Effect of Hearing Impairment and Noise on the Processing of Simultaneous Sentences

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Master of Science (Audiology)

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June, 2011

CERTIFICATE

This is to certify that this dissertation titled ***Effect of Hearing Impairment and Noise on the Processing of Simultaneous Sentences*** is a bonafide work submitted in part fulfilment for the degree of Master of Science (Audiology) by student with Registration No.: 09AUD028. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other university for the award of any diploma or degree.

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June, 2011

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CERTIFICATE

This is to certify that this dissertation titled ***Effect of Hearing Impairment and Noise on the Processing of Simultaneous Sentences*** has been prepared under my supervision and guidance. It is also certified that this dissertation has not been submitted earlier to any other university for the award of any diploma or degree.

Mysore

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DECLARATION

This is to certify that this master's dissertation titled ***Effect of Hearing Impairment and Noise on the Processing of Simultaneous Sentences*** is the result of my own study under the guidance of Dr. K. Rajalakshmi, Reader in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier to any other university for the award of any diploma or degree.

Mysore **Register No. 09AUD028**

June, 2011

Dedicated to

My Parents

Acknowledgement

VPVPNKHK

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Chapter 1

Introduction

``One of the most striking facts about our ears

is that we have two of them--

and yet we hear one acoustic world;

only one voice per speaker'

- Cherry & Taylor (1954)

Imagine yourself at a restaurant with a large group of friends. Conversation trades from one talker to another. As is most situations, this is particularly true when the topic under discussion is of interest, in such situations, interruptions are fairly common. The conversation is riddled with quips, short bursts of humour that add to the mood of camaraderie. Topics switch as one anecdote reminds another talker of some idea. In the background in the meantime, mirth and conversation from nearby areas swirls by. Most listeners with normal hearing find such settings appealing and exciting. This can be attributed to the ease with which they perceive speech. However, this is not the same for individuals with hearing impairment (Noble &Gatehouse, 2006).

In everyday environments, which in fundamental nature are ecologically complex acoustical situation, sounds from several sources interact and a summation of waves from the acoustic sources is found to occur. The auditory system is responsible for interpreting this complex environment. The elementary issue that arises from being exposed on a day to day basis to such an environment is related to the processing of the complex input- “How it that we recognize what one person is saying when others too are conversing at the same time?” And “How can we possibly attend to more than one speaker in sync?” Pertaining to this, Cherry in 1953 reported of novel experiments performed on the recognition of messages to one and two ears (Cherry, 1953). This was the pioneering experiment that addressed the issue termed as “cocktail party problem." Cherry (1953) suggested factors that could ease the task of perception in multitalker situations:

1. Spatial separation of voiced
2. Gestures, Lip-reading etc.
3. Difference in mean speeds, speaking voices, mean pitches, female vs. male, and so on
4. Changes in accents
5. On the probability of transitions (based on voice dynamics, subject matter, syntax)

The cocktail party phenomenon can be viewed from many perspectives. The task is intuitive and simple from a normal hearing listener's point of view. From physiological or psychological perspective, evidence that have been put together to explain this effect is vast and potentially complex due to the many interactions between the signal, the auditory system, and further on, the central nervous system. Acoustically, the problem has been compared to that encountered in attempting to separate, under noise conditions, a single talker's speech from a spectrogram containing speech signals from multiple speakers. This would prove to be a challenge to even an expert in the field of acoustics or linguistics (Bregman, 1990)

A variety of cues are utilized by listeners to perform the segregation task in a cocktail party task, the cues may be related to the speech utterance itself such as rhythmic and temporal cues (offsets, onsets, and prosodic cues) or based on the features of the competing speech signals, which also includes factors like the voice characteristics of the individual talkers (speaking style, vocal tract length, $F0$) and finally listener's inherent knowledge about the context of the ongoing conversation as well as the constraints offered by the particular language . Apart from the use of monaural cues the ability to utilize the binaural difference cues could enhance the ability to selectively attend as well as segregate the competing voices into different perceptual streams (Hirsh, 1950).

Listeners with normal hearing are not only adept at selectively listening to the conversation of interest but are also equally adept in their ability to switch their attentional focus(Wood & Cowan, 1995). On the other hand, the presence of even modest hearing impairments could cause considerable difficulties in speech perception abilities (Noble and Gatehouse, 2006; Gatehouse and Akeroyd 2006). The effectiveness of an individual's ability to selectively attend to a desired element when in a complex scene is determined by the attentional resources that operate on the formation of an auditory object, this has been found vision as well as in audition (Knudsen, 2007; Desimone & Duncan, 1995; Shinn-Cunningham & Best 2008) i.e. the perceptual segregation abilities determine the ability to tune out extraneous messages

This ability of the human auditory system to segregate sounds issued from different acoustical sources in different perceptual streams is referred to as *Auditory scene Analysis (ASA)* (Bregman, 1990). Scene analysis utilizes the perceptual differences between sounds in order to carry out the segregation task and the perceptual difference perceived is a major factor in determining the success of segregation. Perceptual differences have been found to be reduced in situations in wherein the sounds themselves are degraded or in situations where the reception of the sounds by the ear is degraded like in hearing impaired listeners.

In order to gain insight into the mechanism involved in ASA, Bregman (1990) suggested assessing the processes that are aimed at segregating simultaneous acoustic events. Of major importance in this area is the initial work of Cherry (1953). His remarks on the cocktail party problem and the use of Dichotic stimuli to test for it as well as speech intelligibility has had a major impact on in the research area of processing of simultaneous stimuli (Bronkhorst , 2000).

To examine the processing of multiple speech stimuli, two different types of experimental approaches have predominantly been used. One is the *Monaural cocktail Party task* (Gallun, Mason and Kidd,Jr., 2007), in which researchers have generally presented multiple speech stimuli to the *same* ear and have reported on the factors that lead to *errors* in processing only one of two presented stimuli (Brungart, Simpson, Ericson, & Scott, 2001). It has been reported in literature that two kinds of masking mainly contribute to interference that is perceived by the listener in such a task (Kidd, Mason, Rohtla & Deliwala, 1998; Freyman, Balakrishnan, Helfer, 2001; Freyman, Helfer, McCall, &Clifton, 1999; Brungart, 2001b) "***Energetic masking***" which occurs when there is an overlap in temporal and spectral characteristics of the competing signal in such a manner that the individual is unable to detect some of the acoustic information contained in the target speech. "***Informational Masking***" is seen to occur when the target and the competing speech signals are similar therefore leaving the listener unable to segregate the acoustically detectable elements (important for stream segregation) of the target speech from that of the masking speech.

The second type of experimental approach used is the *dual-ear experiment* (Gallun, Mason and Kidd, 2007) in which task, the presentation of one speech utterance is to one ear and the other ear is provided with a separate stimuli. The effects of energetic masking in such a situation are negligible in this dual ear listening configuration as each ear receives an independent speech signal .The effects of informational Masking too are reported to be reduced as the differences in the spatial locations of the sources can be utilized in order to segregate the speech signals (Freyman, Balakrishnan, Helfer, 2001). In such a task, when presented with two dichotically competing yet simultaneous speech utterances, the response mode can either be to-

(1) Ignore one and report the other (*selective attention*): where the subject is asked to ignore any distracting inputs that might occur concurrent to the stimuli of interest and to focus attention on a single source of information and (Broadbent, 1958; Cherry, 1953).

(2) Report both (*divided attention*): where the subject is expected to allocate necessary resources to focus of attention across two or more sources and to respond to by processing information from any one or more than one of them at the same time

(Howard-Jones & Rosen, 1993; Moray, 1959; Spieth, Curtis, & Webster, 1954; Treisman, 1964; Yost, Dye, & Sheft, 1996).

In the real world, attentional performances in most listening situations fall between two extremes. For example, in a multitalker listening task in control and command environments it is often expected of the individual to monitor many of the active channels for relevant information. It is also possible that the listen has prior knowledge regarding the relatively larger importance of certain channels over others and can therefore allocate more attentional resources to it (Kidd, Arbogast, Mason, & Gallun, 2005), at the same time, the individual also has to monitor all the other channels on the off chance that some important information could be obtained from it. This situation is rather different from a real life multitalker cocktail party situation where listeners generally aware of which talker to listen for and can additionally use nonverbal and verbal cues to channel their attention to a new target talker if a break in the conversation do occur. But even in these situations wherein the contextual cues are abundant, there are instances in which a listener’s attention can be steered to highly relevant information originating from sources, such as an unexpected mentioning of name by a talker elsewhere in the venue (Moray, 1959). Thus, it is valid to argue that in real world situations, listeners rarely have the luxury of selectively focusing their attention, while ignoring the other speech signals in the environment

In crowded listening environments, selective attention enables information to be extracted from a talker of interest. However, in many cases, it is desirable to retrieve information from a talker who is outside the immediate focus of attention (e.g., when two people talk at once). Although some early studies showed that listeners with normal hearing perform poorly when asked to recall messages from unattended talkers (Cherry 1953), subsequent studies indicate that listeners are able to process unattended speech to some extent (Moray 1959; Conway, Cowan and Bunting 2001; Rivenez, Darwin, Guillaume, 2006) and can perform remarkably well at following two talkers when instructed to do so in advance (Best, Gallun, Ihlefeld,and Shinn-Cunningham,2006; Gallun, Mason and Kidd, 2007; Ihlefeld & Shinn-Cunningham 2008).

It is possible for normal hearing individuals to select a desired auditory object from out of a sound mixture by just simply attending to it. As the basic units of attention are perceptual objects, in order to carry out selective attention proper object formation is required. It is important for listeners to determine the characteristic feature of the object in order to determine as well as maintain attention upon it. Listeners often miss bits of a message being attended to as a result of masking from competing sources and the lapses that occur in object formation, selection as well as attention switching. Auditory closure abilities help to make up for deficits in such situations. Another necessary factor is the speed with which the various processing strategies occur in order to maintain communication intent in a social situation. Several factors interfere with a hearing impaired listener's ability to communicate in the presence of multiple talkers. In hearing impaired individuals, spectrotemporal abilities are reported to be affected and the importance of this process in a situation with multiple talkers is that is it is required to form an auditory object in the listeners system. In addition to it, degraded peripheral representation leads to impaired as well as slower object formation. This in turn leads to degraded ability to filter out unwanted sources, which will in turn interfere with the ability to understand the source of interest. As the processes involved in selective attention are slower, it results in those listeners missing out on more of a desired message as they attempt to focus as well as switch attention. Additional processing is required to in order to perceptually fill in the missed out message. In addition to this, the processes are likely to be less effective than for a normal listener. The overall effect is that hearing impaired listeners have much greater processing demands and when the demands of the situation exceed capacity, the result can be a a profound inability to follow even the most basic of conversations.

In summary, a basic factor that contributes to the problems faced by hearing impaired listeners is that of poor frequency resolution (Moore, 2007).This results in the signal of interest becoming inaudible or distorted. Also, the more fundamental problem faced by them is of difficulty focusing on one sound source and filtering out unwanted sources (Gatehouse & Akeroyd, 2006). Poor peripheral auditory representation, Failure of object formation and Failure in object selection are the prime difficulties that contribute to the impairment these listeners have in settings with multiple sounds sources.

Need For The Study

Despite more than 50 years of research on the topic of processing of simultaneous sentences, it is still not fully understood why different stimulus configurations exert such a great influence on the degree of success listeners experience when asked to either select one utterance or divide their auditory attention between two utterances (Gallun, Mason and Kidd, 2007). A survey conducted of listeners with hearing loss revealed that the self perception of communication handicap is strong in listening situations calling for divided or rapidly shifting attention (Gatehouse and Noble, 2006). Such subjective reports could indicate towards hearing loss impairing one's ability to deal effectively with simultaneous messages, which can be assessed by the use of Dual task listening experiments.

Studies that have probed into this have mainly focused on divided listening skills in hearing impaired population consisting mainly of older listeners (Strouse, Wilson, Brush, 2000; Singh, Pichora-Fuller, Schneider, 2008; Humes, Lee, Coughlin, 2006) wherein factoring out the contributions of age and hearing loss as well as cognitive status to the results(Best, Gallun, Kidd,Jr., and Shinn-Cunningham, 2010).

There is thus a dearth of literature regarding the processing of simultaneous stimuli in the hearing impaired population.

Aim of the study:

To determine the effect of sensorineural hearing loss and noise on the processing of simultaneous sentences in adult listeners.

Objectives

1. To compare scores of "Control trials" between control and clinical group in quiet and noise conditions.

2. To compare scores of “Selective attention trials” between control and clinical group in quiet and noise conditions.
3. To compare scores of “Divided attention task trials” between control and clinical group in quiet and noise conditions.
4. To compare the tasks in different conditions in each group.

CHAPTER II

REVIEW OF LITERATURE

In most listening situations, a listener's goal is to hear out one sound of interest from amongst a mixture of other interfering sounds. Usually, normal-hearing listeners are remarkably adept at this process and they make use of many physical properties of the stimulus to accomplish this task. Apart from acoustic properties of the sound, in complex or uncertain settings, top-down attention processes are also important for successfully processing a source of interest. An example of such would be provision of *a priori* information about where to listen in a multiple-talker array which has been found to enhance intelligibility of the target under consideration, particularly when there are more than two talkers (Kidd, Jr., Arbogast, Mason and Gallun, 2005). It can therefore be summarized that two factors which contribute towards better processing in situation with simultaneous inputs are attentional capabilities of the listener and the acoustic properties of the signals

Sternberg (1999) defined Attention '*as a means of focusing limited mental resources on the information and cognitive processes that are most salient at a given moment".*

This has led attention to be classified in the following way, the types of attention being:

-Vigilance

-Focused attention

-Divided attention

Focused Auditory Attention:

The phenomenon of focused auditory attention is illustrated by the cocktail party phenomenon (Cherry, 1953). As described earlier, in its most literal sense, it refers to the ability to listen selectively to one conversation during a party or such situations while ignoring the additional noise present in the background.One of the first investigators of auditory attention was Colin Cherry in the 1950s. His interest was regarding whether one could construct a machine that could selectively filter out background sounds, in order to make more audible a particular signal (such as speech in a multitalker situation). The apparent ease with which this process of selective attention is carried out, betrays the fact that it is a complicated process.

Cherry (1953) presented the concept of the ‘cocktail party' effect, which is an example of the phenomenon of auditory selective attention. In order to try to understand this phenomenon he developed the dichotic listening task which involved being presented with two different messages, one to each ear by means of headphones. Cherry in his study then analyzed the listener's ability to focus on one of two speech messages when it was mixed and played to both ears (i.e., diotic), and when unmixed and played to the two ears (i.e., dichotic). The task was to attend to one of the messages while ignoring the second message to an extent in order to do this successfully. To ensure that the participants were attending to the desired message, they were required to repeat the message out loud as accurately as possible, a process known as *Shadowing*. Cherry reported that when two messages were played dichotically, subjects could not report back much about the message in the rejected ear. Cherry then attempted to determine the attributes of the rejected message that were perceived. The results indicated that subjects could not identify words or phrases from the rejected message, could not notice if the change in language or the reversal of speech. Subjects did however recognize instances whenever a 400 Hz tone was played in the rejected ear and when the voice changed from male to female.

Early findings indicated that the task outlined in the concept above was more difficult if the physical features of the attended and unattended message were similar. That is, if both messages were spoken by the same person then the ability to selectively attend to one of the two stimuli was worse than if the messages were delivered by different speakers or if one were a male voice and the other a female voice.

In terms of physical characteristics i.e. acoustically, early studies suggested that only gross physical features were perceived. For example, when the gender, corresponding to the Fo of the voice of the unattended message was varied, participants noticed this, but did not notice if the message changed from English to German (Cherry, 1953). Following Cherry's results, Moray further studied recall of the target and rejected message in a dichotic listening task (Moray 1959). Even as the subject shadowed a passage in the target ear, lists of words were repeatedly played to the other. Subjects could not recall material in the rejected ear, even when explicitly instructed beforehand to try to remember it. Moray stated that the subject's name or other such materials of "importance" to the subject were the only stimuli that could break through the selective attention barrier (Moray 1959, Moray 1970). Moray also reported that only 33% of subjects reported hearing their own name when it was inserted into the irrelevant message. Utilizing more sophisticated technology, Wood and Cowan (1995) replicated Moray's experiment and reported that 34.6% of subjects reported hearing their own name presented in the irrelevant message and this minimally affected the selective attention performance.

From these studies it was initially concluded that only basic physical features could be detected in the unattended message and that this was attributed to the attentional ability of the listener to select out the unattended message in order to focus on the task of shadowing one message. The drawbacks of the studies previously mentioned was that, both Cherry (1953) and Moray (1959) instructed the subjects to recall rejected material only after task completion. Studies conducted by Norman (1969) and Glucksberg and Cohen (1970) addressed the effect of elapsed time on the ability to recall unattended stimuli. Norman interrupted subjects who were shadowing words presented to one ear to ask them to recall digits played to the other ear at that instant. He demonstrated that there was some recall if subjects were interrupted less than 20 seconds upon the presentation of the material. Glucksberg and Cohen further stated that memory for the nonattended material continually decreased as the delay increased from 0 to 5 seconds and that no recall was apparent between 5 and 20 seconds

The basis of Broadbent’s (1958) filter theory was the initial findings of Cherry’s 1953 experiment. It was a theoretical model of selective attention, based upon which environmental stimulation was filtered out of awareness if it was identified as irrelevant to the subject’s current interests on the basis of its gross physical features (e.g., voice, colour, or location). Since the amount of information coming in from both channels (the attended and unattended messages) was more than could be coped with by the resources in the system, it was hypothesized that one message needed to be inhibited or ignored. The main features of the model were as follows:

Sensory store: wherein, the incoming messages were held in a sensory store very briefly.

Sensory filter: whereby, one message was filtered in and the remaining messages were filtered out- all features apart from their basic physical features. Messages filtered in received further processing, while filtered out messages were eventually lost.

These elements of attention were then stated to process messages in the following way: The filter was said to operate on the *basic physical characteristics* of the messages (e.g. gender of the speaker, type of sound). Filtering was also to be a ‘*winner-takes-all*' process, such that only one message was selected for further processing, the rest were lost. Filtering was done *consciously*, in that people decide what they wanted to listen to. Furthermore, people could also switch their attention from one message to another.

The first stage of further processing, as described was to identify the main components of the message (e.g. the words). Broadbent's model successfully accounted for the initial findings that very little cues, except gross physical features of the unattended message were noticed. Filter theory also accounted for the fact that performance on the selective task was reduced when the similarity between the two messages was increased. (Fulcher,2003)

Broadbent’s (1958) model was later challenged by demonstrations of *semantic* processing of unattended information. Moray (1959) found that some subjects detected their own name when it was presented in the unattended auditory channel. Also, the Filter theory asserted that the unattended information, which was not sampled through the selective filter, would not move ahead to the elaborate processing (e.g. processing of word identity and meaning) that was envisaged to occur only in the second, serial state with its limited capacity, but several apparent findings of such processing of the non shadowed messages were reported in the years following Broadbent’s (1958) model.

As well as the Gray and Wedderburn’s (1960) study, other studies conducted revealed that the meaning of the unattended message was processed by listeners. These studies involved experiments wherein subjects did not reject a secondary speech signal but had to detect target words contained in it. Treisman (1964), for example demonstrated that participants could switch between the two channels when the messages themselves were switched during the experimental process. The authors stated that if the unattended channel was not processed for meaning then participants would not have that the messages had been switched. Treisman and Geffen performed an experiment in which subjects listened to messages dichotically and shadowed the primary one while at the same instance trying to detect target words in either of the messages (Treisman & Geffen 1967). The results showed that subjects detected a higher percentage of the target words in the primary message (87%), but it also revealed that 9% of the target words in the secondary message were detected. It was also stated that the target words in either passage were detected more readily if they were introduced in context rather than in a random fashion. Subjects also performed better when instructed to listen for a single word rather than a class of words e.g. any digit in the number series from 1-10. The experiment also incorporated a secondary task of "tapping" on hearing a target word. This task was found to be disruptive to the primary task of shadowing, but more so when the target words were contained in the secondary message than in the primary one (Treisman & Geffen 1967). Even though the subjects were instructed not to shift their attention away from the primary passage at any point of time, the results indicated otherwise. Over 30% of shadowing errors occurred when subjects were tapping to targets that were contained in the secondary message. Thus the presence of a contralateral stimulation was found to be disruptive to the processing of the target message.

Lawson performed a similar experiment to Treisman, but varied in the stimulus, using tones instead of words as targets (Lawson 1966). In contrast to Treisman's findings, the results of the experiment revealed no difference in detection of targets in the primary and secondary passages. Zelniker conducted further experiments on the detection of tones presented to the unattended ear and found that the tones were reliably detected even when played at near-threshold intensities (Zelniker 1974). This was consistent with Cherry's earlier findings that a 400 Hz tone played in the unattended ear was readily recognized.

If selective attention followed a winner-takes-all principle and was based on physical features rather than the meaning of the message, in such a situation, if a participant was instructed to attend to the message in the left ear while ignoring that to the right, the processing would not have been difficult. : Fulcher (2003) reported that upon presentation of stimuli in such a manner Left ear Right ear Dear, 7, Jane 9, Aunt, 6 if the participant were asked to repeat all the items presented then Broadbent's theory predicts that recall would consist of either 'Dear, 7, Jane' or '9, Aunt, 6', since they would be attending to one channel only. However, the author reported that not only could participants recall all of the items, they recalled them as two units 'Dear Aunt Jane' and '976'. In other words, participants did not group the items based on the channel they were presented to but based on their meaning. (Fulcher, 2003)

The findings of the above mentioned study were important as it suggested that more than just the physical characteristics of the stimuli were processed in the unattended message. Findings such as these led Treisman to develop her '*Attenuation' model of attention*' (Treisman, 1960). The key modifications in Treisman's (1960, 1969) model was the assumption that, during the early stage at least, information was processed in parallel manner and selection procedure was carried out at a later stage . The *key features of the model* were that early processing that took place was not an 'all or none' or 'winner takes- all' phenomenon, but rather that the main message got through with the other information being attenuated. Thus the weakened message would still get processed to some extent. The initial selection was based on physical cues, the same as Broadbent's model. If the attenuated information was found to be consistent with the meaning of the message presented to the attended ear, it would then intrude upon and affect performance.

Treisman's model could account for the results obtained by Gray and Wedderburn (1960) experiment, since as per the model, the meaning of the message in the nontarget ear was just attenuated and therefore still able to influence the performance of the target message, rather than being completely ignored. Apart from this, unlike Broadbent's model, this model provided a better account of Cherry's cocktail party effect. This could be attributed to the fact that a significant message to the unattended channel could still be perceived if it was related to the target ear message. This could also be used to explain the reduction in selective attention task performance in the presence of multitalker situations.

Later studies provided evidence to the phenomenon that even more information could be processed from the unshadowed message than was suggested by Treisman's model. Corteen and Wood (1972) used a classical conditioning experimental procedure to pair neutral words with mild electric shocks. As expected when presented with the neutral words, participants were found to show a small increase in the galvanic skin response. This was taken to mean that they were responding in such a manner as they anticipated a shock. However, when these words were then presented in the unattended channel in a dichotic listening procedure, the galvanic skin response evidences earlier were still present despite the fact that participants claimed to be not attending to the words. The implication of such a report was that unattended information could be processed for meaning, even unconsciously.

The next set of models to explain selective attention, the late selection models put forward by Deutsch and Deutsch (1963) Norman (1968) inferred that all information was processed in parallel but that the selection and filtering occurred much later on. Filtering was based on whether the information was pertinent or not to the task as well as to the individual. In a study by MacKay (1973), sentences that contained words with more than one meaning were presented to subjects, e.g. ‘They were standing near the bank'. It could be taken to mean either ‘They were standing near the river bank' or ‘They were standing near the money bank'. Interpretation of the sentence by the participants depended on whether the word ‘river' or ‘bank' was presented in the unattended channel. The word provided a context based on which the sentence was interpreted .Clearly, *the information in the unattended channel was not filtered out and did influence the performance of the target ear under consideration as reported by the authors.*

Figure 2.1 illustrates that the difference between the various approaches to selective attention based on the characteristics of the messages used to accomplish the selection task. While early selection approaches such as Broadbent’s approach was based on physical characteristics, late selection models such as McKay’s approach was based on meaning. Treisman’s (1964) attenuation model falls in between these two as the selection can be based on meaning, physical characteristics, or a combination of the two.

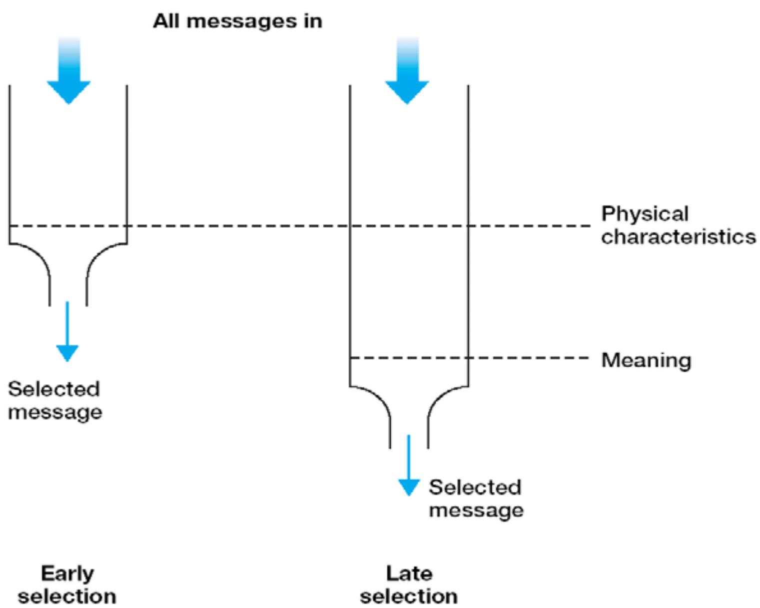

Figure 2.1: *Representation of the difference between early and late selection models of selective attention.*

Brungart & Simpson (2002) conducted a series of experiments that examined the interactions that occurred between within-ear speech and across-ear speech segregation in a hybrid monaural-dichotic cocktail-party condition. The results of the study revealed that listeners were unable to perform both of the segregation tasks simultaneously: they could report a target speech signal that was masked by an interfering speech signal in the unattended ear or one was masked by a single interfering talker in the target ear, but not one that was masked by an interfering speech signals in both ears concurrently. These results suggested that within-ear as well as across-ear segregation were related processes and that they functioned from single shared pool of resources (Kidd, Jr., Mason, Rohtla, Deliwala, 1998).

The authors also hypothesized that the obtained results were consistent with a shared-resource model of attention (Wickens, 1984,1980; Hirst and Kalmar, 1987) where speech segregation ability was constrained by a limited pool of shared attentional resources, and the listeners were to choose to allocate attentional resources either to within-ear speech segregation or to across-ear speech segregation. Such a model could explain the results of the study by assuming that the shared pool had enough attentional resources to do either across-ear segregation or within-ear segregation, but not enough resources to perform both at the same time. This model could also provide cues regarding why the amount of interference caused by the masking sound in the unattended ear caused an increase in the difficulty of the selective attention task in the target ear: when the task in the target ear was comparatively easy relatively fewer attentional resources were required by the within-ear segregation task and adequate resources were left over to segregate the target from the signal in the unattended ear; on the other hand ,when the segregation task in the target ear was more difficult fewer resources were available for across-ear segregation and listeners were more susceptible to interference from a contralateral masking sound.

ATTENTION AND OBJECT FORMATION

The normal mode of analyzing a complex scene is to focus on one object while others objects are in the perceptual background (Shomstein and Yantis, 2004; Duncan, 2006)

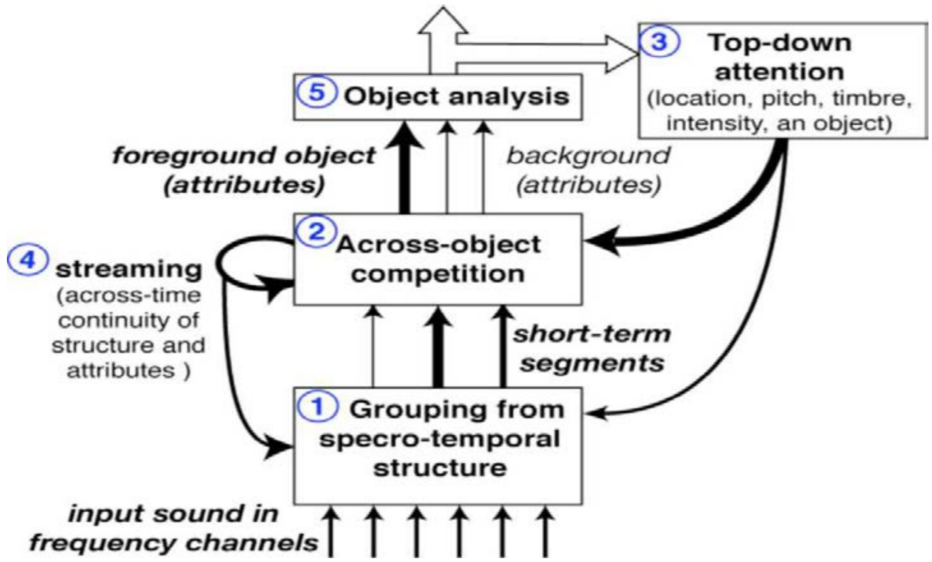

Figure 2.2: *conceptual model of interactions that occur in the auditory domain given by Shinn-Cunningham and Best (2008)*

Short-term segments initially form based on local spectro-temporal grouping cues such as common onsets and offsets, harmonicity, and comodulation (Bregman, 1990; Darwin and Carlyon, 1995).Competition first arises between short-term segments. Some segments may be inherently more salient than others (e.g., because of their intensity or distinctiveness (Cusack and Carlyon, 2003), which biases the inter-segment competition. Top-down attention and streaming (across-time source continuity) help modulate the competition in turn biasing it to favor objects with desirable features (top-down attention) and to continue to maintain attention on the object already in the foreground as it evolves over time (streaming) (Shinn-Cunningham,Ihlefeld, Satyavarta and Larson, 2005; Tata and Ward, 2005; Best, Gallun, Ihlefeld and Shinn-Cunningham, 2006; Winkowski and Knudsen, 2006 Shomstein and Yantis, 2006; Ahveninen , Raij,Bonmassar, Devore, Hämäläinen, 2006). As a result, one object is emphasized at the expense of others in the scene, which enhances analysis of this foreground object (Best, Gallun, Ihlefeld and Shinn-Cunningham, 2006; Best, Ihlefeld and Shinn-Cunningham, 2005). *This model suggests that proper grouping of the acoustic scene is necessary for listeners to selectively attend to a desired source.*

Auditory scene analysis (ASA)

Auditory scene analysis (ASA) is a general process carried out by the auditory system of a human listener for the purpose of extracting information pertaining to a sound source of interest, which is embedded in a background of noise interference (Haykin,Chen 2005). *Sounds* or *acoustic events* are created when physical things happen. The *perceptual unit* that represents such a single happening is called an *auditory stream (*Bregman, 1990) .The basis of ideas of auditory scene analysis can be traced back to work done by the gestaltists of the early 1900's in the visual field. Elements belonging to one stream are maximally similar and predictable, while elements belonging to different streams are maximally dissimilar. Therefore, acoustic events that are grouped into one perceptual stream are to be similar (in timbre, frequency, intensity), to be in spatial or temporal proximity, and to follow the same temporal trajectory in terms of frequency, intensity, position, rhythm, etc. These streams followed the basic principles described by Bregman (1990):

1. Proximity, which characterizes the distances between the auditory features with respect to their onsets, pitch, and intensity (loudness)
2. Similarity, which usually depends on the properties of a sound signal, such as timbre
3. Continuity, which features the smoothly varying spectra of a time varying sound source
4. Closure, which completes fragmentary features that have a good Gestalt; the completion can be understood as an auditory compensation for masking
5. Common fate, which groups together activities (onset, glides, or vibrato) that are synchronous.

The focus of Bregman's work on ASA was initially on primitive, or unlearned, stream segregation. *He stated that t*here are two classes of grouping processes that could be broadly classified as *simultaneous integration* and *sequential integration*. In addition to the grouping processes, he also reported on additional extensions and ideas that were specific to the analysis of speech signals such as pitch trajectory, Harmonics , Spectral continuity .

Object formation can be thought of at the syllable level (e.g elements of sound that are logically contiguous in time and frequency are grouped together), and also at longer time scales Failures in object formation on the syllable level come about when the spectro-temporal features of an object are insufficient to separate the object from the other sources in a mixture (Kidd., Jr., Arbogast, Mason&. Walsh, 2002; Best, Ozmeral, and Shinn-Cunningham, 2007). This can occur for a variety of reasons: the sound mixture may energetically mask so much of the target source that it cannot be segregated out from the background, the mixture may contain other sources that have similar spectro-temporal structure and that tend to group with the desired source, the target signal itself may not be structured enough to support object formation, for instance, if the mixture contains ambiguous or conflicting cues.

Failures to stream objects across time can come about when there are multiple sources with similar higher-order features, such as when a listener hears a mixture of multiple male voices or the target is a set of tones that are masked by similar tones (Brungart, 2001; Kidd., Jr., Mason and Richards, 2003). These failures can result in a target stream of speech that is corrupted by sound elements from a masker or that is missing key elements or syllables. Thus, such failures in the object formation as well as object selection could impair the process of selective attention

Subjective reports from hearing impaired listeners suggest that they have difficulty in situations where normal-hearing listeners rely on selective attention. Reports suggest that hearing impaired listeners have most difficulty when attention must shift rapidly from source to source, like at a cocktail party, resulting in social isolation (Gatehouse and Akeroyd, 2006; Noble and Gatehouse, 2006) Impaired listeners have reduced temporal and spectral acuity compared to normal-hearing listeners (Gatehouse, Naylor & Elberling, 2003; Leek and Summers, 2001; Deeks and Carlyon, 2004; Carlyon, Long, Deeks and McKay, 2007; Bernstein and Oxenham, 2006). If the features that convey speech meaning are degraded due to reduced audibility and diminished spectro-temporal resolution, speech intelligibility will be degraded even in quiet. Moreover, hearing impaired listeners may suffer from effective increases in the amount of energetic masking due to the reduced spectral selectivity of their peripheral auditory filters and higher-than-normal absolute thresholds.

Failures of object formation

Hearing impaired listeners are also likely to have difficulty properly grouping sound sources. A less-robust representation of spectro-temporal content, which is important for grouping, in impaired listeners may cause problems with object formation. Also, robust location, pitch, and harmonic cues may not be available to hearing impaired listeners, further impairing their ability to properly separate the mixture into streams.

Failures of object selection

If hearing impaired listeners fail to properly form auditory objects, they will have difficulty selectively attending to a target. In addition, loss of spectro-temporal detail in the periphery may affect perception of higher-order features that distinguish target from masker. For instance, impairments in pitch perception and sound localization may degrade how precisely hearing impaired listeners are able to focus attention on a target object, even if it is properly formed. These difficulties are likely to contribute to the difficulties hearing impaired listeners have in settings with competing sound sources

DIVIDED ATTENTION:

An alternative to participants focusing on one task and then evaluating how much they were aware of other information around them is an experimental condition to find out whether attention can be divided among several tasks. Divided attention concerns our ability to ‘multitask' within a modality as well as across modalities. While the selective listening task in the dichotic presentation mode involves trying to attend to only one message, in studies of divided attention the task the listener is presented with is to attend to more than one source of information presented simultaneously. The questions on divided attention task that have been looked into have been regarding how well can more than one task at a time be carried out, what kinds of dual tasks are achievable and which are not, and how this ability can be explained.

Early studies have shown two important factors that determine the ability to carry out divided attention tasks: *The similarity of the tasks*: Allport, Antonis, Reynolds (1972) instructed participants to learn a set of words while shadowing a spoken message. They found that the words could be learnt when they were presented visually but not when they were presented in the auditory modality. However, it was also reported that if the messages were sufficiently different then both of the stimuli could be attended to. *How well practised is the task*: Spelke, Hirst, Neisser. (1976) found that, with practice, participants could learn to read a story while writing down a list of words read out to them.

Norman and Bobrow (1975) stated that the major factors that hindered the ability to divide attention were the limited attentional resources as well as the upper limits to the amount of resources that were available. It could also be affected by the quality of the information that forms the input (e.g. speech in the presence of noise, mumbled speech etc). Kahneman (1973) suggested that the amount of resources that could be allocated to a task were flexible. Kahneman(1973) also reported that the upper limit as well as the amount and type of information that could be attended to was determined by an ‘allocation policy', which by itself was determined by several behavioural factors such as *The physiological state*, *Enduring disposition*, *Momentary intentions*. This type of theory, incorporating all the factors above was described as a ***Capacity theory*** since it was based on the notion that there was a general-purpose limited-capacity central processor to carry out the tasks as well as allocate resources to the tasks based on the needs and abilities (Duncan, 1980,)

The assumption of limited capacity was challenged by reports from several studies conducted (Navon, 1984, 1985, 1990; Gopher & Navon, 1980; Navon & Gopher, 1979, 1980), since attention could be not only be successfully divided under certain conditions but could also be improved with practice. Furthermore, the assumption regarding the presence of a single general-purpose processor or resource was deemed inconsistent with the findings of the studies. Rather, it was postulated that several processors/resources could exist each with a specific purpose. This idea led to Multiple-resource models of attention (Navon and Gopher, 1979). The idea was that it was not just the amount of resources a task required that was a factor but the type of information that required it as well. Some tasks interfered with each other not because they both required a large amount of resources each but rather because they required the same type of resources. The process of reading a book requires processing language and counting to 48 in fours requires processing numbers. With a little practice, these tasks could be done at the same time without interfering with each other and causing errors. On the other hand, shadowing spoken words and reading a book both required language processing so they would easily interfere with each other even with practice. Such interference was referred to as ‘crosstalk’. (Pashler,1998)

Best, Gallun, Mason, Kidd, Jr., Shinn-Cunningham (2010) reported on listener's ability to process simultaneous sentences, i.e. to carry out selective and divided attention in the presence of noise and hearing impairment. Two messages of were presented separately to the two ears. The messages were systematically degraded by adding speech-shaped noise. Listeners performed a single task in which report of one message was required and a dual task in which report of both messages was required. Results revealed that as the level of the added noise was increased, performance on both selective and divided attention tasks declined. In the divided attention task, performance on the message reported second was poorer and more sensitive to the addition of than performance on the message reported first. When compared to listeners with normal hearing, listeners with hearing loss showed a larger deficit in recall of the second message than the first. This difference disappeared when performance of the hearing loss group was compared to that of the normal-hearing group at a poorer signal to noise ratio. They thus concluded that, a listener's ability to process a secondary message is more sensitive to noise and hearing impairment than the ability to process a primary message.

Also reported by Best, Ihlefeld, Mason, Kidd Jr., Shinn-Cunningham (2007) the addition of noise had differential effects on performance for the two sources which suggests that the two messages presented in a divided attention task are processed via different mechanisms. The fact that the addition of noise affected performance for the second message more than for the first message suggested that the two messages are processed via different mechanisms. The higher susceptibility of the second message to noise was also consistent with the involvement of a volatile sensory trace. However, an alternative explanation was also considered. The increased difficulty of processing the first message on high noise trials depleted a limited pool of processing resources, leaving fewer resources for processing of the second message. However, if processing load was a primary factor in the task, then some reduction in the performance for the second message would have been expected in the experiment involving variation of spatial separation as well as level of the first message, as the task became more difficult for the primary message. This was not observed, and in fact the opposite trend was evident, with performance of the second message approaching ceiling as the relative level of the primary message decreased. The authors also hypothesized that the observed results were consistent with a model in which one source is actively attended; the other relies more heavily on auditory memory.

A series of experiments were conducted by Gallun, Mason & Kidd, Jr (2007) to assess the cost involved in performing selective and divided attention tasks. The dual ear cost was the loss of formation that occurred when the selective attention task was compared to the performance in a control task involving single ear stimulation, and the dual task cost was indicated by a difference in performance for the divided attention task when compared to a selective attention task, both carried out for dichotic stimulation. The general trend observed was that the listeners performed well in the single control task, but the performance in the selective task decreased, especially for the left ear. Thus, the finding of a dual ear cost indicated towards a failure in selective attention. That is, operational masking was seen to have occurred in that the listeners had difficulty separating the stimulus at the target ear from the non target ear. A further drop in performance was seen to have occurred in the divided attention task for the listeners in both the ears. The dual task costs were the additional drop in performance that was evident when the stimuli from both the channel had to be processed. The authors attributed the dual task cost to the fact that information degrades while being held in the sensory buffer and may be replaced by subsequent sensory stimuli (Cowan, 2002 ; Vogel & Luck, 2002). Results from backward masking studies further support this hypothesis (Massaro, 1975)

An alternative explanation provided by the authors was based on the ‘Perceptual load’ theory (Lavie & Tsal 1994) proposed that the interference found in selective attention task was based on the existence of a lower limit on resource allocation. The system in charge of perception automatically allocates resource to the processing of the stimuli regardless of whether the higher order system has classified them as targets or distracters. Thus, automatic processing of the distracter sentence caused interference in the selective attention task. The explanation was found to be in agreement with the results of Brungart, Simposon, Ericson & Scott’s (2001) study where they found over 90% of the errors to be due to reporting of the nontarget keywords. The percentage of error reported by Gallun, Mason & Kidd, Jr (2007) was only 65%, the authors having attributed this to the differences in tasks, the earlier study having used noise in addition to the stimuli

Altogether, these studies reveal that there are reductions in performances when attempting to carry out selective and divided attention tasks due to numerous reasons, and there exists a lack of consensus on possible explanations to it.

CHAPTER 3

METHOD

The aim of the present study was to investigate the processing of simultaneous sentences. In particular, to determine the effect of hearing loss on the processing of simultaneous sentences as well as to determine the combined effect of noise and hearing loss as well and finally, to compare these performances with that of normal hearing individuals. The following method was adopted to realize the aim of the current study.

3.1 Participants

Data was collected from a total of number of 37 participants. The participants were assigned to one of the two groups, the control group or the clinical group. The control Group comprised of individuals with normal hearing sensitivity and the Clinical Group comprised of individuals with either moderate or moderately severe hearing loss.

3.1.1 Control Group

15 participants were recruited as a part of the control group. And were between the age range of 15 to 55 yrs (mean= 32 years, SD = 6.43years). All the individuals had bilateral normal hearing sensitivity with the pure tone average being less than 15dBHL for octave frequencies from 250 to 8000Hz. The participants had 'A' type Tympanograms, indicative of normal middle ear status. All the individuals were native

speakers of Kannada language. They did not present with any complaints of psychological, cognitive or neurological problems.

3.1.2 Clinical Group

Individuals with postlingually acquired sensorineural hearing loss served as participants in this group. A total number of 22 participants between the age range of 20 and 50 years were recruited. The clinical group was sub grouped into Group A and Group B.

Clinical Group A consisted of a total of 12 Participants. The participants of this group had an age range of 20 to 55 yrs (mean= 37 years, SD= 4.13). All the participants were diagnosed to have bilateral, symmetric moderate sensorineural hearing loss (mean PTA= 46.6dB), flat audiometric configuration with 5dB rise or fall per octave (Lloyd and Kaplan, 1978).

Clinical Group B consisted of a total of 10 Participants. The participants of this group had an age range of 20 to 55 yrs (mean= 39 years, SD= 6.54). All the participants were diagnosed to have bilateral, symmetric moderately severe sensorineural hearing loss (mean PTA= 63.3) flat audiometric configuration with, 5dB rise or fall per octave (Lloyd and Kaplan, 1978).

All the individuals comprising the clinical group were native speakers of Kannada language. The participants had 'A' type Tympanograms indicative of normal middle ear status. They did not have any complaints of psychological, cognitive or neurological problems.

3.2 Test Environment

Testing was carried out in a sound treated room with ambient noise level within specified limits as per ANSI S3.1 (1991).

3.3 Instrumentation

A calibrated two channel diagnostic audiometer, Madsen Orbiter 922 with TDH 39 headphones encased in MX 41AR ear cushion was used to obtain air-conduction thresholds and perform speech Audiometry. Bone conduction testing was done using Radio ear B-71 BC vibrator. A Calibrated Grason Stadler Inc , model-Tympstar middle ear analyzer (v 2.0) was used to assess the middle ear status and rule out middle ear pathology.

Computer Software's used during the course of the study for the preparation of the speech stimuli were:

a. Adobe audition (Version 3): This was used to record the stimuli as well as to carry out consequent editing of the recorded material. Scaling and normalization of the sentences was done using this software to ensure that the onset and termination of the sentence pairs were approximately the same and that the intensity of all the sounds was brought to same level.

b. Matrix Laboratory (MATLAB v.6) was used to prepare an algorithm to embed the noise at different SNRs.

3.4 Stimuli:

Speech materials from the Competing Sentence Test –Kannada (Hemalatha , 1982) which consisted of 25 sentence pairs was utilized in the study. The sentences were of similar length and contained approximately equal number of words and syllables. Both the sentences of the pair contained a common theme. The sentences were designed to minimize perception by key words alone. The sentence construction was such that they could be easily interchanged i.e. the first half of the target sentences and the second half of the second sentence could be combined to make a third sentence that was syntactically and semantically acceptable. The complete list with the translation is given in Appendix A .

Naturally produced sentence by a female native Kannada speaker with normal vocal tract effort was used for the preparation of the stimuli. The test items were spoken naturally; peak intensities of the sentences were monitored to avoid distortion. The sentences were recorded using a digital recorder with a 16 bit processor at 44 KHz sampling frequency with a high fidelity microphone placed at a distance of 10 m from the speaker. The list was edited using adobe audition (v 3). All the sentences were normalized to ensure that intensity was at the same level. The recorded sentences were prepared as dichotic stimuli by inserting the sentences into two separate tracks which were channelized to the Left and the Right. The stimuli was scaled to ensure that the onset and offset of each of the sentence pair was similar .The pairs of stimuli were concatenated with an inter stimulus interval of 10 sec.

For test blocks wherein noise was added, MATLAB algorithms were incorporated to embed the prepared sentences in speech shaped noise at two SNRs 0, -6 dB as recommended by Best, Gallun, Mason, Kidd, Shinn-Cunningham (2010). Speech-shaped noise was created by filtering randomly generated broadband noises with the average frequency spectrum of the set of sentences used in the experiment. For all the dichotic stimuli, the noise was independent in the two ears but equal in level.

A 1000 Hz calibration tone with the RMS value, the same as the vocalic amplitudes of the syllables in the sentences was incorporated at the onset as a reference calibration signal.

The prepared test material was recorded onto an audio CD. The recorded dichotic material was played to the participants by routing the CD output through the calibrated Madsen audiometer with TDH-39 supraural earphones

3.5 Procedure

The following procedure was adopted to carry out the study-

Otoscopic evaluation of all subjects was done to rule out any outer ear and/or tympanic membrane pathologies.

Audiological evaluation

Pure tone audiometric thresholds were obtained for both air-conduction (at octave frequencies of 250 Hz- 8000 Hz) and bone-conduction (at octave frequencies of 250 Hz- 4000 Hz) using modified Hughson - Westlake procedure (Carhart & Jerger, 1959) as recommended by ANSI S3.21 1978(R 1997). Speech eudiometry was done to obtain the speech recognition thresholds and speech identification scores. Immittance evaluations were carried out to ensure normal middle ear functioning. Tympanometry was carried out using a 226Hz probe tone with a pump rate of 50dapa/unit time.

Testing was then carried out in the following conditions.

All the tasks were carried out in two experimental conditions, *In Quiet condition* and *in noise condition,* where in, for the latter, all the stimuli were presented at two SNRs of spectrally shaped speech noise 0dB SNR and -6 dB SNR. The order of presentation of the 3 tasks in the two experimental conditions varied from subject to subject, randomized through a 'lottery without replacement'/ 'simple random sampling' method (Kalton, 1983).

Familiarization of test stimulus

The individuals were initially ***familiarized*** with the test material. The test material, consisting of a total of 50 sentences was presented auditorily at comfortable and at a clearly audible level to all the subjects before the onset of the testing. Prior to the familiarization, the clients were informed that the sentences presented to them would be the test stimuli for the following tests and were instructed to attend to the input provided.

3.5.1. *"Control Trials"*

Wherein only one message was presented to one ear and the subjects were to report the presented stimulus.

Presentation Level

For the normal hearing subjects, levels were set by measuring the quiet speech recognition threshold and presenting the speech stimuli at a fixed level above this threshold (35dB SL)

For the hearing impaired subjects, presentation level was set by measuring the quiet speech recognition threshold and presenting the speech stimuli at a fixed level above this threshold (35dB SL) , in subjects who found this level uncomfortable, the level was set at that determined to correspond to the most comfortable level

Instructions to the subject for this task were:

“You will hear a sentence in the left/ right ear; you will have to repeat the sentence verbatim”

3.5.2. “Selective attention task (Single-task trials)”

The stimuli were presented dichotically and listeners were to report verbally the sentence heard in the target ear. Before the presentation of the stimuli, the subject was made aware of which ear was the target ear by means of a visual representation of the same. Presentation of the stimuli to the target ear was randomized such that each ear was the target ear 50% of the time. The presentation level was at the same level as for the control task

Instructions to the subject for this task were:

"You will hear two different sentences, one in each ear simultaneously. You are to ignore the sentence in your Non target ear and to repeat the sentence perceived in the target ear".

3.5.3. "Divided attention task (Dual task trials)"

Dichotic stimuli were presented and the listeners were to report verbally the message from the target ear followed by the message from the non target ear. Ahead of the presentation of the stimuli, the subject was made aware of which ear was the target ear by means of a visual representation of the same. The stimuli were randomized and presented in such a manner as to ensure that each ear was the target ear 50% of the time. The presentation level was at the same level as for the control task

Instructions to the subject for the task were:

"You will hear two different sentences presented simultaneously, one to each ear. You will have to repeat both the sentences, first the sentence heard in the target ear followed by the sentence heard in the non target ear"

3.6 Scoring

3.6.1 Control Trials: Total numbers of sentences presented were 5; each assigned a score of 20% for a verbatim response.

3.6.2 Selective attention trials: Single report paradigm was employed for the task. Two types of responses were scored i.e. either correct or error.

Error was defined as:

a. Any instances where portions of the two sentences are interchanged resulting in a new sentence.
b. Instances of syntactic confusion.
c. Omission or substitution of any crucial words which would alter the meaning of the given sentence.

Total number of sentences presented was 10; each assigned a score of 10% for a correct response, the maximum possible score being 100%

3.6.3 Divided attention trials: Three types of response were scored.

a. Both the sentences are correct. (Both M1 and M2)
b. Only one member of the stimulus pair is correct. (Single Correct)(M_1 or M_2)
c. Neither member of the stimulus pair is correctly reported.(Double error)

Here, the sentences were scored correct even if the words were changed, provided the meaning of the sentence remained the same

Total numbers of sentences presented were 10; each assigned a score of 10% for a correct response, with a possible maximum score of 100% for the target stimuli and 100% for the non target stimuli.

Thus, from each of the participants, data was obtained for the 3 experimental conditions

1. in quiet
2. at 0dB SNR
3. at -6dB SNR , for the three tasks- i.e. control task, Selective attention task and divided attention task.

The data obtained from the above conditions were then tabulated and subjected to appropriate statistical analyses.

Chapter 4

Results and Discussion

The objectives of the study were to assess the processing of simultaneous sentences in normal hearing individuals and in individuals with moderate and moderately severe hearing impairment under the 3 tasks i.e. control task, selective attention and divided attention in 3 conditions, in quiet, 0dB SNR and -6dB SNR. Furthermore, the third task (Divided attention) was scored separately for both the target and the non target responses and was therefore considered as two tasks i.e. divided attention M1 (response to target stimuli), Divided attention M2 (response to secondary stimuli) for ease of statistical analysis . Henceforth, the tasks would therefore refer to control tasks, selective attention tasks, divided attention M1 and divided attention M2. The third noise condition -6dB SNR was not included in the data set for statistical analysis since individuals with moderate and moderately severe hearing loss were unable to perform the 4 tasks.

The data of processing of simultaneous sentences collected for the three groups, under the four tasks in the two conditions were analyzed using Statistical Package for the Social Sciences (SPSS for windows, Version 16). The following statistical tests were carried out

1. Descriptive statistics was performed to find out the mean and the Standard deviation (S.D)

2. Mixed ANOVA (2 way repeated measures for conditions and tasks with between subject factor as groups) was administered to know the main and interaction effects among the subjects, conditions and tasks.

3. If significant differences were noticed among the groups across the tasks and conditions, across the tasks and conditions, MANOVA was done and Duncan's post hoc analysis was carried out to assess the significance.

4. Repeated measures of ANOVA were used to analyse the performance of each group across the tasks and conditions and Bonferroni's post hoc analysis was carried out to assess the significance of the difference for each task.

5. Paired sample t test was administered to each of the groups to analyze the performance between conditions.

Comparison of mean and standard deviation across groups for the tasks and conditions.

Table 4.1 provides data of the mean and standard deviation values (SD) for the three subject groups across the task and conditions. The results indicate that the best performance was noticed in the control task in quiet condition and then in 0dB SNR for all three groups. Among the simultaneous stimulation condition, the mean scores obtained in the selective attention tasks were higher than those obtained in the divided attention tasks

Table 4.1:

Mean and standard deviation of the percentage correct scores (max=100%) obtained by the three groups for the tasks in quiet and noise conditions.

Groups → Tasks and condition↓	Normal hearing group (N=15)		Moderate hearing loss Group(N=12)		Moderately severe hearing loss group(N=10)	
	Mean	SD	Mean	SD	Mean	SD
Control task in quiet	100	.00	100	.00	100	.00
Control task in 0dB SNR	100	.00	98.33	5.77	92.00	10.32
Selective attention in quiet	94	7.36	79.17	6.68	69.00	11.00
Selective attention in 0dB SNR	85.33	5.16	66.67	9.84	56.00	5.16
Divided attention - M1 in quiet	88	7.74	75.00	10.00	59.00	11.00
Divided attention - M1 in 0dB SNR	75.33	6.39	55.83	11.64	43.00	9.48
Divided attention- M2 in quiet	79.33	7.03	57.50	9.65	45.00	8.49
Divided attention- M2 in 0dB	67.33	4.07	43.33	13.02	18.00	11.35

For the control task in noise, similar performances were seen in the normal hearing group and in the moderate hearing loss group, with the mean reducing to 92% in the moderately severe hearing loss group. In the selective attention task, where there was a semantically similar sentence presented to the ear opposite to the target, scores in three listener groups reduced indicating that the message in the unattended ear interfered with performance. In the divided attention task, performance for M1 was consistently poorer than selective attention task performance and performance for M2 was on an average worse than the performance for M1. The mean scores across the groups were seen to be better in the quiet condition over the noise condition. The results also indicated that with increasing degree of hearing loss, decrease in the processing of the stimuli was present.

A similar trend in results was reported by Best, Gallun, Mason, Kidd, Shinn-Cunningham (2010). They conducted a study on normal hearing and individuals with moderate-moderately severe hearing loss wherein the mean values obtained for the control task was better than for the single task(selective attention) trials, which was better than for the dual task trials(divided attention), M2 responses being poorer than M1. Poorer performance in noise condition (0dB SNR) over quiet condition was also reported by the authors. The reductions in performances obtained in the study across tasks as well as between the normal and hearing impaired subjects were of a lesser magnitude than that obtained in the current study. The differences in the magnitude of reduction in performance may be attributed to methodological differences. The stimuli used in the study by the authors were speech materials were taken from the Coordinate Response Measure (CRM) corpus (Bolia, Nelson, Ericson & Simpson, 2000), which consisted of sentences of the form “Ready <call sign>, go to <colour> <number> now.” Therefore, the task was of the form of identification of keywords in the sentence. Apart from differences in material used and the scoring method adopted, the response modality in the current study was verbal response of the stimulus perceived, and in the study by Best, Gallun, Mason, Kidd, Shinn-Cunningham (2010), it involved clicking with the computer mouse on a graphical user interface, which reduced the memory loading of the task.

Comparison of group performances across tasks and conditions

In order to assess if there existed any interaction among the three subject groups, four tasks and the two conditions, Mixed ANOVA was carried out. Mixed ANOVA revealed that there was significant difference in the main effect of tasks [$F (3,102) =497.913$, $p<0.001$), conditions [$F (1, 34) =230.098$, $p<0.001$). Test of between subjects effects also revealed that there was significant differences between the groups [$F (2, 34) = 93.36$, $p<0.001$) as well. Further, the interactions between task × group [$F (6,102) =28.88$, $p<0.001$), condition × group [$F (2, 34) =7.777$, $p<0.05$), task × condition [$F (3,102) = 20.787$, $p< 0.001$) were also found to be significant. Mixed ANOVA failed to show any interaction in task × condition × group [$F (6,102) = 2.034$, $p>0.05$).

Bonferroni’s Pair wise comparison was carried out between the tasks as Mixed ANOVA showed significant main effect of tasks. The results have been tabulated in Table 4.2. The analysis of the data set revealed significant differences between the four tasks.

Table 4.2:

Level of significance for significance of difference between tasks

	Control task	selective attention	divided attention M1	divided attention M2
Control task		P<0.05	P<0.05	P<0.05
selective attention			P<0.05	P<0.05
divided attention M1				P<0.05

Duncan's post hoc analysis of the main effect between the groups also revealed significant differences between the groups (α defined at 0.05). There was a significant reduction in scores as the degree of hearing loss increased. The results obtained in this study regarding the main effects and the interactions are in agreement with the results obtained by Best, Gallun, Mason, Kidd, Jr., Shinn-Cunningham (2010) who also reported of a significant main effect of task and SNR. Furthermore, they also reported that all task conditions -control task, single task (selective attention) trials, dual task trials (divided attention) were significantly different from one another for both normal hearing as well as for hearing loss group.

Since Mixed ANOVA revealed significant interaction effects, the data was also subjected to MANOVA and subsequently Duncan's post hoc analysis to see the influence of the groups across the tasks and conditions. The results of MANOVA revealed significant difference in the task and condition performance across groups. Duncan's post hoc analysis was then carried out to see the influence of groups in each of the task and condition. The results obtained are discussed below.

Comparison between groups in control task at 0dB SNR condition

Duncan's post hoc analysis revealed that there was no significant difference between the normal hearing and moderate hearing loss group for the control task at 0dB SNR, but the performance of the moderately severe hearing loss group was significantly different from the normal hearing and moderate loss groups.

Table 4.3:

Mean, SD and level of significance for between group comparisons of control task for noise condition (max possible score=100%)

	0dB SNR

	Mean	SD	Sig
Control Group	100	.00	p>0.05
Moderate SNHL group	98.33	5.77	
Control Group	100	.00	P<0.05
Moderately severe SNHL group	92.00	10.32	
Moderate SNHL group	98.33	5.77	P<0.05
Moderately severe SNHL group	92.00	10.32	

The high scores exhibited by normal hearing individuals are in agreement with reports of similar performances by several authors(Gallun, Mason & Kidd, Jr.,2007;Drullman and Bronkhorst, 2000; Brungart & Simpson, 2002; Best, Gallun, Mason, Kidd, Shinn-Cunningham, 2010). This can be attributed to the stimuli utilized in the present study. Sentences are the easiest signal to understand as they provide the listener with acoustic information, semantic and contextual cues and linguistic content, i.e. greater redundancy (Miller, Heise & Lichten, 1951). Due to speech redundancy, normal-hearing individuals can understand the signal even though it may be highly degraded, (Wilson & Strouse, 1999). The absence of a significant difference in the performance by individuals with moderate loss may be attributed to the inherent redundancy offered by the stimuli as well as to the additional redundancy that the familiarization process afforded them. In addition to it, according to Wilson & Strouse (1999) some hearing impaired individuals have understanding ability equal to a normal hearing person while others understand very little regardless of presentation level . Humes (1996) showed that the degree of sensorineural hearing loss is the primary variable for speech understanding in noise, the greater the degree of loss the poorer the performance. This could account for the relative poorer performance by individuals with moderately severe hearing loss for speech perception in noise (Dubno, Dirks, Morgan, 1984; Duquesnoy, 1983; Plomp, 1986; Plomp, Mimpen, 1979).

Comparison between groups in selective attention task in quiet and 0dB SNR conditions

Table ***4.4***

Mean, SD and level of significance for between group comparison of selective attention task in quiet and noise

	Quiet			0dB SNR		
	Mean	SD	Sig	Mean	SD	Sig
Control Group	94.00	7.36	P<0.05	85.33	5.16	P<0.05
Moderate SNHL group	79.17	6.68		66.67	9.84	
Control Group	94.00	7.36	P<0.05	85.33	5.16	P<0.05
Moderately severe SNHL group	69.00	11.00		56.00	5.16	
Moderate SNHL group	79.17	6.68	P<0.05	66.67	9.84	P<0.05
Moderately severe SNHL group	69.00	11.00		56.00	5.16	

(Max score=100%)

The post hoc analysis carried out for the data set revealed significant differences in the performance of the control group and the hearing impaired groups, as well as significant differences between the two hearing impaired groups. Performance exhibited by individuals with moderate hearing loss was poorer than that by the control group consisting of normal hearing individuals and the poorest performance was by the moderately severe hearing impaired group. The addition of noise further degraded the performance of the three groups, although the trend in performance between the groups remained the same.

Previous experiments have shown that, listeners are able to attend to the signal in the target ear without any measurable interference from masking sounds to the unattended ear. Cherry (1953) found that a listener's ability to shadow a speech signal presented to one ear was unaffected by the presence of unrelated speech material in the unattended ear. Moreover, other researchers have reported that the ability to selectively attend to a single ear extends to the case where multiple talkers are presented to the unattended ear (Drullman and Bronkhorst, 2000) as well as dichotic tone detection tasks with target tone in one ear and a random frequency informational masker in the unattended ear (Neff, 1995 ; Kidd, Mason,Rohtla 1995). These reports are in disagreement with the results obtained in the current study. A major factor that could explain the disagreement could be the nature of the stimuli presented to the non target ear, it being unrelated to the target stimulus in the above mentioned studies and vice versa in the current study. Drullman and Bronkhorst (2000) found that the addition of a masking talker in the unattended ear had no effect on the listener's ability to segregate competing talkers in the target ear. The most likely explanation for this discrepancy with the results of the current study is the difference in the vocal characteristics of the masking voices used in the listening tasks. In the current study, the dichotic stimuli had vocal characteristics of just a female talker; on the other hand, in Drullman and Bronkhorst's study, the target talker and the masker talker were of different a gender which is perceptually an easier task to carry out and could thus account for the lack of reduction in performance in the selective attention task.

Situations are evident where across-ear interference does occur in dichotic listening. Such as, when the semantics of the speech signal in the unattended ear is related in some way to the signal in the target ear, errors often occur in the target ear listening task (Brungart & Simpson, 2002). In the present study, it was found that the presence of the speech signal in the contralateral ear made it significantly difficult for the listeners to extract information from the talker in the target ear. Such a pattern of performance was found in earlier experiments by Brungart and Simpson (2002, 2003) that examined within-ear and across-ear interference using the CRM stimuli. Similar results have also been reported by Gallun, Mason & Kidd, Jr (2007), Moray(1959), Wood and Cowan(1995), Treisman(1960) in normal hearing individuals for different kinds of speech stimuli and by Best, Gallun, Mason, Kidd, Jr., Shinn-Cunningham (2010) in normal hearing as well as individuals with moderate-moderately severe hearing loss. Such reductions in performance can be attributed to informational ‘‘across-ear’’ interference that occurs from a masking talker in the ear opposite the target talker for selective attention in quiet condition and possible interactions between the informational and energetic ‘‘within-ear’’ interference that occurs from a masking stimuli in the same ear as the target speech for the task in noise condition (Brungart, Simpson, 2002, 2003, 2005; Gallun, Mason & Kidd, Jr., 2007)

It has been reported in literature that impaired listeners have reduced temporal and spectral acuity in comparison to normal hearing listeners (Leek and Summers, 2001, Deeks and Carlyon, 2004, Bernstein and Oxenham, 2006, Carlyon, Long, Deeks & McKay, 2007). Speech intelligibility for them would be degraded even in quiet if the features that convey speech meaning are degraded due to reduced audibility as well as a diminished spectrotemporal resolution. Hearing impaired listeners also suffer from effective increases in the amount of energetic masking that is due to the reduced spectral selectivity of their peripheral auditory filters and the amount of masking increases as the degree of loss increases. Altogether, these factors cause less of a target source to be audible to a hearing impaired listener compared to a normal hearing listener in the same acoustic setting (Shinn-Cunningham, 2008)

Normal-hearing listeners can direct top-down attention to select desired auditory objects from out of a sound mixture as well as are able to enhance it and suppress competing maskers (Shinn-Cunningham, Best 2008) This could explain the relatively smaller reductions in performance seen in them in the current study over the control task. In hearing impaired individuals, failures in selective attention that cause such a drastic reduction in performance can result from failures in 1) separating the target from the other sources i.e. failures in object formation 2) directing attention to the correct object in the scene i.e. failures in object selection.

Dealing with failures of object formation, it has been found that **h**earing impaired individuals are also likely to have difficulty properly grouping sound sources. The spectro-temporal cues that convey speech meaning are also the basis of short-term grouping (Bregman, 1990; Darwin and Carlyon, 1995). Therefore, a less-robust representation of spectro-temporal content as seen in impaired listeners may cause problems with object formation. For example, the onsets, offsets, modulation, and harmonic structures which are important for forming objects over short time scales in a multitalker environment are less perceptually distinct for individuals with hearing loss than normal-hearing counterparts(Leek & Summers, 2001; Buss, Hall, & Mason, & Walsh, 2002; Moore, Glasberg, & Hopkins, 2006; Bernstein & Oxenham, 2006). Broader than normal frequency selectivity in impaired listeners also results in fewer independent frequency channels to represent the auditory scene, making it harder to perceptually segregate the component sources (Gaudrain, Grimault, Healy, & Bera, 2007).In addition, they also appear to have difficulty encoding the spectrotemporal fine structure in sounds which are critical for robust pitch perception, for speech intelligibility in noise, and for the ability to make use of target object information in moments during which the interfering source is relatively quiet i.e. “listening in dips” (Rosen, 1992; Pichora-Fuller, Schneider, MacDonald, Brown, & Pass, 2007; Lorenzi, 2008). Discussing in terms of object formation, fine structure may also enable a listener to segregate target energy from masker energy and therefore form a coherent object from the discontinuous target glimpses

If there is failure to properly form auditory objects, they will have difficulty selectively attending to a target. When objects form properly, biased competition between objects works to suppress the objects outside the focus of attention. When objects fail to form properly, the competing sources will not be suppressed effectively, and therefore will cause greater perceptual interference (Desimone & Duncan, 1995, Shinn-Cunningham, Best 2008).

Comparison between groups in divided attention task in quiet and 0dB SNR conditions

Divided attention M1

The Table 4.5 and 4.6 reveal the results of the Duncan's post hoc analysis of the performance between groups for the divided attention task, in quiet and in noise. As depicted in the Table 4.5 below, mean scores for divided attention M1 were significantly reduced for the two groups of individuals with hearing impairment. This decrease in performance in the two groups is significantly different from the performance by the control group and the performance for the M1 task is significantly different between the two groups of hearing impaired subjects, for quiet as well as for noise

Table 4.5

Mean, SD and level of significance for between group comparison of divided attention-M1 task in quiet and noise

	Quiet			Noise		
	Mean	SD	Sig	Mean	SD	Sig
Control Group	88.00	7.74	P<0.05	75.33	6.39	P<0.05
Moderate SNHL group	75.00	10.00		55.83	11.64	
Control Group	88.00	7.74	P<0.05	75.33	6.39	P<0.05
Moderately severe SNHL group	59.00	11.00		43.00	9.48	
Moderate SNHL group	75.00	10.00	P<0.05	55.83	11.64	P<0.05
Moderately severe SNHL group	59.00	11.00		43.00	9.48	

(Max score=100%)

Divided attention M2

The results obtained for the post hoc test indicate that the performance of the control group for the divided attention M2 task, in quiet and in noise is significantly different from the scores obtained by the moderate and moderately severe hearing impaired groups. In addition, the performances of the two groups in quiet and in noise are significantly different from each other.

Table 4.6

Mean, SD and level of significance for between group comparison of divided attention-M2 task in quiet and noise

	Quiet			Noise		
	Mean	SD	Sig	Mean	SD	Sig
Control Group	79.33	7.03	P<0.05	67.33	4.57	P<0.05
Moderate SNHL group	57.50	9.65		43.33	13.02	
Control Group	79.33	7.03	P<0.05	67.33	4.57	P<0.05
Moderately severe SNHL group	45.00	8.49		18.00	11.35	
Moderate SNHL group	57.50	9.65	P<0.05	43.33	13.02	P<0.05
Moderately severe SNHL group	45.00	8.49		18.00	11.35	

(Max score=100%)

In the divided attention task, performance was poorer for each message than for the one message reported in the selective attention task. For M1, the difference was comparatively smaller. Similar results were reported by Best, Gallun, Mason, Kidd, Shinn-Cunningham (2010) which they attributed to an increase in confusion errors (having to report both messages increased the chances of subjects interchanging the words) and an increase in random errors (a consequence of processing load). For M2, they reported that the deficit relative to the single task was far greater because of a much larger occurrence of random errors (Best, Gallun, Mason, Kidd, Shinn-Cunningham, 2010).Poorer performance in M2 over selective attention task, as well as M1 was also seen in the present study.

Broadbent (1954) proposed that simultaneous inputs to the auditory system are to some extent processed serially. In his study, he presented two sequences of digits simultaneously to the two ears and reported that, although listeners could recall all digits, the responses were always made to one ear followed by the other. Therefore, Broadbent (1957, 1958) postulated that simultaneous sensory inputs are stored temporarily via immediate auditory memory which is then processed by a limited capacity mechanism serially (Lachter et al. 2004). A consequence of such a scheme is that the secondary message in the pair is to be stored while the primary message is processed. Apart from this, with the dual-response design the responses themselves have to be made sequentially, be it in any response mode. It is possible that the poorer performance on M2 is related to the fact that it must be retained in memory longer than M1 during the response interval (Sperling 1960). Authors have commented on the fact that information degrades while being held in the sensory buffer and may be replaced by subsequent sensory stimuli (Vogel & Luck, 2002) The results of the present study, showing large reduction in performance for the message reported second (M2), can be attributed to its degradation as it is retained in the memory due to processing of the first message as well as due to the sequential mode of response. Similar conclusions have also been reported in other studies (Ihelfeld & Shinn-Cunningham2008; Best, Gallun, Mason, Kidd, Jr., Shinn-Cunningham, 2010).

Gallun, Mason & Kidd, Jr.(2007) also reported that the performance in the divided listening task was poorer than in the selective listening task as expected, although there was a substantial reduction in the selective listening condition due to the presence of distracting speech stimulus . However, it was reported that for the divided listening task the costs (Difference between divided attention and selective attention) in performance calculated were much greater when the listener task was to monitor both ears for speech identification than when the listener only had to identify speech in one ear and detect the presence of speech in the opposite ear. The authors speculated that the costs of dividing attention are correlated to *the extent to which the two tasks require the same or different pools of processing resources*. When two identification tasks were required, the observer was utilizing the same pool of resources. This is in agreement with the postulates of the multiple resource models (Navon & Gopher,1979)

In both normal hearing and hearing loss groups, in the current study it was found that addition of the noise affected the performance for M1 in the divided attention task in nearly the same way that it affected performance in the selective listening task. Also, the ability to report M2 decreased more dramatically with addition of noise which was attributed by Best, Gallun, Mason, Kidd, Shinn-Cunningham (2010) to an increase in random errors in the study they conducted. These results support the conclusion that the processing of simultaneous messages interacts with the quality of the inputs (Best, Gallun, Mason, Kidd, Shinn-Cunningham, 2010). In the model described earlier in which simultaneous inputs are processed serially, the inputs that are processed second are held in the form of raw sensory representations that are volatile and have been found to degrade with time (Broadbent, 1957; Brown ,1958; Durlach & Braida ,1969). This could explain why performance in M2 is particularly sensitive to the integrity of the acoustic input. A degraded input like with the addition of noise would degrade even further in this store and would not be useful by the time it was fully processed. Various authors claim of a trade-off between SNR and the time interval during which period a sensory trace must be maintained. Best, Gallun, Mason, Kidd, Shinn-Cunningham (2010) in their study noted that that the effect of noise on M2 was almost exclusively due to an increase in the random errors noted and that confusion errors were quite constant as a function of the various SNRs they utilized. This therefore supports the idea that sensory degradation and maybe not an increased confusion between the streams could probably be responsible for the dramatic effect of noise on the recall of M2.

An alternative explanation to this result is that the increased difficulty of processing M1 in trials with noise effectively drained a limited pool of processing resources, leaving fewer resources for processing of M2 to occur. This rationale was used previously to explain the effect of noise on the reduced ability of individuals to store part of a single-attended message for later recall (Rabbitt ,1968; Pichora-Fuller, Schneider, Daneman, 1995).

Comparison of performance between the tasks.

Normal hearing Subjects group

To assess the performance of normal hearing individuals across the tasks in quiet and noise conditions, repeated measure ANOVA was carried out for the conditions separately. The results revealed significant difference across the tasks [$F(3, 42) = 27.22$, $p < 0.001$] in quiet as well as in noise condition [$F(3, 42) = 150.45$, $p < 0.001$]. Bonferroni's post hoc analysis was performed to see the difference between tasks in quiet and noise conditions separately. The results of the pairwise comparison indicated significant difference across all the tasks in quiet and noise condition separately ($\alpha = 0.05$). Hence, paired t test was administered between the tasks in noise and quiet condition. The results have been tabulated in Table 4.7. Paired t test revealed significant differences between the three pairs of task i.e. selective attention, divided attention – M1 and M2 in the quiet vs. noise conditions.

Table 4.7

t values and level of significance for comparison between tasks in quiet and noise conditions in normal hearing group

	Tasks and conditions	t	df	Sig. (2-tailed)
Pair 2	selective attention quiet - selective attention 0dB SNR	4.516	14	.000
Pair 3	divided attention M1 in quiet - divided attention M1 0dB SNR	6.141	14	.000
Pair 4	divided attention M2 quiet - divided attention M2 in 0dB SNR	6.874	14	.000

Moderate hearing loss group

Two separate repeated measures of ANOVA tests were carried out for this group across the tasks, one analysis for performance in quiet and the other for the performance in noise. Results revealed that there was significant differences between the tasks in quiet [F (3, 33) = 94.686, p< 0.001] as well as between the tasks in noise [F (3, 33) 85.457, p< 0.001].To determine which tasks were different from each other, Bonferroni's pairwise comparison test was carried out. The analysis revealed that the trend in moderate hearing loss group across the two conditions (quiet and noise) were the same, with there being significant differences between all the tasks in the two conditions except the selective attention and divided attention M1 task. Paired t test was then carried out to assess if there was a significant difference between tasks across the two conditions. The results as shown in Table 4. 8 indicated that there was significant difference between 3 tasks in the quiet and noise condition, with the scores in the 0dB SNR condition being poorer than in quiet for the selective and divided-M1 and M2 tasks. The control task in noise and quiet did not show a significant difference.

Table 4.8

t values and level of significance for comparison between tasks in quiet and noise conditions in moderate hearing loss group

		t	df	Sig. (2-tailed)
Pair 1	control task, quiet - control task, 0dB SNR	1.000	11	.339
Pair 2	selective attention quiet - selective attention 0dB SNR	5.000	11	.000
Pair 3	divided attention M1 in quiet - divided attention M1 0dB SNR	5.702	11	.000
Pair 4	divided attention M2 quiet - divided attention M2 in 0dB SNR	3.957	11	.002

Moderately severe hearing loss group

To assess if the performance for the tasks in this group were different, repeated measure ANOVA was carried out separately for the quiet and noise conditions. The analysis revealed significant differences between the tasks [F (3, 42) = 27.22, p< 0.001] in quiet as well as in noise [F (3, 27) = 146.923, p< 0.001]. To determine the tasks which differed in scores from each other, Bonferroni's pairwise comparison was carried out for the quiet and noise conditions separately. The analysis revealed that there was a significant difference between all the 4 tasks in noise as well as in quiet conditions. Sampled t test was then carried out and the results are revealed in Table 4.9

Table 4.9

t values and level of significance for comparison between tasks in quiet and noise conditions in moderately severe hearing loss group

		t	df	Sig. (2-tailed)
Pair 1	control task, quiet - control task, 0dB SNR	2.449	9	.037
Pair 2	selective attention quiet - selective attention 0dB SNR	4.333	9	.002
Pair 3	divided attention M1 in quiet - divided attention M1 0dB SNR	4.311	9	.002
Pair 4	divided attention M2 quiet - divided attention M2 in 0dB SNR	9.000	9	.000

Discussion for the comparison between tasks

A similar trend was seen across the three groups for the comparison of performances between the tasks. In all the groups, the performance was found to reduce as the tasks performance demanded the need for larger attentional and processing resources. The mean scores obtained across the groups for the selective attention tasks were significantly poorer than those obtained in the control task (Brungart and Simpson 2002, 2003). As previously described, this could be attributed to the informational masking effect due to the presence of a similar message, by the same talker in the nontarget ear. This would result in interference in the processing of the target sentence and therefore a reduction in performance in normal hearing as well as hearing impaired groups(Brungart & Simpson, 2002). In the group with hearing impairments, this effect is further exacerbated by the reduced temporal and spectral acuity compared to normal-hearing listeners (Leek and Summers, 2001; Deeks and Carlyon, 2004; Bernstein and Oxenham, 2006). Due to reduced audibility and diminished spectro-temporal resolution, the features that convey speech meaning are degraded; therefore speech intelligibility will be degraded even in quiet when compared to normal hearing individuals in the same situation (Shinn-Cunningham, Best 2008). Hearing impaired listeners also have difficulty properly grouping sound sources as well as with object formation due to the reduced ability to process spectro-temporal content. Also, robust location, pitch, and harmonic cues may not be available to them; further impairing their ability to properly separate the mixture into streams (Bregman, 1990; Darwin and Carlyon, 1995).This in turn would result in difficulty selectively attending to a target. In addition, loss of spectro-temporal detail in the periphery may affect perception of higher-order features that distinguish target from masker (Desimone & Duncan, 1995).

In the divided attention task, there was a further reduction in performance over the selective attention task in all the groups which is in agreement with several studies (Ihelfeld & Shinn-Cunningham, 2008, Best, Gallun, Mason, Kidd, Shinn-Cunningham, 2010).These authors have stated various explanations for such a finding. One such explanation for the same is based on the limited availability in processing resources available. The processing of M1 drains a limited pool of resources, therefore leaving limited or no resources for the processing of M2 depending on the task (Rabbitt ,1968; Pichora-Fuller, Schneider, Daneman, 1995). Another explanation concerns the degradation M2 undergoes as it is stored in a memory buffer while M1 is process as well as while M1 was being reported (Broadbent, 1957; Brown ,1958; Durlach & Braida

,1969; Cowan, 2002 ; Vogel & Luck, 2002). The further degradation in response in hearing impaired listeners is also explained in terms of an "effort hypothesis." According to this hypothesis, hearing loss makes the immediate speech task more demanding, leaving fewer processing resources for storing the to-be-recalled items. This hypothesis is also supported by studies that have used a secondary task that is non-auditory and thus does not depend directly on the quality of the auditory stimuli (Rakerd et al.1996). For the task explored in this study, namely the immediate recall of simultaneous messages, it is possible that hearing loss may also have a direct effect on the processing of M2 by degrading its spectrotemporal representation in the auditory system. In other words, hearing loss may compromise a listener's ability to process simultaneous messages in a similar way to added noise, by degrading the sensory trace that is used for the processing of a source outside the primary focus of attention (Shinn-Cunningham & Best 2008).

Discussion for the effect of condition

Across the groups, performance was found to degrade with the addition of noise for the selective attention as well as for the divided attention task-M1 as well as M2. For the tasks, poorer performance could be explained based on the shared-resource model of attention (Wickens, 1984,1980; Hirst and Kalmar, 1987) where speech segregation ability was constrained by a limited pool of shared attentional resources, and the listeners were to choose to allocate attentional resources either to within-ear speech segregation or to across-ear speech segregation. In the presence of noise, selective as well as divided attention tasks would require within-ear segregation to reduce the effects of energetic masking as well as across ear segregation to deal with further informational masking as well as formation of a stream for the divided attention tasks (Gallun, Mason & Kidd, Jr , 2007). In addition to this, the divided attention task M2 is particularly sensitive to the integrity of the acoustic input. This could be because a degraded input will degrade even further as it is stored as a raw representational form in a buffer until the serial processing of the simultaneous inputs is carried out and therefore may not even be useful by the time it is fully processed (Best, Gallun, Mason, Kidd, Shinn-Cunningham, 2010). The inability to perform at poorer SNRs like -6dB by the hearing impaired groups can be attributed to the above mentioned reasons as well as the perceptual deficits exhibited by them in the form of reduced frequency and temporal resolution, inability to listen in gaps as well as poor spectrotemporal fine structure resolution that further degrades their performance (Moore,2007)

SUMMARY AND CONCLUSION

One of the challenging situations that humans face on a day to day basis involves acoustic environments comprising of multiple talkers in addition to the background noise that is inherent to most situations, be it in the form of the distant humming of the fan or the music being played in the background. The difficulty in processing information in such a complex acoustic environment is what has been termed the cocktail party problem (Cherry, 1953). In such situations, we resort to the use of the various characteristics of the signals (such as the Fo, the transition cues, onsets, offsets etc) in order to segregate the various streams of speech and focus on the source of choice (Bregman, 1990). Reports in literature have stated that normal hearing listeners have found to be adept at this process of listening selectively to a source of interest in spite of additional sources in a crowded setting, and are also capable switching or dividing attention as need arise (Wood and Cowan, 1995). Due to the highly complex nature of the signal involved, these abilities are fragile, such that any degradation, be it in the form of excessive noise, or unclear speech or even hearing impairments can, cause great difficulties when there are competing sources (Noble and Gatehouse, 2006; Gatehouse and Akeroyd, 2006).

Despite years of research on the processing of such simultaneous events, the effects of degradation of the input as well hearing loss in young adults have not been well studied. Considering the subjective reports of individuals with hearing impairment regarding the difficulties they face in speech perception in the presence of noise, there is a need to report on the performance of such individuals in order to set the stage for further research to address the issue as well as to generate data on difficulties faced by individuals in a realistic situation.

The purpose of the study was to compare the performance of normal hearing and hearing impaired individuals in three tasks designed to provide information regarding their abilities to process simultaneous inputs. A total of 37 subjects were recruited to take part in the study of which 15 subjects had normal hearing sensitivity, 12 subjects had moderate hearing loss and 10 subjects with moderately severe hearing loss. The three groups of subjects were age matched and were between the ages of 20 to 55 years in order to factor out the contributions of declining cognitive performance associated with older subjects. The tasks consisted of a control task to assess baseline performance (monaural presentation of signal), a selective attention task and a divided attention task (wherein the processing of the primary target message as well as that of the secondary target message was assessed). All the tasks were carried out in three conditions; quiet condition and 0dB, as well as -6dB SNR conditions. The stimuli used during the course of the study were dichotic stimuli from the competing sentence test – Kannada developed by Hemalatha in 1992. A total of ten stimuli per task was used for the selective as well as divided attention tasks rendering a maximum score of 100%.

The data generated was then subjected to appropriate statistical analysis consisting of the descriptive statistical analysis, Mixed ANOVA, MANOVA, repeated measures of ANOVA and Paired sample t test. The following results were obtained

- Descriptive statistics provided the mean and Standard deviation values for the three groups across the tasks in the quiet and noise condition. It revealed that the scores across the groups were the poorest in the divided attention task for the secondary target message (M2). The mean scores of the moderately severe group were the least followed by that of the moderate hearing loss individuals. The addition of noise further degraded the performance for the selective and divided attention task over the quiet condition, and this reduction in performance increased as the degree of hearing loss increased

- The results indicated towards an interaction between the task and subjects and task and condition for both the normal hearing and hearing impaired groups.
- Also, the performance of the normal hearing as well as the moderate hearing impaired group was significantly different from that of the moderately severe impaired group in the 0dB SNR condition.
- The performance of the normal hearing, and the two hearing impaired groups were found to be significantly poorer in the selective attention task over the control task and the amount of reduction in performance was different between the groups as well.
- The increased processing involved in the divided attention task, caused a further reduction in performance in all three groups. This reduction in performance was the most in the individuals with moderate loss and the least in the normal hearing group.
- The reduction in performance for the secondary target message (M2) was considerably more than that for M1, especially in the moderately severe group and the addition of noise for this task affected the performance of both M1 as well as M2.

The explanations given for similar such results obtained in literature have been diverse. While some of the hypothesized reasons rely on the properties of the attentional resources available, others reason towards the degradation the message undergoes as it is held in a store while other signal is being processed as well as the reduced ability of the auditory system to process degraded stimuli, especially in the presence of hearing impairment. The role of energetic and informational masking, as well as the reduced spectro-temporal abilities and grouping/segregation abilities of the hearing impaired individuals have been discussed as well.

Limitations of the study:

- The number of stimuli used per task was only ten. Therefore, the mean scores may overestimate the actual difficulties faced by the listeners.
- Results were reported for performance only at 0dB SNR as the tasks proved to be too difficult for the hearing impaired subjects at -6dB SNR. Testing could have been carried out at other SNRs as well (+3,-3 dB SNR) to assess if improvements in performance occurred with positive SNRs
- The mode of response required sequential verbal output which could have brought into play the effects of memory.
- The scoring was carried out on a strict criterion which required correct response of the entire stimuli. Scoring based on the number of words or phonemes repeated would have provided a more sensitive estimate.

Implications of the study:

- It provides a basic understanding of the performance, as well resources necessary to process stimuli in the presence of multiple stimuli in both normal’s as well as hearing impaired individuals.

- Improved performance of individuals in quiet could suggest that environmental modifications, behavioural changes, or technology involved in improving the SNR should be effective in reducing the challenges face by hearing impaired individuals in complex environments.
- The results indicating towards the secondary talker being more affected could be used to assess the benefit of bilateral amplification. Listening tasks involving extraction of information from simultaneous sources could provide additional benefits regarding the bilateral benefits.

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APPENDIX A

Kannada Sentences used as Stimuli in the Competing Sentence Test

(Hemalatha, 1982)

1.	£ÀªÀÄä vÁ¬Ä ªÀÄ£ÉUÉ §A¢zÁÝgÉ.	:	CtÚ FUÀ Hl ªÀiÁqÁÛgÉ.
2.	gÁªÀÄÄ FUÀ wArUÉ §gÁÛ£É.	:	gÁdÄ ªÀÄ£ÉUÉ HlPÉÌ ºÉÆÃUÁÛ£É.
3.	ºÀÄqÀÄUÀgÀÄ FUÀ DrÛzÁgÉ.	:	ºÀÄqÀÄVAiÀÄgÀÄ FeÁÛ EzÁgÉ.
4.	ªÉÄÃµÀÄÖç ¢£Á ¸ÀÆÌ¯ïUÉ	:	«zÁåyðUÀ¼ÀÄ ¨ÉÆÃqïð

	ºÉÆÃUÁÛgÉ.		ªÉÄÃ¯É §jÃvÁgÉ.
5.	£ÀªÀÄä CªÀÄä CAUÀrUÉ ºÉÆÃUÁÛgÉ.	:	¤ªÀÄä C¥Àà ªÀÄ£ÉUÉ §vÁðgÉ.
6.	¨ÉAQAiÀÄ ºÀwÛgÀ ºÉÆÃzÀgÉ ¸ÀÄqÀÄvÀÛzÉ.	:	PÁrUÉ M§âgÉÃ ºÉÆÃUÀ¨ÁgÀzÀÄ.
7.	CªÀ¼ÀÄ ZÉ£ÁßV ºÁqÀÄ ºÉÃ¼ÁÛ¼É.	:	£À£ÀUÉ gÀªÀiÁ ¸ÀAVÃvÀ PÀ°¸ÁÛ¼É.
8.	gÉÊvÀgÀÄ PÀµÀÖ¥ÀlÄÖ PÉ®¸À ªÀiÁqÁÛgÉ.	:	PÀÆ°UÀ¼ÀÄ vÀÄA¨Á §qÀªÀgÀÄ.
9.	ºÀ¸ÀÄ ºÀ¹ ºÀÄ®Äè w£ÀÄßvÉÛ.	:	JªÉÄä PÉÆZÉÑÃ° ªÀÄ®UÀÄvÉÛ.
10.	gÀ« ¥ÀÄ¸ÀÛPÀ NzÁÛ£É.	:	¸ÀÄgÉÃ±À avÀæ £ÉÆÃqÁÛ£É.
11.	£ÀªÀÄä vÁ¬Ä PÉ®¸À ªÀiÁqÁÛgÉ.	:	¤ªÀÄä CtÚ C°è ºÉÆÃVÛzÁÝgÉ.
12.	UÉÆÃ¦ ºÀwÛgÀ zÀÄqÀÄØ E®è.	:	gÁªÀÄÄ £À£ÀUÉ ºÀt PÉÆqÀ¨ÉÃPÀÄ.
13.	£ÀªÀÄä £Á¬Ä vÀÄA¨Á ZÉ£ÁßVzÉ.	:	¨ÉPÀÄÌ ªÀÄ£É ªÉÄÃ¯É NqÀÄvÁÛ EzÉ.
14.	£ÀªÀÄä ªÀÄ£É ºÀwÛgÀ ªÀiÁPÉðmï EzÉ.	:	¨ÉPÀÄÌ ªÀÄ£É ªÉÄÃ¯É NqÀÄvÁÛ EzÉ.
15.	EªÀvÀÄÛ CªÀ£À ªÀÄ£ÉÃ° ºÀ§â.	:	£Á¯É EªÀ£À ºÀ½îAiÀÄ°è eÁvÉæ.
16.	¹ÃvÉ ªÀÄ£ÉÃ° UÀÄ¯Á© VqÀ EzÉ.	:	PÀªÀÄ®£À vÉÆÃlzÀ°è ªÀÄ°èUÉ VqÀ EzÉ.
17.	C°è ªÀÄgÀzÀ PÀÄað EzÉ.	:	E°è ¹éÃmï mÉÃ§¯ï EzÉ.
18.	¢£Á ¨É½UÉÎ PÉÆÃ½	:	¸ÀAeÉ DgÀÄ WÀAmÉUÉ

	PÀÆUÀÄvÉÛ.		PÀvÀÛ¯ÁUÀÄvÉÛ.
19.	F gÀ¸ÉÛÃ° ªÁºÀ£ÀUÀ¼À NqÁl eÁ¹Û.	:	D ¢£À MAzÀÄ DQìqÉAmï DAiÀÄÄÛ.
20.	±ÉÆÃ¨sÀ PÉA¥ÀÄ ®AUÀ ºÁPÉÆÌArzÁ¼É.	:	°Ã® ºÀ¹gÀÄ ¹ÃgÉ GmÉÆÌArzÁÝ¼É.
21.	D ¥ÀQë DPÁ±ÀzÀ°è ºÁvÁð EzÉ.	:	J¯Áè PÁUÉUÀ¼À §tÚ PÀ¥ÀÄà.
22.	zÉÆÃtÂAiÀÄ°è ¤Ãj£À ªÉÄÃ¯É ºÉÆÃUÀ§ºÀÄzÀÄ.	:	ºÀqÀV£À°è HjAzÀ HjUÉ ºÉÆÃVÛÃ«.
23.	£ÀªÀÄä ªÀÄ£É ºÀwÛgÀ CAUÀr EzÉ.	:	¤ªÀÄä §mÉÖ ªÁå¥ÁgÀ eÉÆÃgÁVzÉ.
24.	£Á£ÀÄ ±À¤ªÁgÀ zÉÃªÀ¸ÁÜ£ÀPÉÌ ºÉÆÃVzÉÝ.	:	¤Ã£ÀÄ EªÀvÀÄÛ ¥ÀÆeÉ ªÀiÁqÀ¨ÉÃPÀÄ.
25.	£À£Àß vÀAV ºÀwÛgÀ §¼É EzÉ.	:	¤£Àß CPÀÌ£À ¸ÀgÀ ZÉ£ÁßVzÉ.