supports the view that localization and speech hearing may be related to each other. The suggestion from the foregoing analysis is of closer links between localization and speech recognition in multitalker or interfering noise conditions than in direct one-to-one listening.

In connection with this, we note that there was a marked effect on rated speech recognition difficulty when some speakers in a group could not be seen (item 35, AV = 1.7) compared with when they could be (#31, AV = 2.4), more, indeed, than when small group conversation was described as simply being in a background of noise (#33, AV = 2.1). The problem is no doubt due in part to the absence of opportunity to use visual cues. It has been shown (TerHorst et al, 1993) that hearing-impaired listeners have reduced ability, compared with normal-hearing listeners, to benefit from spatial separation of speech and noise, and this is especially so when speech is located to the side of the listener. The lateral presentation condition is analogous to the circumstance of a speaker being out of sight in a group setting; hence, this observed experimental phenomenon may be implicated in the greater reported difficulty found here. It remains to be determined how localization ability bears on performance on the spatially related speech task.

**Aided versus Unaided**

In both speech hearing and localization, aided listening was rated as providing significant improvement over unaided. The effect of aiding was slightly but not significantly greater for speech hearing over localization. This may be expected, given that hearing aids are currently designed with the primary goal of improving speech hearing in particular. No statistically significant difference was found in the effect of one as against two hearing aids among listeners matched closely for hearing level. There were slightly higher average scores, aided and unaided for Sections I and III, and on Section II, for those fitted with one as against two aids. This may reflect a higher level of reported disability among people who prefer bilateral fitting (Mueller, 1986); the 4FAHL of the bilateral subgroup is slightly lower than the average for the whole sample of hearing-impaired listeners, but their self-ratings of disabilities and handicaps are slightly greater than the average.

The lack of difference in reported localization disability under unilateral versus bilateral aided listening can be considered along with the finding by Byrne et al (1992). For people experienced in hearing with their particular type of fitting, which was the case in the present study, and with 4FAHL less than 50 dB, an advantage of bilateral over unilateral fitting for localization performance is not clearly demonstrable. The average hearing levels of the two subgroups compared here was just under 45 dB. The finding that aided localization was reported as better than unaided is not necessarily at variance with experimental studies that suggest that aiding makes localization marginally worse (e.g., Noble and Byrne, 1990). In such experiments, signals are usually presented at optimum loudness levels under unaided as well as aided conditions. In the everyday world, listening unaided will usually amount to hearing signals at levels below their optimum audibility.

**CONCLUSION**

The reported ability of people with interaurally symmetrical hearing impairment to
localize sounds, unaided, is significantly less than that of people with no reported abnormality of hearing. This disability is significantly and independently (of age or hearing level) associated with handicaps, such as feelings of confusion, loss of concentration, and a need to escape from places where sounds seem mixed up together. There do not seem to be limitations placed by localization disability upon independent action within the everyday environment; furthermore, the average self-rated confidence level of this hearing-impaired sample is high. Whether that finding is representative of the hearing-impaired population in general is not known. Self-assessed localization ability, both along with and independently of hearing level, is associated with reported speech hearing ability. Both functions are also rated as significantly improved under either unilateral or bilateral aided listening conditions.

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REFERENCES


APPENDIX

The following items form the three sections of the questionnaire. Sections I and III had two response forms: listening while wearing hearing aids and listening unaided. A four-point response
scale was used throughout: “nearly always,” “often,” “sometimes,” “almost never.” In Sections I and III, there were two other possibilities: “not applicable” and “wouldn’t hear it.” Items marked with an asterisk (*) were not included in the analyses reported here (see text for explanation).

Section I — Localization

1. You are at home in a quiet room. There are other people in the house (friends or family). They are talking in another room and you can hear them. Can you tell which part of the house those people are in?
   *2. Do you turn the wrong way when someone that you can’t see calls out to you?
3. You are outdoors in an unfamiliar place. You can hear the sound of someone mowing a lawn. You can’t see where they are. Do you know where the sound is coming from?
   *4. You are sitting around a table or at a meeting with several people. There is some background noise. You can’t see everyone. Do you find it hard to know which person is speaking?
5. You are in an unfamiliar house. It is quiet. You hear a door slam. Can you tell what part of the house the sound came from?
6. You are in a high-rise apartment or office building. You can hear sounds from another floor. Can you tell whether the sound is coming from above or below you?
   *7. You are standing on the footpath of a busy street. A car horn sounds. Do you have difficulty telling which direction it came from?
8. You are outside. A dog barks loudly. Can you tell where it is without having to look?
9. You are standing on the footpath of a busy street. Can you hear which direction a bus or truck is coming from before you see it?
10. In the street, can you judge how far away someone is, from the sound of their voice or footsteps?
   *11. You are outdoors in an unfamiliar place. Someone calls out from somewhere above you (such as a balcony or bridge). Do you find it hard to tell where the voice is coming from?
12. You are standing on the footpath of a busy street. Can you tell, just from the sound, roughly how far away a bus or truck is?

*13. You are outside. You can hear an airplane. Do you find it hard to tell where the plane is in the sky, by the sound alone?
*14. If you have a problem telling where something is coming from, does it help if you move around to try to locate the sound?

Section II — Handicap

15. Are you a confident person?
16. You are in a place that is unfamiliar to you. Do you get nervous or feel uncomfortable in this situation because of trouble telling where sounds are coming from?
17. Does difficulty telling where sounds are coming from lead you to avoid busy streets and shops?
18. Because of difficulties telling where sounds come from, is a visit to the shops something you don’t do by yourself?
19. You are invited into a stranger’s home. Do you feel less at ease in the stranger’s home than in a home that is familiar to you?
20. If you are in a busy place, such as a crowded shopping center or city street, do the sounds you hear seem all mixed up or confused?
21. When sounds are mixed up or confused, does this cause you to feel confused or unsure about exactly where you are?
   *22. Does wearing your hearing aid(s) reduce any feelings of confusion you may experience?
23. When sounds are mixed up or confused, does this cause you to lose concentration on what you were doing or thinking?
24. You are in a place where sounds seem mixed up and confused. You are by yourself. Do you feel a need to leave that place quickly to go to a place where you will feel more comfortable?
   *25. Does wearing your hearing aid(s) increase any feelings of confusion you may experience?

Section III — Speech Hearing

*26. You are talking to a friend on the telephone while some other sound is occurring elsewhere in the room. Do you have difficulty following the telephone conversation?
27. You are at home talking with a friend or relative. There is a television on in the
same room. Can you follow what the other person says?
28. You are at home talking with a friend or relative. You are in a quiet room. Can you follow what the person says?
29. You are at a gathering or in a club. There are many people about, and it is noisy. You are with a group of people having a conversation. Can you follow the conversation?
30. You are sitting at a dinner table with a group of three or four friends and relatives. It is an otherwise quiet place. Can you follow the conversation?
31. You are sitting at a dinner table or in a meeting with a group of people. You are having a group discussion. You can see everyone at the table. Can you follow the conversation?
*32. You are in a crowded church or meeting hall. There is a public speaker at the front. You can see the speaker's face, and he or she is using a microphone. Do you have difficulty understanding what is said?
33. You are with a group of three or four people in a busy restaurant. Can you follow the conversation?
34. You are with one person in a relatively quiet place. You can hear what the person is saying. Once you can hear them, can you follow everything that person says?
35. You are talking with a group of people whom you know. Some of the people who are taking part in the conversation are out of sight. Can you follow the conversation?
*36. You are shopping with a friend or relative in a large shopping center. Do you have difficulty following the conversation?
*37. You are talking with a group of people whom you know. You are in a relatively noisy place. Do you find it difficult to distinguish who each speaker is during the conversation?
38. You are with a group of people whom you know. There is no background noise. The conversation switches rapidly from one speaker to the next. Can you follow the conversation?