Mobile Phones and Aided Speech Perception: Is there any Interferency

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Abstract

This study was designed to investigate the performance of digital and analog hearing aids when a person with hearing impairment is using mobile phone with GSM or CDMA wireless technology. Thirty participants with hearing impairment (aged 15-55 years with hearing loss not exceeding 60 dBHL and naïve hearing aid user) participated in the study. Phonetically balanced word lists and questions were presented to the aided ear of the participants while they were using either GSM or CDMA wireless system. For speech perception assessment both analog and digital hearing aids were used in microphone and telecoil positions. Results showed that the performance of digital hearing aid in microphone position was better than in telecoil position with both GSM and CDMA wireless systems. Further, speech intelligibility was better with the CDMA than GSM system in both analog and digital hearing aids.

Introduction

In recent times telecommunication has become an important part in everybody's life including that of persons with hearing impairment. An important telecommunication device these days is the mobile phone the use of which has achieved a level of inevitability in everyone's lives. The use of mobile phones has been increasing at a stunning rate over the last decade.

The mobile phones use radio frequencies (RF) for transmission of signals. These RF cause interference in speech intelligibility when hearing aid users are themselves the users of mobile phones or when they are in the vicinity of a mobile phone user (bystander). The extent of this interference depends on various factors such as the type of signal processing used in mobile phone (analog or digital), type of signal processing in hearing aids (digital or analog), the distance between mobile phone and base station and the input mode to the hearing aid (microphone or telecoil). Analog wireless mobile phones have evolved into the more advanced digital wireless mobile phones that are being used in the present times. These latter systems were designed to allow frequencies to be re-used in a small geographic area thereby increasing the available users' density.

The use of digital cell phones causes the emission of radio waves that is transmitted over a wireless network during mobile phone conversation. These radio waves emitted by the mobile phones are referred to as radio frequency (RF) emission. The RF emission creates an electro-magnetic (EM) field around the mobile phone's antenna and this EM field has a pulsating pattern. It is this pulsing energy that may potentially be picked up by the hearing aid microphone or telecoil circuitry and perceived by the hearing aid wearers as a "buzzing" sound. When held

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against a hearing aid of both analog and digital type digital cell phones sometimes produce a "buzzing" noise. In severe cases it can even render the phone unusable (Kozma-Spytek, 2003).

To complicate the matters more the digital technology for transmitting calls over a wireless network differs depending on the carrier service provider (Kozma-Spytek, 2003). The digital mobile phones use different technologies to achieve this, such as Time Division Multiple Access (TDMA), Global System for Mobile Communication (GSM) and Code Division Multiple Access (CDMA). Recent studies by Strange, Byrne, Joyner, Wood, Burwood and Symons (1995) carried out at National Acoustic Laboratories (NAL) indicate that most hearing aid users, who can successfully use a telephone on a landline connection or an analog mobile phone, are also able to use CDMA digital mobile phone more competently when compared to GSM mobile phones. Even when interference was present in CDMA technology it had a static like sound that did not affect speech intelligibility to a large extent (Skopec, 1998). The effect of RF interference on speech intelligibility also depended upon the type of hearing aid used. It is widely known that digital hearing aids are less affected by RF interference than analog ones (Kuk & Nielsen, 1997; Kozma-Spytek, 2003). Other factors that affect speech intelligibility in hearing aids during mobile phone use include distance of the mobile phone to the base station and proximity of the hearing aid user to the mobile phone.

The purpose of this study was to answer the following questions:

1. Which mobile phone technology, GSM or CDMA, gives better speech intelligibility by reducing interference for a hearing aid user?
2. Which hearing aid technology, i.e., digital or analogue, is better for cell phone communication?
3. In which hearing aid setting, i.e., microphone or telecoil, is the interference from mobile phone low?

Method

The purpose of this study was to evaluate Speech Recognition Score (SRS) with GSM and CDMA technology in participants with sensorineural hearing loss using digital and analog hearing aid. The speech recognition score was evaluated in microphone (M) and telecoil (T) settings of both the digital and the analog hearing aids.

Participant inclusion criteria

Thirty participants with hearing impairment in the age ranging from 15 to 55 years participated in the study. Among these sixteen were males and fourteen were females who passed the following selection criteria:

1. Fluent in Kannada language, with acquired hearing impairment.
2. Moderate to moderately-severe degree (pure tone average ranging from 41 to 60 dBHL) of sensorineural hearing loss in the test ear.
3. Speech recognition score greater than or equal to 80% in the test ear.
4. Normal middle ear functions as assessed by tympanometry and acoustic reflex threshold.
5. No complaint of neurological disorder.
6. Naive user of hearing aid.

Instruments used

1. A calibrated dual-channel diagnostic audiometer
2. A calibrated immittance meter
3. A digital BTE hearing aid having dual channels with a fitting range of mild to moderately-severe degree of hearing loss and a linear analog BTE hearing aid having microphone setting, telecoil setting and gain ranging from mild to moderately-severe degree were used for this study. These two hearing aids were selected as these hearing aids have the fitting range for the degree of hearing loss of the participants.
4. A personal computer with Connex software, version 5.6, incorporated in NOAH 3.0 version and Hi Pro was used for programming the digital hearing aid.
5. A hearing aid test system with digisp-ANSI feature was used for the insertion gain optimization of the BTE hearing aids.
6. Two types of mobile technologies in digital wireless systems were -
   a) Mobile phone using GSM technology:
      - Motorola Timex 1503731S using GSM system of 1800 MHz carrier frequency for delivering the speech stimuli.
      - Nokia 2100 model using GSM system of 1800 MHz carrier frequency and
   b) Mobile phone using CDMA technology:
      - Reliance RD 203 f15 model using CDMA wireless system were used for receiving the speech stimuli.

It was ensured that the mobile phones were fully charged and had full signal coverage during testing.

Test material

For assessing the speech performance:

1. Kannada word lists developed by Yathiraj and Vijayalakshmi (2006) to estimate speech intelligibility. There were total eight lists of words. Each list consisted of twenty words and comprised of all speech sounds of Kannada language.
2. Every day questions in Kannada developed at the Department of Audiology, All India Institute of Speech and Hearing, (AIISH) Mysore, was used to estimate the Speech Recognition Score (SRS). There were a total of ten lists. Each list consisted of five questions such that most of the speech sounds of Kannada language were present in each list.

Procedure

The study was carried out in three stages.

Stage I: Selection of participants

Stage II: Hearing aid fitting

Stage III. Evaluation of the objectives of the study

Stage I: Selection of participants

a. Pure tone audiometry: Pure tone thresholds were obtained at octave intervals between 250 Hz and 8000 Hz for air conduction stimuli and between 250 Hz and 4000 Hz for the bone conduction stimuli.
b. Speech audiometry: Speech recognition score in quiet condition were carried out at 40 dBSL (re: SRT).
c. Immittance audiometry: Tympanogram and acoustic reflex thresholds were measured.

Stage II: Hearing aid fitting

a. Digital and analogue BTE hearing aids were used in this investigation. The digital BTE hearing aid was programmed based on the hearing threshold and NAL-NL1 fitting formula. Programming was done for both microphone and telecoil settings and fitted to the ear that showed better speech recognition score in case of bilateral hearing loss. In case of unilateral hearing loss the better ear was blocked with the EAR foam ear plug to avoid participation of that ear. Fine tuning was done based on aided threshold and the feedback obtained from the participant.
b. For the fitting of the analog hearing aid real ear insertion gain optimization was conducted with the NAL-R target fitting using Fonix FP 40-D hearing aid test system

Stage III: Evaluation of the objectives of the study:

The speech recognition measurements were conducted in the real life situation with the female tester with normal vocal quality presenting the word list and questions with live voice. The tester was fluent in Kannada language. While obtaining the data for the objective of the study for all the participants care was taken to maintain the tester's voice constant with normal vocal effort. The following steps were used for evaluation of the objectives of the study:

a. Speech Recognition Score (SRS) through the GSM mobile phone system when the participant was wearing the digital hearing aid in M setting. After fitting the hearing aid in M setting one of the phonetically balanced (PB) word lists selected randomly from eight PB word lists was presented by the tester using live voice. Each word list consisted of 20 words. Speech stimuli were presented through a mobile phone having GSM system. Participants received the speech stimuli through the Nokia 2100 GSM mobile phone system and were instructed to repeat those words. Mobile phones through which participants were receiving the speech stimuli were positioned within 1 to 3 cm of the participant's aided ear according to their comfort. Positioning was done by holding the mobile phone at an angle of 45 degree (re: nose, which is the normal position). The response was scored with one point for each correct repetition of the test word, maximum score being twenty. Speech recognition was also measured by presenting a list of every day questions. One set of five questions was selected randomly and presented to the participant by the same tester. The participant was made to listen to the speech through the same mobile phone and was instructed to answer to those questions. The response was scored with one point for each correct answer to the questions, maximum being the five.

b. SRS was measured through the GSM mobile phone when the participant wore the digital hearing aid in T setting. After changing the programming of the hearing aid from M to T, the above procedure was repeated for getting the SRS.

c. SRS was obtained through GSM mobile phone system when the participant wore the analog hearing aid in M setting. After fitting the analog hearing aid in M setting same procedure described above was repeated for obtaining the SRS.

d. SRS was measured through GSM mobile phone system when the participant wore the analog hearing aid in T setting. After changing the setting from M to T setting and increasing the volume setting to $3/4^{th}$ of the total rotation the above procedure was repeated.

e. SRS through CDMA mobile phone system was measured when the participant wore the digital hearing aid in M setting. After fitting of the digital hearing aid in M setting the above procedure was repeated.

f. SRS through CDMA mobile phone system was measured when the participant wore digital hearing aid with T setting. After changing the programming from M to T same above procedure was repeated.

g. SRS was obtained through the CDMA mobile phone system when the participant was wearing the analog hearing aid in M setting. After fitting the analog hearing aid in M setting the above procedure was used.

h. SRS through the CDMA mobile phone system was obtained when the participant was wearing the analogue hearing aid in T setting. After changing the setting from M to T setting and increasing the volume setting to $3/4^{th}$ of the total rotation, same procedure was repeated.

The above steps were repeated in the following conditions:

1. Comparison of performance SRS between GSM and CDMA system
2. Comparison of performance between analog and digital hearing aids
3. Comparison of performance between in M and T settings

For fifty percent of the participants the testing was first done with GSM and for the other fifty percent of the participants testing was first done with CDMA mobile phone system. This procedure was repeated for each participant. The data thus obtained were tabulated and subjected to statistical analysis.

Results and Discussion

The data obtained from thirty participants were analyzed and compared under the following test variables. They were:

1. Use of GSM system while aided with digital hearing aid in M setting and PB words used as stimulus (GSM-D-M-PB).

2. Use of GSM system while aided with digital hearing aid in M setting and questions used as stimulus (GSM-D-M-Q).
3. Use of GSM system while aided with digital hearing aid in T setting and PB words used as stimulus (GSM-D-T-PB).
4. Use of GSM system while aided with digital hearing aid in T setting and questions used as stimulus (GSM-D-T-Q).
5. Use of GSM system while aided with analog hearing aid in M setting and PB words used as stimulus (GSM-A-M-PB).
6. Use of GSM system while aided with analog hearing aid in M setting and questions used as stimulus (GSM-A-M-Q).
7. Use of GSM system while aided with analog hearing aid in T setting and PB words used as stimulus (GSM-A-T-PB).
8. Use of GSM system while aided with analog hearing aid in T setting and questions used as stimulus (GSM-A-T-Q).
9. Use of CDMA system while aided with digital hearing aid in M setting and PB words used as stimulus (CDMA-D-M-PB).
10. Use of CDMA system while aided with digital hearing aid in M setting and questions used as stimulus (CDMA-D-M-Q).
11. Use of CDMA system while aided with digital hearing aid in T setting and PB words used as stimulus (CDMA-D-T-PB).
12. Use of CDMA system while aided with digital hearing aid in T setting and questions used as stimulus (CDMA-D-T-Q).
13. Use of CDMA system while aided with analog hearing aid in M setting and PB words used as stimulus (CDMA-A-M-PB).
14. Use of CDMA system while aided with analog hearing aid in M setting and questions used as stimulus (CDMA-A-M-Q).
15. Use of CDMA system while aided with analog hearing aid in T setting and PB words used as stimulus (CDMA-A-T-PB).
16. Use of CDMA system while aided with analog hearing aid in T setting and questions used as stimulus (CDMA-A-T-Q).

A. Comparison between GSM and CDMA System:

Mean and standard deviation (SD) for each of the above mentioned variable were found out. The data were statistically analyzed using paired samples t-test for obtaining the pair-wise comparison among the groups. The results showed that for all the paired variables, between GSM and CDMA with digital hearing aid in M setting using PB words, digital hearing aid in T setting using PB words, digital hearing aid in T setting using questions, analog hearing aid in M setting using PB words, analog hearing aid in M setting using questions, analog hearing aid in T setting using PB words and analog hearing aid in T setting using questions, there was a significant difference ($p < 0.05$) with CDMA showing better performance than GSM. Only in one condition i.e., comparison between GSM system with digital hearing aid in M position and CDMA system with digital hearing aid in M position there was no significant difference ($p>0.05$) found when questions were presented as a stimulus. The performance was almost same for both the conditions.

B. Comparison between analogue and digital hearing aids in M and T settings.

Since the testing was done on the same participants repeated measures ANOVA and Bonferroni's multiple comparison test were performed to compare the performance of digital and analog hearing aids in M and T settings within the GSM and CDMA system when PB words and questions were used as stimuli.

1. Performance of speech was assessed while using GSM system with digital and analog hearing aids in M and T settings and PB words were used as stimulus. It was found that there was a significant difference seen between the SRS obtained with digital and analog hearing aids [$F(3, 87) = 132.01$, $p<0.05$]. The SRS of digital hearing aid was found to be much better in both M and T settings compared to that of an analog hearing aid. Study done by Kuk and Neilsen (1997) showed that with GSM system conventional analog BTE hearing aid produced spikes with large amplitude compared to that of digital hearing aid which suggests that performance with digital hearing aid was better than analog hearing aids.

   It has also been found in the present study that M setting was significantly better than T setting ($p<0.05$) for digital and analog hearing aids. This difference of M and T settings were seen more for analog hearing aid and with GSM system. Repeated measure ANOVA showed that when questions were used the performance of speech using GSM system with digital and analog hearing aids were significantly different from the SRS obtained with digital hearing aid being better than analog ($p<0.05$) except in one condition i.e., at T setting digital and analog hearing aids perform the same [$F(3, 87) = 143.55$, $p>0.05$]. Within M and T settings performance with M setting was significantly better than with T setting ($p<0.05$) within and across digital and analog hearing aids.
2. Repeated measures ANOVA showed that when PB words were used the performance using CDMA system with digital hearing aid was better in M and T settings than with analog hearing aid. There was significant difference obtained between digital and analog in M setting and between digital and analog hearing aid in T setting ($p<0.05$). However, within digital and analog hearing aid in M and T settings there was no significant difference in the performance ($p>0.05$).
3. Repeated measures ANOVA showed that when questions were used as stimulus with CDMA system there was no significant difference between digital and analog hearing aids in M setting and digital and analog hearing aid in T settings. Performance within digital hearing aid at M and T settings were also having no significant difference ($p>0.05$), whereas performance within analog hearing aid at M and T setting significant difference was seen with performance in M setting being better than with T ($p<0.05$). Within digital hearing aid in M and T settings performance was same whereas within analog hearing aid the performance with T was lower than with M setting.

The overall performance in the present study with GSM and CDMA system using digital and analog hearing aids in M and T settings suggested that when PB words and questions were used there was significant difference in the performance between M and T settings of the hearing aids, with performance in M being better than in T setting. This is due to the fact that in addition to the electromagnetic interference the T setting of the hearing aid also produces base band interference that further reduces the speech recognition score (Kozma-Spytek, 2003). The findings of the present study supported that of Byrne and Burwood's (2001) study which found

that with microphone input it would pick up interference at 10 meters and with telecoil input at about 17 meters. This study with GSM and CDMA wireless system along with digital and analog hearing aid in M and T settings suggested that speech understanding difficulties expressed by participants with hearing impairment was more with GSM than with CDMA mobile technology. The problems appear to be compounded when participants were using the hearing aids in telecoil setting due to the additional base band interference. The reduction in speech recognition was more when the participants were using analogue hearing aids.

Summary and Conclusion

The mobile phone use has become one of the rapidly growing segments in telecommunication. Individuals with hearing impairment who use mobile phone of either GSM or CDMA transmission system while wearing digital or analog hearing aids face problem in understanding speech. This is due to the electromagnetic interference that occurs and affects the understanding of speech. Research findings show that this interference is more when participant with hearing impairment uses GSM wireless system than a CDMA wireless system (Skopec, 1998; Kuk & Nielsen, 1997). The uses of analog BTE hearing aids cause more interference than digital BTE hearing aids irrespective of the mobile phone technology (Kuk & Nielsen, 1997). In addition to that interference at T position was found to be more than at M position due to the additional base band interference (Kozma-Spytek, 2001). There is a dearth of studies reported in literature evaluating the speech reception score using live voice, in natural situation, that is most often faced by everybody including participants with hearing impairment.

The overall results indicated that speech recognition with CDMA system was better than with GSM system for both digital and analog hearing aids. The overall results were as follows:

a. The paired samples t-test showed that overall performance with the CDMA wireless system was better in understanding the speech than GSM system while using both analog and digital hearing aids.
b. With GSM system the overall performance in M setting was better than in T setting. However with CDMA system using both analog and digital hearing aids in M and T setting the performance was the similar for the PB words. For questions while using CDMA system with analog and digital hearing aids the performance was almost similar in M and T settings with the digital hearing aid whereas with analog hearing aid the performance was better in M setting than in T setting.

The following inferences can be drawn:

1. Perception of speech through CDMA wireless system was better than that through GSM wireless system in participants with hearing impairment who were aided with either digital or analog hearing aids.
2. The overall perception of speech was better with digital hearing aids than with analog hearing aids when participants with hearing impairment are using either GSM or CDMA wireless systems.
3. The performance on speech recognition with hearing aid in M setting was found to be better than in T setting for GSM wireless system whereas for CDMA wireless system, the performance of M setting was better than T. This difference was however not as significant as with GSM system.

Implications

It is necessary to advice individuals with hearing impairment about the type of hearing aid and facilities that can be availed with that particular hearing aid technology. Based on the present study clients with hearing impairment can be advised to use digital hearing aid and CDMA wireless system as it gives more clear speech and less interference. M setting was more advisable than T setting for both analog and digital hearing aids. Such information would be useful during counseling of a prospective hearing aid user.

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