QUALITY JUDGEMENT OF HEARING AIDS USING SFECTROGBAPHIC ANALYSIS

A DISSERTATION SUBMITTED IN PART FULFILLMENT FOR THE DEGREE OF MASTER OF SCIENCE (SPEECH AND HEARING)

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CERTIFICATE

This is to certify that dissertation entitled "QUALITY JUDGEMENT OF HEARING AIDS USING SPECTROGRAPHIC ANALYSIS" is the bonafide work in part fulfilment for M.Sc. in Speech and Hearing, of the student with Reg. No.

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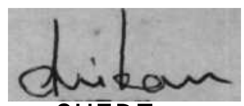
CERTIFICATE

This is to certify that dissertation entitled "QUALITY JUDGEMENT OF HEARING AIDS USING SPECTROGRAPHIC ANALYSIS' is prepared under my guidance.



GUIDE.

DECLARATION

The dissertation "QUALITY JUDGEMENT OF HEARING AIDS USING SPECTROGRAPEIC ANALYSIS" is the result of my own study undertaken under the guidance of Dr. (Miss) Shailaja Nikam, Professor and Head, Dept. of Audiology, All India Institute of Speech and Hearing, Mysore-6, and has not been submitted earlier at any university for say other Diploma or Degree.

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C O N T E N T S

INTRODUCTION

The evaluation of hearing aid performance is not an end in itself, but an integral part of the total rehabilitation of the hearing impaired patient.Hearing aid is a critical tool in the rehabilitation of hard of hearing. In the aural rehabilitation programmes which are planned by medical and non-medical specialists,the audiologist is responsible for determining whether a given indvidual will benifit from medical or surgical care.In the cases where the indviduals can not be helped by surgical methods,it becomes pertinent on the part of the audiologist to assess the need for and selection of an indvidual hearing aid.

There are no records of earliest attempts through which man aided his hearing.Hearing aids have been used for rehabilitation since 19th century.Since their inception in 17th century, though there have been many modifications but their basic functions remain same.Hearing aid literally means a device capable of'Aiding the hearing'. Modern hearing aid is a miniature electronic device which amplifies the sound energy.The sound enegy can not be amplified directly,it is first converted into electrical energy,amplified and again changed to acoustic energy in an amplified form at the receiver.

Other aspects of habilitative process are determined and limited by the capability of the hearing aid to provide the optimal signal to the ear. To serve our clients better we require hearing aids which are durable,handy,inexpensive, robust and produce the speech signal faithfully.The selection of an approprisrte and requires extensive knowledge of the performance characteristics of the hearing aids.Even after wide intensive research,there is little agreement about the parameters which an "ideal hearing aid " must posses.As the knowledge about the human auditory system and its physiology is limited and man has not been able to understand these mystries completely, so it is not known fully which specific parameters should be emphasized.

A hearing may also be regarded as a part of a speech transmission system.But here the communication is between a normal speaker and a hearing impaired listener and hearing aid is a weaaable device which, for cosmetic reasons, is usually made as small as practically possible.An ideal hearing aid should amplify speech signals so that they are received at an adequate level for understanding and, for uses with sensorineural loss,it should modify signals in a ways that compensates for the analytical capacity of the ear.It is not difficult to meet first of these requirements,but the second has remained almost an intractible problem.

The purpose of hearing aid evaluation and measurement of electroacoustic as well as psychoacoustic characteristics is to provide - best suitable " hearing aid to a client.The acoustic properties of speech and the factors affecting its intelligibility for listeners with normal and impaired hearing should be examined,while considering what electroacoustic characteristics will he appropriate for hearing aids.

She physical characteristics of speech and the mechanism of voice production have been the subject of numerous investigations (Littler 1965; Fletcher 1953;Flangan 1972). Daring production of the speech vocal cords close and open at rates ranging from75 to 500/sec. depending upon the intonation and voice quality.The average number of interruptions per second are about 120 for males and 240 for females.The frequency characteristics for speech depend upon the laryngeal tone and on resonances within vocal cavities, which are continually modified in the act of speaking. Resonance in the vocal tract reinforce particular frequency bands of laryngeal tone, and for vowels and dipthongs several characteristics frequencies known as formants can he identified.

Sound spectrograph is an instrument that helps in examining the frequency,intensity and time characteristics of particular phoneme or words (Koenig et. al 1946,Potter et al. 1947).The spectrograph samples speech,a few words at s time and leaves a visible record showing how the sound energy in a series of specified bands varies from one input to the next. Another form of analysis gives the average power spectrum in a passage of speech which is long enough to include a large number of speech sounds.

NEED FOR STUDY

Hearing aid evaluation is judgement as to the merits of a hearing aid and is better determined by means. Of a electroacoustic instrumentation. Quality judgemets by indviduals are questionable at best because they are so easily influenced by suggestions or variables outside condition..

Methods of hearing aid evaluation has been subjected of scrutiny for many years. Most thoughtful practitioners of the art have felt that present methods have something to be desired and several alternatives are being considered. These alternatives include the use of damped wave trains, narrow hands of noise and impedance audiometry. The ideal of course would he a truly objective method. Mast clinicians and hearing aid specialists have been trained in the traditional methods of making comparisons between aids in much the same manner that an earliest generation took "spectacles" out of trays to try them out. In the same way, we appear to be going in circles. For example, hearing aid specialist has been ridiculed in the past for "Do you hear me now?" techniques. While others turning screws and saying, "Does that sound better?"

They sre using strictly subjective methods while they pronounce that hard of hearing person is not capable of judging what is truly in the line of correction of his impairment.

There seems to be general agreement that present methods of hearing aid evaluation are inadequate.Many clinicians feel that hearing aid selection procedue are often long boring and frustrating.Most of them do not enjoy particularly enjoy monitoring the patient response to PB test, by the end of tests, the patient is usually fatigued and as bored as exasperated as tester.Many believe that the time can be shortened by the use of a speech sound pressure measuring instrument....... especially one whose components and response slopes have a direct correlation with the ultimate amplification pattern ...... a so called "master hearing aid" (Delk,1975).

When performing the electroacoustic tearing,stimulus presented to hearing should be considered csrefully.Most of the commercially available unit on today's market present only pure tone stimuli to the aid* Historically,pure tones of selected frequencies were choosen as a test stimuli because they were readily generated and could be precisely controlled.Present testing units provide either continuous pure tones across a broad range or discrete frequencies within a range from 250 Hz to 6000 Hz.The aid is still being tested with repeated presentations of single pure tones, even though the extended range of frequencies is available at present. The pure tone is the stimulus that the aid will most probably will never again receive in a like manner while being used by the user.In real life,the aid being worn receives a indefinitely large number of stimuli,all simultaneously and is designed to amplify those portions of signal most meaningfully to the particular listener.Electroacoustic analysis,using pure tone stimuli,does not really tell us how well an aid amplifies complex input signals.

Ideally,the future calls for electroacoustic testing making use of shaped spectrum as input stimuli.The signal presented to the aid will not be sinusoidal but will be complex,and will be altered or shaped to present various combinations of acoustical energy to the aid.For example the aids response could be measured to an input spectrum shaped to represent the acoustical energy present in the human speech,with greater low frequency energy than high frequency energy.Obviously the aid designed to amplify speech would alter the input spectrum and provide a different shaped spectrum as an output. The difference between input an output spectrum would represent the aids response.The response would be a more realistic and complex signal,rather than tradional response to pure tones.By varying the spectrum of the signal, the aid's response to different acoustical environments would be obtained giving a much more realistic measure of aid's performance. Very few studies have been reported, which utilize the method of analyzing hearing aid processed sentences with the help of sound spectrograph and no such study has been done in India.

PURPOSE OF THE STUDY

This study aims at judging the quality of a few selected hearing aide using sentences as hearing aid processed stimuli and ranking them in order of their performance.

REVIEW OF LITERATURE

The hearing aid evaluation has been an important clinical procedure for over two decades. The traditional method of hearing aid evaluation was originally described by Carhart almost 35 years ago. Audiologist have been engaged in selecting and monitoring of wearable amplification for the hearing impaired for these years. Carhart (1950) stated, "The problem of hearing aid selection is currently the most controversial aspect of clinical audiology*. This statement still holds good even after 33 years.

LITRATURE REVIEW

Hallpike (1934) commented that individuals with preebycusis reported a considerable amount of difficulty in understanding speech, when there was a competing noise or other conversation in the same environment.

Berry (1939) and Holmgren (1939) recommended that at least part of the testing should be conducted with the competing speech or noise in the background for the people who have difficulty in speech discrimination. Even though others have made similar statements, they have been almost universally ignored.

Carhart has reported in a book edited by pollack (1975) that Bunch (1930) responded to Walter Huth'a design of hearing aids in the following way: "Your hearing aid is designed for normal listeners rather than hard of hearing persons. Look at this hatch of audiograms from persons with hearing losses and see how their deficits slope in different directions. You showed build a whole family of hearing aids with different responses".

FREQUENCY SELECTIVE AMPLIFICATION

Watson and Knudson (1940) published on article entitled "Selective Amplification of Hearing Aids". They stated, in their introductory paragraph, "Selective amplification has become a by-word in hearing aid termionology and great claims have been made for it. Yet many who have used the words and made the claims have understood very little about its fundamental principles or its application to hearing aids** They wrote in their article that in recent years several methods for providing selective amplification had been purposed, but they were not impressed with some of these methods. In fact they stated, "Some of the methods are absurd . ... others are of sufficient worth to justify discussion of their advantages and disadvantages*. They pointed the out that it was necessary that methods using the subject's own observation with regard to various aspects such as threshold, most comfortable loudness level, and equal loudness level be employed. According to these authors such judgement is made with surprising accuracy. They concluded that the most effective means for "prescribing" selective amplification is the most comfortable equal loudnees curve. They utilized a IK Hz tone, adjusting it to comfortable setting, and then using it as a reference point for finding equal loudness curve?. They found that selective amplification prescribed in this way proved to be superior to uniform or flat frequency response amplification for some, but not all, cases, in some cases uniform amplification proved to be more effective. They summarized that selective amplification was superior to uniform amplification in ears with ia sensorineural hearing impairment whereas sniform amplification seemed to be more effective for the impairment of a conductive nature.

Carhart (1946) described the procedure to evaluate hearing aids in an article entitled "Tests for the selection of Hearing Aids". With some variations and refinements, these procedures are still widely used. (ASHA, 1967} Barney 1972). It is no tribute to him to find that most clinics are still essentially following the same procedures (Ross 1976). Four dimensions of hearing aid performance were explored: effective gain, tolerance limit, efficiency in noise and word discrimination* The remainder of the paper describes*in which these things can be evaluated. Carhart (1946) also mentioned tests for tolerance and suggested the use of connected speech to allow the patient to determine whether or not speech is tolerable at various levels. The test for efficiency in noise as described by Carhart also has a fourstep method in which the maximum level of noise that can be present without destroying the hearing aid user's ability to understand speech is determined. Carhart noted that the above set of measurements:

H "made possible the selection of a hearing aid better suited to the patient's indvidual needs. While it is true that many patients obtained equivalent perform mance with different hearing aids on one or more of the test items, every item differentiated performance in a sizable proportion of cases. Selection was made sometimes in terms of one criterion, sometimes in terms of several criteria. With patients for whom performance was equivalent on several instruments, selection could be based on auxiliary factors of convenience, weight, and esthetic preferences" (Carhart, 1946c, page 739).

FIXED FREQUENCY GAIN CHARACERISTIES

Davis et. al. (1946) published an article "The selection of Fearing Aids" which is essentially the report of the Psychoacoustic and Electroacoustic Laboratories at

Harvard university. The major conclusions of the study were that:

"The appropriate frequency characteristics for a hearing aid is not correctly indicated by current principles of 'audiogram fitting' or 'selective amplification'. A uniform frequency characteristics that can be varied by a tone control between 'flat' and a moderate accentuation of high tones will provide the most satisfactory performance for all or nearly all cases of hearing loss.

Minor variations from the ideal frequency characteristics are relatively unimportant, but the maximum acoustic output must be chosen to suit the tolerance for each patient. Tolerance measurements must be made carefully, with due regard for psychological factors and the desirability of increasing tolerance gradually by experience. For the usual hard -of-hearing patients any detailed 'fitting' is wasteful of time and effort. The differentials between instruments that are indicated by most current tests are largely illusory.

Routine test procedures should be designed to detect the unusual and difficult cases of hearing loss that require special attention. For such cases smaller differences between instruments may be significant, and more elaborate selective tests are appropriate. The additional tests most likely to prove useful are those based on

1. The maximum (input) operating range;
2. The maximum score on appropriate word lists; and
3. The minimum signal-to-noise ratio for intelligibility.

Such tests are unnecessary, however, for the majority of patients". (Davis et al, 1946, pages 87, 88).

It was their belief that the patient is usually primarily interested in obtaining a hearing aid which has pleasing or natural quality, but they conceded, "Unfortunately the quality preferred by the patient is not alwaysr compatible with greatest intelligibility but with respect to other secondary requirements the patient's personal opinions are the chief criteria."

Davis et. al. listed five essentials in hearing aid fitting:
1. Power- a hearing aid must produce sufficient acoustic power to override the patient's deafness;
2. Tolerance levels- apeech intelligibility must be obtained without serious discomfort, pain or tickle;
3. Fidelity- the hearing aid must be capable of reproducing a signal which is meaningful to the wearer, e.g. simple connected speech when clearly and loudly spoken must be inte-

lligible to him;

4. Wearibility- the instrument and earmould must be tolerable to the wearer;

5. Sensitivity- is highly desirable although not absolutely essential, "that the instrument render intelligibility in ordinary speech that is delivered to it at a conversational level".

These five items are considered in first order of importance.

According to Davis et al (1946) second order objectives were increases in range of versatility and adequate performance, complete tolerability and wide dynamic ranges for speech input, increased intelligibility, a wide range of voice and listening conditions, and the durability and reliability of longe battery life. Third order considerations included making speech and music pleasing, esthetic appearence and mechanical convenience etc.

In considering selective amplification, Davis et. al. (1946) spent some time on the short comings of the audiogram fitting. It was pointed out that the frequency response characteristics of hearing aids are influenced by the baffle effects (head diffraction effects), leakage around the earmould, etc. They pointed out that the audiogram is a measure of auditory threshold sensitivity and that listening is usually done above this level. Furthermore, equal loudness contours tend to be more nearly regular or horizontal than the threshold, particularly in the range of speech frequencies. As mentioned earlier Wataon and Knudson (I940) suggested that hearing aids be fitted to equal loudness contours at a comfortable listening level, and reported that such loudness judgements eould be made relatively easily and consistently, but Davis et al. reported it to be difficult to obtain equal loudness contours from individuals who are not trained listeners. From this they concluded, "It is possible to specify the desirable frequency characteristics more successfully by a simple general rule then by the interpretation of the patients audiogram". They stated on the basis of these observations that.

1. It is probably necessary to have some type of screening of the hearing aid itself to eliminate any obviously inferior instruments;
2. The patient's audiogram is often misleading in the guide to selecting hearing aids;
3. The selective amplification method is fallacious; and
4. Individual detailed fitting is futile in that the ability to discriminate between instruments is achieved only in the minority of the cases and further, the tests for such are either too arbitrary or too elaborate and/or in conclusive.

The recommendations of Davis et. al. were supported in large measure by the results of a similar but an independent study performed almost at the same time in Great Britian known as the Med.Res. Co. study (Medical Research Council, 1947). In both studies it was concluded that for the majority of hearing aid users a single frequency gain characteristics would provide the optimum amplification. On the surface, the two studies also appeared to recommend similar frequency gain characteristics above 750 Hz and a moderate difference in relative gain below this frequency. The Harvard study recommended that the frequency response be uniform between 300 and 4000 Hz or have a moderate high-frequency emphasis of 4 to 6 dB per octave over this range, and that frequencies below and above this range the response showed fall off sharply. The MRC study recommended a frequency response that increased at the rate of roughly 12 dB per octave up to a frequency of 750 Hz and that at higher frequencies on of two alternate responses to be used, either a flat response or an upward sloping response of 5 dB/octave.

There were, however, important differences between the two studies in the methods used to specify the frequency gain characteristics of hearing aids. If these differences are taken into account then the recommended frequency-gain characteristics are found to differ significantly (Resnick, 1977)+ Finally, Davis et. al. emphasized that each hearing aid user should be provided with a well fitting indvidually moulded ear piece that is comfortable and a hearing aid which has adequate gain. In addition orientation and training ahould be provided as necessary. But they warn that "even with the most perfect hearing aid, not all cases will achieve satisfactory results".

HEARING AID SELECTION

Carhart (1950) wrote an article "Hearing Aid Selection by University Clinics" in which he made some very pertinent comments with regard to the necessity for hearing aid evaluations. He indicated the necessity for ensuring that the indvidual wth the hearing impairment understands the benefits and also the limitation which he may face with the use of amplification and emphasized that this is best done when the audiologiat is fully aware of the environmental situations in which the patient must function.

Carhart (1950) also mentioned that many people do not need to undergo the detailed hearing aid evaluation that is often encountered in speech and hearing clinics. He suggested that most cases are rountine cases that could be taken care of without considerable management; it is the problem cases that ahould be the concern of speech and hearing clinic.

Carhart indicated that day would come when in hearing aid clinic, patients with special hearing aid problems ref-erred through physicians will be examined. Carhart went on to express the hope that, "The time zhould come when all concerned will have the advantage of co-operation bet-ween otologist, audiologist and company representatives. Each will then in his own way be serving the hard of hear-ing population more effectively". Rose (1979) states, "It is unfortunate that Carhart's expectations were not wholly fulfilled.. . . . One is led to believe that in today's market all patients are to be considered special cases. This is turn leads all involved, physicians, audiologist and hearing aid dealers to distrust one another. Certainly this confuses rather than clarifies the situation in so far as the hearing impaired public is concerned".

In another 1950 article entitled "Volume control Adju-stment in Rearing Aid Selection" Carhart discussed the ad-vantages of using the comfort or most comfortable loudneas level for adjusting hearing aids for hearing aid selection. It was his belief that the comfort level method offered a psyehophysical procedure for equaling gain settings of di-fferent hearing aids and he observed a high test reliability for the comfort level method, the margin of uncertainity being only ± 4 dB. He noted that there were significant differences from one talker to tester to another and warned that if monitored live voice were to be used that the influence of each talker must be clarified and advised that while following this particular procedures, the aided threshold should be obtained twice with each instrument. He believed that the measurement of residual loss for speech based on equivalent comfort level settings often revealed differences in instruments which should he considered for a choice among different hearing aids. He also admonished, "The clinical fact that must not be ignored is that patients do vary widely from one another in the performance and the efficiency they achieve on all major types of measures, including residual loss for speech".

CLINICAL HEARING AID EVALUATION

Koening (1950) in the Bell Telephone Laboratories reported on the subjective effeets of binaural hearing. Carhart (1950) discussed the added benefits of two hearing aids even with body worn binaural hearing aids. It was his opinion that binaural fittings would be of significant importance to many persons with a mild or moderate loss of hearing resulting in increased ability to eope with noisy situation, greater effective gain when the reception of faint sound was critical, and improved precision of auditory orientation in a complex environment.

Wright (1950) in his article "Binaaral Hearing in ing Impaired" considered these factors as being signifieant when investigating the effects of binaural hearing. These are "factors related to threshold levels, the factors related to suprathreshold levels and factors related to the ability of the person to utilize vastly dissimilar sound patterns for each ear". Wright pointed that although ears may he similar in terms of equal loudness or equal binaural hearing at one level, increases in intensity do not necessarily result in change equal at the two ears. Thus binaural hearing or binaural loudness occurs only at one loudness level. He concluded that binaural hearing aid use for the hearing impaired has been oversimplified.

Jeffers (I960) used what might be termed as "clinical" approach to evaluate hearing aids baaed on speech quality judgement* She asked the subjects to compare the quality of sound produced by various hearing aids by having them to listen to five aids that were arranged in four pairs. Subjects listened with one aid of a pair, and then with the other following removal of the first; She concluded that judgements; of speech quality differentiated strongly among hearing aids with different electroacoustic characteristics. The test formant, first used by Jeffers (I960) and later by Weldele and Millin (1975) was recommended for use in the clinical setting as a means of selecting hearing aids.

Shore, Bilger and Hirsh (I960) published on article, "Hearing Aid Evaluation, Reliability of Repeated Measurements". In their study, 15 subjects were divided into three categories. Each category had equal number of conductive, mixed and sensorineural hearing loss cases. Each subject has a hearing loss sufficient to warrant.amplification, and were tested on five different days. The testing comprised of:

1. Pure tone audiograms
2. Monaural and Binaural speech reception thresholds.
3. Monaural and Binaural discrimination score.
4. Monaural and Binaural discrimination score in noise with recorded materials at signal to noise ratio of 0 dB.

Four different types of conventional body type hearing aids were selected. Audiometric findings of ten subjects were sent to four hearing aid manufacturers and they were asked to select an appropriate instruments. It was found that their own judgement of hearing aids agreed rather closely with two of the manufacturers. The third manufactuer's suggestions for hearing aids did not agree with those cf the clinicians. The fourth manufacturer indicated his inability to make specific recommendations due to many inconsistencies in the comparison of pure tones and speech discrimination. Tests with various patients with all hearing aids and all tone settings were repeated on four different days. Their test results indicated that differences attributable to different hearing aids occur most often for gain and less often for discrimination in quiet and that difference was not significant for discrimination in noise.

They concluded that the reliability of measures was not sufficient to warrant extensive use of time in trying to find specific differences among aids. They pointed out differences in the hearing aids were not sensitive to the usual measures of speech audiometry.

Mc Connell, Silber and mc Donald (I960) in response to the Shore et al article discussed test retest consistency of clinical hearing aid tests. They used test retest of the individual's ability to discriminate the phonetically balanced word lists and concluded that adequately trained indviduals could yield reliable results regardless of whether the test retest was completed by one or two different audiologists. They stressed the role of audiologist in the fitting of hearing aids.

Haskins and Hardly (I960) discussed clinical studies and stereophonic hearing. The study was designed to investigate clinical findings with following groups:

1. Group that has for better peripheral than central auditory function.

2. This group consiated of indviduals with a mild loss on one side and a moderate to severe loss on other side.

3. This group had moderate-to-severe bilateral sensorineural impairment with good speech discrimination.

4. The fourth group had moderate-to-severe bilateral mixed type of hearing impairments.

5. This group had moderate to severe bilateral conductive impairments.

All the groups benifited from binaural amplification with exception of Group I and Group 2. The authors speculated that children would also benefit from binaural hearing aid use. But Jerger, Carhart and Dirks (1961) reported that when using both binaural and monaural hearing aid amplification, they were unable to find any appreciable advantage for two hearing aids over one.

Zerlin (1962) introduced a test method, in which he presented type-recorded speech to two hearing aids and recorded the output of the aids on separate tracks. Speech was processed similarly through successive pairs of hearing aids. Experimental play back consisted of the delivery of the hearing aid processed speech to listners via monaural earphones. The listner could select any channel with alternating pressing of two response buttons. This allowed for paired comparison for hearing aid evaluation. The results suggested that the procedure was efficient in relation to traditional tests of speech recognition and listener judgements produced greater differentation among aids than did conventional measures of monosyllabic speech recognition.

Punch (1981) lists the several potential advantages of the paired-comparison method over other possible techniques for eliciting listener's judgements:

1. The instructional task is relatively simple to explain and comprehend. The listener has only to inform the tester which recording of the pair produces better quality, or more highly intelligible speech.

2. This method allows sufficiently rapid sequence of exposure of the two stimuli to avoid problems associated with auditory recall, and reducing the listeners task to eomparision of two elements only.

3. The response itself is uncomplicated, consisting only of a written or verbal statement of the listener's choice of the hearing aid based on the given criterion.

4. Data generated by this procedure are readily amenable to master hearing aid test situation, as well as to computer processing which is considered important for future application.

A potential problem associated with this technique is that of discrepancy in the spectrum of the signal at the listener's eardrum under such conditions when compared to the spectrum of the signal when the hearing aid was actually worn by the listener. A portion of this change occurs by virtue of the difference observed when a signal is presented to the hearingaid microphone with the aid worn by the listener in the sound field (Dalsgaard, 1977). In addition, reproduction ofthe hearingaid processed signals via audic-metric earphones, when contrasted with situation in which the aid is actually worn, results in sound pressure level below opproximately 500 Hz and enhanced level in the vicinity of 3000 Hz* The former effect is due to acoustic leak, while the later is due to ear canal resonance effects. (Cox and Studebaker, 1977).

Recent investigations by Punch and Parked (1981) indicated that judgements based on different instructional sets, quality versus relative intelligibility, produced out come that correlate poorly with one another.

Studies by Witter and Goldstein (1971) supported the results of Jeffers (I960) and confirmed that quality judgements were sensitive to electroacoustic differences in hearing aids. From these studies it was concluded that aids exhibiting high-fidelity characteristics such as wide band width and good transient response were judged to produce higher quality speech.

Witter and Goldstein (1971) raised the possibility that hearing aid rankings based on quality preferences might be influenced by the specific stimuli used. Stimuli consisting of male and female voices produced different over all rankings. Punch (1978) using on ad&tation of Zerlin's (1962) technique with KEMAR and Zwislocki Coupler, showed that the preferences assigned for a male voice, a female voice and music were statistically correlated with those assigned for each of other two stimuli. These results failed to reveal a hearing aid stimulus interaction in the context of aided quality judgements. Findings also revealed each of hearing aid listener interaction in group of normal and hearing impaired listeners. Indvidual listeners with each subject group produced highly similar bankings on the basis of their quality judgement.

Ross, Barret and Trier (1966) indicated that the criteria for hearing aid condidancy is generally described to be 30 dB loss a greater in the better ear. Many people who have communication difficulty are not considered to be candidates for hearing aid because of these criteria. To determine whether or not persons with hearing impairments leas than this did benifit from hearing aids, they sent a questionnaire to 23 persons who had been issued hearing aids in the previous six months and whose hearing toss was less than 30 dB. They were asked to iste themselves on a fine point scale* Results indicated that their ability to understand speech was enhanced while wearing the hearing aid in all six general Situations. They reported greatest satisfaction quiet situations, the least for noisy environment. According to Ross et al (1966) one indication for the use of amplication with indviduals who have a high frequency loss was improved speech discrimination scores at speech levels higher than 40 dB.

Reddell and Calvert (1966) examined the possibility of audiologic data as means of selecting amplification for an indvidual 34 subjects with high tone hearingloss were tested. These subjects did not have any previous experience with hearing aids. The manufacturers were asked to make a hearing aid based on indviduals data. Tests results with particular aid were compared with two commercially available hearing aids selected by other audiologic procedures. The mean SRT and tolerance for loud speech was slightly better for experimental aid. The subjects "preponderantly" preferred the experimental aid. From these results it was reasserted that selective amplification is good technique for hearing aid selection.

Jerger, Speaks and Malmquist (1966)used monosyllables in quiet and sentence intelligibility tests in noise to evaluate the performance of listeners with three different hearing aids. They tested 36 hard of hearing subjects with various types of losses. Monosyllabic words in quiet failed to differentiate among hearing aids but sentence intelligibility tests in noise reflected meaningful differences among aids. Hearing aids with least distortion seemed to be best for all patients and one with the most distortion seemed to be least valuable to all patients.

Resnick and Becker (1963) concluded that there are insufficient physical differences among hearing aids to justify hearing aid selection process. They thought that time should he spent in counselling the hearing aid purchaser, providing him a copy of the audiogram and sending him to a reputable hearing aid dealer. The patient should be advised to return to the clinic with purchased hearing aid for an evaluation.

Kasten, Lotterman, and Revoille (1967) tested a number of hearing aids. They observed that the mean gain versus frequency curve of the sample of aids differed from those published by the manufacturers for about half the models tested. They cautioned the audiologist that the hearing aid response supplied by the manufacturer may be different from the response given by a unit.

Olsen and Carhart (1967) compared the speech discrimination scores obtained in quiet and against two different types of competition as reproduced by a high fidelity system and by three different hearing aids and found small different hearing aids and found small differences among systems in quiet but large differences in speech or noise competition. They concluded that hearingimpaired people experience a great deal more difficulty in understanding speech when faced with competition than generally has been realized. The limitations in the hearing aids further complicate the listening task. These findings especially hold good with sensorineural hearing loss patients.

Jerger and Thelin (1968) studied a group of hearing aids which had wide variety of gains, frequency responses and various amounts of harmonic distortion. Synthetic Sentence test developed by Speaks and Jerger (1965) was used with a competing speech message. The test material was recorded through the hearing aids and then these tapes were played to five normal hearers to adjust the competition to obtain approximately is 75 percent correct performance.

They used indviduals with symmetrical sensorineural hearing losses. Their findings indicated that "subjects with flat losses yielded results in good agreement with normal listeners but as the audiometric slope changed from the gradual to the steep the correlation with the performance of normals became progressively weaker". On this basis they concluded that one can not generalize from behavioural results on normals to the behavioural results on hearing impaired listeners. They also noted that there were strong correlations between the physical entities of the hearing aid performance and the behavioural results, particularly the regularity of the frequency response. There was also on inverse correlation between synthetic sentence identification scores and harmonic distortion, i.e. better scores were obtained with instruments having a greater amount of harmonic distortion. This finding and lack of generalization from normal heares to the hearing impaired is directly contradictory to the earlier findings of Jerger, Speaks and Malmquist (1966).

Lotterman, Hasten and Revoille (1967) published an article "On Acoustic Gain andThreshold Improvement of Hearing Aid Selection". The acoustic gain and threshold improvement in hearing aids was 10 dB less than the measured using 2 CC Coupler. They cautioned that clinical audiologist should be aware of the fact that the manufacturer's specifications of gain are obtained at the full-on gain position with approximately 50 dB SPL-input and that this does not represent the performance of a given instrument at its use setting.

Olsen and Tillman (1968) published on article entitled, "Hearing Aids and Sensorineural Hearing Loss* in which they listed four common misconceptions with regard to hearing aid use:

1. The patient with a sensori-neural hearing loss can not expect to receive sufficient help from a hearing aid to justify its purchase and use.
2. For the patients with sensori-neural impairment, any hearing aid will offer satisfactory results provided only that it has sufficient power to overside his loss in sensitivity.
3. The position or orientation of unilateral hearing aid in the acoustic environment which the user wishes to monitor has little to do with the communication efficiency he will achieve; and
4. The patient with unilateral hearing impairment can expect to receive no help from the hearing aid.

The authors observed with regard to first misconception that a sensorineural hearing loss may cause a deficit in discrimination ability which the presently available hearing aids may not overcome. But this does not preclude the use of hearing aid because in quiet and slightly noisy listening environments, many indviduals with a sensorineural hearing loss achieve good listening efficiency with a hearing aid. However, in a moderately noisy environment the individual with a sensorineural hearing loss will encounter significantly greater difficulty than does the normal listener.

Hearing aids do not yield equally high performance nn-der various kinds of test situations. Olsen and Tillman opined that speech must be tested in the presence of noise or other comp-eting material in order to give indications how well the indvidual will do with a hearing aid in his normal environment. With regard to third fallacy, it was painted out that perhaps the position of the hearing aid or hearing aid orientation to the sound source would not pro-bably make any difference, if an indvidual was to sit in quiet environment. The orientation of the hearing aid is critical, if the noise is coming from the several sources. Regarding fourth misconception, they noted that indviduals can benefit from CROS hearing aids which will give them a much better signal–to-noise ratio and thus a much better ability to discriminate sounds coming from the bad side.

Carhart and Olsen (1920) reported discrimination scores for one syllables words heard against competing sentences measured at the same sensation levels during aided-unaided response testing. Four types of subjects were used: pre-sbycusis, sensorineural nonpresbycusis; conductive losses; and normal hearing subjects. Each group consisted of 12 subjects. Subjects were were tested in binaural, monaural direct and monaural indirect conditions using various signal to noise ratios. Results were summarized as four main findings. First, "The SPL at which a spondee threshold for hearing impaired occurs were poorer when measured at the ears by the hearing aid system than when measured unaided in the sound field". The second finding was that the intelligibility for these words presented in quiet was poorer with a hearing aid than when heard via loudspeaker at an equivalent sensation level. Third, sensorineural loss patients and presbycusis patients had more trouble in the presence of competing sentences during aided trials than did the normal or conductive loss patients. The fourth finding indicated that all groups had poorer intelligibility scores when competing sentences were used and signals were reproduced through the hearing aid than when presented at a sufficiently intense level via loudspeaker.

Barney (1972) published a survey on hearing aid evaluation procedures. He intended to determine procedures, methods, and materials being used in hearing aid evaluations in the various clinics. A questionnaire was mailed to 214 clinics having audiology programs which were accredited by the American Board of Examiners in Speech Pathology and Audiology of the American Speech and Hearing Association. The clinics were classified into four types: University or College training centres, hospitals, Veterans Administration hospitals, and others. The others included clinics in which there were certified audiologists but they did not meet criteria for any of the other three categories. 195 clinics returned the data. Nineteen of these were incomplete and thus were excluded from the study. The results indicated that most often used procedure is the same one that was reported 25 years earlier by Carhart. Barney's conclusions were equivocal in that either the old procedure is adequate or the procedures are of little value bat may be used as a matter of convenience.

Some of the specific findings of the 176 completed replies were: 18 of the clinics were not performing hearing aid evaluations and it was against the clinic policy of one; none of the clinics studied reported using a master hearing aid; 43 of the 67 universities or colleges which were doing hearing aid evaluation were testing hearing aids on the patient; 19 of 22 V.A hospitals were conducting hearing aid evaluations while the hearing aid was worn. One of the V.A. hospitals also indicated that it was against the clinic policy to da* hearing aid evaluations* There were 29 clinics that have master hearing aids, there are none listed in the study that used master hearing aids to do hearing aid evaluations* This study adequately points out that there was no specific hearing aid evaluation used by all clinics at that time.

Lentz (1972) reported on markedly improved speech discrimination in the presence of noise when using directionally sensitive microphone. Sung, Sung and Angelelli (1975) also studied the effects of directionality sensitive hearing aid microphones and concluded that the aids with the greatest directional effect were superior for listening to speech in relatively difficult listening situations.

Victoreen (1973) is perhaps one of the most staunch advocates of hearing aid prescription fitting. He presents an answer to the hearing aid fitting dilemma in his book entitled "Basic principles of otometery" (1973). He uses & damped sinusoid wave train to determine those sound pressures which return to the ear those loudness relationships which most nearly relate to the normal hearing. A custom built aid is ten constructed to meet the necessary amplification and frequency response contours.

Berger, Hagberg, and Rane (1977) in a publication entitled "Prescription of Hearing Aids: Rational, Procedure, and Results" described "a practical and easy step-by-step set of procedures for fitting hearing aids in a more objective manner than other methods". One aspect of their procedure is to determine the hearing loss at various frequencies and then through a relatively simple formula indicate the gain necessary for that person at the various frequencies.

Jerger and Hayed (1976) published an article entitled "Hearing aid Evaluation" in which they reported a new method of hearing aid evaluation. They stressed that the evaluation is not an end it self, but rather it is an important part of total rehabilitation. They list four specific goals:

1. To determine the most suitable hearing aid arrangement for the indvidual.
2. To determine differences among arrangements in real life listening conditions.
3. To provide information on realistic expectations of hearing aid use for patient counselling.
4. Make accountable rehabilitative recommendations to patients.

We are not aware of any studies which have attempted to delineate the differences among hearing aids using sentences as the input stimuli and analyzing the hearing aid processed sentences with the help of spectrograph. So in order to try out this the present study was undertaken.

METHODOLOGY

The present study aimed at judging the quality of a few selected Hearing Aids, using hearing aid processed sentences and ranking them in order of their performance. This study included the following.

1. Recording of sentence list.
2. Recording of sentences through various hearing aids.
3. Analysis of hearing aid processed sentences.
4. Comparison of controlled recordings with the hearing aid processed sentences (experimental).

Seven hearing aids were selected at random out of the 22 hearing aids. In this way, we were able to get a fairly representative sample which included at least one hearing aid of the several manufacturers in India. Hearing Aids were designated H-1, H-2, H-3, H-4, H-5, H-6 and H-7. All the hearing aids were checked and it was ensured they were functioning properly.

The gain characteristics of these hearing aids were measured using B & K hearing aid test box (Type 4217), a 2 CC Coupler, a condenser microphone (B & K Type 4144) and a frequency analyzer (Type 2107). Measurement of gain characteristics of hearing aids helped to set the aids at half of their average gain at IK Hz. This level was arbitrarily selected to avoid excessive diasortion due to overloading. The following table shows the half average gain at IK Hz for various hearing aids.

Hearing Aid	Gain at IK Hz	Tone	Half Avg. Gain	Actual Gain Obtained
H-1	59.0 dB	N	29.5 dB	29.0 dB
H-2	63.0 dB	N	31.5 dB	31.0 dB
H-3	54.0 dB	N	27.0 dB	27.0 dB
H-4	32.5 dB	-	16.25 dB	16.0 dB
H-5	47.0 dB	F	23.5 dB	24.0 dB
H-6	59.0 dB	N	29.5 dB	29.5 dB
H-7	54.0 dB	N	27.0 dB	27.0 dB

The sentences which were used as stimuli were as unders

1. We were away a year ago.
2. May we all learn a yellow lion roar.
3. Did you thank him?

The first sentence consisted of voiced sounds which included vocalics (vowels and vowel like sounds). Second sentence had voiced sounds like vowels, vowel like sounds and consonants which are voiced, including, nasals and trills. The third sentence was composed of voiced and un-voiced sounds which included stops and fricatives. These sentences were selected because they included various linguistic features listed above and the time required to speak out these sentences was either equal to or less than 2.4 sec., which facilitated the analysis of sentences on spectrograph.

Two young adult speakers, one male and one female were selected for recording of the sentences. English was a second language for the male speaker while is was mother tongue for the female speaker. Both the speakers were free from any speech and hearing disability. The subjects were given considerable practice in order to familiarize with the sentences.

The speakers were advised of the nature of the experiment. Speech samples were recorded in a sound-treated roam with the speakers seated so that they were 16 inches from the microphone. They were instructed to read the sentences at a normal level (i.e. conversational level and normal rate) Before recording, the subjects read the sentences silently and then read it aloud. The signal from the condenser microphone was fed to frequency analyzer and outpat from the frequency analyzer was connected to a two-channel high quality professional tape-recorder (UHER SG 631 LOGIC). Also, the VU meter of the tape recorder was observed to see that the speech was reasonably steady and at a suitable level to ensure a good recording. Sentences spoken alternatively by male and female speaker were recorded. Each speaker was given half a minute rest to avoid any fatigue of the vocal organs.

For the experimental recording, the receivers of various hearing aids were connected to a condenser microphone (B& K Type 4144) using 2 CC Couplers and it was confirmed that aids were at half average gain setting. Through the frequency analyzer (B & K Type 2107) the output was recorded on a high fidelity tape recorder (UHER SG 631 LOGIC). All the three sentences were transduced through all the seven hearing aids in a random order, while speakers speaking the sentences in the same manner as in the control recordings. Each recorded sample warn preceded by on identifying statement and a brief recording of the ambient noise background. The recordings were made over a period of two consecutive days with a roughly random order of samples. Figure I & 2 show instrumentation set up for control as well as experimental recordings.

The recorded tape containing control and experimental recordings was played on the spool tape-recorder. The output from the tape-recorder was fed to sound spectrograph (Vibralyzers 7030 A). The input selector of spectrograph was set to the position which suited best to the output impedance of the signal source. The FL-I-HS switch was set

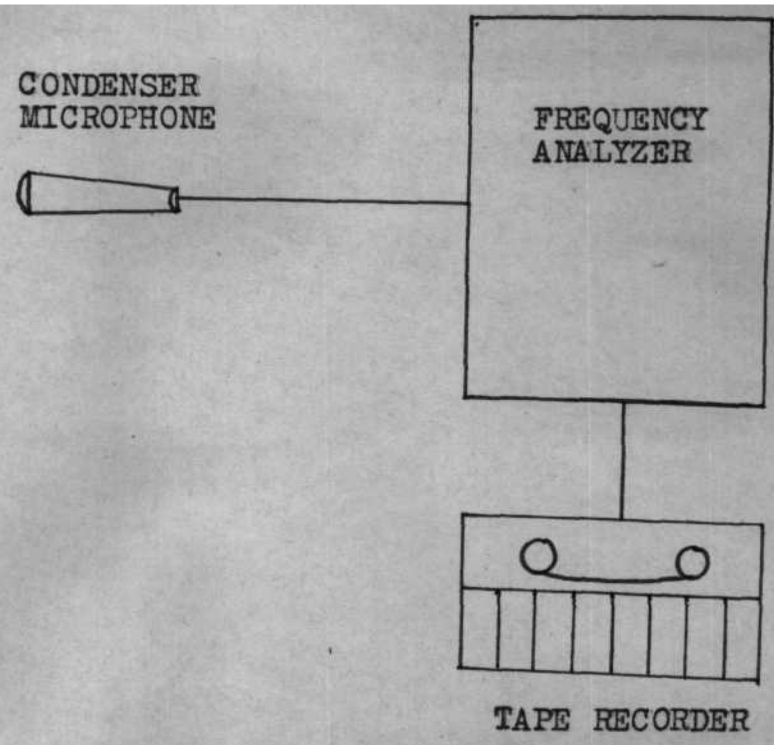

Fig. I Instrumentation set up for control recordings.

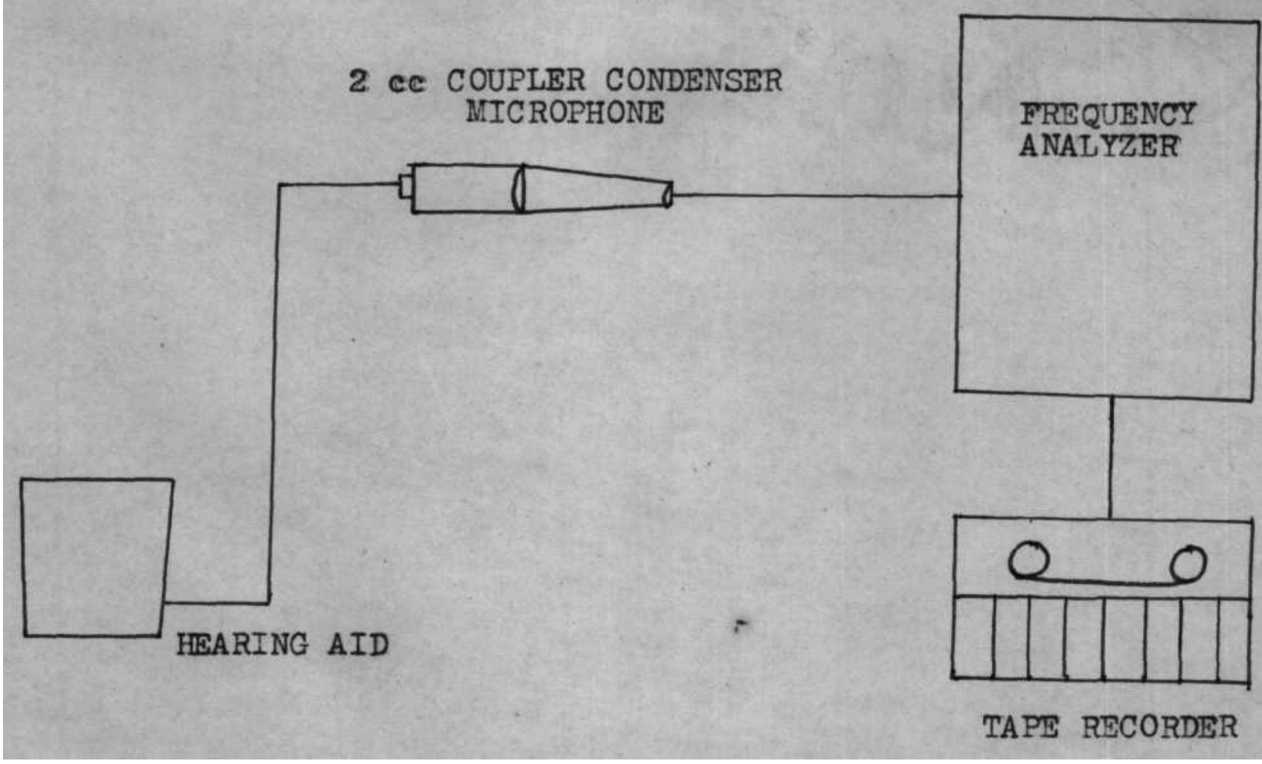

Fig. 2 Instrumentation set up for experimental recordings.

to the HS position. The record level control was set depending upon the signal strength. The REC-OFF-REP was placed in the Record position. Record level control was turned up until a suitable VU meter reading was obtained depending upon the sentence length. RECORD-REPRODUCE switch was kept in the record position. Later on REC-REP switch was turned to REP immediately after desired recording was over, in order to avoid the erasingof the recorded signal. The recorded signal was monitored later on to check the quality of the recorded signal. The monitor gain control was adjusted for a convenient volume level, while the drum was manually rotated.

The drum was rotated until a switch click was heard that indicated the end of the recorded signal. After looking at the index plate at the bottom of the drum, the number wag noted. Both the springs on the drum were pushed down so that they rested on the bottom flange of the drum. A fresh piece of sonogram paper around the drum wth the coated side facing outward was placed. Both the edges were brought forward and the edge held in the left hand was placed over the edge held in the right hand.

The paper was firmly held around the drum andbushed down until it stopped against the bottom flange. Then the top spring was raised to secure the upper edge of the paper.

Then the paper on the drum was rotated until the overlap was directly over the index number noted previously.

Using the AGC control, the desired amount of AGC action was selected. The mark level control was set for the desir-ed pattern contrast. REC-OFF-EEP was set to the reproduce position. The REPRODUCE LEVEL was adjusted to set a suit-able reading. The Band Selector switch was set to WIDE position.

The stylus was lifted slightly and engaged with the lead screw, making sure the stylus wire was touching the paper. The stylus was allowed to travel up the paper an-til the upper short point indicator lights. In this way the spectrograms for control and experimental recordings were taken. After the marking was complete, the stylus was disengaged and returned to the bottom of lead screw.

In the second part of the study, eight judges were selected for perceptual analysis. The judges had on equal ratio of male and female. Seven judges were post-graduate students of speech and hearing and 8th judge was a qualified speech pathologist and audiologist. The judges were allowed to listen to six control recordings of three sentences spoken by male and female speaker in order to familiarize them with the control recordings. This was later on followed by experimental recordings. The tape was played in a quiet room at a comfortable level. They were asked to rate each hearing aid after hearing to all the sentences by male and female speaker, for frequency, gain and distortion based on 5 point scale which is shown below:

Parameter Scale	Frequency	Gain	Distortion
1	Exteremly good	High	Slight
2	Good	Moderately High	Mild
3	Fairly good	Moderate	Moderate
4	Poor	Moderately Low	Moderately High
5	Very poor	Low	High

Based on these indvidual rankings af frequency gain and distortion, each aid was given a composite ranking.

STATISTICAL PROCEDURES

Part-1

The recordings of male and female speaker were analyzed with the help of spectrograph and compared. Hearing aids were ranked based on relevant factors both for male and female speakers for 3 sentences. The ranking of these 3 sentences were compared for reliability and difference among hearing aids using the Fried man's Test for male and female speakers. The test static Q, Kendall's Coefficient and

Spearman's Coefficient of Correlation if was obtained. The judgements based on these statistical measure were found to be reliable and showing a significant difference among hearing aids, a combined ranking for male and female speaker based on the average ranks was calculated. The combined rankings of male and female speakers for sentences was compared. These showed a reliable difference among aids, these ranking were combined to give a overall ranking to hearing aids for spectrographic analysis.

Part-II

The perceptual judgement provided by the various raters, was judged for agreement among raters and reliability of rankings using Kendall's Coefficient Q, the variance ratio F and Spearman's Coefficient of Correlation -f . There was reliable agreement between judges, for the ranking of hearing aids, hence a true ranking of the hearing aids was obtained based on combined estimates of judges and this was compared with the combined ranking obtained for spectrographic analysis to check the difference among two judgements. Further, the judgements of male and female judges were compared to see if they differed significantly using the Friedman's Test.

ANALYSIS OF RESULTS AND DISCUSSIONS

The spectrograms obtained from male and female speakers were compared and analysed based on the following:

1. Fundamental Frequency.
2. Frequency range.
3. Harmonics missing or weak.
4. Resonance missing, weak or emphasized.
5. Resonance bar positions.
6. Irregular vertical striations and
7. Noise components.

Hearing aids were ranked based on these above factors for 3 sentences both for male and female speaker. The data is shown in the table I. Rankings of the both male and female speaker were subjected to statistical analysis for verification of the two hypothesis:

1. There is no reliable agreement in the rankings of the hearing aids provided by the three sentences.
2. There is no systematic tendency for any of the hearing aids to be given low or high rank based on these three sentences or all possible rankings are equally likely.

To verify these hypothesis, the Friedman's Test was applied and the test static Q, the Kendall's Coefficient of Concordance V and Spearman's Correlation Coeffieientf was calculated and values are as provided in the table 2.

Table I. Ranking of Hearing Aids for male and female speaker based on spectrographical judgement.

Sentence	Male Speaker		Female Speaker	
	Hearing Aid	Rank	Hearing Aid	Rank
I	H-I	4	H-1	4
	H-2	1	H-2	2
	H-3	3	H-3	
	H-4	7	H-4	7
	H-5	5	H-5	6
	H-6	2	H-6	1
	H-7	6	H-7	5
II	H-I	5	H-1	5
	H-2	2	H-2	2
	H-3	4	H-3	3
	H-4	6	H-4	7
	H-5	7	H-5	4
	H-6	1	H-6	1
	H-7	3	H-7	6
III	H-1	5	H-1	5
	H-2	2	H-2	4
	H-3	3	H-3	2
	H-4	7	H-4	7
	H-5	4	H-5	6
	H-6	1	H-6	1
	H-7	6	H-7	5

Table 2. Showing values of Q, W and ρ for male and female speakers.

Speaker	Male	Female
Q	*10.714	**13.285
W	0.59	0.73
f	0.39	0.59

*Significant at 0.1 Level

** Significant at 0.05 Level

Perfect agreement is indicated by a W=I and lack of agreement by a W=O.

ρ varies between -I and +1, with values close to zero indicating little or no association.

We have to reject both the null hypothses and conclude that there is reliable agreement in the rankings of hearing aids provided by different sentences 1, 2 and 3 for male as well as female speaker and clearly indicating that there are consistent differences among hearing aids.

As it can be seen that there is reliable agreement for rankings of the hearing aids provided by three sentences both for male and female speaker (W=0.59, 0.73 respectively) we can have the estimation of true rankings based on the combined estimates provided by these sentences for male as well as female speaker as shown in the table 3.

Table 3. True rankings for male and female speaker based on combined estimates.

Hearing Aids Speaker	H-1	H-2	H-3	H-4	H-5	H-6	H-7
Male	4	2	3	7	6	1	5
Female	3.5	2	3.5	6	5.5	1	5.5

The Friedman's Test was applied to the above data e, W and ρ were calculated, values are as under:

Table 4. Values of Q, W and for data in table 3.

Parameters	Q	W	ρ
Values	8.78	0.73	0.46
Significant at 0.2 Level		+	+

Though we are taking a slightly greater risk by selecting a 0.2 level of significance but still with some reservations, based on above findings, it can be concluded that the data provide reliable evidence that of consistent differences among aids and judgments of the hearing aid ranking do not differ significantly based on male and female voices. This statement is further strengthened because we have a ρ of 0.46. As there is reliable agreement between the judgements provided by male and female voice, we can have a combined rankings for male and female speaker as under.

Table 5. combined rankings for male and female voices based on spectrographical analysis.

Hearing Aids	H-1	H-2	H-3	H-4	H-5	H-6	H-7
Bankings	4	2	3	7	6	1	4

In part II of the study, ratings provided by 4 male and 4 female listners respectively, for 7 hearing aids as shown in table 6.

Table 6. Eatings of 4 male and 4 female listeners based on perceptual judgement.

Hearing Aids Judges	H-1	H-2	H-3	H-4	H-5	H-6	H-7
1	4.5	6	4.5	7	3	1	2
2	2.5	6	5	7	2.5	1	4
3	4.5	7	4.5	6	3	1	2
4	1	6	2	7	5	3.5	3.5
5	5	6	4	7	1.5	1.5	3
6	3	6	2	7	4	1	5
7	6	4.5	2	7	3	1	4.5
8	6	3.5	3.5	7	2	1	5
Total of Ranks	32.5	45	27.5	55	24	11	24
Final Ranks	6	5	3	7	2	1	4

The ranking from four male judges and four female judges for perceptual rating were compared separately with the help of the Friedman's Test, the table 7 shows various values.

Table 7. Q, W and values for data in Table 6.

Judges Parameters	Male	Female
Q	* 17.73	**1922
W	0.73	0.80
ρ	0.65	0.73

*Significant at 0.01 Level

**significant at 0.05 Level

W and ρ values are + ve.

From the table it can be concluded that male judges show high degree of correlation in their rankings which also holds true for female judges. This indicates hearing aids differ significantly with respect to each other.

As there is agreement between male judges and also for female judges,their rankings can be combined to give an independent judgement of true ranking for male and female judges as shown in the tables.

The Friedman's Test was applied to see if male and female judges differed in their rankings, Q, W and ρ were calculated, values are depicted in table 9.

Table 8. Combined rankings of male and female judges.

Judges	H-1	H-2	H-3	H-4	H-5	H-6	H-7
Male	3	6	5	7	4	1	2
Female	5.5	5.5	3	7	2	1	4

Table 9. The values of Q, W and ρ for data in table 8.

Parameters	Q	W	ρ
Values	9.91	0.82	0.65
Significance	at 0.2 level	+	+

When a significant level of 0.2 is used, a slightly greater risk is taken and as Q is significant at 0.2 level, we conclude there is no reliable difference in the judgement, of male and female judges (W=0.82, ρ=0.65) and the hearing aids differ consistently among themselves.

Using the statistical analysis Kendall's Coefficient af Concordance W, Snedecor'e distribution for F and Spearman's Coefficient of Correlation ρ were calculated to know whether there is significant agreement between judges as a whole. The table 10 chows the values.

Table 10. The values of W, F and ρ for data in table 6.

Parameters	W	F	ρ
Values	0.485	6.592	0.41
Significance	+	at o.1 level	

The size of the Coefficient of Concordance indicated that there was high degree of agreement among 8 judges in ranking of the 7 hearing aids. W was further tested for significance using Snedecors's distribution for F which was found to he highly significant at 0.1 level. Spearman's Coefficient Correlation ρ again showed that there was agreement between judges for ranking of hearing aids.

Having established that there was a significant measure of agreement between judges, a 'true ranking' of the hearing aids was made based on the combined estimates of judges which is shown in the bottom row of the table 6.

Further combined rankings of male and female speakers for spectrographic and perceptual judgements were compared. The test statistic Q of Friedman was 8.78 which is net significant at 0.1 level. It can be concluded that there is significant difference in ratings provided by spectrographic analysis and perceptual analysis. Though it can be noticed that Q of 8.78 is significant at 0.2 level and Coefficient of concordance W and ρ are 0.73 and 0.46 respectively showing no difference in the rankings of hearing aids, but the null hypothesis has been rejected to reduce the changes of error in judgement.

DISCUSSIONS

The results of this study shows that it is possible to evaluate the efficiency in performance of hearing aids using the spectrographical and perceptual analysis and rank them in terms of proficiency. This is based on the assumption that instrumental analysis is necessary to understand how the quality of speech is affected as auditory transcriptions of speech can never isolate the acoustic cues which may be necessary to judge the quality of speech through hearing aids. This might be one of the probable reasons why judgemets of spectrographic analysis did not correlate significantly well with perceptual judgements.

When we compare the rankings obtained by spectrographic analysis and perceptual analysis pair by pair certain similarities can be noticed. There is agreement regarding the best hearing aid and the worst hearing aid, as well as the third best hearing aid. These are H-6, H-4 and H-7. There is partial agreement about the H-7, it has a rank of 5 for spectrographic analysis and 4 perceptual analysis and similarity for H-1 with its ranks of 4 and 6 for spectragraphic analysis and perceptual analysis respectively.

There is complete disagreement for H-2 and H-5 which get ranking of 2;5 and 6;2 for Spectrographic analysis ana perceptual analysis. Had we accepted the 0.2 level of confidence, these different pairs would have got the same rating, therefore it was much safer to accept the null hypothesis. This forces us to accept the conclusion that rankings provided on the basis of Spectrographic analysis and perceptual analysis are highly dissimilar for these aids.

Perceptual analysis is based on the assumption that physical differences among hearing aids can be reflected in behavioural tests (Jeffers and Smith 1964). Shore, Bilger and Hirsh (1960) showed that when CID W22 and recorded PB word list spoken by Rush Hughes were used to evaluate hearing aid performance the reliability of these measures was "not good enough to warrant the investment of a large amount of clinical time with them in selecting hearing aids". But they noted that reliable differences might be found among factors "not yet .... claimed to be measurable by the audiologist".

The results of the study by Ramani (1975) showed that it was possible to qualify the hearing aids though behavioural tests and the performance difference, which was consistent could bemeasured. Jeffers and Smith (1964) also asserted that the physical differences among hearing aids can be reflected in behavioural tests. The hearing aid H-6 was found to be superior on both Spectrographic analysis and perceptual analysis as it had a low distortion, good frequency response and speech was reproduced faithfully and internal noise was minimum. The hearing aid H-4 consistantly got a lower ranking for sentences spoken by male and female speaker. The hearing aid had a low gain, high distortion and high internal noise to the extent that it was difficult to recognize various spectrographic patterns. It had a frequency response of 3K Hz, manufacturer's data did not specify frequency response but the maximum acoustic gain provided by the manufacturer is about 60 dB, which further indicated that the H-4 is a low gain hearing aid. This fact has been judged very well both by Spectrographic analysis and perceptual analysis. As we are well aware that our usual conversation level of speech is also about 60 dB SPL, so this aid might be useful in the case of recruitment.

Jerger, Speaks and Malmquist (1966) found that hearing aids with least distortion seemed to be best for all patient and the one with the most distortion seemed to be least valuable for all patients. They also attempted to investigiate a performance taks that would reliably distinguish the difference among three hearing aids and whether on the basis of the performance taks, can these aids be rank ordered.

The results showed that the physical difference among three hearing aids were reflected behaviourally by the PAL-8 task which further supported the present perceptual study.

Jeffers (I960) used what might be termed as "clinical" approach to evaluate hearing aids based on speech quality judgement. She concluded that judgements of speech quality differatiated strongly among hearing aids with different electroacoustic characteristics. This test formant, first used by Jeffers (I960) and latter Weldele and Millin (1975) was recommended for use in the clinical setting as a means of selecting hearing aids. The present study also showed that hearing aids can be ranked based on the speech quality judgement.

Studies by Jeffers (1960) and Witter and Goldstein (1971) suggested the quality judgements were sensitive to electro-acoustic differences in hearing aids. From those studies it was concluded that aids exhibiting high-fidelity characteristics such as wide bandwidth and good transient response were judged to produce higher quality speech, which supports the present study.

Witter and Goldstein (1971) raised the possibility that hearing aid ranking based on quality preferences might be influenced by the specific stimuli. Stimuli consisting of male and female voices produced different over all ranking. If O.I level of significance was used as criteria instead of 0.2 level of significance for comparision of combined rankings of male and female speakers based on spectrographic analysis, the results would have supported the study of Witter and Goldstein. When the ranking provided by male and female judges were compared for combined male and female voices ratings, they differed significantly at 0.1 level, though the results were not significant at 0.2 level. From the above data it can be concluded that combined ranking for male and female voice shows some disagreement for spectrographic analysis , and there have also been differences between male and female judges on the combined rating of sentences based on perceptual analysis at 0.1 level. Punch (1970) using on adaptation of Berlin's (1962) technique with REMAR and the Zwislocki coupler, showed that the preferences assigned for a male voice, a female voice and music were statistically correlated. These results failed to reveal a hearing aid stimulus interaction in the context of aided quality judgements. Findings also revealed individual listeners within each subject group produced highly similar rankings an the basis of their quality judgemets. This supports our findings based on spectrographic analysis asr well as perceptual analysis.

Jerger and Hayes (1976) stated that the effective hearing aid evaluation technique must delineate differences among hearing aids in a systematic manner, achieve face validity by employing test materials resembling more closely conversational speech and be a simple procedure that utilizes standard clinical instrumentation. Jerger, Malmquist and Speaks attempted to investigate a performance task that would reliably distinguish the difference among hearing aids and whether on the basis of the performance task, can these aids be ranked. The results showed that the physical difference among three hearingaids were reflected behaviourally by the PAL-8 task, which further supports the present perceptual study. Suny and Hodgson (1971) found that hearing aid with the better high frequency response produced better intelligibility for monosyllabic words regardless of the mode of signal input. The configuration of the frequency response curve in the region of 1.5 to 3K c/s appeared to be associated with the intelligibility of monosyllabic words, With respect to the above study, and results obtained it could be stated that frequency response of the aid H-6 was maintained well at this range while is was poorly maintained for the hearing aid H-4.

The study of Jerger et al (1972) has indicated that it is possible to devise behavioural measures that would in fact differentiate among hearing aids with differing physical characteristics. Since there have not been any studies comparing judgements based on apectrographic analysis and perceptual analysis to best of our knowledge, the conclusions arrived at from the present study are only tentative which require further exploration. The following concusions seem indicated based on the present study:

1. There is reliable agreement in ranking of the each hearing aid; provided by different sentences 1, 2 and 3 for male as well as female speaker i.e. ranking of the same aid for different sentences was reliable. Thus it can be stated sentences themselves did not influence the performance of the aid.

2. The data provide reliable evidence of consistent differance among hearing aids for male as well as female speakers.

3. Judgements of the hearing aid ranking do not differ significantly based on combined estimates provided by three sentences for male and female speaker.

4. There is reliable overall agreement among judges for the rankings based on perceptual analysis for different hearing aids.

5. Bankings provided by male and female judges for various hearing aids for combined male and female voice rating did not differ significantly.

6. Combined ranking based on spectrographic analysis and perceptual analysis differ significantly.

SUMMARY AND CONCLUSIONS

The aim of the present study was to judge the quality of hearing aids using hearing aid processed stimuli and ranking them based on spectrographic analysis. In the second part of the study hearing aid processed stimuli were presented to eight judges and they were asked to rank the hearing aids based on perceptual judgements. Seven hearing aids were selected at random so that, at least one hearing aid from various manufacturers was included for study. The following three sentences were used,

r. We were away a year ago.

2. May we all learn a yellow lion roar.

3. Did you thank him?

Two subjects, one male and one female were choosen as speakers. They were given considerable practice with these sentences. These sentences were recorded on a professional spool tape recorder. Then the subjects were again asked to speak the three sentences through the various hearing aids. The receiver of the hearing aid was connected to condenser microphone through 2 C C Coupler which was inturn connected to a frequency analyzer (B&K 2107). The output from the measuring amplifier was recorded on the spool tape recorder. All the aids were adjusted to their half average gain at IK Hz. Both the subjects were instructed to speak the sentences alternatively. The order of the sentences was randomized to avoid any order effect. Each subject was given 30 sec. rest after speaking the sentence. Spectrograms were taken for control as well as experimental recordings. In total 48 spectrograms were taken for control and experimental recordings. The hearing aids were ranked separately for three sentences for male and also for female speaker. After comparing with control spectrogram reliability of the ranking for hearing aids and also for sentences spoken by male and female speaker was checked. Suitable statistical methods were employed to test various hypothesis.

In the second part of the study, the tape was played in a quiet room, at comfortable level to four male and four female judges and they were asked to rate the hearing aids in terms of frequency response, gain and distortion. The ratings of male and female judges were compared to check if the ranking differed significantly. Overall reliability of judgement for various judges was also checked.

Using the Friedman's Test, overall rankings, which are given in table II, for spectrographic analysis and perceptual analysis were compared, and it was found that these rankings differed signifieantly.

Through spectrographic analysis and perceptual analysis it was possible to judge "best" and "worst" hearing aid and they obtained the same ranking. It was also found the quality of the hearing aids differ depending upon their physical characteristics.

Table II. Combined rankings for male and female speakers

Hearing Aids Analysis	H-1	H-2	H-3	H-4	H-5	H-6	H-7
Spectrographic	4	2	3	7	6	1	5
Perceptual	6	5	3	7	2	1	4

Future Research Possibilities:

1. Identical recordings should be used to make on objective comparison between various hearing aids.
2. Judges in the case of perceptual judgements should be asked to rate the hearing aids based on the paired judgements.
3. More such studies should be done to demonstrate the superiority or reliability of one method over other i.e. spectrographic analysis or perceptual judgement.

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