A comparative study of the performance with conventional analog and digital hearing aid with trimmer control at different signal-to-noise ratio

Register No.02SH0025

An Independent Project submitted as part fulfillment for the first year M.Sc. (Speech and Hearing), Mysore

ALL INDIA INSTITUTE OF SPEECH AND HEARING,

MYSORE - 570 006

MAY, 2003

Dedicated to Lord

&

My Mentor, Periyappa

Certificate

This is to certify that this Independent Project entitled **"A comparative study of the performance with conventional analog and digital hearing aid with trimmer control at different signal-to-noise ratio"** is the bonafide work in part fulfillment for the degree of Master of Science (Speech and Hearing) of the student with Register No. 02SH0025

Mysore
May, 2003

Director
All India Institute of
Speech and Hearing
Mysore - 570 006

Certificate

This is to certify that this Independent Project entitled "A **comparative study of the performance with conventional analog and digital hearing aid with trimmer control at different signal-to-noise ratio"** has been prepared under my supervision and guidance.

Mysore
May, 2003

Guide
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Declaration

This independent project entitled **"A comparative study of the performance with conventional analog and digital hearing aid with trimmer control at different signal-to-noise ratio"** is the result of my own study under the guidance of **Dr. K. Rajalakshmi,** Lecturer in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier in any other University for any other Diploma or Degree.

Mysore Register No. 02SH0025

May, 2003

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INTRODUCTION

The essence of hearing loss has its effect on the communication and the resulting impact on the speech, language, cognition and psychosocial development and functioning (Vernon & Andrews 1990). Thus management of hearing loss is very challenging and is termed as Auditory or Aural Rehabilitation.

The American Speech and Hearing Association 1984 refers to aural rehabilitation as "Services & procedures for facilitating adequate receptive and expressive communication in the individuals with hearing impairment selection of appropriate amplification is a crucial component of this aural rehabilitation process (as cited in Montano, 1994). The inability to understand speech at home, at work, in social situations, at meetings, or on the telephone -ultimately motivate listener with hearing impairment to try amplification.

It follows that the primary goal of amplification for listeners with hearing impairment is to restore the ability to hear and understand speech. Hearing aid is an instrument which amplifies sound to a degree and manner that will enable a hearing impaired person to utilize his or her hearing in an effective manner (Staab & Lyberger, 1994).

There are lot of modifications in the field of hearing aid from the time it was developed and thus many variations are available. The first amplification system were 'MECHANICAL HEARING AIDS' which were in use in 1800 and were available till the early part of 1900's.

After this 'THE CARBON TRASMITTER' were developed which was based on the principle of telephone. Alexander Graham Bell is credited with inventing the electric hearing aid. Carbon hearing aids were followed by Vaccum-tube hearing aids appeared in 1938 and offered much greater amplification possibilities, wider frequency response and lower distortion.

Hearing aid technology has had some dramatic changes in a relatively brief span of years. The Vaccum tube hearing aid was only about 25yrs old when the transistor appeared. Today's hearing aids are based on the invention of the Transistor by Bell Telephone Laboratories in 1947. The development made possible much smaller in size and sturdy, lower battery consumption and a flexibility of design never before possible. Along with this the development of hearing aid components, such as microphones, receivers, capacitors and integrated circuit, contributed to significant electro acoustic advances and the application of automatic signal processing technology.

Analog hearing aids have improved considerably over the last decade. However, the introduction of digital technology at a reasonable cost is significantly impacting the development of new hearing aids (Sandlin, 1994). The first application was the computer simulation of a hearing aid which served as a useful, though cumbersome, research tool. This began in the middle 1960's at Bell Telephone Laboratories for hearing impaired telephone users (Levitt, 1987). These combined both analog and digital techniques to achieve practical result.

Digital hearing aids are represented by two classes of instrument: the quasi-digital (hybrid) hearing aid and the all digital hearing aid.

In quasi-digital hearing aid, conventional analog amplifier and filters are controlled by digital means. This approach uses a computer for programming the hearing aid.

In all-digital hearing aids, both the processing of the audio signals and the control for the processing are done by digital means. Analog signals transdused by the microphone are sampled and then converted back to analog form after processing to drive the earphone.

These hearing aids allow the user not only to customize the hearing aid according to type and configuration of hearing loss but also to various hearing environments they are exposed to.

The major break through came with the development of specified digital signal processing (DSP) chips in 1982, designed specifically for high speed signal processing and allowing for real-time processing of audio signals in small size. These are called "all- digital" hearing aids which convert the analog signal to digital form and then processing is carried out. These instruments have increased precision over conventional analog hearing aids. These aids can also be programmed for a specific individual using a programmer in a short time. It can also be used for feedback controls and sophisticated noise reduction (Credahy and Levitt, 1994).

The major disadvantage of the completely digital hearing aid is that it is very expensive compared to conventional analog hearing aids. A new low cost digital technology is available for those who cannot afford the high end products. These hearing aids include DSP chips which convert analog signal to digital form and then processing is carried out. These are controlled by timers instead of a computer for programming.

Even though the hearing aid technology is improving over years, for appropriate selection of amplification the advantages of the hearing aids over each other has to be investigated. Studies comparing the performance of programmable hearing aids with conventional analog hearing aids have found that programmable hearing aids are better (Endo et al 1991; Hall & Jacobs, 1992; Smedley & Schow, 1992 & Sweetow & Shelton, 1996).

Some investigators have found better performance of digital hearing aid when compared to programmable hearing aid (Roeser & Taylor, 1988; & Arlinger. et. al., 1998 & Berlinger and Karlson, 1999). A study carried out by Bentler. et. al., 1998 & Bille et al., 1999 revealed no significant difference determined between the two hearing aids.

Hearing in noise is the greatest complaint they receive from the patients. Currently available technologies can help solve this problem. Directional microphone hearing aids along with other technologies that directly improve the signal to noise ratio for a listener with hearing impairment can dramatically improve speech recognition performance in noise. (Laurel. A. Chistensen, 2000).

Background noise represents a special problem for people with hearing impairment with cochlear damage resulting in a reduced frequency discrimination and dynamic range which are responsible for substantial loss of speech intelligibility in difficult listening situations (Duquesnoy, 1983; Festen & Plomp 1990; Plomp 1994, Moore et al., 1995). In addition the linear amplification of background noise by the hearing aids contribute to the masking of the speech signal in various everyday social settings.

Signal processing in digital hearing aids offers the potential to analyze the input signal for the presence of speech and noise components and through further processing to enhance the speech and suppress noise which might result in a better speech recognition for the user. Other potential advantages of clinical relevance related to DSP in hearing instruments are: more precise adjustment of electro-acoustic parameters: self monitoring capacity: self testing: and self calibration: efficient feed back control and automatic control of signal levels and adjustment to changing acoustic environments (Levitt, 1987).

On the other hand; Killion (1997) states that although DSP technology is able to reduce noise, the signal processing is sufficiently degraded in the process that there is no net improvement in speech intelligibility.

Previous studies with digital master hearing aids have given ambiguous results (Levitt et al., 1990 Murray & Hanson, 1992) and thus further clinical studies are needed.

The aim of the study is to demonstrate the merits of digital hearing aids with trimmer controls as compared against analog behind the ear hearing aids in terms of performance. Hence, the present study was carried out to compare the users performance with conventional analog hearing aids and digital hearing aids with trimmer control at different signal to noise ratios.

REVIEW OF LITERATURE

Improved hearing means improving quality of life. The design of technology of hearing aids has undergone a considerable amount of change. The main aim being reducing size and improving the sound quality. In terms of placement, the wearable personal hearing aids have come a long way from the body worn hearing aid to the presently introduced completely in the canal implantable hearing aids. To provide a hearing aid with good sound quality, the technology has advanced from the conventional analog hearing aids to programmable hearing aids and presently to the completely digital hearing aids.

Conventional analog hearing aids:

Although technologic development have resulted in many styles and applications, all contemporary hearing aids operate basically on the same principal. Analog hearing aids allow for representation of a continuously changing physical variable (i.e., sound) by another physical variable (i.e., electrical current) (Staab & Lybargar, 1994). This is achieved by the use of microphone, amplifier, and receiver of the hearing aid.

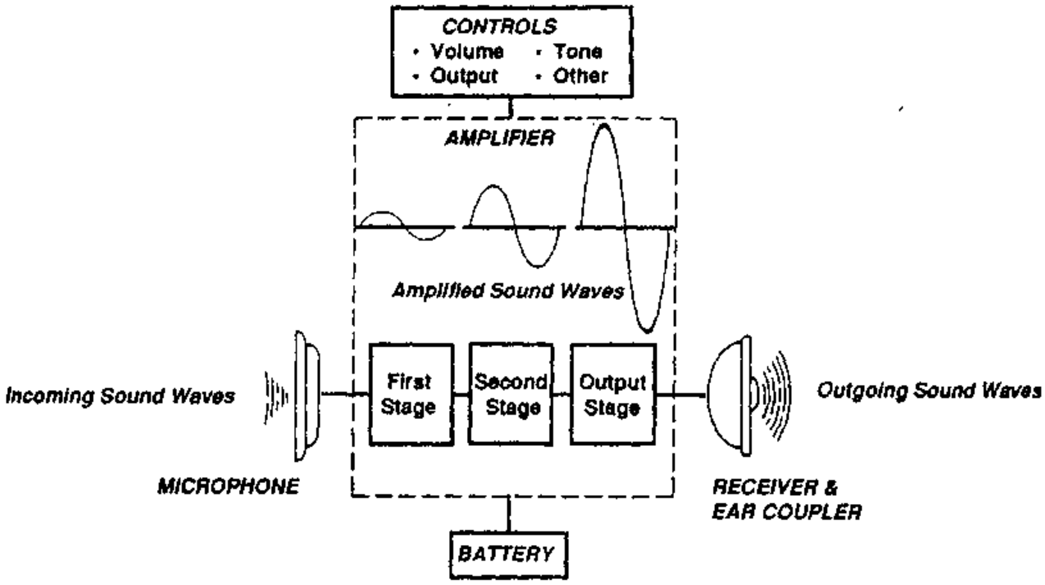


Fig.l: Block diagram of an conventional analog hearing aid

(Source: Staab, and Lybarger, 1994)

As shown in the above figure, the microphone picks up the signal and is converted to an electrical signal. This signal is then amplified corresponding to sound pressure variations and later converted back to the acoustic energy at the output by the receiver. The amplifier, in addition to providing a desired maximum amount of amplification, is generally equipped with gain control (VC) which can be manipulated by the user. The hearing aid may also have other provisions such as feedback controls, telephone pick-ups and output limiting. The amplification process is powered by the use of batteries. The receiver is coupled to the user's ears with a mechano-acoustic coupler or an ear mould. Signal processing refers to the manipulation of the signal to enhance or extract the information that it contains. These conventional hearing aids make use of analog signal processing. It is mainly employed in the hearing aids to improve the S/N ratio. It can be either non adaptive signal processing i.e., which does not change the basic performance of hearing aid, once its controls are set (e.g, directional microphone) or adaptive signal processing i.e., the processing function changes the performance of the hearing instrument in changing input signal environment (e.g, automatic volume control, automatic signal processing etc.) [Staab & Lybargar, 1994],

Classical linear amplification is unable to compensate for the pitch & the loudness recruitment of a particular hearing loss. Output limiting circuits are available with conventional analog hearing instruments that limit the loudness of acoustical stimuli at high intensity levels. But, they do not have the capability to compress sounds into the reduced dynamic range of hearing-impaired patient. Further loud low pitch noise can cause compression circuitry to reduce the amplifier gain at all frequencies, resulting in reduced intelligibility of soft speech sounds. The above problem can be overcome by the use of automatic signal processing i.e., by low frequency gain reduction. The limitation is that the gain and output requirements remain the same even if the dynamic range of a listening situation change (Hall and Jacobs, 1991a).

Advantages:

- Low cost
- Manual controls available.
- Lower battery consumption compared to programmable and digital hearing aids.

Disadvantages:

- Cannot be used in different listening situations effectively.
- Distortion may be present.
- Low fidelity of the signal compared to programmable and digital hearing aids.

Digital hearing aids:

A true digital hearing aid is a "wearable computer" that will allow for software adjustment of hearing aid parameters (Staab, 1985). Graupe and Causey (1975) first attempted making a digital hearing aid. This uses advanced signal processing technologies for noise reduction and intelligibility enhancement. The digital aid evolved after resolved two major technological problems,

i. Development of a digital signal processor fast enough to operate in real time and
ii. The more difficult problem of circuitry small enough and sufficiently low in power consumption for practical use in a small wearable unit.

High speed array processors (array of numbers is processed simultaneously instead of only one number at a time) were introduced during the 1970's and shortly after wards, a digital hearing aids was developed. Another important development was the introduction of high speed digital signal processing (DSP) chips in 1982.

Fully digital hearing instruments were announced at the end of 1995 and were commercially available by 1996. Most of these aids are multi channel and use various types of compression. In all digital aids the sound signals are sampled in discrete from and are represented by a series of data points. Digital signals are thus a series of pulses or rapidly changing voltage levels that vary in discrete units or increments between two fixed levels. The first step in digital processing of the continuous signals is that of sampling the signals at discrete intervals in time. A system that does this is called sampled data system.

A second important step is that in which each sample of the waveform is converted to numerical form, this is done using an all-digital system. The device used to convert a continuous waveform to digital form (i.e., to a sequence of numerical values representing the waveform at discrete intervals in time) is called analog-to-digital (A/D) converter. A digital output of an A/D converter can be processed by either a general purpose digital computer or by special purpose DSP (Digital Signal processing) chips. After processing the digital signal is converted back to a continuous analog signal using a digital-to-analog (D/A) converter.

The A/D converter has two main functions, of sampling refers to how often the device stops and measures the amplitude and is called the sampling frequency (Nyquist frequency). Quantization refers to how finely the amplitude variations are measured and is called the number of bits used in conversion process. In general, higher the sampling rate and greater the number of bits, more accurate the digital representation of the original analog waveform will be. An introduction of error (aliasing) occurs if there is any frequency greater than half the sampling frequency. Aliasing can result in distortion and in order to avoid this, the frequency above the Nyquist frequency (highest frequency of interest) are attenuated using an anti-aliasing filter which consists of low pass or band pass filter with an extremely steep cutoff. A similar low pass filter an anti imaging filter is used at the output of the system to eliminate spurious frequency component that might be introduced in the conversion from discrete to continuous signals (Schweitzer, 1998).

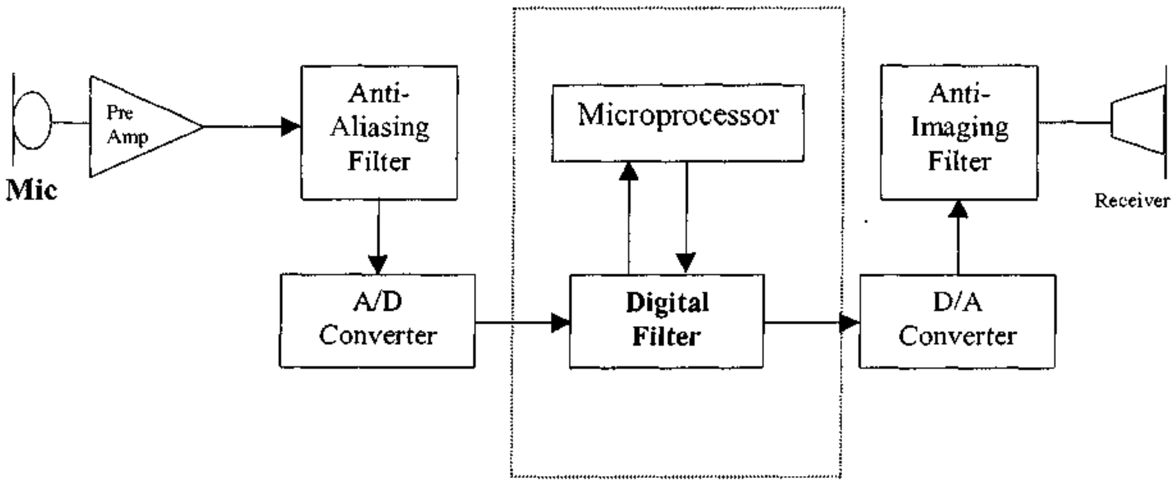


Fig.2: Block diagram of an all-digital-hearing aid.

(Source: Schweitzer, 1998)

Thus, a digital hearing aid is a wearable computer. It uses DSP as a sampling technique to eliminate the need for conventional analog components (i.e., transistor, resistors, diodes and capacitors). Hence more specific control of the signal is possible.

Advantages:

- Digital hearing aids have the ear conversions. Thus the variables such as ear canal volume; middle ear impedance, shell fit and jaw movements are eliminated or reduced by incorporating them into the programming measures.
- Digital cochlear dynamics (Ross .M, 2000).

- Speech enhancement algorithm.
- Artificially intelligence system enhancement critical to speech sounds.
- Dynamic speech recording.

***Disadvantages**:*

- Low battery life due to high current drain.
- Highly complex algorithms are needed to control its performance.

A number of research studies have focussed on the individual differences in speech understanding performance for listeners with hearing impairment. Investigators have carried out studies to compare the performance of digital hearing aids and programmable and analog aids. Studies reveal varied results.

Signal-to-noise ratio is defined as the relationship between the loudness of the signal (speech) and the loudness of the noise. When signal-to-noise ratio is positive, the signal is louder than noise. When the signal-to-noise ratio is negative, the noise is louder than the signal.

Roeser and Taylor in 1988, found major improvements in digital hearing aids over programmable hearing aids because of its extended signal processing ability.

Speech understanding in noise remains a major complaint even when hearing aids are worn (Plomp, 1978; Tyler et. al., 1983; Kochkin, 1994).

According to the literature there is definitely a significant difference between programmable aid and conventional analog hearing aid. (Johnson et al, 1988;

Rigdahl et al, 1988; Endo et al, 1991; Hall & Jacobs,1991 a & b; Hodgson, 1991; Kiessling & Steffens, 1991; Smedley & Schow,1992; Benziger and Bonta, 1993; Redden & O'Neil 1944; Kochkin,1996; Sweetow & Shelton, 1996; Parving et al, 1997& Voll, 1999).

However, there is no clear cut evidence for such significant difference in studies comparing programmable and digital hearing aids. (Roeser and Taylor, 1988; Hall & Sandlin, 1997; Arlinger et al., 1998; Bentler et al., 1998; Febry, 1998; Arlinger & Billermark 1999 & Bille et al., 1999).

Historically, hearing and understanding speech in background noise is the primary concern of individuals with hearing loss and the chief complaint of hearing instrument wearers.

In a study of user satisfaction, Kochkin (1996) found that 71% of those wearing conventional hearing instruments were dissatisfied with their performance in background noise. Today, technology is available that can improve signal-to-noise ratio and make it possible for hearing instrument wearers to hear and understand in more challenging environments.

Kochkin, 1996; Warland et al., 1997, have found improved comfort and less annoyance in noise situations, better sound quality and in certain situations, a reduction in the spread of masking form one frequency region to another.

Listeners with hearing impairment have greater difficulty in understanding speech in noise. Better speech understanding in noise is desired by a majority of hearing aid users (Stock et al., 1997).

Many technologies exist that improve the signal to noise ratio for a listener with hearing impairment. The most common and familiar device is the frequency modulation system; which has been used for years to improve the SNR for children in the classroom. Frequency modulation systems are not widely used by adults due to cosmetic concerns.

Bentler and Duve (1997) tested subjects wearing hearing aids incorporating several different circuits to look at hearing aid performance. The result reveals that the linear peak clipping body aid did not perform as well at the higher input probably because of distortion.

C. Mike Hall and Robert Sandlin (1997) in their clinical study compared digital hearing aid with digitally programmable hearing aids in 20 subjects. Self judgement questionnaire was used. All 20 subjects reported a preference for the digital hearing aid over their digitally programmable instrument.

Speech discrimination scores of 8 patients tested with + 15dB SNR, good speech discrimination scores were obtained for true digital hearing aid. Even fairly good discrimination scores were obtained at an SNR as small as +5dB.

Hall and Sandlin (1997) reported better word recognition scores at lower presentation levels with true digital hearing instruments and better speech understanding at lower signal-to-noise ratio as compared to digitally programmable hearing aids.

Febry in 1998 suggested that digital hearing aid offered improved feedback reduction over their analog counterparts when used with proper fitting ear-moulds. He also found digital hearing aids provided better signal fidelity than the analog devices. Arlinger et al (1998) compared digital hearing aid and programmable hearing aid and found that speech recognition scores in noise was better and sound quality ratings were higher in digital haring aids.

Compared to traditional linear technology, these advanced technology products typically receive excellent subjective ratings by patients (Boymans, et al., 1999; Humes, et al., 1999; Walden, et al., 1998).

Signal processing strategies overcome the deleterious effects of such deficits on speech recognition. That is, simple amplification of the speech signal will not provide the individual maximum communicative benefit, particularly in adverse listening environments.

In digital hearing aids with noise reduction algorithms, artificial intelligence discerns whether an incoming sound is noise or not. By the way, the word "algorithm" simply means a series of instructions: digital noise-reduction algorithms are long series of numerical calculations that determine if the acoustic properties of an incoming sound are closer to those of noise or speech. (If the incoming sound is determined to be noise then the gain is reduced for both speech as well as noise in single channel system).

If the digital hearing aid is multi channel (all of them so far are then the noise reduction algorithm tells the hearing aid to reduce the gain for the speech and the noise, in which ever channel serves the noise). Digital noise-reduction algorithms on the other hand, may currently improve the subjective experience of listening in noise by making the difficult listening situations more comfortable for the listener. (Ted Venema, 1999).

Later Arlinger and Billemark in 1999 studied the subjects who preferred Digifocus digital hearing aid compared to the programmable hearing aid over a period of one year. After l year of acclimatization, they found stronger preference for Digifocus hearing aid by their subjects. The use of Abbreviated Profile Of Hearing Aid Benefit (APHAB) and Gothenburg Profile Questionnaire revealed more clear sound, better sound quality and better music appreciation with the digital hearing aid after one year of use.

Though the above studies have shown that digital hearing aids are superior, Bille et al., in 1999, investigated 28 hearing impaired subjects in the age of 32 to 89 years over a period of 6 to 9 weeks and found no significant difference between digital and programmable hearing aids with respect to over all performance, satisfaction and speech recognition in noise. The only parameter showing slightly better rating for the digital hearing aid was comfort listening in the presence of traffic noise. Similar results are also reported by Bentler et al., (1998) and Berminger and Karlsson(1999).

Normal hearing listeners achieve 50% intelligibility at approximately -7dB SNR and 100% intelligibility at Od dB SNR and require +10dB SNR. to achieve 100%intelligibility. (Voll, 2000).

The recent introduction of digital signal processing (DSP) into hearing aids allows more sophisticated techniques to be implemented than could be done with analog technology. (Edwards, 2000).

Poornima .N. (2000) compared the performance with conventional analog and programmable and digital hearing aids and found no significant difference between conventional analog and digital hearing aids except for speech identification scores in noise, there was significant difference between conventional analog and programmable hearing aid and there was no significant difference between programmable and digital hearing aid. The hearing aids were also compared with noise and without noise, significant difference was found for analog, programmable aid. There was no significant difference for digital haring aid between two conditions.

Taken form the data of Warland et al., (1997) compares the ratings of performance of two different DSP hearing aids with more traditional technologies. It is seen, especially in the more difficult listening situations, both of the advanced technology products are rated significantly more positive than the traditional products. (Schum, 2000).

Prinz, I, K Nubel, M Gross. (2001) Compared different types of hearing aids. Digital hearing aid (DigiFocus Compact/Oticon) and an analog, programmable 2-channel automatic hearing aid (Siemens VIVA 2 Pro) were compared. 13 of the 17 subjects chose Digifocus compact and 2 the Siemens VIVA 2Pro.

Speech recognition at 65dB showed no significant difference between analog and digital hearing aids in quiet and in noise.

Febry, 1998, who has attempted to quantify the benefit differences between these (analog and programmable) two product groups has suggested that, at least in their current form, DSP instruments offer little measurable advantage over digitally programmable analog signal processing devices. In an effort to evaluate the speech understanding influences that 14-band modulation based noise reduction can have speech intelligibility Latzel and Keissling (1998) evaluated the aided speech understanding of 20 hearing instrument wearers in 2 controlled competing noise environments. There was a significant improvement in speech understanding ability at the 55dB noise level evident in the aided condition Vs unaided condition. (Smriga, 2000)

METHOD

The study was undertaken to compare the hearing aid user's performance with conventional analog and digital hearing aids with trimmer controls (Low cost digital hearing aid).

a) Subjects:

20 Kannada speaking hearing impaired subjects were included in this study, with the age of 25 - 70 years.

Selection criteria:

The subjects had,

(i) Post lingually acquired hearing loss

(ii) No significant associated psychological or speech disorder

(iii) Audiological criteria.

The audiological evaluation of each subject was carried out using a calibrated clinical audiometer Maico, MA53, in a sound treated two room situation with earphones enclosed with in ear cusions and audiocups. PTA, SRT and SIS were determined. Subjects with PTA of above 45dB and within 70dB were included in this study. After ENT clearance and based on the above findings, the subjects who were candidates for hearing aid use were included in the study.

The outcome of the hearing aid should be used both interms of subjective and objective terms (Arlinger et al., 1998). Hence the following tests were administered.

1. Real ear aided response measurement
2. Speech tests
3. Subjective evaluation using a questionnaire.

Test procedure:

Initially both the hearing aids were fitted using insertion gain measurements. This measurement was carried out using calibrated Fonix 6500C hearing aid test system (computer controlled real-time analyzer version V3.09 Esys).

L REAR:

Real ear measurement utilizes techniques that are safe and comfortable for the patient, and offers a reliable, simple and objective measurement of hearing aid performance within the ear canal. The REAR usually is preferred over insertion gain. When measuring certain special hearing aid features, such as directional microphone, compression or signal processing circuitry (Muller, 1992).

Instrum entation:

The Fonix 6500 - C hearing - aid test system (computer controlled real time analyzer version V3.09E system) was used to determine the REAR for both the hearing aids. The prescriptive formulae used for hearing aid selection was POGO.

The client was seated in front of the speaker of Fonix 6500C which was placed 30 cms from the surface of the clients head (near the temple) and pointing towards the ear to be tested. The loud speaker kept at an azimuth angle of 45° (half way between the client's nose and ear). The height of the loud speaker was kept at a level with or little above the ear. The system was calibrated and sound field calibration was done using ipsilateral comparison procedure.

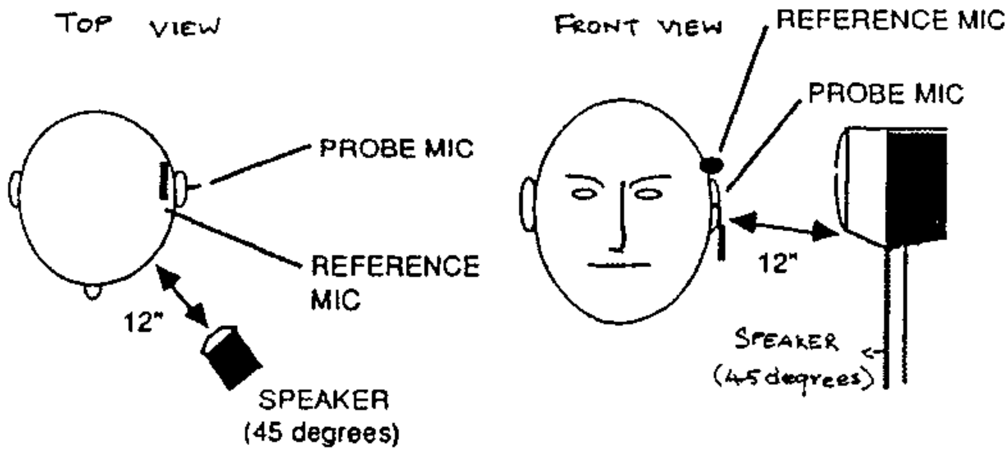


Fig.3: REAR measurement test arrangement

Then the ear tip was placed next to the probe tube so that the tube rested along the bottom of the canal part of the ear tip, with the tube extending at least 5mm(l/5") past the canal opening. Using the marker the probe tube was marked where it meets the outside surface of eartip. When the probe was placed in the ear, it was taken care that the marking was near the target notch of the subject. Then the aid was placed on the patient at desired volume control and aided response was recorded at the input levels of 50 dB SPL and 70 dB SPL (Muller and Hawkins, 1992).

Speech tests:

Aided (using the two hearing aids) measurements were carried-out using two types of speech materials Paired words (Rajashekar, 1976) and Phonetically Balanced words (Mayadevi, 1974) in Kannada mentioned in Appendix 1 and 2. For paired words correct response was scored as one and incorrect response as zero. The response for phonetically balanced words were converted into percentage. The testing was carried out in the double room situation in a sound field condition, using a calibrated clinical audiometer MA53 (Calibrated as per the instructions in the manual provided by the manufacturer). The calibrated loud speakers were placed at 45° azimuth and 1 meter away from the subject.

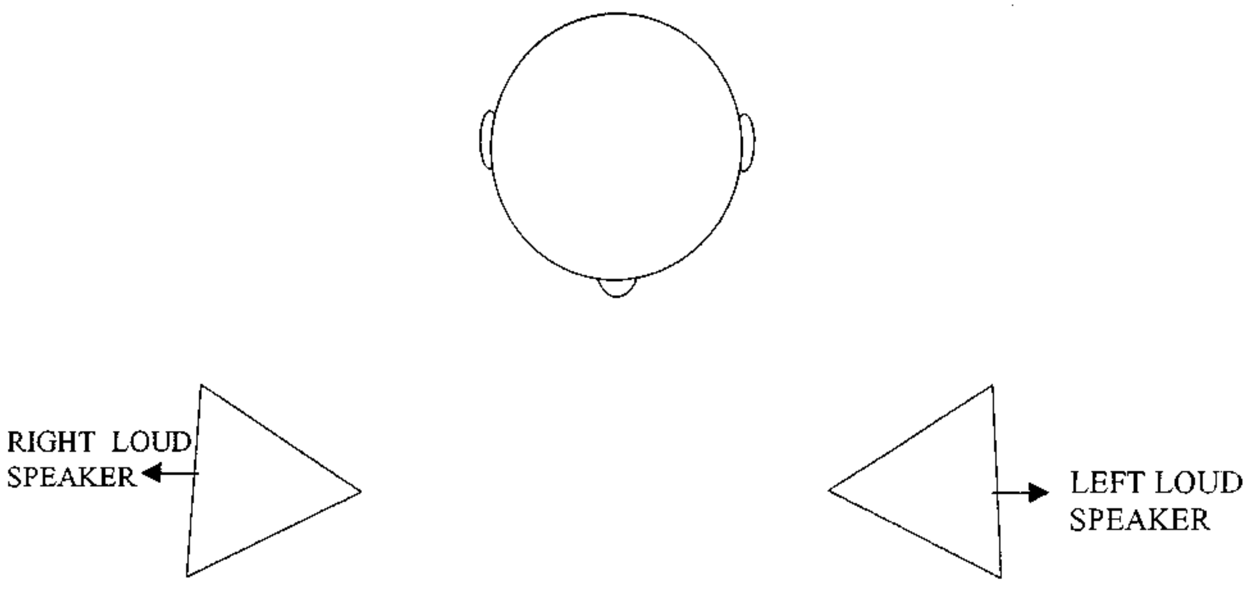


Fig.4 Top view of the test situation

Both measurements were carried out at 3 different S/N ratios i.e., 0 dB, + 10 dB and + 20 dB were considered. Speech stimuli was presented from the speaker of the test ear side and noise on the other side.

3. Subjective Evaluation:

One of the best ways to measure the outcome of the hearing aid fitting is the use of self-assessment inventories (Muller, 1996). Therefore, a questionnaire was given to the subject to evaluate both the hearing aids in various conditions. The questionnaire used in this study is in Appendix 3. Different situations evaluated were;

a) Listening to Kannada passage (Appendix - 4) read from a distance of 5 feet.

b) Listening to music from a distance of 5 feet in a quiet conditions at moderate loudness level.

c) Conversation over the telephone with the hearing aid set to telecoil position and with an increase in volume control.

RESULTS AND DISCUSSION

The present study aimed at comparing the haring aid users performance with conventional analog and digital hearing aid with trimmer controls at 3 different signal to noise ratios. 20 Kannada speaking hearing impaired individuals participated in the study. They all had acquired hearing loss post lingually and had no associated psychological, physical or any speech and language problems.

The following tests were administered to collect the data on each subject:

- Real ear aided response measurements (REAR) and
- Speech tests
- Subjective evaluation using a questionnaire.

Analysis of the data:

The data obtained by speech testing were tabulated and subjected to statistical analysis. Descriptive statistics is used to discuss the results obtained.

- ***REAR:***

Using Real ear probe microphone measurements the hearing aid was selected. Prescriptive hearing aid evaluation was done using POGO procedure (Me Candless & Lyregaad, 1983).

- ***Speech Tests:***

The speech tests were done in the presence of speech noise in three different signal-to-noise ratio levels 0dB, -l0dB, -20dB for both the hearing aids. The mean, standard deviation and t scores of the data were calculated and is shown in the following Table.

Particulars	0 dB SNR		-10 dB SNR		- 20 dB SNR	
	Digital with TC	Analog	Digital with TC	Analog	Digital with TC	Analog
Mean	**5**	4.85	4.4	3.8	3.45	1.8
SD	**0**	0.35	0.489	0.748	0.8046	0.8717
t-score	1.92*		3.00*		6.22**	

*P<0.05 **P<0.01

Table - 1: Mean, Standard deviation (SD) and t values for paired words at different SNR for digital hearing aid with trimmer control and analog hearing aid.

Particulars	0 dB SNR		- 10 dB SNR		- 20 dB SNR	
	Digital with TC	Analog	Digital with TC	Analog	Digital with TC	Analog
Mean	85.75	81	69.25	61.5	41	14.25
SD	6.94	7.84	11.96	11.52	10.07	6.759
t-score	2.03*		2.08*		9.86**	

*P<0.05 **P<0.01

Table - 2: Mean, Standard deviation (SD) and t values for phonetically balanced words at different SNR for digital hearing aid with trimmer control and analog hearing aid.

The significant difference between the hearing aids (analog hearing aid and digital hearing aid with trimmer control) for three different conditions (0 dB SNR, -10 dB SNR, - 20 dB SNR) were analyzed with the parametric t - tests for both paired words and phonetically balanced words. The probability level of < 0.05 was considered as statistically significant.

Significant differences are discussed under the following condition between the hearing aids.

I. 0 dB SNR

II. - 10 dB SNR

III. - 20 dB SNR

The paired words and phonetically balanced words were compared in all three conditions between the hearing aids, the following results were obtained.

I 0 ***dBSNR***

At OdB SNR no significant difference between the conventional analog and digital hearing aids for paired words scores were obtained (t = 1.92 NS). Significant difference between the hearing aids for phonetically balanced words were obtained (t = 2.03 S).

II *-10 dBSNR*

At - 10 dB SNR significant difference between the hearing aids for paired words were obtained (t = 3.00 S). Significant difference between the hearing aids for phonetically balanced words were obtained (t = 2.08 S).

III *-20 dBSNR*

At - 20 dB SNR significant difference between the hearing aids for paired words were obtained (t = 6.22 S). Significant difference between the hearing aids for phonetically balanced words were obtained, (t = 9.8 S)

Thus, based on speech test results, it could be inferred that there is significant difference between the analog and digital hearing aids with trimmer control.

This findings are in accordance with those of Prinz .1, K, Nubel, M Gross (2001), similarly indicating digital hearing aid preference over other types.

Roeser and Taylor in 1988, found major improvements with digital hearing aids over programmable hearing aids because of its extended signal processing ability.

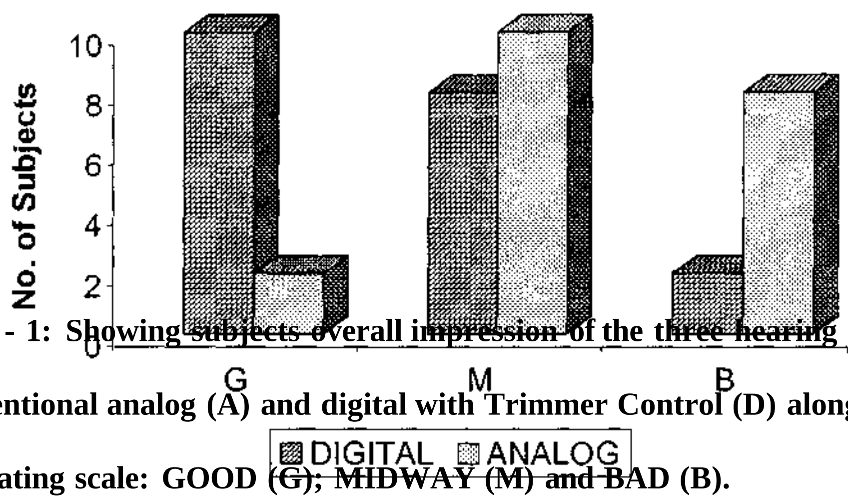
A study carried out by Arlinger and Billermark in 1999 have reported that there was significant difference in terms of speech identification scores when a digital hearing aid (Digifocus) was tested in subjects at one month and one year time period. They found stronger preference to Digifocus hearing aid by their subjects.

As discussed earlier, due to the noise reduction circuitry, the significant differences were seen for the SIS in noise condition. Signal processing in digital hearing aids offers the potential to analyze the input signal for the presence of speech and noise components, and through further processing to enhance speech and suppress noise which would have resulted in better speech recognition of the user (Bille et. al., 1999). The lack of difference in SIS without noise between conventional analog with digital hearing aids can also be attributed to compression which takes place in digital hearing aids at higher stimulus levels.

• ***Subjective Evaluation :***

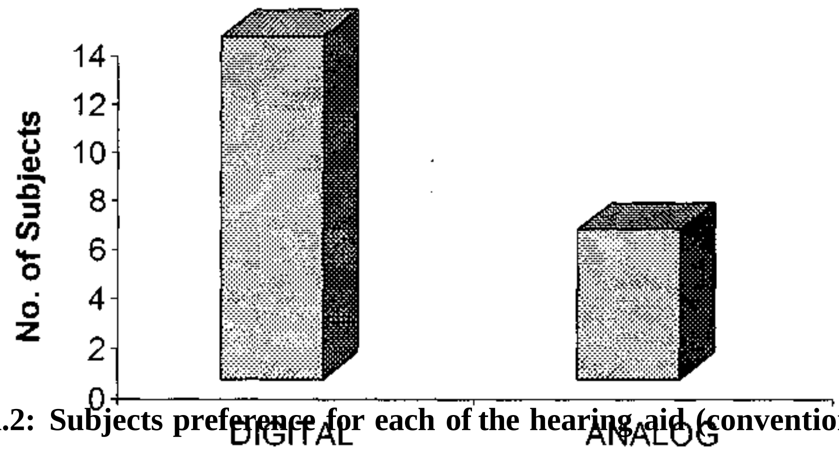
A questionnaire (Appendix 3) was used for subjective evaluation which was filled by the subject along with a structured interview with the examiner.

The results of the questionnaire are represented graphically.



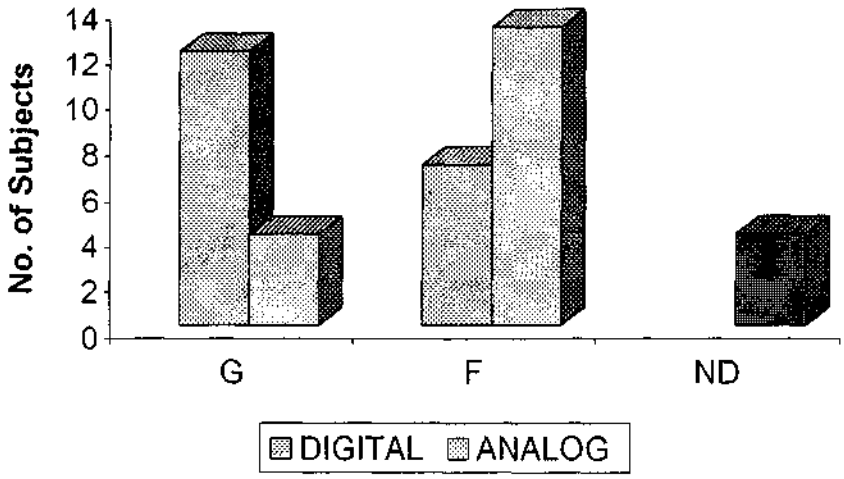
Graph - 1: Showing subjects overall impression of the three hearing aids. (Conventional analog (A) and digital with Trimmer Control (D) along the 3 point rating scale: GOOD (G); MIDWAY (M) and BAD (B).

The graph represents subjective rating on three point rating scale (G - Good, M - Midway and B - Bad) for both digital hearing aid with trimmer control and analog hearing aids. It is seen that the digital hearing aid with trimmer control is rated as good compared to analog. Here ten people have rated digital hearing aid with trimmer control as good and two have rated analog as comparatively good. Eight subjects have rated digital hearing aid with trimmer control as midway and ten rated analog as midway. Two subjects have rated digital hearing aid with trimmer control as bad and eight have rated analog as bad. From the above graph it is evident that the overall impression of digital hearing aids with trimmer control were definitely better than conventional analog hearing aid.



Graph.2: Subjects preference for each of the hearing aid (conventional analog(A); DIGITAL with trimmer control(D)

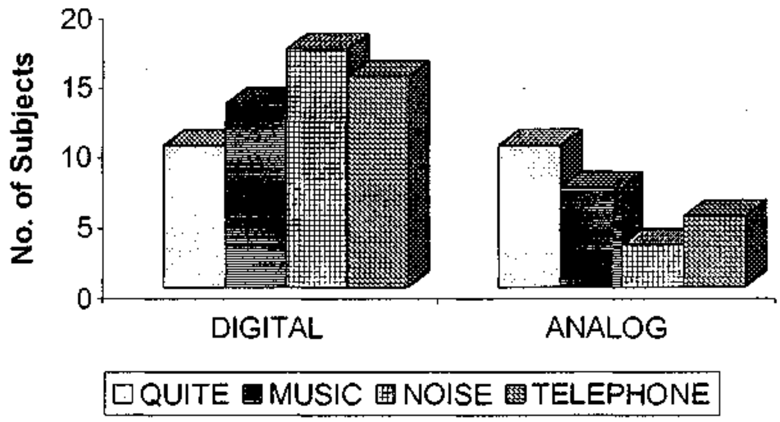
The graph shows that subjects preference also does not differ much from previous results. More subjects (14 out of 20) had preferred Digital hearing aid with trimmer control, the reasons were good sound quality, more clear and better in telephonic conversation. Six of the subjects could not rate the listening comfort with analog and digital hearing aids with trimmer control as they reported that speech sounded the same through both the hearing aids.



Graph 3: Subjects sound quality ratings of the two hearing aids (conventional analog (A); Digital hearing aid with trimmer controls (D) along a 3 point rating scale (Good (G); Fair (F) and No difference.(N)

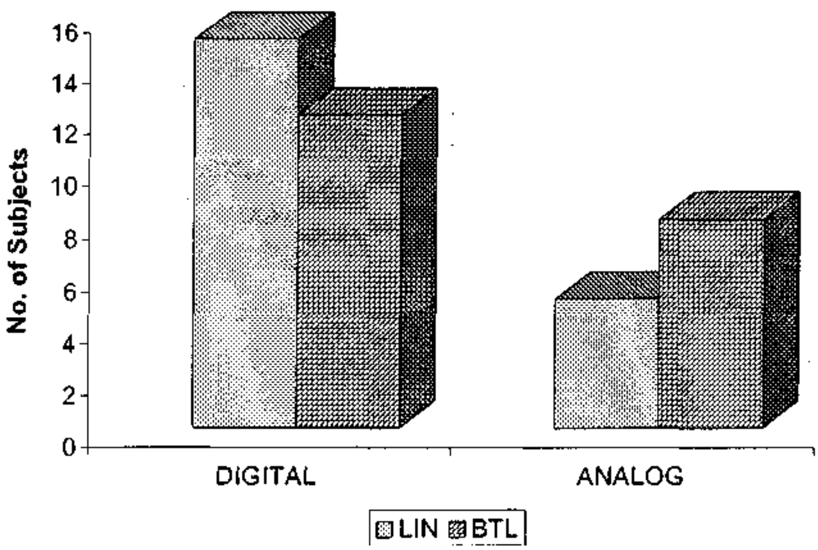
Graph - 3 shows subjective sound quality rating both for analog and digital hearing aids with trimmer control on three point rating scale. Here we observe that twelve people have rated digital hearing aid with trimmer control as being good compared to four people rating analog as good. Seven people have rated digital hearing aid with trimmer control as being fair compared to thirteen people rating analog as fair. Four subjects have rated as no difference.

As observed from the graph sound quality ratings reveal that digital hearing aid had definitely better sound quality as compared to the conventional analog hearing aid.



Graph - 4: Subjects preferring the hearing aid (conventional analog (A), Digital hearing aid with trimmer control (D) to be better in different conditions.

There was no difference between the two hearing aids in quiet condition, digital hearing aid with trimmer control was preferred in the presence of background noise. And also it ranks higher for appreciating music, and telephonic conversation, but still few of the subjects liked analog hearing aid for appreciating music.



Graph - 5: Number of subjects preferring the aid in Loud Sound (BTL - Better Tolerance for Loud sounds) condition and rating the aid which had Less Internal Noise (LIN) Conventional analog (A); Digital (D) hearing aid with trimmer control

From graph 5, it can be inferred that, better tolerance for loud sounds and less internal noise perceived by the subjects with digital hearing aid with trimmer control.

Thus it can be concluded from the subjective evaluation that digital hearing aids with trimmer control were better in all most all different conditions.

From the above results it is seen that there was an agreement between speech test results and the questionnaires which was also reported earlier by C. Mike Hall and Robert Sandlin (1997). This may be due to digital noise reduction algorithm, which improves the subjective experience of listening in noise by making the difficult listening situation more comfortable for the listener.

The human bias regarding the hearing aid type, cost technology and recency effect could bias the judgment of human listeners, thus making it difficult to get valid and reliable subjective outcome of measures during investigations of this nature. (Bentler & Diltberner, 1998). The lack of homogeneity in listeners with hearing impairment, even with same degree and type, results in wide range of psychophysical abilities and inabilities.

Febry, (1998), who has attempted to quantify the benefit differences between these (analog and programmable) two product groups has suggested that, at least in their current form, DSP instruments offer little measurable advantage over digitally programmable analog signal processing devices.

Taken form the data of Warland et al., (1997) and comparing the ratings of performance of two different DSP hearing aids with more traditional technologies, it can be seen especially in the more difficult listening situations, both of the advanced technology products are rated significantly more positive than the traditional products. (Donald J, Schum, 2000).

Poornima .N. (2000) compared the performance with conventional analog and programmable and digital hearing aids. The hearing aids were compared in two conditions (with noise and without noise) significant difference were found for analog and programmable hearing aids. There was no significant difference for digital hearing aids between two conditions.

It was seen that digital hearing aid had advantage in speech identification scores in the presence of noise. Thus, the manufacturer's claims concerning conversation in noisy surrounding, ability to hear softer sounds and brightness or clearness of sounds, which favor the digital hearing aid compared with their analog signal processing hearing aids, could be supported by the present study except for the speech identification scores in noise and higher rating in listening to music.

Recommendation for future research:

- Fully digital hearing aid can be compared to Digital with trimmer control and Programmable hearing aid.
- The study can be replicated for existing users of hearing aid.
- Study can be carried out to check whether acclimatization would affect.

SUMMARY AND CONCLUSION

Aural rehabilitation has the provision of amplification as its major component for an individual with hearing disability. In the recent years, there has been tremendous development in hearing instrument technology concerning both in terms of design and strategies for amplification. The current study was carried out to provide a scientific evidence of the efficacy of latest technology. The study aimed at comparing the users performance on speech test with conventional analog and digital hearing aid with trimmer control at different signal to noise ratios. In this study 20 post-lingually hearing impaired subjects with pure tone average between 41dBHL and 90dBHL participated.

The results indicated that there was significant difference between Analog and Digital hearing aid with trimmer control at all three signal to noise ratio conditions (0 dB SNR, - 10 dB SNR and - 20 dB SNR) except for paired words at 0 dB SNR. The subjective impression of cases also matched the objective data with digital aid which were rated high in performance. The study also highlights the importance of subjective evaluation in different listening situation along with other clinical investigations for appropriate selection of hearing instruments. Further studies are needed to support the efficacy of later technology in hearing instrumentation.

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Appendix - 1

SRT - Spondee Word List (Rajashekar, 1976)

1. mara – giḍa
2. kallu – maṇṇu
3. t̪a:i – t̪and̪e
4. ganṭu – mu:ṭe
5. and̪a – tʃand̪a
6. at̪t̪a – it̪t̪a
7. sut̪t̪a – mut̪t̪a
8. mane – maṭ^{h}a
9. hola – gad̪d̪e
10. beṭṭa – guḍḍa
11. naḍe – nuḍi
12. i:ga – a:ga
13. namma – nimma
14. be:ḷe – ka:ḷu
15. alli – illi
16. gedʒdʒe – pudʒe
17. mi:na – me:ʄa
18. kaʃta - suk^{h}a
19. a:st̪i – pa:st̪i
20. guru –ʃiʃya
21. d̪a:na - d̪^{h}arma
22. kelasa – karaya
23. kanasu – nanasu
24. paʃu – pakʃi
25. band̪^{h}u – baḷaga

Appendix - 2

PB word list (Mayadevi, 1974).

1. ma
2. t̪a
3. sa
4. tʃa
5. d̪a
6. t̪a
7. ra
8. ṇa
9. pa
10. va
11. na
12. dʒa
13. ka
14. la
15. ha
16. ḷa
17. ga
18. d̪a
19. ja
20. ʃa

1. tʃa
2. da
3. na
4. ka
5. ba
6. ra
7. ga
8. pa
9. ma
10. va
11. ḍa
12. t̪a
13. na
14. ḷa
15. dʒa
16. s a
17. ta
18. ʃa
19. dʒa
20. la

Appendix - 3

Praʃne ma:llke

1) nImma ʃravaṇjantṛaḍa bagge nImagIruva abhIpra:ja ve:ṇu?

	tʃenna:gIḍe	parava:gIlla	tʃenna:gIlla
A			
B			
C			

2) ParikshIsIruva ja:va ʃravaṇajantṛavaṇṇu a:jḍukoḷḷalu

ItʃtʃisuṭṭIra:? ja:ke?

A ☐ **B** ☐

3) ʃravaṇajantṛaḍa ʃabḍaḍa guṇa maṭṭa he:gIḍe?

	tʃenna:gIḍe	parava:gIlla	tʃenna:gIlla
A			
B			
C			

4) ja:va ʃravaṇajantṛaḍallI mIʃIṇIṇa abḍʰa (internal noise)

kaḍIme Iḍe, enḍu aṇṇIsuṭṭaḍe?

A ☐ **B** ☐

5) nIʃʃabḍa va:ṭa:varaṇaḍallI ja:va ʃravaṇajantṛa tʃeṇṇa:gIruṭṭaḍe, enḍu

ṇImma aṇIsIke?

A ☐ **B** ☐

6) gala:ṭijiruva va:ta:varaṇadallI ja:va ʃravaṇajantra upajo:gIsabahudu endu nImma anIsike?

A B

7) ja:va ʃravaṇajantravannu d^harIsIda:ga tumba: dʒo:ra:da ʃabdavannu ta:ḷa bahadu, endu annIsuttade?

A B

8) ja:va ʃravaṇa jantravannu dharIsI ni:vu saŋgitavannu tʃenna:gi a:nandisabahudu?

A B

9) ṭelIfo:n nalli ma:tana:ḍalu ja:va ʃravaṇajantra tʃenna:gIde endu nImma anIsIke?

A B

10) ʃravaṇo:pakaraṇa gaḷa bagge nImma anIsIkegaḷIddare vjaktapaḍIsI?

A

B

C

Appendix - 4

Kannada Passage

beŋgaḷu:ru namma radʒjad̪a ond̪u d̪oḍḍa u:ru. i: u:rannu namma radʒjad̪a "bamba:i " ennuvaru. InḍIja:d̪a d̪oḍḍa nagaragaḷallI Id̪u ond̪u. i: u:rannu no:ḍalu dʒanaru be:re be:re ra:dʒjagaḷInd̪a, be:re u:rugaḷInd̪a baruvaru. Id̪allad̪e namma radʒjad̪allIruva be:lu:ru, dʒo:g, nand̪I Ivugaḷannu no:ḍalu dʒanaru baruvaru. i: na: ḍInallI reʃmejan̪n̪u belejuvaru.

krIʃṇa nad̪Iju, sahja:d̪rI parvat̪agaḷallI mahabaleʃwarad̪a hat̪t̪Ira huṭṭut̪t̪ad̪e. Id̪u huṭṭuva prad̪e:ʃavu ramaṇi:ja st̪ʰa:na. Id̪u mahara:ʃtra, karna:ṭaka mat̪t̪u a:ndʰraprad̪e:ʃagaḷalli harId̪u, baŋga:la kollIjannu se:rut̪t̪ad̪e. Id̪akke upanad̪Igaḷu halavu. koIna, t̪uŋgabʰad̪ra, gʰaṭaprabha, bʰi:ma, malaprabʰa avugaḷallI kelavu. koIna naḍIge aṇe kaṭṭannu kaṭṭI vId̪jut̪annu ut̪pa:d̪ane ma:ḍut̪t̪a:re.