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ADJECTIVE RATINGS AND DIMENSION ANALYSES OF PERCEIVED SOUND QUALITY OF HEARING AIDS. III.

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ABSTRACT

Ten normal hearing subjects and three hearing impaired subjects rated the perceived sound reproduction of eight hearing aid systems, fitted into individual earmoulds, on a number of adjective scales. Three program sections were used. The ratings were subjected to various forms of factor analysis. For the normal hearing subjects the resulting factors were interpreted as "hardness/sharpness - softness", "clearness/distinctness", "distance", "fullness/volume", and a "disturbance" factor. Some of these factors were suggested in the data from the hearing impaired subjects, whose judgment problems are discussed separately.

INTRODUCTION

This is the fourth paper in a series of reports on perceived sound quality of hearing aids. The background and the purposes with the work are described in the earlier reports (Gabrielsson & Sjögren 1974, 1975 a, 1975 b).

The present report represents a follow-up of the technique with adjective ratings used in the 1974 and 1975 b papers. In these reports the subjects made adjective ratings concerning the perceived sound quality of hearing aids whose reproductions were recorded on tape over a 2 cc coupler. In the present experiment, however, the eight hearing aids used in the 1975 b paper were directly fitted into individual earmoulds of the subjects, that is, as hearing aids are used in reality. This would permit a comparison between reproductions over the 2 cc coupler and reproductions into real ears. Since the experimental procedure was very demanding both for the subjects and for the experimenter (see later), the experiment was limited to comprise only ten normal hearing subjects. Some exploratory studies were also made with three hearing impaired subjects.

The plan of the present report mostly conforms to that of the 1974 and 1975 b papers. Since there is much in common with these papers the description of the method is abbreviated here.

METHOD

Rating scales (adjectives)

A total of 50 adjectives were used as rating scales. They included the 40 adjectives used in the 1975 b paper and 10 new adjectives suggested by people suffering from various hearing losses in their ansvers to a questionnaire. All adjectives are given in Swedish alphabetical order in Table I together with translations into English.

Stimuli and listening conditions

The stimuli were constituted by three different programs presented over each of eight hearing aids. The programs were three of those used in the 1975 b paper (also in 1975 a) and the hearing aids were those used in both 1975 papers. Listening levels were set by the experimenters to correspond to a natural level for the respective programs (see below).

The programs were:

Program 1 (P1): Oscar Peterson's jazz trio (piano, bass, drums). Recorded in a gramophone studio. Level: about 70 dB SPL, Gramophone record: "Verve 2304 062". Sample from the tune "Something's coming".

Program 2 (P2): Excerpt from Gustav Mahler: Symphony No. 5. Recorded in the Concert Hall of Stockholm, Stockholm Philharmonic Orchestra. Level: about 80 dB SPL. Gramophone record: "Lyssna 4". Sample from the fifth movement of the symphony.

Program 3 (P3): Recording from a coffee break in the laboratory, some fifteen persons chatting. Level: about 71 dB SPL.

Each program section lasted for about 15 seconds but was repeated three times in succession (with some second's interval between the repetitions) so that each presentation lasted for about 45 seconds.

The hearing aids (here called systems) were:

System 1 (S1): Broad-band system. Copy of the respective master tape, bandwidth 100-15000 Hz ± 3 dB, distortion less than 1 %. This system was thus no hearing aid, but the tape copy was listened to by headphones TDH39, cushion MX41AR.

System 2 (S2): Body-worn hearing aid, type A.

System 3 (S3): Body-worn hearing aid, type B

System 4 (S4): Body-worn hearing aid, type C with tone-control setting "N" ("normal").

System 5 (S5): Body-worn hearing aid, type C with tone-control setting "L" ("low").

System 6 (S6): Body-worn hearing aid, type C with tone-control setting "H" ("high") together with an extra tube 80 mm length between earphone and earmould.

System 7 (S7). Body-worn hearing aid, type D.

System 8 (S8): Body-worn hearing aid, type E.

Frequency curves and harmonic distortion for systems S2-S8 were given in the earlier 1975 reports.

The stimuli were presented monaurally to the best ear by the respective hearing aid fitted into each subject's individual earmould (except for S1 as noted above). The shifting between different hearing aids was handled by the experimenter, who also controlled the fitting of the individual earmoulds to avoid leaking. The subjects were sitting one or two at a time in an anechoic chamber. The experimenter handled the tape recorder and other equipment in an adjoining room but entered into the anechoic chamber at each shift of hearing aids. The aids were kept in the anechoic chamber, invisible for the subjects.

Subjects

There were ten normal hearing subjects (less than 20 dB hearing loss 125-8000 Hz), six males and four females, 19-35 years old. Three of them were used to listen to sound reproduction systems of high fidelity class.

Three subjects had hearing loss, one male and two females, 31-50 years old. Their audiograms are given in Figure 1. All subjects were paid.

Procedure

In total there were 24 different combinations of program sections and hearing aid systems (3 programs x 8 systems). These are referred to as P x S combinations. Since there were 50 adjectives each subject made 24 x 50 = 1200 judgements. This required three

experimental sessions of about two hours each. Unlike the earlier experiments it was not possible to use a randomized order of all P x S combinations, since this would necessitate very frequent shifts of the hearing aids and thus lead to much discomfort and waste of time both for the subjects and for the experimenter. The principle of completely randomized order was therefore abandoned and the following modified procedure was adopted. In each of the three experimental sessions only three systems were used, different for different sessions. Since there were eight systems, this means that there were only two systems left for the third and last session; however, in this last session also one of the earlier systems appeared once more to provide a certain check of the respective subject's ratings. Which systems appeared in which session was randomized independently for each subject.

For each system the three programs were presented four times each in a randomized order. For each such time the subjects made ratings in about 1/4 of the 50 adjectives on the respective list. There was one adjective list for each P x S combination with the order of the 50 adjectives randomized different for different lists and different subjects.

The instruction was similar to that used in the earlier experiments with adjective ratings (1974, 1975 b). Briefly summarized, the subject should rate the sound reproduction in each P x S combination on a 0-9 scale for each of the adjectives, 9 meaning that the reproduction had a "maximum" of the quality designated by the respective adjective, and 0 meaning that the reproduction had nothing of the quality in question. It was emphasized that the judgments should refer to the sound reproduction, not to the sounds "as such". The subjects were also told that the results might be of relevance for future tests and designs of hearing aids and so high concentration was necessary despite a certain monotony of the task.

In each session there were 9-12 preliminary trials including presentations of all three programs over each of the three systems included in the respective session. Moreover System 1 was always included in the preliminary trials (even if it not ap-

peared later in the session) to serve as a kind of reference. During the preliminary trials the subjects adapted to the experimental procedure and to an appropriate tempo in their ratings. There was a break in the middle of each session. At the end of the last session the subjects answered various questions related to the experiment.

For the three hearing impaired subjects the above procedure was modified in certain respects. At the beginning of each session they made individual adjustments to a "most comfortable level" for each of the systems to be used in that session. They listened to a tape loop containing the first five seconds of each program and adjusted a gain control until the listening level was "comfortable" (neither too loud nor too soft). The resulting levels were then used in the main experiment. For all three subjects the experimental procedure had to be "liberalized" in certain ways, for instance, to explain the instruction more fully, to check if certain adjectives were hard to understand, to permit more rests and more sessions etc. Undoubtedly (and quite understandable) these subjects experienced the task as much more difficult and tiring than the normal hearing subjects (see further under Results).

Data treatment

The inter-rater reliabilities of the ratings were estimated for each of the 50 adjectives using analysis of variance procedures described by Winer (1962, p. 124; 1971, p. 283). Thereafter the ratings were averaged over subjects to provide mean ratings for each of the 1200 P x S x A combinations (3 programs x 8 systems x 50 adjectives). These 1200 means constitute the basic data for a number of different factor analyses according to procedures described in the 1974 and 1975 b reports.

The data from the three hearing impaired subjects were treated separately and only certain parts of the above-mentioned analyses were made for these data.

The results presented in the following refer to the normal hearing group only. Some results for the hearing impaired subjects are given in a separate section.

RESULTS

Reliabilities of ratings

The inter-rater reliabilities for each of the adjectives appear to the right in Table I. For 40 out of 50 adjectives the reliability is in the range 0.50 - 0.80. Low reliabilities occur for the adjectives "hissing" ("fräsande"), "hollow" ("ihålig"), "near" ("nära"), "scraping" ("skrapande"), "harsh" ("sträv"), and "thin" ("tunn"). On the whole the reliabilities are considered to be satisfactory especially when considering the relatively low number of subjects in the present experiment. Another indication of satisfactory reliability is given by significance tests. Testing the significance of the differences between mean values for systems (over programs and subjects) in each of the adjective scales the resulting F ratios were significant at 5% or 1% significance level in all adjective scales except those with low reliabilities mentioned above.

Factor analysis on correlations between adjectives

Five factors accounted for 85.7 % of the total variance. The solution was rotated to "simple structure" according to the varimax criterion (orthogonal axes) and according to the "simple loadings" criterion (oblique axes). Both rotations gave highly similar results as regards the interpretation of the five factors and also regarding the factor scores for the P x S combinations. The oblique rotation had a somewhat better "simple structure" considering the "hyperplane count" and appeared somewhat more plausible in certain details. The oblique solution is given in Table I.

In factor I (F I) the adjectives with the highest positive factor loadings are "loud", "sharp", "shrill", "noisy", "harsh", "ringing", "hard", and "clashing". On the other side of the continuum the highest loadings occur for "soft", "subdued", and "calm/quiet". This is highly reminiscent of the "hardness/sharpness -softness" found in the earlier reports (1974, 1975 b). However, there is also a component of "loudness" ("loud - soft") entering into this dimension here.

The factor scores for the P x S combinations appear in Table II. As in the 1975 b report, the two highest factor scores on the "hard/sharp/loud" side of F I occur for the program with symphonic music (P2) as reproduced by S3 and S7. The frequency curve for these two systems (as measured over a 2 cc coupler, see 1975 b) is characterized by resonance peaks in the region 1000 - 3000 Hz which is probably an important reason for giving a "loud/sharp" character of their reproductions. Further P2 represents a higher sound level than the other two programs which explains that nearly all reproductions of this program occur more often on the "hard/sharp/loud" side than they do at the other programs. Looking at the rank order of the systems within each of the three programs (as given in Table II) leads to the conclusion that S3 and S7 (also S6 at P3) are extreme on the "hard/sharp/loud" side, while the broadband system (S1) and a system with a frequency curve rising towards the bass region (S5) are those giving the most "soft" reproduction.

In factor II (FII) the highest positive factor loadings occur for "shut up/closed", "muddy/confused", "blurred", "clashing/indistinct", and "noisy/indistinct". The highest loadings on the other side appear for "distinct", "clear", "open", "airy", "clean/pure", "brilliant", and "bright". This factor is apparently the same as F II in the 1975 b report, a "clearness/distinctness" factor with a feature also of "room impression", contrasting reproductions sounding "open" and "airy" against reproductions of a "shut up/closed" type.

Comparing the factor scores for the systems within each of the programs (Table II) reveals that the broad-band system S1 is outstanding, as expected, on the "clear/distinct" side, followed by S2, a system with a fairly wide frequency region and with the frequency curve rising towards the treble. On the other side, the most "indistinct" systems are S6 and S5. The reasons are probably found in the bass boost occurring for S5 and in the relatively narrow bandwidth of S6 (this can only be part of the explanation, however).

In factor III (F III) there is only one high factor loading on each side of the continuum appearing for "near" and "distant", respectively. Such a "near-distant" factor has been suggested in earlier reports but most often was fused into another factor as "clearness/distinctness" (1975 b) or "loudness" (1974). The factor scores for F III reveals that this factor probably has much to do with the programs as such, since the most positive scores (representing the "near" side) occur for P3 and P1, both of them recorded near to the sound sources in a relatively small room, while the most negative scores (the "distant" side) appear for P2, which was recorded more at distance in a concert hall. However, there are certain consistencies in the position of the systems within each of the programs. S3 appears utmost on the "near" side in all three programs, followed by S2 or S7, which might be related to the prominent peaks in the frequency curves around 2000 and 3000 Hz. Which system appears utmost on the "distant" side is more varying, but S5 and S8 often appear there.

In factor IV (F IV) there is one outstanding factor loading on the positive side appearing for "thin", while the highest loadings on the opposite side occur for "full" ("full-toned") and "noisy/rumbling/much bass". This factor may be labelled "fullness" or "volume" and appeared in the 1975 b report in combination with "brightness-darkness". A similar fusion is suggested here by the moderate loadings of "bright" and "dark" on the "thin" and "full" side, respectively.

This factor, too, probably reflects much of the program characteristics, since the highest factor scores on the "full" side appear for the "complex" symphonic music in P2 and the simultaneous speech of many persons in P3, in contrast to the "thin" texture of clearly separated instruments in P1. However, there are certain consistencies in the positions of the systems. Thus S5 appears utmost on the "full" and "bass" side of the continuum (due to its emphasis on the bass region in the frequency curve) followed by S2. On the other "thin" side there appear systems with relatively narrow bandwidth like S7, S8, and S3.

In factor V (F V), finally, there are high positive factor loadings for "white noise/hissing", "hissing", "crackling/crunching", "sparkling/crackling", and "whistling/whizzing". This factor is apparently related to various "disturbances" in the reproduction. Such a factor did not appear in the 1975 b report - in fact, it could not appear because none of these adjectives were included in that experiment (this highlights the importance of the adjective selection). However, "white noise/hissing", "hissing", and whistling/whizzing" appeared in the 1974 report without resulting in a separate factor as here (they were mainly fused into the "hardness - softness" factor). This might give a certain credence to the assumption that disturbances like "white noise", "hissing" etc are more apparent at direct listening by real hearing aids than when the reproduction is recorded on tape over the 2 cc coupler. This is also indicated by comments from some subjects, and also conforms to the impression of one of the authors (A.G.) who listened to all P x S combinations by means of his individually fitted earmould.

As seen in the factor scores S2, S8, and S7 seem to be most affected by such disturbances, while S1 (not an hearing aid) and S5 (with its relative de-emphasis of the treble region) are most free from them. F V has a moderate positive correlation (+0.43) with F I and with F II (+0.30), which means that there is a certain relation between the "disturbance" factor and the "hardness/sharpness - softness" and "clearness/distinctness" factors. For instance, the "softer" and "clearer" systems tend to lie on the "non disturbance" side in F V (compare the factor scores for different systems in F I - F V, and in F II - F V).

The correlations between other factors in this oblique solution were negligibly low.

The five factors described above also appeared in a factor analysis on correlations between adjectives starting from a matrix of A x S means, that is, means for adjective x system combinations taken in average over the three programs. Still other factor analyses on correlations between P x S combinations and three mode factor analyses add nothing new to the picture and are omitted here.

Evaluative ratings

The mean ratings (over normal hearing subjects) for the adjectives "pleasant", "painful", and "true to nature" are given for all P x S combinations in Table III.

As regards "pleasantness" S1 is rated highest for all three programs (which is of course to be expected) followed by S5 and S2. An exception from this occurs at P3, the speech program, at which S5 gets a lower rating than at the two music programs.

It thus seems that the bass boost of S5 affects reproduction of speech in a negative manner. However, the least "pleasant" or most "painful" reproductions occur for one or more of the narrow-band systems at all three programs.

As regards the "true to nature" ratings S1 is again rated highest followed by S2 and S5 at the music programs. At the speech program, however, S1 is followed by two narrow-band systems, S3 and S8. These two last-mentioned systems get higher ratings for the speech program than they get at the music programs. This is also the case for S7, another narrow-band system. Thus the narrow-band systems compare relatively well with broad-band systems as S2, S4, and S5 as regards "true to nature" reproduction of speech, while they lag behind when it comes to music.

A separate analysis was made concerning which of the other adjectives correlated highest (positively and negatively) with the ratings for "pleasant", "painful", and "true to nature", see Table IV.

The results conform well to what may be expected. Thus the highest positive correlations with the "pleasant" ratings occur for the adjectives "uniform/smooth", "calm/quiet", "soft", clean/pure", "brilliant", and "airy". On the opposite the highest positive correlations with the "painful" ratings occur for "clashing/hard", "sparkling/crackling", "hard", "harsh", "sharp/keen", "screaming", and "ringing". For the "true to nature" ratings the highest positive correlations occur for "impression of room", "airy", "clear", "uniform/smooth", "open", "brilliant", "calm/quiet", "clean/pure", and "distinct/clear".

More details may be seen in Table IV. Such information may be useful when trying to understand and predict the relation between ratings in various "perceptual" scales (like "hard", "clear". "soft", etc) and "overall" evaluations as those used here (that is, "pleasant", "painful", and "true to nature").

In this context one may also look at the factor loadings for these three evaluative scales in the five factors given in Table I. It is noted, for instance, that "pleasant" and "true to nature" occur on the "soft" side in the "hardness/sharpness - softness" factor (F I), on the "clear/distinct" side in F II, and on the "non-hissing/crackling/sparkling" part of the continuum in F V. Although their loadings in the "near-distant" factor (F III) are relatively low, it is noted that "true to nature" appears on the "near" side, while "pleasant" occurs on the "distant" side of the continuum.

As in the earlier experiments the subjects answered various questions about judgment principles, ambiguities in adjective meanings and the like. The answers and comments were so similar to those reported in the 1975 b paper that they need not be repeated here.

Results from hearing impaired subjects

As noted earlier the participation of three hearing impaired subjects was intended to give some preliminary information about difficulties, necessary modifications of the procedures etc, which must be considered in following experiments with hearing impaired subjects. Of course no detailed comparison with the results from the normal hearing subjects was intended, nor were these three subjects considered as forming some kind of homogeneous group.

The data were in fact treated as for the normal hearing subjects (see below), but the main "results" of this part of the investigation are more concerned with the behavior and comments from the three subjects. As could be expected, the use of many various adjectives presented problems both due to certain limitations in individual vocabulary and to difficulties directly associated with the hearing loss (for instance the meaning of "true to nature" could certainly be understood in principle but its perceptual re-

ference is apparently more or less lacking). It was thus necessary for the experimenter to give various indications about the meaning of the adjectives and to explain the instruction more fully. The shifting between several hearing aids was more troublesome than for the normal hearing subjects. A contributing cause to this was that two of the subjects were very sensitive to differences in perceived loudness between the aids. Even though adjustments to a "most comfortable level" were made at the beginning of each session (see Procedure) it was thus necessary to allow some further adjustments within the respective sessions. Another troublesome point was that all three subjects used headworn hearing aids and experienced the sound reproduction of the bodyworn aids used here as quite different.

Factor analyses on correlations between adjectives were performed for the group of three subjects as well as for each subject individually. From a statistical point of view these analyses are of course hard to justify due to the few data and questionable reliability. However, keeping in mind the highly explorative character of this part of the experiment it may still be interesting to see if any kind of interpretable factors would result. A number of analyses were tried. In all of them (both for the group and for each subject separately) there was a fairly evident indication of a "distinctness/clearness" factor with the adjectives "distinct", "clear", and "pure/clean" representing the highest loadings on one side of the continuum, while "blurred", "muddy/confused", "rough/raucous", and "noisy/indistinct" were extreme on the other side. There was also a fairly evident indication of a "hardness/sharpness - softness" factor with one extreme represented by "clashing/hard", "shrill", and "sharp/keen" and the other extreme by "soft", "soft/gentle", and "uniform/smooth". In some of the analyses there were certain indications of a "disturbance" factor ("hissing", "white noise/hissing") and a factor related to "room impression".

DISCUSSION

In general the results from the present experiment are similar to those obtained earlier in this series of experiments. The

dimensions found by factor analyses agree well with those summarized in the 1975 b report. Thus it may be concluded that the dimensions of perceived sound quality of hearing aids are fairly independent of whether the listening takes place by recording over a 2 cc coupler or by aids directly fitted into earmoulds.

However, this statement must immediately be qualified in several respects. First of all the results refer only to normal hearing subjects, which is, of course, a severe limitation in this context. Second, the fact that the dimensions seem to be the same does not necessarily mean that the positions of the aids in these dimensions are the same when listened to over coupler as when fitted into real ears (that would indeed be very surprising). This question may be studied by comparing the factor scores for the eight systems in those dimensions that are common for this experiment and the nearest preceding experiment (1975 b). Such a comparison no doubt suggests similar positions for certain systems (for instance, that S3 and S7 are most extreme in "hardness/sharpness", that S1 and S2 are most "clear/distinct" etc.) but also more or less varying positions of other systems. (A detailed comparison is hardly justified since the subjects were different in those two experiments and also very different in number, further because of a somewhat different context of rating scales and slight differences in the interpretations of the dimensions). A third point to notice is that there in fact appeared a dimension in the present experiment that was not found earlier, namely a "disturbance" factor ("white noise/hissing" etc. see comments under Results).

The references to the frequency curves of the eight systems when discussing the interpretation of the factors (see Results) may be questionable, since they deal with measurement over a 2 cc coupler. In the absence of an adequate method for measuring the impedance of real ears the coupler measurements may be used as approximations. This, of course, also contributes to the difficulties of making direct comparisons between our last two experiments.

The experiences gained from the participation of the three hearing impaired subjects are highly valuable for the future work. Several difficulties have to be met in one way or another: limitations of vocabulary, high sensitivity to loudness changes, many troublesome points in the experimental procedure such as frequent shifts of hearing aids etc. A big problem will also be the difficulty of

forming "homogenous" groups of subjects with similar kinds and degrees of hearing loss. However, we have now by strict experimental procedures established a descriptive system for perceived sound quality for normal hearing subjects. This should serve as a platform and basis for evaluation in the future work with hearing impaired people, in which no doubt often less stringent procedures must be used and flexibility is required in many respects.

Although the present results should be taken with extreme caution it is interesting to see that at least two earlier known dimensions also appeared in the analyses on the hearing impaired subjects (the "clearness/distinctness" and "hardness/sharpness - softness" dimensions). In coming experiments using adjective ratings or similar techniques it may be useful to try to select subjects with less vocabulary problems (there are wide individual differences among hearing impaired people in this respect). The technique with similarity rating (see 1975 a report) presents another possibility that avoids much of the language problems. On the whole many different and flexible approaches have to be used in combination, even very informal ones, to get a clearer picture of the perception and evaluation of sound quality in hearing aids by the persons who actually need them.

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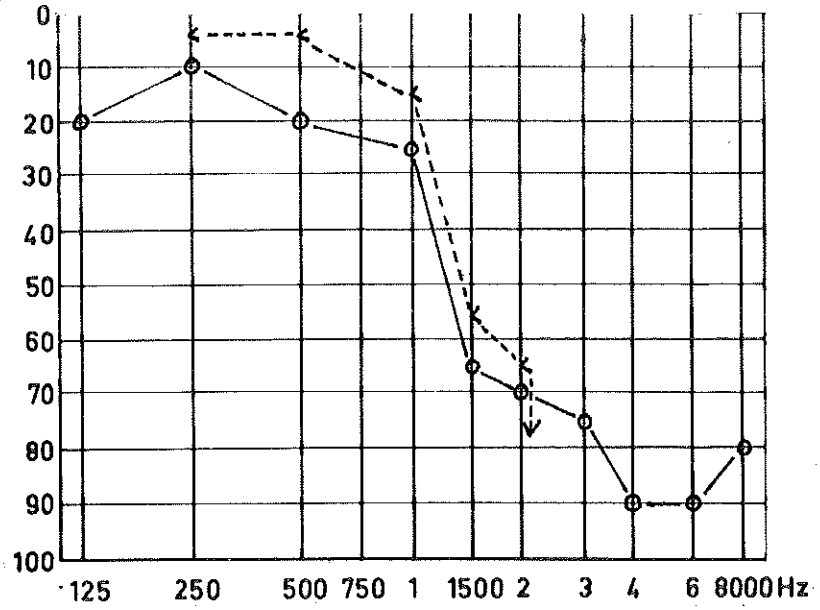

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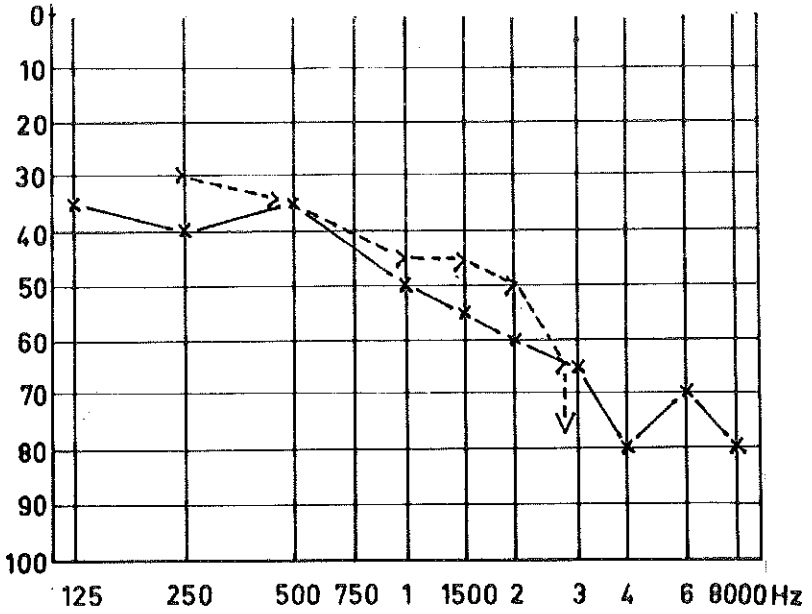

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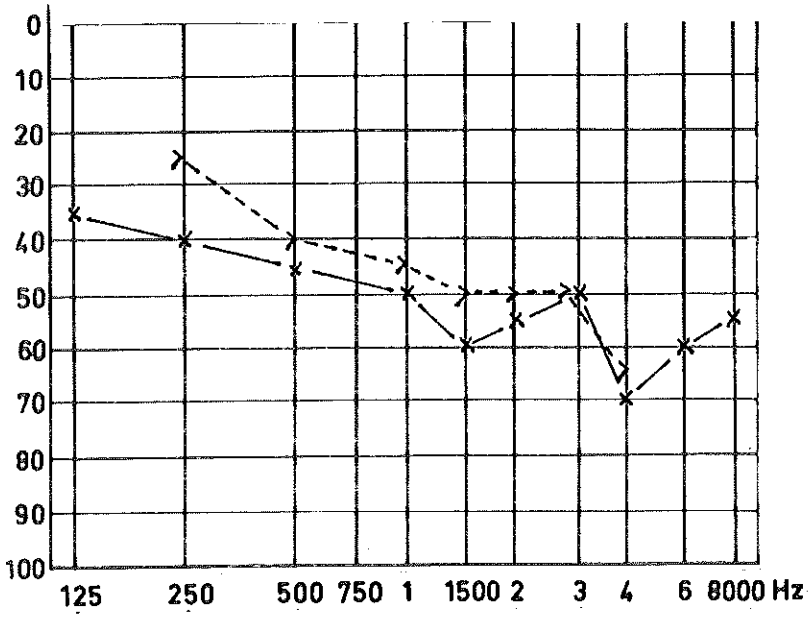

Subject 3

Figure 1. Audiograms for three hearing impaired subjects

TABLE I. Factor loadings ("simple loadings" criterion) and inter-rater reliabilities for 50 adjectives.

Adjectives	Factors I	II	III	IV	V	Reliability
Avlägsen ("Distant")	-.19	.02	-.83	.01	-.02	.60
Behaglig ("Pleasant")	-.44	-.52	-.34	-.07	-.19	.62
Briljant ("Brilliant")	-.01	-.77	-.12	.04	-.31	.51
Brusig ("White noise/Hissing")	-.13	.10	.13	-.16	.95	.71
Bullrig = Stark ("Noisy = Loud")	.84	.39	-.03	-.31	-.06	.77
Bullrig = Mycket bas ("Noisy/Rumbling = Much bass")	-.14	.42	-.13	-.71	.04	.68
Bullrig = Otydlig ("Noisy = Indistinct")	.23	.72	.06	-.05	.20	.67
Dov ("Dull")	-.38	.56	-.41	-.38	.14	.75
Dämpad ("Subdued")	-.75	.26	-.41	.04	-.12	.77
Från ("Harsh") ("Rough/Harsh")	.79	.23	-.17	.17	.05	.75
Fräsande ("Hissing")	.08	-.13	.06	.09	.86	.30
Fyllig ("Full/-toned/")	.23	-.46	-.22	-.74	-.15	.48
Grumlig ("Muddy/Confused")	-.24	.85	-.03	-.06	.22	.66
Gäll ("Shrill")	.85	.01	-.08	.23	.06	.74
Hård ("Hard")	.75	.06	.20	.14	.16	.79
Ihålig ("Hollow")	.02	.67	.17	.08	.35	.31
Instängd ("Shut up/Closed")	-.42	.88	-.09	.19	.04	.58
Jämn ("Uniform/Smooth")	-.40	-.48	.03	-.26	-.28	.65
Klar ("Clear")	-.25	-.90	-.09	.07	.08	.66
Knastrande ("Crackling/Crunching")	.08	.11	.34	-.21	.74	.49
Ljus ("Bright/Light")	.02	-.75	.08	.40	.10	.55
Luftig ("Airy")	-.38	-.81	.05	-.05	.04	.64
Lugn ("Calm/Quiet")	-.71	-.19	-.18	-.04	-.17	.64
Matt ("Faint/Feeble")	-.43	.48	-.42	-.16	-.18	.58
Mjuk ("Soft")	-.63	-.06	-.22	-.19	-.29	.75
Mullrande ("Rumbling")	.14	.69	-.13	-.51	-.11	.62
Mörk ("Dark")	-.20	.53	-.27	-.55	-.02	.69
Naturtrogen ("True to nature")	-.46	-.62	.21	-.21	-.14	.59
Nära ("Near")	-.27	.06	.88	-.04	.06	.40
Plågsam ("Painful")	.55	.35	.15	.10	.32	.59
Ren ("Clean/Pure")	-.14	-.78	-.23	.13	-.21	.64
Ringande ("Ringing")	.77	.19	-.28	.18	.14	.70

Table I continued

Adjectives	Factors I	II	III	IV	V	Reliability
Rumskänsla ("Impression of room")	-.49	-.60	.18	-.31	.08	.62
Skarp ("Sharp")	.86	-.19	.01	.21	.08	.75
Skrapande ("Scraping")	.06	.50	.51	.15	.31	.26
Skrikig ("Screaming")	.65	.09	.22	.34	.06	.68
Skrovlig ("Rough/Raucous")	.14	.63	.09	.04	.29	.55
Skrällig = Otydlig ("Clashing = Indistinct")	.29	.76	.08	.13	.08	.57
Skrällig = Hård ("Clashing = Hard")	.73	.21	.15	.13	.18	.75
Sprakande ("Sparkling/ Crackling")	.30	.20	.09	.15	.58	.56
Stark ("Loud")	.91	-.03	-.17	-.18	.19	.79
Sträv ("Harsh")	.34	.51	-.10	.38	.25	.38
Suddig ("Blurred")	-.08	.78	-.09	-.36	.11	.47
Svag ("Soft/Gentle", opposite to "Loud")	-.88	-.11	-.14	.24	-.09	.60
Tunn ("Thin")	.09	-.06	-.17	.91	-.06	.34
Tydlig ("Distinct/Clear")	-.01	-.91	.03	-.05	.02	.56
Vass ("Sharp/Keen")	.64	-.02	.16	.27	.29	.73
Vinande ("Whistling/Whizzing")	.48	-.17	-.34	-.10	.52	.57
Väsande ("Hissing/Wheezing")	.02	-.03	-.16	.09	.95	.43
Öppen ("Open")	-.28	-.90	-.05	.05	.20	.52

TABLE II. Factor scores for systems 1 - 8 within each of programs 1-3.

	Factors									
	I		II		III		IV		V	
Program 1	S_3	1.20	S_6	.82	S_3	1.41	S_7	1.76	S_2	1.35
	S_7	.99	S_7	.36	S_2	.72	S_6	1.42	S_8	1.07
	S_6	.33	S_5	.09	S_7	.66	S_8	1.36	S_7	.67
	S_2	-.01	S_8	.01	S_1	.19	S_1	1.34	S_3	.40
	S_4	-.07	S_4	-.13	S_6	.14	S_3	1.21	S_6	.09
	S_8	-.61	S_3	-.61	S_4	-.29	S_4	.51	S_4	-.08
	S_5	-.84	S_2	-1.40	S_5	-.35	S_2	-.50	S_5	-1.11
	S_1	-1.12	S_1	-2.10	S_8	-1.36	S_5	-1.05	S_1	-1.51
Program 2	S_3	2.11	S_6	.95	S_3	.25	S_7	.72	S_8	1.00
	S_7	2.11	S_5	.94	S_2	.05	S_3	.38	S_7	.73
	S_2	.90	S_7	.59	S_7	-.01	S_1	.03	S_2	.41
	S_6	.88	S_8	.52	S_4	-.65	S_8	-.22	S_4	-.08
	S_4	.50	S_4	.03	S_6	-1.22	S_6	-.29	S_3	-.12
	S_8	.16	S_3	-.07	S_8	-1.34	S_4	-.31	S_6	-.33
	S_5	-.27	S_2	-1.10	S_5	-1.83	S_2	-1.62	S_5	-1.13
	S_1	-1.05	S_1	-1.84	S_1	-1.92	S_5	-1.86	S_1	-1.51
Program 3	S_6	.26	S_5	1.58	S_3	1.87	S_8	.55	S_2	1.62
	S_7	.00	S_6	1.32	S_7	1.62	S_7	.14	S_8	.93
	S_3	-.26	S_7	.79	S_2	.71	S_3	.05	S_7	.53
	S_2	-.52	S_4	.77	S_6	.54	S_6	-.23	S_6	.53
	S_8	-.92	S_8	.63	S_1	.38	S_4	-.26	S_3	-.15
	S_4	-.99	S_3	-.21	S_8	.32	S_1	-.48	S_4	-.24
	S_5	-1.21	S_2	-.37	S_4	.08	S_5	-1.29	S_5	-.61
	S_1	-1.58	S_1	-1.56	S_5	.01	S_2	-1.36	S_1	-2.45

TABLE III. Mean ratings over 10 subjects in the "pleasant", "painful", and "true to nature" rating scales.

Program 1

	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
Pleasant	5.8	4.5	3.2	4.0	4.8	3.6	2.6	4.4
Painful	1.9	3.1	3.8	2.8	1.9	3.6	4.5	3.3
True to nature	5.4	5.2	3.8	3.5	4.5	3.7	3.1	3.8

Program 2

Pleasant	6.2	4.0	3.1	3.5	4.9	4.0	2.7	3.5
Painful	1.0	3.3	4.2	3.0	2.7	4.0	5.1	3.2
True to nature	5.6	4.9	3.4	3.9	3.8	2.9	2.9	3.3

Program 3

Pleasant	6.1	4.3	3.5	4.2	3.5	3.1	2.4	4.1
Painful	1.3	3.6	2.7	2.9	2.6	4.2	4.2	3.1
True to nature	6.4	4.3	4.5	4.0	4.2	3.4	4.1	4.5

TABLE IV. Adjectives showing highest correlations with the "pleasant", "painful", and "true to nature" scales

Pleasant	Painful	True to nature
-.84 Clashing/Hard	.92 Clashing/Hard	.85 Impression of room
-.84 Clashing/Indistinct	-.88 Soft	-.83 Harsh
.83 Uniform/Smooth	-.87 Uniform/Smooth	.82 Airy
-.83 Scraping	-.87 Calm/Quiet	-.81 Ringing
-.80 Hard	.85 Sparkling/Crackling	.81 Clear
.80 Calm/Quiet	.83 Hard	.81 Uniform/Smooth
.78 Soft	.81 Harsh	.77 Open
.77 Pure/Clean	.81 Sharp/Keen	-.76 Rough/Raucous
-.77 Hollow	-.80 Soft/Gentle	-.76 Clashing/Indistinct
.77 Brilliant	.80 Screaming	-.76 Clashing/Hard
.77 Airy	.78 Ringing	-.74 Noisy/Indistinct
-.76 Harsh	.76 Clashing/Indistinct	.73 Brilliant
-.74 Sharp/Keen	-.76 Clean/Pure	-.72 Noisy/Loud
.74 Soft/Gentle	.75 Shrill	-.72 Hollow
-.74 Noisy/Indistinct	.75 Noisy/Indistinct	.71 Calm/Quiet
.72 Clear	.74 Noisy/Loud	.71 Clean/Pure
-.72 Sparkling/Crackling	.74 Rough/Raucous	.71 Distinct
-.72 Crackling/Crunching	.74 Loud	-.66 Hard
-.70 Noisy/Loud	.72 Sharp	-.66 Shrill
.69 Impression of room	-.70 Airy	.66 Soft/Gentle
-.68 Rough/Raucous	.68 Crackling/Crunching	.65 Soft
.67 Open	.67 Hollow	-.64 Sparkling/Crackling
-.67 Screaming	.67 Hissing	-.62 Sharp/Keen
-.67 Shrill	-.67 Brilliant	-.58 Muddy/Confused
-.66 Ringing	-.67 Subdued	-.55 Screaming
.61 Subdued	-.65 Clear	-.53 Sharp
-.61 Loud	-.65 Impression of room	-.50 Scraping
-.59 Hissing	.63 Hissing/Wheezing	-.50 Blurred
-.58 Sharp/Keen	.58 White noise/Hissing	
-.58 White noise/Hissing		
.56 Distinct		