INFLUENCE OF AGE, COGNITION AND PROFICIENCY OF THE NON-NATIVE BACKGROUND LANGUAGE ON SPEECH RECOGNITION OF NATIVE LANGUAGE

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CERTIFICATE

This is to certify that this dissertation entitled **"The Influence of Age, Cognition and Proficiency of the Non-Native Background Language on Speech Recognition of Native Language"** is the bonafide work submitted in part fulfillment for the Degree of Master of Science (Audiology) of the student with Registration No: **18AUD021**. 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 other Diploma or Degree.

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CERTIFICATE

This is to certify that this dissertation entitled **"The Influence of Age, Cognition and Proficiency of the Non-Native Background Language on Speech Recognition of Native Language"** has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru,
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DECLARATION

This is to certify that this Master's dissertation entitled **"The Influence of Age, Cognition and Proficiency of the Non-Native Background Language on Speech Recognition of Native Language"** is the result of my own study under the guidance of Dr. Geetha C., Reader in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysuru, and has not been submitted earlier in other University for the award of any Diploma or Degree.

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ABSTRACT

Due to age-related decline occurring in the auditory and higher-order processing centers, older individuals face more difficulty in comprehending speech in the noisy backgrounds than younger adults. The aim of the present study was to determine the influence of age and language of the background speech babble (native (Kannada) vs. non-native two-talker babbles (Tamil, Telugu, Hindi and English)) on speech recognition of Kannada sentences. The study also aimed to assess the relationship between proficiency of each of the background languages, working memory and speech recognition of Kannada sentences in older Kannada-English bilingual speakers. The Kannada sentence recognition performance was measured for 20 young and 14 older adults in the presence of five two-talker babbles. The language proficiency scores (all five languages) were acquired for all participants and digit span scores were obtained only for the older adults. The results revealed poor recognition scores in Kannada and English two-talker babble conditions which implies that both linguistic familiarity and similarity could play a role in release from masking. Further, the older group performed poorly due to their age-related decline in cognitive functions despite achieving release from masking. The relationship between language proficiency scores and recognition scores across five babble conditions revealed a negative correlation only for Kannada proficiency with Kannada babble condition. This proves that linguistic similarity plays major role than linguistic familiarity in release from masking. The correlation analysis between auditory working memory (forward and backward digit span scores) and the speech recognition scores in older adults failed to reveal significant correlation among

most conditions which could be due to the lack of linguistic complexity of the stimuli used to assess auditory working memory.

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CHAPTER 1

INTRODUCTION

Speech mostly occurs in the presence of an interfering acoustical activity. Our brain has the unique capability to separate speech from background noise, which aids in speech perception (Bregman, 1990). Several studies were done in the past to evaluate the influence of one language (usually non-native language) on speech perception of native language. Presence of more than one language in the environment is common due to the influence of modern mass media like cinema, newspaper and television, and migration of people from one state to other for many reasons such as studies, business, etc. Studies had reported an improvement in the perception of speech when the distracter was of a different language from the target (Van Engen, 2007). Calandruccio et al. (2013) had observed linguistic masking release between language pairs English-Dutch and English-Mandarin. The release was higher for English and Mandarin language pairs since there were many dissimilarities between the two languages. Apart from the linguistic differences between the languages, it has also been reported that the amount of knowledge of the target and the background language modulates the size of the release from masking (Brouwer & Bradlow, 2014).

In the Indian context, a few studies have assessed the influence of background language on speech perception of native language (Preeta, 2015; Raja Suman, 2018; Shashank, 2017). Preetha (2015) reported that Kannada sentence recognition scores in the presence of two-talker English babble were better than that of Kannada babble in Kannada-English bilingual listeners. Shashank (2017) had obtained Kannada word recognition scores in native Kannada speaking children and adults in the presence of two-talker Kannada and Hindi babbles. The results revealed significantly better recognition scores for Hindi babble than Kannada babble. The authors have reasoned that it is due to the linguistic mismatch between the target and the masker, hence informational masking is less leading to better recognition scores in the presence of the non-native babble than in the presence of native language babble.

Raja Suman (2018) studied the influence of two-talker babbles of native (Kannada) and four different non-native languages that varied in degree of proficiency (Tamil, Telugu, Nepali, and English) on Kannada sentence recognition. The study also aimed to assess the relationship between proficiency of each of the background languages and speech recognition of Kannada sentences in Kannada speakers. The results showed that speech recognition scores (SRS) for Kannada sentences were better when a non-native babble (Tamil, Telugu, English, Nepali) was used than native babble (Kannada) in Kannada-English bilinguals. Additionally, a negative correlation was found between proficiency of Kannada, Tamil, and Telugu and the SRS, whereas English and Nepali revealed no correlation.

All the above-mentioned studies have assessed the influence of speech babble constructed with different languages on speech perception in young adults. Due to age-related decline occurring in the auditory and higher-order processing centers older individuals face more difficulty in comprehending speech in the noisy backgrounds than adults (Gennis et al., 1991; Helfer & Freyman, 2008; Wong et al., 2009; Anderson et al., 2013). Tun et al. (2002) reported that the target speech recall had more significant interference in older listeners than younger individuals when the distractor was meaningful. This information could help in predicting that older adults could utilize linguistic mismatch to perform in speech intelligibility tasks. Alageel, Sheft, and Shafiro (2017) had observed a significant linguistic release of masking in older adults with and without hearing loss for speech identification in English-Spanish language pairs.

Ingvalson, et al. (2017) had studied the speech perception of accented sentences in older and younger adults in correlation with the cognitive functions. The cognitive functions that could predict the speech recognition in adults were different from that of younger adults. There was an association between the speech perception performance and working memory in older adults. Besides, older adults exhibited less accuracy in accented speech perception than younger adults.

Whereas, Schoof and Rosen (2014) had reported that the speech reception thresholds (SRT) in the presence of two-talker babble did not correlate with the cognitive processing skills (working memory and processing speed). However, the older adult group exhibited declines in these cognitive skills. The older individuals performed well in speech recognition task in the presence of amplitude-modulated and steady-state noise conditions despite their cognitive decline suggesting that the auditory and cognitive processes involved in perceiving speech in noise could differ depending on the type of masker.

1.1.The Need for the Study

There are several studies done to assess the effects of language used to construct speech babble on the listener's speech recognition in their native language. Studies have shown that the linguistic content of masker can influence speech recognition (Preeta, 2015; Raja Suman, 2018; Shashank, 2017; Van Engen & Bradlow, 2007; Vineetha, Suma & Nair, 2013). However, the role of certain factors such as age, language proficiency is not well documented. Hence, there is a need to evaluate these factors in the context of informational masking.

1.1.1 *Need for studying the role of age and cognition on the speech perception in the presence of speech babble*

For comprehension of speech in the presence of noise, normal listeners undergo sequential and concurrent streaming of speech from noise. In addition to streaming, working memory also plays a role in understanding speech in noise. Studies have shown that these cognitive tasks are affected as the individual ages (Snyder & Alain, 2007; Waters & Caplan, 2005). Nevertheless, the results of the studies evaluating the role of age and cognition on speech perception in the presence of speech babble are inconsistent. Though research has shown that older adults are more susceptible to informational masking than young adults (Arbogast, Mason, & Kidd Jr, 2005; Agus et al., 2009: Li et al., 2004;), a few studies did not show a difference between the two age groups (Larsby et al., 2005; Schoof & Rosen, 2014) or did not show any association between working memory and SRS of normal hearing older adults (Schoof & Rosen, 2014).

In the study conducted by Alageel et al. (2017), speech recognition performance was assessed in younger and older adults in the presence of native and non-native speech babbles. They observed a significant release of masking in older adults with normal hearing and mild hearing loss, although the effect was lesser when compared to younger adults. Whereas Larsby et al. (2005) had observed that although the normal hearing older group exhibited more distraction from meaningful noise and had longer reaction times, the perceived effort was not higher when compared to the normal hearing younger adults.

Ronnberg et al (2008) describes working memory as a factor that connects the linguistic input with the phonological representations in semantic long-term memory. Thus, any age-related declines in working memory or limited linguistic input due to background noise/competing message could potentially affect speech perception. A study conducted by Gordan-Salant and Fitzgibbons (1997) reported that normal elderly listeners, when compared to younger listeners, performed poorly in sentence recall task but not for word recall task. Hence, they concluded that elderly listeners' speech understanding performance in noise can be affected by the added memory demands of a sentence recognition task.

However, evidences provided by Schoof and Rosen (2014) showed that the SRS in the presence of two-talker babble did not correlate with the cognitive processing skills (working memory and processing speed) though the older adult group exhibited declines in these cognitive skills. The older individuals performed well for speech recognition in amplitude-modulated and steady-state noise conditions despite their cognitive decline. These equivocal results found by studies evaluating the influence of age and cognition on native language perception mandate the need to investigate the influence of age on speech perception in the presence of different language babbles and the correlation between the cognitive skills and speech performance in older adults.

1.1.2. ***Need for including two-talker speech babbles constructed using different languages as maskers***

A few studies have investigated the influence of background language on speech perception using multi-talker babble (four, six or ten-talker) as a masker (Anitha, 2003; Jain et al., 2014). When there are many speech streams in the babble, the semantics of the multi-talker babble is lost and it is perceived as speech noise. More informational masking was observed if the number of the competing speech streams were smaller. Freyman et al., (2004) had observed a similar increase in informational masking on the open-set sentence recognition test when lesser talkers were used in the babble.

Speech-on-speech recognition in the presence of two-talker maskers containing languages distinct from the target speech showed significant reductions in information masking (Freyman et al., 2001; Van Engen & Bradlow, 2007). Moreover, maximum informational masking was found to occur for two-talker babbles (Freyman et al., 2004). Hence, it is essential to study the effect of speech babble with a lesser number of talkers to test the influence of the language content of the masker. Also, the auditory and cognitive processes involved in perceiving speech in noise could differ depending on the type of masker (Schoof & Rosen, 2014).

In the Indian context, few studies had assessed the influence of background language on speech perception (Vineetha et al., 2013; Jain et al., 2014; Raja Suman, 2018). However, Preeta (2015) and Shashank (2017) had chosen a non-native language that was quite familiar to the listeners. For example, the non-native language considered in Preeta's study was English. The participants in her study were Kannada-English bilinguals with Kannada as a native language.

Though most regions and schools in Karnataka teach English and Hindi as second languages, the exposure to other languages is abundant, especially those which are spoken predominantly in south India such as Tamil, Telugu, and Malayalam. In the present study, in addition to the south Indian languages (Tamil and Telugu), Hindi, an Indo-Aryan language, is also considered. It is a familiar language among many since it is being taught as a third language in many schools, although proficient use of the language is less than Kannada. Tamil, Telugu, and Kannada, although belong to a Dravidian language family, there are significant linguistic and phonetic dissimilarities between these languages. Nevertheless, the linguistic distance between Telugu and Kannada is less compared to Tamil. Hence, the five different background languages represent different degrees of proficiency.

Raja Suman (2018) has evaluated the influence of different languages (Kannada, English, Tamil, Telugu and Nepali) varying in the degree of proficiency in younger adults. The same has not been evaluated in older adults. In younger adults, the lowest SRS was obtained in the presence of Kannada babble, followed by Telugu, English, and Tamil babbles (Raja Suman, 2018). Thus, the study would help to find out whether older adults with normal hearing would follow the same trend as younger adults or vice versa. Since the amount of exposure to the target language would be much more in older adults, one could expect differences in terms of speech perception when considering the influence of the proficiency of the background language. Alageel et al. (2017) investigated the presence of release of masking in native English-speaking older adults in the presence of a single non-native language babble (Spanish) and not in the presence of more than one non-native babbles with varying proficiency. Hence, there is a need to investigate the effect of native (Kannada) vs. non-native maskers (Tamil, Telugu, Hindi, English) on the native language perception in older adults; and the correlation between the proficiency of the language and speech perception in the presence of speech babble in older adults.

1.2.Aim of the study

The present study aimed to assess the influence of age and two-talker babbles of native (Kannada) vs. non-native languages (Tamil, Telugu, Hindi, and English) on speech recognition of Kannada sentences. The study also aimed to assess the relationship between working memory, proficiency of each of the background languages and speech recognition of Kannada sentences in Kannada speakers in older adults.

1.3.Objectives of the study

The objectives of the present study are-

1. To assess the effect of native (Kannada) and non-native maskers (Tamil, Telugu, Hindi, English) on the native language perception in older adults.

2. To evaluate the relationship between the proficiency of each of the background languages and speech recognition of Kannada (native) sentences in older adults.

3. To assess the effect of age on native language perception,

4. To evaluate the relationship between working memory and speech recognition of Kannada (native) sentences in older adults.

CHAPTER 2

REVIEW OF LITERATURE

Young individuals with normal hearing are often capable of separating the unwanted competing signals from the speech signal. Due to aging, the ability to segregate and direct their attention towards speech reduces leading to difficulties in understanding speech under adverse conditions even if they possess normal audiometric thresholds (Gordon Salant & Fitzgibbons, 1993). Difficulties faced while perceiving speech under adverse conditions is commonly termed as “cocktail party problem” (Cherry, 1953). The cocktail party problem in elderly listeners can be due to changes in the peripheral system, cognition (Frisina & Frisina, 1997; Tun et al., 2002) and auditory processing (Ross et al., 2010; Tremblay et al., 2003) due to aging.

The adverse conditions in which elderly individuals exhibit poorer speech recognition scores include background noise (Dubno, Dirks, & Morgan, 1984), reverberation (Helfer & Wilber, 1990), or when signal is time-compressed (Gordon-Salant & Fitzgibbons, 1993) in comparison to younger individuals. Carhart et al. (1969) reported that competing speech causes more detrimental effects of masking than other noises amidst the presence of spectral and temporal fluctuations caused by energetic and informational masking.

Informational masking occurs when the target speech is often confused with two or more talkers; hence target speech is represented peripherally and centrally unlike energetic masking wherein the target speech is covered up by the masker at a peripheral level (Helfer & Feryman, 2008). Masker's linguistic content (Simpson & Cooke, 2005) or other factors such as native or familiar speech babble (Brouwer et al., 2012; Jain et al., 2014) majorly determine the amount of informational masking.

The present study aimed to determine the role of age, working memory, and language proficiency of the background speech babble in native language sentence perception. The studies related to the informational masking and the factors affecting the informational masking are reviewed under the following headings:

2.1 Informational masking

2.2. Factors influencing informational masking

2.2.1. Role of linguistic similarity between that target and the masker in speech perception

2.2.2. Effect of age on informational masking

2.2.3. Number of competing talkers on informational masking

2.2.4. Effect of signal to noise ratio on informational masking

2.2.5. Role of F_0 or gender of the talker on informational masking

2.2.6. Role of cognition and memory in informational masking

2.1 Informational masking

Informational masking results from similar acoustic or linguistic properties between the signal and the masker making them difficult to separate and thus interfering with the recognition of the target at a more central processing level (Mattys et al., 2009;

Brouwer et al., 2012). It involves several stages of processing that interact with each other, such as, separation and perceptual streaming of auditory spectral components to form auditory objects, attention, working memory along with other executive and cognitive processes. Hence, there are several factors that could affect informational masking (Durlach, 2003). This section of the study focuses on major factors that could affect informational masking.

2.2. Factors influencing informational masking

Informational masking depends on factors that inhibit or facilitate stream segregation (Cunningham, 2008; Goosens et al., 2016), including linguistic, such as, differences in language between masker and target (Cooke et al., 2008; Brouwer et al., 2012), the signal-to-noise ratio (Freyman et al., 1999), number of talkers in masker babble (Simpson & Cooke, 2005), age and cognition (Pichora-Fuller, 1995; Cherry,1953; Koch et al., 2011). Other factors that can also affect the release of masking are the spatial orientation of masker and target (Arbogast et al., 2002), accentedness (Calandruccio et al., 2010), and gender of a talker (Brungart et al., 2001).

2.2.1. *Role of linguistic similarity between that target and the masker in speech perception*

Linguistic similarity between that target and the masker is one of the crucial factors affecting informational masking. According to the *target-masker similarity hypothesis* (Brouwer et al., 2012), the more similar the target and the masker are, the harder it is to separate them perceptually. One of the assumptions of the hypothesis is that dissimilarity of language between the target and the masker speech could improve recognition of target speech (Van Engen & Bradlow, 2010; Calandruccio et al., 2010; Brouwer et al., 2012).

In support of this notion, various experiments have been conducted to understand the influence of native, unfamiliar or non-native language on the perception of sentences in native language (Cooke et al., 2008; Brouwer et al., 2012; Calandruccio et al., 2013; Vineetha et al., 2013; Jain et al., 2014) and they report that speech recognition was better when the content of the masker was different (non-native or unfamiliar) from the target speech (native). Such dissimilarity between the target and masker provides a more uncomplicated perceptual segregation, causing lesser confusion for the listener to understand the target speech (Brouwer et al., 2012).

Engen and Bradlow (2007) studied the effect of native language perception in native listeners and non-native listeners in the presence of babbles constructed with native and non-native languages. The results revealed that native English listeners performed better in the presence of Mandarin babble than the English babble due to the "linguistic interference" caused by the similarity between the target (English) and masker (English babble) languages. Van Engen (2009) reported similar results wherein native English-speaking listeners received a more significant release from masking with Mandarin speech babble, and Mandarin-speaking listeners experienced relatively higher interference from Mandarin two-talker babble.

While the above studies dealt with monolingual listeners, Brouwer et al. (2012) had investigated the perception of native (English) and non-native (Dutch) sentences in English monolinguals and English-Dutch bilinguals in the presence of English and Dutch two-talker babbles which consisted of meaningful and semantically mismatched sentences. The observed release of masking in the English-Dutch bilinguals was significant when the target and masker were mismatched and observed more difficulty with native language masker or semantically anomalous with the target sentence. Calandruccio and Zhou (2014) found similar results with English-Greek bilinguals. An Indian study conducted by Raja Suman (2018) studied the influence of two-talker babbles of native (Kannada) and non-native languages (Tamil, Telugu, Nepali, and English) on speech recognition. The results showed that SRS for Kannada sentences were better in the presence of non-native babble (Tamil, Telugu, English, Nepali) than native babble (Kannada) in Kannada-English bilinguals.

However, Mattys et al. (2010) had observed no differences in English-Cantonese bilinguals' English phrase recognition scores when presented in the presence of English and Cantonese one-talker babble. They posited that non-native listeners relied on the acoustic cues of the target and not on the lexical-semantic information of the competing language. This experiment included two-word phrases as the target since target sentences used in other studies provide higher cognitive load that reduces the ability to understand speech in the native language context. Even Vineetha et al. (2013) had noticed no perceptual benefit of speech recognition with a linguistic mismatch in Kannada-English bilinguals. The possible reason could be due to the equal proficiency of both native and non-native languages within the participants and the higher number of talkers for the competing speech. The above findings suggest that informational masking is more effective when the masker language is known to the listener due to the involvement of higher-order decoding processes that are specific to certain languages (Cooke et al., 2008).

The second assumption of the target-masker similarity hypothesis is that the listener’s familiarity or knowledge of the target or masker language could influence the target-masker similarity. A study conducted by Lecumberri and Cooke (2006) observed masking release in Spanish-English bilinguals in both Spanish and English background masker conditions using English consonant recognition. Authors suggest that Spanish background would be more difficult to ignore than English background speech, but the linguistic familiarity of the English language would have also played a significant role.

Furthermore, Van Engen (2007) observed the masking release of English target speech from either Mandarin or English background speech. They showed reduced masking release in Mandarin-English bilinguals compared to English native listeners when masker language changed from Mandarin to English. Hence, these studies suggested that a listener's familiarity with the target or masker language could affect target speech recognition.

Presently, due to the advancement in media technology, people currently are exposed to other non-native languages. Findings from an Indian study conducted by Jain et al. (2014) showed that the Kannada listeners performed well in the presence of familiar language (Kannada) six and ten- talker speech babbles than in the unfamiliar language (Malayalam) babble condition. These findings are contradictory to previous studies (Cooke et al., 2008; Brouwer et al., 2012; Calandruccio et al., 2013) which had shown a decrease in recognition scores when native language babble was used rather than a non-native language babble. The authors hypothesized that this was due to the cognitive factors wherein the participants got more distracted with the unfamiliar language as the background. Moreover, in both Kannada and Malayalam as Dravidian languages, the phonetic-acoustic similarity could have caused the differences in the results.

People are exposed to more than one language due to modern media, school, migration to another country, or state in search of education or job would be familiar with other non-native languages. Therefore, assessing an individual's non-native language proficiency will help us understand it is influence on their speech scores. The study was conducted by Raja Suman (2018) to assess the relationship between familiarity/proficiency of each of the background language (English, Kannada, Hindi, Tamil & Telugu) and speech recognition of Kannada sentences in Kannada speakers. Results revealed a negative correlation between language proficiency and speech recognition scores for Kannada, Tamil, and Telugu, whereas English, and Nepali revealed no correlation.

However, these findings contradicted the findings of Brouwer et al. (2012) and Van Engen (2010). They indicated that sentence recognition in the second language was more difficult than when the masker language was in their second language compared to their native language. Thus, stating that target speech was most difficult to understand when the masker speech was linguistically similar to the target speech, regardless of the target’s knowledge of the competing language.

To conclude, though there are multiple studies evaluating the influence of background language, only the study conducted by Raja Suman (2018) had evaluated the influence of different languages varying in the degree of familiarity in younger adults. Raja Suman had not included older adults. The amount of exposure to the target language would be much more in older adults, thus, one could expect differences in terms of speech perception when considering the influence of proficiency of the background language. Hence, the present study included older listeners.

2.2.2. Effect of age on informational masking

Age-related deterioration of speech perception abilities could be due to the changes occurring in the peripheral and central auditory systems including the cognitive structures (Humes & Dubno, 2010). Typically, older individuals have increased difficulty perceiving speech in complex listening environments particularly in the presence of another competing speech than younger adults even under controlled conditions (Humes & Dubno, 2010). Studies suggest a more significant informational masking in the elderly could be attributed to the age-related decline in cognitive factors such as, attention, working memory, and inhibition (Pichora-Fuller & Souza, 2003; Rajan & Cainer, 2008; Humes & Dubno, 2010).

Amidst these age-related changes, Agus et al. (2009) had reported that both young and older subjects were equally inclined to informational masking. Zobel et al. (2019) conducted an experiment to assess the effect of aging on spatial release from informational masking. The study included native Dutch-speaking young and elderly listeners and their performance on word and sentence identification amidst a two-talker babble (different special orientations) was measured. Their results revealed an age-related decline in masking release although both groups exhibited benefit from the mismatch in the spatial orientations. As higher order cognitive functions deteriorate with age, the ability to segregate quickly and analyze auditory objects declines which in turn causes a reduction in amount of masking release (Anderson & Craik, 2017; Drag & Bieliauskas, 2010).

In light to linguistic mismatch, Tun et al. (2002) had assessed target speech recall (English) in older and younger adults in the presence of background masker composed of either meaningful utterances or non-meaningful random strings of words or an unfamiliar language (Spanish). Their results indicated that older adults performed poorly compared to younger adults, especially when the distractor was meaningful.

Alageel et al. (2017) had also investigated the effects of aging on linguistic release of masking. Participants of their study were native English listeners who were instructed to listen to English sentences amidst two-talker Spanish or English babble maskers at different SNRs (-2.5, 0, and 2.5 dB typical for both). They revealed that older adults (normal hearing or a mild hearing loss) benefitted from linguistic dissimilarity between the target and masker and were able to achieve a release from informational masking. In terms of masking release, there was no significant differences observed between the groups.

While Li et al. (2004) failed to show any age-related changes in release of masking, the above study states otherwise, that is, young adult listeners demonstrated a slightly higher linguistic release than older adults though the dissimilarity between the signal and the masker was shown to be beneficial for both the groups. The authors attribute factors such as distortion in auditory processing, cognitive status, and diplistening ability, which would have contributed to the decline in the performance of older adult listeners despite normal hearing thresholds. The equivocal results from the earlier studies compelled the need for the current study wherein the native language perception in older adults in the presence of more than one non-native babbles with varying proficiency was assessed.

2.2.3. Effect of number of talkers in the speech babble on information masking

A study done by Miller (1947) assessed the intelligibility of words when presented in multi-talker babble conditions, ranging from one to eight talkers. They found that the difference in masking effect was equal to SRT difference of approximately 8 dB for a single-talker babble over a two-talker babble and speech babbles consisting of 4-, 6- and 8-talkers resulted in an additional masking of over 3 to 4 dB. Thus, their findings indicate that there was a gradual decline in intelligibility as the number of talkers increases. Moreover, Danhauer and Leppler (1979) reported that consonants recognized in 4-, 9- talker babble conditions were less compared to white noise at SNR below 5 dB.

Carhart et al. (1975) assessed the intelligibility of spondees in a multi-talker babble with varying number of talkers (1, 2, 3, 16, 32, 64, 128, ∞). Results revealed that the intelligibility scores between the multi-talker babble and speech noise varied with the increase in the number of talkers. One talker babble condition obtained a minimum difference of 6.2 and a maximum of 9.8 in the three-talker condition, whereby it gradually decreased and stabilized as the speakers increased. Consequently, they concluded that two, three, and four-talker babbles are effective in informational masking.

Using sentence recognition tasks, Rosen et al. (2013) assessed the recognition thresholds in 14 adults with typical hearing in various masking conditions (unprocessed speech babble, noise-vocoded versions of the babbles, noise modulated with the wide-band envelope of the speech babbles, and unmodulated noise). The speech babble masker was composed of 1-, 2-, 4-, 8- and 16-talkers. They observed that the masker was most efficient when it was similar to that of the target. As the number of talkers increased (1 to 2 or 4), significant changes in subject performance was observed and minimal changes in 8- and 16- talker conditions. The words were more intelligible when maskers were composed of small number of talkers (1 and 2) and unintelligible in a 4-16 talker babble conditions.

Hence, an efficient information masking effect occurs when the number of talkers composed in a babble masker are less (2-, 3-, or 4). As the number of talkers within the masker increases, the lexical-semantic content decreases, leading to more energetic masking. Hence, in the present study, babbles composed of two talkers was used.

2.2.4. ***Effect of signal-to-noise ratios (SNRs) on information masking.***

A study conducted by Van Engan and Bradlow (2007) assessed the speech-in-noise recognition in native English-speaking listeners when the language of the competing 2- and 6-talker babble was either the same (English) or different (Mandarin) from the target (English) sentences. The performance scores were compared at different SNR values (+5, 0, and −5 dB). Results revealed that irrespective of the background language, listeners performed better at higher SNRs since segregating the target from the babble was better, attributing to the intensity cues. Similar conclusions were stated in several other studies (Brower et al., 2012; Brungart et al., 2001; Cooke et al., 2008; Wu et al., 2005)

In the Indian context, Jain et al. (2014) conducted an experiment to assess speech recognition in the presence of multi-talker babbles composed of native (Kannada) and non-native (Malayalam) languages at two different SNRs, -3 and 0 dB SNRs. The results obtained were similar to the previous findings wherein the speech recognition in noise was significantly better for higher (0 dB SNR) than lower (-3 dB SNR) SNRs for both the languages.

To conclude, linguistic masking release could be affected by energetic factors, and a significant masking release was observed only at higher SNRs in most studies. Hence, in the present study 0 dB SNR was chosen.

2.2.5. Role of F_0 or gender of the talker on information masking

Brungart et al. (2001) assessed the efficiency of speech recognition concerning the F_0 differences between talkers of target and speech masker. They obtained better speech perception scores when the F_0 was different between the target and the masker. According to the authors, the effect on speech perception scores was attributed to energetic masking when the target and masker talkers were the same. Additionally, lexical-semantic interferences due to the similarities between the talkers could affect the speech scores (informational masking).

Cooke et al. (2007) had studied native and non-native listener performances on speech recognition tasks for F_0 and gender differences. They reported that both natives and non-natives received equal benefits when the talkers' F_0 and gender were different. The same gender condition was found to be confusing for the non-natives but, similar pattern of performance was observed for native and non-natives in the same talker condition. Cullington and Zeng (2008) experimented on the amount of masking provided by female, male, and child maskers wherein they conclude that the female masker provided the least amount of masking compared to male and child maskers.

The current study had constructed a babble masker composed of two talkers, a male and a female talker, in order to avoid the F_0 cues (Brokx & Nooteboom, 1982) which could result in more informational masking. This was done as difference between the pitches of the target and masker increases the probability of errors such as omissions and substitutions while perceiving target speech.

2.2.6. Role of cognition and memory in informational masking.

Cooke et al. (2008) reported that the listener's focus could be divided by the presence of a distractor or babble, and this could have an impact on informational masking. Several reasons can cause such distractions like a change in the semantic content or might be other cross-modality distractors. The presence of a foreign language as a background could also deviate the attention of the listener (Jain et al., 2014). Kahneman (1973) stated that if any other task simultaneously executed with a speech task, the attention resources used to get exhausted or depleted.

Similarly, memory loads could also affect speech perception performance. Conditions like sequentially listening to multiple talkers have shown to involve more working memory resources than listening to a single target (Nusbaum & Morin, 1992) since it adds more linguistic complexity (Lewis, Vasishth, & Van Dyke, 2006). Authors reported that the representation of speech maintained in working memory is likely to be phonological (Mattys et al., 2012) means that reduced memory capacity affects sub-lexical and lexical processes, which are important for identifying known or unknown words (Morton & Patterson, 1980).

Studies consider working memory to be an essential process that aids in language processing during conversation, in paying attention to the conversation, retain its information and ignore the irrelevant information (Rudner et al., 2011). Studies have shown that these cognitive tasks are affected as the individual ages (Snyder & Alain, 2007; Waters & Caplan, 2005; Füllgrabe et al., 2015; Salant & Cole, 2016; Fullgrabe & Rosen, 2016). Nevertheless, the results of the studies evaluating the role of age and cognition on speech perception in the presence of speech babble are inconsistent. Fullgrabe and Rosen (2016) found that the speech intelligibility in noise scores correlated with working memory (reading span test) in normal-hearing older adults but not in younger adults. The authors reasoned that, since advancing age affects higher-order auditory signal processing, working memory-based compensatory mechanisms would help interpret the degraded internal representations of the speech signal.

Additionally, Ingvalson et al., (2017) had studied the speech perception of accented sentences in older and younger adults in correlation with the executive functions (inhibitory control, cognitive flexibility, and working memory). They found that the effects of working memory predicted the speech perception performance in older adults along with interactions of hearing acuity with inhibitory control and cognitive flexibility.

In contrast to the earlier findings, Nuesse et al. (2018) conducted a study in 46 elderly native German-speaking individuals wherein sentence perception test (in German) in five different adverse conditions, one of which included an informational masking condition (two-talker German babble). Cognition was measured using working memory (digit span and reading span tests). Their results indicated that there was no significant link between speech recognition and working and short-term memory. The authors stated the inefficiency of the selected cognitive tests set to precisely tap the cognitive functions involved in the understanding of speech in adverse listening conditions as a possible reason for their results.

Whereas, Schoof and Rosen (2014) had reported that the SRT in the presence of two-talker babble did not correlate with the cognitive processing skills (working memory and processing speed). However, the older adult group exhibited declines in these cognitive skills. The older individuals performed well in speech recognition in the presence of amplitude-modulated and steady-state noise conditions despite their cognitive decline suggesting that the auditory and cognitive processes involved in perceiving speech in noise could differ depending on the type of masker.

Since there are equivocal results of the influence of age and cognition on speech perception under complex conditions; the current study also aimed to investigate the correlation between the cognitive skills and speech performance in the presence of a familiar and unfamiliar language as maskers in older adults. In addition, babbles constructed with lesser number of talkers ensured informational masking and age-related declines in cognitive functions could influence speech understanding in such complex conditions. Thus, the present study aimed to check the role of age, working memory, and two-talker babbles of native (Kannada) and non-native languages (Tamil, Telugu, Hindi, and English) in sentence recognition. Moreover, the familiarity of non-native language babble could influence the speech recognition scores thus, the study also aimed to assess the relationship between proficiency of each of the background languages and speech recognition of Kannada sentences in Kannada-speaking older adults.

CHAPTER 3

METHOD

Standard group comparison method was used to determine the influence of age on the speech recognition performance of native Kannada sentences in the presence of speech babbles constructed using sentences in native and non-native language. This study also aimed to find the correlation between language proficiency, cognition of older listeners and their speech recognition scores. The study was carried out in five different stages which are:

I. Routine audiological evaluations.
II. Construction of two-talker babbles.
III. Assessment of speech recognition performance in the presence of different speech babbles.
IV. Assessment of language proficiency.
V. Assessment of auditory working memory.

3.1. Participants

A total of 34 participants (14 older adults and 20 younger adults) in the age range of 55 to 72 years (Mean = 59.21; SD = 4.38) and 18 to 25 years (Mean = 21.4; SD = 2.54) respectively, participated in the study.

All the participants were selected based on the inclusion criteria mentioned below.

- For older adults, the pure tone average (PTA) thresholds (four frequency) did not reveal disabling hearing loss (i.e. hearing thresholds were < 30 dB HL) while the younger adults had normal hearing thresholds (< 15 dB HL) (WHO, 2008).
- ‘A’ or ‘As’ type of tympanogram with ipsi-lateral and contra-lateral acoustic reflexes were present in both the ears.
- SPIN scores were above 60% at 0 dB SNR for both the groups.
- All the participants passed Minnesota Mental Status Examination (Folstein, Folstein & McHugh, 1975).
- All listeners were native Kannada speakers with English as their second language.
- All participants had a minimum of 12th grade of education in English medium school and had Kannada as their second language or Kannada medium school with English as their second language.

Informed consent was taken from the participants who fulfilled the above criteria. Participants were excluded from the study based on the following criteria:

- History of any otological, neurological, or speech and language disorders.
- Impairment in cognitive domains such as attention, executive function, and memory.

3.2. Test environment

The tests were carried out in a sound treated double room suite. The ambient noise levels had met the specifications detailed in Maximum Permissible Ambient Noise Levels for Audiometric Test Rooms (ANSI S3 -1999).

3.3. Instrumentation

- A calibrated diagnostic audiometer and the transducers TDH-39 headphones and B-71 bone vibrator (ANSI S3.6-2004 specifications) was used to conduct pure-tone and speech audiometry.
- A calibrated GSI-Tympstar immittance meter was used for immittance evaluation.
- HP intel core i3 laptop was used to present the stimulus.
- MOTU microbook II, acts as an audio interface between the microphone and the laptop, was used in order to record the passages read out by the speakers.

3.4. Materials used

- The speech recognition thresholds (SRT) were obtained using list of Kannada paired words developed at the Department of Audiology, AIISH.
- The Kannada PB word lists developed by Yathiraj and Vijayalakshmi (2005) were used to obtain Speech identification scores (SIS) and speech in noise (SPIN) scores.
- The Kannada sentence lists developed by Geetha, Kumar, Manjula and Pavan (2014) were used as target sentences to acquire the SRS in all the conditions.

- The auditory working memory was assessed using the digit span test which was run in a software ‘Smrithi-Shravan version 1.0’ developed by Kumar and Sandeep (2013).
- The language proficiency (of all five languages) was assessed using the Modified language Proficiency questionnaire developed by Yathiraj, Jain, and Amruthavarshini (2018).
- Reading passage from level II of the Early Reading Skills developed by Brajesh and Goswami (2012) and ‘Nariyal’ passage was used to record the Hindi two-talker babbles. Standardized reading passages (300 words) developed by Savithri and Jayaram (2005) and short stories from story books/newspapers was used to construct the Tamil, Telugu and Kannada two-talker babbles. The Rainbow passage developed by Fairbanks (1960) and a short story from a story book was used to construct the English two-talker babbles.

3.5. Procedure

3.5.1. Stage I: Routine audiological evaluation.

The pure tone thresholds were estimated using the Modified Hughson and Westlake procedure (Carhart & Jerger, 1959) and the pure tone average was calculated by considering the thresholds of 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz. Using 226 Hz probe tone, the tympanogram was obtained bilaterally by varying the pressure from +200 daPa to -200 daPa. The ipsi-lateral and contra-lateral acoustic reflexes were measured bilaterally for the frequencies 500 Hz, 1000 Hz and 2000 Hz (Jerger, 1970).

The Speech-In-Noise (SPIN) scores were estimated using the Kannada Phonemically Balanced (PB) word list developed by Yathiraj and Vijayalakshmi (2005) wherein the PB words were presented in the presence of noise at 0 dB SNR ipsi-laterally. The participants with sores above 60% at 0 dB SNR were selected for both the groups. Poor speech perception scores without accompanying pure tone changes can indicate central auditory decline (Helfer & Wilber, 1990) hence, participants scoring less 60% were rejected from the study.

3.5.2. Stage II: Construction of the two-talker babbles

Speakers. A male and a female native speaker each for all four languages (Kannada, Tamil, Telugu, & Hindi) were chosen to readout the reading passages/short stories. Speakers of both genders were considered in order to avoid the F_0 cues (Brokx & Nooteboom, 1982) which could result in more informational masking as the differences in the pitches of the target and the masker increases the probability of errors such as omissions and substitutions while perceiving target speech.

Recording. The native/proficient speakers of each of the five languages were selected to record the masker babbles. The passages or short stories read by the speakers were recorded using a condenser microphone, placed 10 cm away from the speaker's mouth, which was connected to MOTU microbook II. The recorded babble was analyzed in HP intel core i3 laptop with Adobe audition version 3 set as the platform. The recorded sample was normalized by 50% and mixed the babbles using Adobe Audition version 3 at sampling rate of 44.1 KHz. The average RMS values of the babbles and the Kannada sentences were recalculated such that they were presented at 0 dB SNR.

3.5.3. Stage III: Assessment of speech recognition performance in the presence of different speech babbles.

Presentation. The stimulus was presented diotically (the target and the masker given to both ears) from HP intel core i3 laptop through the TDH-39 headphones which was connected to calibrated diagnostic audiometer. The intensity of the stimuli was balanced so that it was presented at the Most Comfortable Level (MCL) of the listener. The listeners were instructed to accurately repeat the sentences orally and words repeated by the listener was marked in a scoring sheet.

Scoring. The scoring was based on the proper identification of the key words and each sentence within the list contains up to four key words. Maximum of forty key words were considered. The sentences were not repeated in order to avoid practice effect and the sentences in different conditions were presented randomly so that order effect is avoided.

3.5.4. Stage IV: Assessment of language proficiency.

The Modified Language Proficiency Questionnaire developed by Yathiraj, Jain, and Amruthavarshini (2018) was used to assess the language proficiency under categories such as understanding, speaking, reading and writing. The test material is a modified version of the adapted Language Experience and Proficiency Questionnaire (Maitreyee & Goswami, 2009). The questionnaire contains 8 set of questions wherein the subject was instructed to rate themselves on a scale of 1 (least) to 4 (highest) after the questions were read carefully. The maximum possible score is 100.

3.5.5. Stage V: Assessment of auditory working memory.

The auditory working memory of the older listeners was assessed using the auditory digit span test which was administered in two phases; forward and backward phase. This was done using the software 'Smrithi-Shravan version 1.0' (Kumar & Sandeep, 2013). The stimulus, consisting of digits from one to nine except seven, were presented randomly with increasing level of difficulty. Initially four digits were presented with 250 ms of inter stimulus interval and the string of digits increases (maximum up to 10 digits) with every correct response of the participant. In forward digit span test, the participants were presented with a random string of numbers and they were instructed to repeat these numbers in the same order as presented and in the backward span test, the listeners were asked to repeat the digits in the reverse order of presentation. The auditory working memory capacity was calculated as the total number of digits the listeners can recall out of 16 trials in sequencing and digit span. The scores were automatically calculated by the software and the final scores for each of the test were considered for analysis.

3.6. Statistical analysis

The statistical tests were carried out in Statistical Package for Social Sciences (SPSS) version 20 software. Shapiro-Wilks test of normality revealed that the data did not have normality, hence, non- parametric tests were used to analyze the data. Friedman's test was used to analyze the influence of two-talker babbles on SRS in older adults. Pair-wise comparisons of SRS in five two-talker babble conditions and language proficiency scores was carried out using Wilcoxon signed rank test. Spearman's rho correlation was used to study the relationship between language proficiency and SRS, between working memory scores and SRS. Mann-Whitney test was used to analyze the influence of age on SRS.

CHAPTER 4

RESULTS

The objective of the present study was to assess the influence of age and language of the babble (constructed with Kannada, Tamil, Telugu, Hindi and English) on speech recognition of Kannada sentences. The study also aimed to assess the relationship between proficiency of each of the background languages, working memory and speech recognition of Kannada sentences in older Kannada speakers. Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS) version 20. Shapiro-Wilks test of normality revealed that the data did not meet normality, hence, non-parametric tests were used to analyze the data.

4.1. Effect of native (Kannada) and non-native maskers (Tamil, Telugu, Hindi, English) on the native language perception in older adults.

The SRS was obtained in the presence of competing babbles constructed with five different babbles (Kannada, English, Hindi, Tamil and Telugu). The participants were scored according to the number of key words identified (maximum four within a sentence). Mean, standard deviation (SD) and interquartile range (IQR) of SRS obtained for different conditions in older adults are listed in the Table 4.1. The lowest mean SRS was obtained in English followed by Kannada babble conditions while the highest mean SRS was obtained in the presence of Tamil speech babble.

Table 4. 1

Mean, SD, Median and IQR of SRS in the presence of five different two-talker babble conditions (Kannada, English, Hindi, Tamil, and Telugu) in older adults.

Two-talker babble conditions	Older adults				
	N	Mean	SD	Median	IQR
Kannada two-talker babble	14	22.2143	3.21484	22.0000	5.25
English two-talker babble	14	20.5000	2.10311	20.0000	4.00
Hindi two-talker babble	14	30.5000	4.41588	32.0000	7.50
Tamil two-talker babble	14	32.1429	3.99725	33.5000	4.25
Telugu two-talker babble	14	30.1429	3.10972	30.0000	4.50

Note. Maximum possible speech recognition scores = 40; SRS = Speech recognition scores.

The Friedman's test results showed a significant effect of different language babbles on SRS in older adults [χ^2 (4) = 40.247, p < 0.05]. Pair-wise comparisons between the five two-talker babble conditions were carried out using Wilcoxon signed rank test (Table 4.2).

Table 4.2

Comparison of SRS between different language babbles in older adults using Wilcoxon signed rank test.

Conditions	Kannada two-talker babble	English two-talker babble	Hindi two-talker babble	Tamil two-talker babble	Telugu two-talker babble
Kannada two-talker babble					
English two-talker babble	-1.511				
Hindi two-talker babble	-3.113*	-3.300*			
Tamil two-talker babble	-3.299*	-3.191*	-1.263		
Telugu two-talker babble	-3.299*	-3.302*	-0.035	-2.331	

Note. *$p < 0.05$; SRS = Speech recognition scores.

The Wilcoxon signed rank test results revealed that SRS in the presence of Kannada babble was significantly different from that obtained in the presence of all other babbles except English. The same results were obtained in the presence of English babble. There was no significant difference between Hindi, Tamil and Telugu conditions.

4.2. Relationship between the proficiency of each of the background languages and speech recognition of Kannada (native) sentences in older adults.

The Modified Language Proficiency Questionnaire developed by Yathiraj, Jain, and Amruthavarshini (2018) was used to assess the language proficiency for all five languages (Kannada, English, Hindi, Tamil, and Telugu) in older adults. The participants (Kannada-English bilinguals) were scored out of 100. Table 4.3 shows Mean, SD and IQR of the language proficiency scores for all five languages in older adults.

The purpose of selecting English, Hindi, Tamil, and Telugu as non-native languages is that there is exposure to these languages is different in Karnataka and the proficiency of the language was expected to be different depending on the language. Hence, before carrying out the correlation analysis, Friedman's test was done to verify if there was actually a difference in proficiency between different languages.

Friedman's test results revealed a statistically significant difference [χ^2 (4) = 54.88, $p < 0.05$] among different conditions. Wilcoxon signed-rank test was used for pair-wise comparisons between the five proficiency scores. The results revealed a significant difference between the language proficiency scores between Kannada and English (Z = -3.304, $p < 0.05$), Hindi and Kannada (Z = -3.301, $p < 0.05$), Hindi and English (Z = -3.300, p < 0.05), Tamil and Kannada (Z = -3.301, $p < 0.05$), Tamil and English (Z = -

3.297, $p < 0.05$), Tamil and Hindi (Z = -3.305, $p < 0.05$), Telugu and Kannada (Z = -3.300, $p < 0.05$), Telugu and English (Z = -3.301, $p < 0.05$) & Telugu and Hindi (Z = -3.301, $p < 0.05$)]. There was no statistical difference in proficiency between Telugu and Tamil language proficiencies (Z = -1.965, $p > 0.05$).

Table 4.3

Mean, SD, Median and IQR of the language proficiency scores for all five languages (Kannada, English, Hindi, Tamil, and Telugu) in older adults.

Language proficiency	Older adults				
	N	Mean	SD	Median	IQR
Kannada proficiency	14	90.2143	2.86030	90.5000	4.75
English proficiency	14	71.5714	4.30946	71.5000	7.25
Hindi proficiency	14	43.1429	7.77429	42.0000	5.50
Tamil proficiency	14	20.0714	1.59153	20.0000	1.00
Telugu proficiency	14	21.7857	2.35922	20.0000	4.25

Note. Maximum possible proficiency scores = 100.

Table 4.4

Correlation between language proficiency scores and SRS of Kannada sentences obtained in the presence of five background languages in older adults.

Conditions	Kannada two-talker babble	English two-talker babble	Hindi two-talker babble	Tamil two-talker babble	Telugu two-talker babble
Kannada proficiency	-0.580*				
English proficiency		-0.197			
Hindi proficiency			-0.077		
Tamil proficiency				-0.037	
Telugu proficiency					-0.260

Note. * $p < 0.05$.

Spearman's rho correlation was used to analyze the correlation between the language proficiency scores of all five languages (Kannada, English, Hindi, Tamil, and

Telugu) and the SRS of Kannada sentences in five different language backgrounds (Kannada, English, Hindi, Tamil, and Telugu) in older adults. Table 4.4 depicts the results of correlation (ρ-rho) analysis for each of the conditions. The results revealed no correlation between language proficiency scores and the SRS ($p > 0.05$) in any of the conditions except a significant negative correlation of Kannada language proficiency with SRS in Kannada two-talker babble condition.

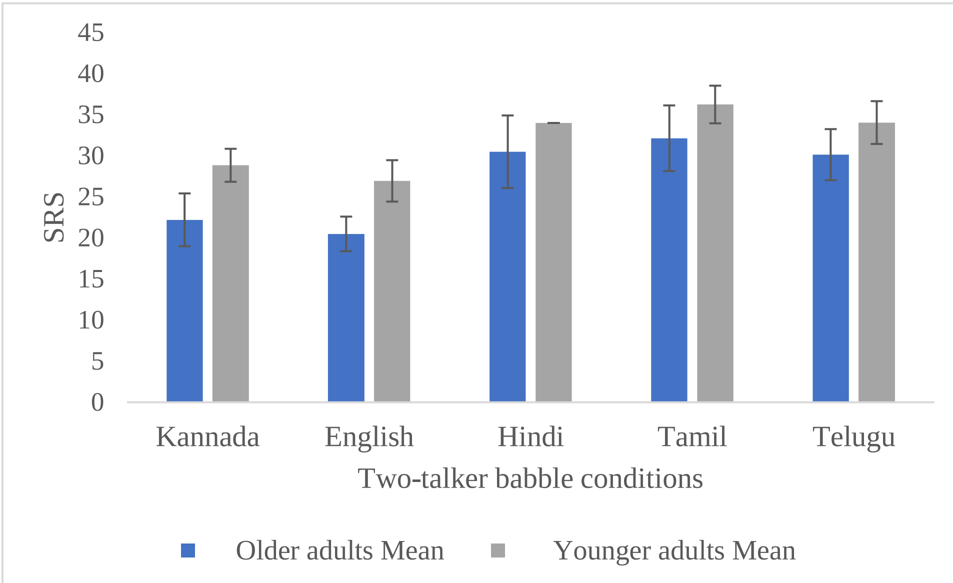
4.3. Effect of age on native language perception.

Figure 4.1 depicts the comparison of the mean SRS between younger and older adults across five two-talker babble conditions. The graph clearly indicates the difference in the performance scores wherein younger adults performed better than the older adults. Further, for both the groups, the highest mean scores were obtained in the Tamil and Telugu two-talker babble conditions while the lowest mean scores were obtained in Kannada and English two-talker babble conditions.

In order to assess the effect of age on the SRS Mann-Whitney U test was used. The results showed a significant difference between the SRS for younger and older adult groups in all conditions [Kannada ($Z= -4.541$, $p < 0.05$), English ($Z= -4.745$, $p < 0.05$), Tamil ($Z= -3.921$, $p < 0.05$), Telugu ($Z= -3.30$, $p < 0.05$) and Hindi ($Z= -2.505$, $p < 0.05$)]. The older adults obtained significantly poorer scores compared to the younger adult group.

Figure 4.1.

Comparison of the mean speech recognition scores (SRS) of older and younger adults across five two-talker babble conditions.



4.4. Relationship between working memory and speech recognition of Kannada (native) sentences in older adults.

The auditory working memory was assessed in two phases, forward and backward phases and their final scores, automatically calculated by the software 'Smrithi-Sravan', was considered for analysis. Spearman's rho correlation was used to compare the forward and backward digit scores with the SRS in five competing babble conditions for older adult group. The results of Spearman's rho correlation are given in Table 4.5.

The results revealed no significant correlation between the forward and backward digit span scores and SRS in older adults in most conditions. There was a significant difference only between forward digit span with Tamil two-talker babble condition, and backward digit span with Hindi two-talker babble condition.

Table 4.5

Correlation of SRS in five two-talker babble conditions with forward and backward digit span values in older adults.

	rho (**ρ**) value				
Conditions	Kannada two-talker babble	English two-talker babble	Hindi two-talker babble	Tamil two-talker babble	Telugu two-talker babble
Forward digit span	0.216	0.164	0.268	0.555*	0.246
Backward digit span	0.289	-0.082	-0.576*	-0.06	-0.139

Note. *$p < 0.05$; SRS= Speech recognition scores.

CHAPTER 5

DISCUSSION

The present study aimed to assess the influence of age and speech babble constructed with different non-native babbles on speech recognition. The study also aimed to assess the relationship between working memory and speech recognition, and the relationship between proficiency of each of the background languages and speech recognition of Kannada sentences in Kannada speakers in older adults.

5.1 Effect of native (Kannada) and non-native maskers (Tamil, Telugu, Hindi, English) on the native language perception in older adults.

The results indicated that the Kannada SRS was poor in the presence of native (Kannada) babble condition and significantly better for non-native babble conditions (Tamil, Telugu, Hindi) except English. These results are similar to the findings of Brouwer et al. (2012) wherein they found that the English-Dutch bilinguals had more difficulty with native language masker or when the masker was semantically similar to the target sentence. The authors reasoned that due to the lack of difference between the target and the masker languages, auditory segregation of target and masker becomes harder resulting in confusions. Thus, decrease in the informational masking in the presence of an unfamiliar or a non-native language masker provides a linguistic mismatch to improve speech perception (Calandruccio et al., 2010; Calandruccio & Zhou, 2014; Stibbard & Lee, 2006).

The results also revealed that poor SRS was obtained for the English two-talker babble condition which is a contradicting finding compared to the previous studies

(Cooke et al., 2008; Calandruccio et al., 2010; Van Engen & Bradlow, 2010; Calandruccio et al.,2013). Lecumberri and Cooke (2006) supported the notion that the target-masker similarity could depend on some listener-related factors such as listener's knowledge or familiarity with the target and masker languages. Their findings revealed that the monolingual (English) listeners experienced release from masking when the background speech was composed of an unknown language (Spanish). However, in the case of bilingual listeners, they did not benefit from Spanish competing speech. Although the above findings were in favor to the results of the current study, Van Engen (2010) and Brouwer et al. (2012) have reported results contradicting the suggestion that language familiarity alone is predictive of masking release. They found that sentence recognition in second language was more difficult when the masker language was also in their second language compared to their native language. Thus, stating that target speech was most difficult to understand when the masker speech was linguistically similar to the target speech, regardless of the listener's knowledge of the babble language.

The participants for the study were Kannada-English bilinguals, wherein their proficiency scores indicated non-native proficiency for English language and native-like proficiency for Kannada (according to the Modified Language Proficiency Questionnaire developed by Yathiraj et al., 2018). Despite the non-native proficiency for English language, listeners tend to be more familiar with English rather than other non-native languages (like Tamil or Hindi) since they were exposed to English since school-age and was used more frequently in everyday situations. This could render more intelligibility to the English two-talker babble masker hence affecting target recognition (Brouwer et al., 2012).

5.2. Relationship between the proficiency of each of the background languages and speech recognition of Kannada (native) sentences in older adults.

The Spearman's correlation indicated a statistically significant negative correlation only between Kannada proficiency scores and SRS obtained with Kannada two-talker babble. In the current study, the mean language proficiency scores were highest for Kannada followed by English, Hindi, Telugu and Tamil. The mean SRS for Kannada sentences was the least for Kannada and English two-talker babble conditions due the linguistic similarity between the target sentence and background babble in addition to listener's increased proficiency of the masker language (Brouwer et al., 2012). Similar results were obtained by Raja Suman (2018) in young Kannada-English bilingual listeners and reasoned that the proficiency of Kannada language is the highest, as expected, had adversely affected the Kannada sentence perception when Kannada two-talker babble was used. Moreover, Calandruccio and Zhou (2014) conducted a study on English-Greek bilinguals (proficient in both English and Greek languages) and English-speaking monolinguals. Results revealed that the monolingual group had exhibited a slightly better performance in the target-masker mismatched condition although a statistical significance was not found. This proves that although both linguistic similarity and familiarity influenced target perception, the differences between the target and masker languages have contributed majorly to the enhanced speech recognition (Calandruccio et al., 2010; Brouwer et al., 2012; Raja Suman, 2018).

Similarly, in the current study, the lowest proficiency scores were obtained for Tamil and Telugu languages while the highest SRS was obtained in Tamil and Telugu two-talker babble conditions. The improvement in Kannada sentence recognition could be attributed to the lack of familiarity towards the language of the babble, but majorly the language mismatch between the target and the masker has played a greater role considering the fact that a significant correlation was not found between Tamil and Telugu language proficiency and speech recognition in Tamil and Telugu two-talker babble conditions. Therefore, a listener's proficiency of the babble language could affect their target speech recognition abilities but the target-masker language mismatch has a much greater role in achieving release from masking.

5.3. Effect of age on native language perception.

The third objective was to determine the effect of age on SRS in five two-talker babble conditions. The SRS was compared between younger and older adult group and the results revealed a significant difference of SRS between the two groups. Although both groups benefitted from the linguistic mismatch but older adults exhibited poorer scores than younger adults. Informational masking can be affected by both top-down (eg., linguistic knowledge) and bottom-up (eg., spatial separation) factors and younger listeners are more efficient than elderly listeners in manipulating these cues to achieve release from masking. Tun et al. (2002) had reported that target speech recall was affected in older adults whether the competing masker was meaningful or not but greater interference in recall was observed for English (native) masker language than for Dutch (non-native). Authors reasoned that it was due to the fact that younger adults were more able to auditorily segregate the distractor speech from the target. Such selective listening could be a relative allocation of attentional resources to one source or another (Kahneman, 1973) occurring at a higher cognitive level. Since advancing age can have detrimental effects on cognitive tasks (Snyder & Alain, 2007; Waters & Caplan, 2005), older adults were unable to effectively segregate the distractor, despite of their meaningfulness, from the target speech.

The findings of the current study support the results of Alageel et al. (2017) which indicated that older adults performed more poorly than young adults at speech recognition in the presence of a speech masker although the older adults demonstrated significant benefit from linguistic mismatch between the target and the masker. The authors reasoned that older adults performed poorly due to deficits in temporal fine-structure processing (Sheft et al., 2012) which could have interfered with segregation of the target and masker talkers, reducing the availability of language specific acoustic cues that support linguistic masking release. Moreover, elderly subjects exhibited decreased target identification even though a prior information of the masker (two-talker babble) was provided (masker primer) compared to younger listeners (Feng et al., 2018). The poor segregation abilities could be attributed to the decline in the masker-priming effect which leads to decreased ability to inhibit the masker. An aging central auditory system fails to respond to this repeated interference thereby making it harder for the older adults to focus on the target even though they were familiarized with the masker prior to target presentation.

In terms of bottom-up cues, energetic components such as spatial separation of masker and target can affect informational masking. Zobel et al. (2019) conducted an experiment to assess the effect of aging on spatial release from informational masking. The study included native Dutch-speaking young and elderly listeners, and their performance on word and sentence recognition in the presence of two-talker babble (different special orientations) was assessed. Their results revealed an age-related decline in masking release although both groups exhibited benefit from the mismatch in the spatial orientations. Their results supported the findings of Helfer and Freyman (2008). As higher order cognitive functions deteriorate with age, the ability to segregate quickly and analyze auditory objects declines which in turn caused a decline in amount of masking release.

5.4. Relationship between working memory and speech recognition of Kannada (native) sentences in older adults.

As stated by Tun et al. (2002), executive control was important when the listener had to recall the target from background speech. It is also a known fact that aging can have detrimental effects on an individual's cognition, it could make them susceptible to informational masking (Arbogast et al., 2005; Agus et al., 2009; Li et al., 2004). Thus, the fourth objective of this study was to understand the relationship between auditory working memory (forward and backward digit span) and the SRS in five two-talker babbles in older adults. The results revealed only a significant correlation among two conditions; forward digit span and Tamil two-talker babble condition and also backward digit span with Hindi two-talker babble condition. With these correlational patterns it can be generalized that the auditory working memory did not completely influence the speech recognition scores in older adults which contradicts the findings of Pichora-Fuller et al., 2015; Ingvalson et al., 2017; Vermeire et al., 2019; Fullgrabe and Rosen, 2016b.

Whereas, findings of Schoof and Rosen (2014) reported that the speech reception thresholds (SRT) in the presence of two-talker babble did not correlate with the cognitive processing skills (working memory and processing speed) in older adults, although, the older adult group exhibited declines in these cognitive skills. They stated that age-related cognitive decline may not necessarily affect speech in noise recognition. Nuesse et al. (2018) conducted a study in 46 elderly native German-speaking individuals wherein sentence perception test (in German) in five different adverse conditions, one of which included an informational masking condition (two-talker German babble). A set of cognitive tests included tests for working memory (digit span and reading span tests). Their results indicated that there was no significant link between speech recognition and working and short memory. The authors stated the inefficiency of the selected cognitive tests set to precisely tap the cognitive functions involved in the understanding of speech in such adverse listening conditions as a possible reason for their results.

In order to test working memory, test materials and conditions must be chosen to closely approximate the complex listening task condition due to the modality-specific nature of working memory (Pichora-Fuller et al., 1995; Baldwin and Ash, 2011; Besser et al., 2013). Therefore, in the current study, if the test material was sentences or words instead of digits, there might have been more promising results.

Pichora-Fuller et al. (1995) assessed the age-related effects of working memory measured in two different modalities; listening working memory span (LSWM) and reading working memory span (RSWM). Sentences were used as target and was presented in quiet for the listening task. Results revealed that younger adult group outperformed the older adult group and the older adults performed poorly for the LSWM task compared to RSWM test. These findings were attributed to the age-related decline in higher-order auditory processing in older adults. Supporting findings were also found by Baldwin and Ash (2011). Therefore, according to these findings, an appropriate task (like

LSWM) may have the potential to tap the age-related deterioration in speech perception. As stated by Smith and Pichora-Fuller (2015), memory, repetition and speech comprehension were distinct factors and not overlapping with each other, hence, could be measured separately depending on the linguistic complexity of the test stimuli.

CHAPTER 6

SUMMARY AND CONCLUSION

The purpose of the present study was to determine the influence of age and language of the background speech babble (native (Kannada) vs. non-native two-talker babbles (Tamil, Telugu, Hindi and English)) on speech recognition of Kannada sentences. The study also aimed to assess the relationship between proficiency of each of the background languages and speech recognition, between working memory and speech recognition of Kannada sentences in older Kannada-English bilingual speakers.

The sentence recognition performance was assessed for 20 younger (Mean age = 21.4) and 14 older (Mean age = 59.21) Kannada-English bilinguals in the presence of native (Kannada) and non-native (English, Hindi, Tamil & Telugu) two-talker babbles. The results revealed that speech recognition in older adults was poorer in the presence of Kannada and English two-talker babble conditions compared to Tamil and Telugu two-talker babble conditions. This proves that older adults were able to take advantage of the linguistic mismatch between the target and the babble to improve speech perception. Additionally, both language similarity (Kannada) and language familiarity (English) between the target and the babble could have influenced the release from informational masking.

A self-rating questionnaire, consisting of four sections (understanding, speaking, writing and reading), was used to measure the language proficiency scores in older adults for all the five languages (Kannada, English, Hindi, Tamil & Telugu). Results of the statistical analysis carried out to determine the relationship between the language proficiency scores and SRS in five two-talker babble conditions revealed a significant negative correlation between Kannada language proficiency and SRS in Kannada speech babble. Across the other conditions, no such significant correlation was found which implies that the linguistic differences between the target and the masker is more prominent than the listener's knowledge about the babble language in release from masking.

The effect of age on the native language perception across five different language babbles was assessed by comparing the SRS between younger and older adult group. The results revealed a statistically significant difference between the SRS of younger and older adults across the five two-talker babbles. The SRS were comparatively poorer for the elderly group than the younger group which can be attributed to the aging related decline in higher order cognitive processes responsible for the perceptual separation of target from the masker especially when the target (Kannada sentence) and masker (Kannada two-talker babble) was linguistically similar or familiar (English).

The final objective was to determine the relationship between auditory working memory and the SRS obtained in the presence of five two-talker babbles among older adults. Forward and backward digit span tests was used to assess the auditory working memory. The results did not reveal a significant correlation among most of the conditions (except Hindi and Tamil two-talker babble). The possible reason could be due to the lack of linguistic complexity of the test stimuli to approximate to the complex listening situations (two-talker babble conditions).

To conclude, older adults achieved release from informational masking by taking advantage of the linguistic mismatch between the target sentence and the babble but their speech performance was poorer compared to younger adults. This can be inferred to the age-related declines in the cognitive processes that facilitate the perceptual separation of the target signal from such complex listening conditions. Although, both similarity and familiarity of masker and babble languages seem to influence the release from masking, the dissimilarity between the target and masker language play a major role. Furthermore, the relationship between auditory working memory and speech perception in informational masking conditions could be determined if the stimuli used to assess working memory was linguistically complex as the listening condition.

6.1. Clinical implications

- The study gives an insight into how different languages with different proficiency could influence speech perception in older adults.
- Measurement of speech recognition using speech babble would be helpful in simulating real life situation.
- This study would also be helpful in correlating age-related cognitive deficits with the release of masking and selecting appropriate masker for experiment using speech recognition test.

6.2. Future implications

- Linguistic release can be assessed using different target and babble languages.
- Benefit from linguistic mismatch can be investigated for aided and unaided conditions in older population.

- A similar study could be conducted by assessing auditory working memory with words or sentences as stimuli.

REFERENCES

Agus, T. R., Akeroyd, M. A., Gatehouse, S., & Warden, D. (2009). Informational masking in young and elderly listeners for speech masked by simultaneous speech and noise. *The Journal of the Acoustical Society of America*, *126*(4), 1926-1940.

Alageel, S., Sheft, S., & Shafiro, V. (2017). Linguistic masking release in older adults. *The Journal of the Acoustical Society of America*, *141*(5), 3746-3747.

Anitha, R. (2003), Effect of multi-talker babble of different languages on the speech recognition scores in Kannada. *Independent Project*. Done at the Department of Audiology, AIISH, Mysore.

Anderson, S., White-Schwoch, T., Parbery-Clark, A., & Kraus, N. (2013). A dynamic auditory-cognitive system supports speech-in-noise perception in older adults. *Hearing research*, *300*, 18-32.

Anderson, N. D., & Craik, F. I. (2017). 50 years of cognitive aging theory. *The Journals of Gerontology: Series B*, *72*(1), 1-6.

Arbogast, T. L., Mason, C. R., & Kidd Jr, G. (2005). The effect of spatial separation on informational masking of speech in normal-hearing and hearing-impaired listeners. *The Journal of the Acoustical Society of America*, *117*(4), 2169-2180.

Baldwin, C. L., & Ash, I. K. (2011). Impact of sensory acuity on auditory working memory span in young and older adults. *Psychology and Aging*, *26*(1), 85.

Besser, J., Koelewijn, T., Zekveld, A. A., Kramer, S. E., & Festen, J. M. (2013). How linguistic closure and verbal working memory relate to speech recognition in noise—a review. *Trends in amplification*, *17*(2), 75-93.

Bent, T., Baese-Berk, M., Borrie, S. A., & McKee, M. (2016). Individual differences in the perception of regional, nonnative, and disordered speech varieties. *The Journal of the Acoustical Society of America*, *140*(5), 3775-3786.

Brajesh P. & Goswami S. P. (2011). An Adaptation of Early Reading Skills (ERS) in Hindi (ERS-H). *Departmental Project,* Developed in Department of Speech Language Pathology, AIISH, Mysore.

Brokx, J. P. L., & Nooteboom, S. G. (1982). Intonation and the perceptual separation of simultaneous voices. *Journal of Phonetics*, *10*(1), 23-36.

Brouwer, S., Van Engen, K. J., Calandruccio, L., Dhar, S., & Bradlow A. R. (2012). Linguistic contributions to speech-onspeech masking for native and non-native listeners: Language familiarity and semantic content. Journal of the Acoustical Society of America, 131(2), 1449–1464.

Brouwer, S., & Bradlow, A. R. (2014). Contextual variability during speech-in-speech recognition. *The Journal of the Acoustical Society of America*, *136*(1), EL26-EL32.

Brungart, D. S. (2001). Informational and energetic masking effects in the perception of two simultaneous talkers. *The Journal of the Acoustical Society of America*, *109*(3), 1101-1109.

Calandruccio, L., Yuen, C., Van Engen, K., Dhar, S., and Bradlow, A. (2008). “Assessing the clear speech benefit with competing speech maskers,” Am Sp-Lang-Hear Ass National Meeting, Chicago, IL.

Calandruccio, L., Dhar, S., & Bradlow, A. R. (2010). Speech-on-speech masking with variable access to the linguistic content of the masker speech. *The Journal of the Acoustical Society of America*, *128*(2), 860-869.

Calandruccio, L., Brouwer, S., Van Engen, K. J., Dhar, S., & Bradlow, A. R. (2013). Masking release due to linguistic and phonetic dissimilarity between the target and masker speech. *American Journal of Audiology*.

Calandruccio, L., & Zhou, H. (2014). Increase in speech recognition due to linguistic mismatch between target and masker speech: Monolingual and simultaneous bilingual performance. *Journal of Speech, Language, and Hearing Research*, *57*(3), 1089-1097.

Caplan, D., & Waters, G. (2005). The relationship between age, processing speed, working memory capacity, and language comprehension. *Memory*, *13*(3-4), 403-413.

Carhart, R., & Jerger, J. F. (1959). Preferred method for clinical determination of pure-tone thresholds. *Journal of speech and hearing disorders*, *24*(4), 330-345.

Carhart, R., Tillman, T. W., & Greetis, E. S. (1969). Perceptual masking in multiple sound backgrounds. *The Journal of the Acoustical Society of America*, *45*(3), 694-703.

Carhart, R., Johnson, C., & Goodman, J. (1975). Perceptual masking of spondees by combinations of talkers. *The Journal of the Acoustical Society of America*, *58*(S1), S35-S35.

Cherry, E. C. (1953). Some experiments on the recognition of speech, with one and with two ears. *The Journal of the acoustical society of America*, *25*(5), 975-979.

Cooke, M., Garcia Lecumberri, M. L., & Barker, J. (2008). The foreign language cocktail party problem: Energetic and informational masking effects in non-native speech perception. *The Journal of the Acoustical Society of America*, *123*(1), 414-427.

Cullington, H. E., & Zeng, F. G. (2008). Speech recognition with varying numbers and types of competing talkers by normal-hearing, cochlear-implant, and implant simulation subjects. *The Journal of the Acoustical Society of America*, *123*(1), 450-461.

Danhauer, J. L., & Leppler, J. G. (1979). Effects of four noise competitors on the California consonant test. *Journal of Speech and Hearing Disorders*, *44*(3), 354-362.

Drag, L. L., & Bieliauskas, L. A. (2010). Contemporary review 2009: cognitive aging. *Journal of geriatric psychiatry and neurology*, *23*(2), 75-93.

Dubno, J. R., Dirks, D. D., & Morgan, D. E. (1984). Effects of age and mild hearing loss on speech recognition in noise. *The Journal of the Acoustical Society of America*, *76*(1), 87-96.

Durlach, N. I., Mason, C. R., Kidd Jr, G., Arbogast, T. L., Colburn, H. S., & Shinn-Cunningham, B. G. (2003). Note on informational masking (L). *The Journal of the Acoustical Society of America*, *113*(6), 2984-2987.

Fairbanks, G., (1960). The Rainbow Passage. In Voice and Articulation drillbook (2nd ed., pp.124-139. New York: Harper.

Feng, T., Chen, Q., & Xiao, Z. (2018). Age-Related Differences in the Effects of Masker Cuing on Releasing Chinese Speech From Informational Masking. *Frontiers in psychology*, *9*, 1922.

Festen, J. M., & Plomp, R. (1990). Effects of fluctuating noise and interfering speech on the speech- reception threshold for impaired and normal hearing. *The Journal of the Acoustical Society of America*, *88*(4), 1725-1736.

Folstein, M.F., Folstein, S.E., & McHugh, P.R. (1975). ‘‘Mini-Mental State’’: A practical method for grading the cognitive state of patients for the clinician. Journal of Psychiatric Research, 12, 189-198.

Francis, A. L., Tigchelaar, L. J., Zhang, R., & Zekveld, A. A. (2018). Effects of second language proficiency and linguistic uncertainty on recognition of speech in native and nonnative competing speech. *Journal of Speech, Language, and Hearing Research*, *61*(7), 1815-1830.

Frank, T. (2000), ANSI update: Maximum permissible ambient noise levels for audiometric test rooms. American Journal of Audiology, 9(1), 3 – 8.

Freyman, R. L., Balakrishnan, U., & Helfer, K. S. (2001). Spatial release from informational masking in speech recognition. The Journal of the Acoustical Society of America, 109, 2112–2122.

Freyman, R. L., Balakrishnan, U., & Helfer, K. S. (2004). Effect of number of masking talkers and auditory priming on informational masking in speech recognition. *The Journal of the Acoustical Society of America*, *115*(5), 2246-2256.

Frisina, D. R., & Frisina, R. D. (1997). Speech recognition in noise and presbycusis: relations to possible neural mechanisms. *Hearing research*, *106*(1-2), 95-104.

Füllgrabe, C., Moore, B. C., & Stone, M. A. (2015). Age-group differences in speech identification despite matched audiometrically normal hearing: contributions from auditory temporal processing and cognition. *Frontiers in aging neuroscience*, *6*, 347.

Füllgrabe, C., & Rosen, S. (2016). Investigating the role of working memory in speech-in-noise identification for listeners with normal hearing. In *Physiology, psychoacoustics and cognition in normal and impaired hearing* (pp. 29-36). Springer, Cham.

Gennis, V., Garry, P. J., Haaland, K. Y., Yeo, R. A., & Goodwin, J. S. (1991). Hearing and cognition in the elderly: new findings and a review of the literature. *Archives of Internal Medicine, 151*(11), 2259-2264.

Gordon-Salant, S., & Fitzgibbons, P. J. (1995). Recognition of multiply degraded speech by young and elderly listeners. *Journal of Speech, Language, and Hearing Research*, *38*(5), 1150-1156

Gordon-Salant, S., & Fitzgibbons, P. J. (1993). Temporal factors and speech recognition performance in young and elderly listeners. *Journal of Speech, Language, and Hearing Research*, *36*(6), 1276-1285.

Gordon-Salant, S., & Fitzgibbons, P. J. (1997). Selected cognitive factors and speech recognition performance among young and elderly listeners. *Journal of Speech, Language, and Hearing Research*, *40*(2), 423-431.

Gordon-Salant, S., & Cole, S. S. (2016). Effects of age and working memory capacity on speech recognition performance in noise among listeners with normal hearing. *Ear and Hearing*, *37*(5), 593-602.

Goossens, T., Vercammen, C., Wouters, J., & van Wieringen, A. (2017). Masked speech perception across the adult lifespan: Impact of age and hearing impairment. *Hearing research*, *344*, 109-124.

Helfer, K. S., & Wilber, L. A. (1990). Hearing loss, aging, and speech perception in reverberation and noise. *Journal of Speech, Language, and Hearing Research*, *33*(1), 149-155.

Helfer, K. S., & Freyman, R. L. (2008). Aging and speech-onspeech masking. Ear and Hearing, 29, 87–98.

Humes, L. E., & Dubno, J. R. (2010). Factors affecting speech understanding in older adults. In *The aging auditory system* (pp. 211-257). Springer, New York, NY.

Ingvalson, E. M., Lansford, K. L., Fedorova, V., & Fernandez, G. (2017). Cognitive factors as predictors of accented speech perception for younger and older adults. *The Journal of the Acoustical Society of America*, *141*(6), 4652-4659.

Jain, C., Konadath, S., Vimal, B. M., & Suresh, V. (2014). Influence of native and non-native multitalker babble on speech recognition in noise. *Audiology research*, *4*(1).

Jerger, J. (1970). Clinical experience with impedance audiometry. *Archives of otolaryngology*, *92*(4), 311-324.

Jerger, S., Elizondo, R., Dinh, T., Sanchez, P., & Chavira, E. (1994). Linguistic influences on the auditory processing of speech by children with normal hearing or hearing impairment. *Ear and hearing*, *15*(2), 138-160.

Kahneman, D. (1973). *Attention and effort* (Vol. 1063). Englewood Cliffs, NJ: Prentice-Hall.

Koch, I., Lawo, V., Fels, J., & Vorländer, M. (2011). Switching in the cocktail party: Exploring intentional control of auditory selective attention. *Journal of Experimental Psychology: Human Perception and Performance*, *37*(4), 1140.

Kumar, A., & Sandeep, M. (2013). Development and Test Trail of Computer Based Auditory-Cognitive Training Module for Individuals with Cochlear Hearing Loss. *Departmental Project*, Developed in Department of Audiology, AIISH, Mysore.

Larsby, B., Hällgren, M., Lyxell, B., &Arlinger, S. (2005). Cognitive performance and perceived effort in speech processing tasks: effects of different noise backgrounds in normal-hearing and hearing-impaired subjects. *International Journal of Audiology*, *44*(3), 131-143.

Lecumberri, M. G., & Cooke, M. (2006). Effect of masker type on native and non-native consonant perception in noise. *The Journal of the Acoustical Society of America*, *119*(4), 2445-2454.

Lewis, R. L., Vasishth, S., & Van Dyke, J. A. (2006). Computational principles of working memory in sentence comprehension. *Trends in cognitive sciences*, *10*(10), 447-454.

Li, L., Daneman, M., Qi, J. G., & Schneider, B. A. (2004). Does the information content of an irrelevant source differentially affect spoken word recognition in younger and older adults?. *Journal of Experimental Psychology: Human Perception and Performance*, *30*(6), 1077.

Liu, X. Z., & Yan, D. (2007). Ageing and hearing loss. *The Journal of Pathology: A Journal of the Pathological Society of Great Britain and Ireland*, *211*(2), 188-197.

Maitheyee, R. & Goswami, S., P. (2009). Language Proficiency Questionnaire – An adaptation of LEAP-Q in Indian context. Student research at AIISH Mysore (Articles based on dissertation done at AIISH). Vol. VII. 214-229.

Mattys, S. L., Brooks, J., & Cooke, M. (2009). Recognizing speech under a processing load: Dissociating energetic from informational factors. *Cognitive Psychology*, *59*(3), 203-243

Mattys, S. L., Carroll, L. M., Li, C. K., & Chan, S. L. (2010). Effects of energetic and informational masking on speech segmentation by native and non-native speakers. *Speech Communication*, *52*(11-12), 887-899.

Mattys, S. L., Davis, M. H., Bradlow, A. R., & Scott, S. K. (2012). Speech recognition in adverse conditions: A review. *Language and Cognitive Processes*, *27*(7-8), 953-978.

McFadden, D. (1993). A speculation about the parallel ear asymmetries and sex differences in hearing sensitivity and otoacoustic emissions. *Hearing research*, *68*(2), 143-151.

Miller, G. A. (1947). The masking of speech. *Psychological bulletin*, *44*(2), 105.

Morton, J., & Patterson, K. (1980). Deep dyslexia: A new attempt at an interpretation. In *Deep dyslexia* (pp. 91-118). Academic Press New York/London.

Nuesse, T., Steenken, R., Neher, T., & Holube, I. (2018). Exploring the link between cognitive abilities and speech recognition in the elderly under different listening conditions. *Frontiers in psychology*, *9*, 678.

Nusbaum, H. C., & Morin, T. M. (1992). Paying attention to differences among talkers. *Speech perception, production and linguistic structure,* 113-134.

Obler, L. K., Fein, D., Nicholas, M., & Albert, M. L. (1991). Auditory comprehension and aging: Decline in syntactic processing. *Applied psycholinguistics*, *12*(4), 433-452.

Pershad, D., & Verma, S., K. (1989). Handbook of PGI Battery of Brain Dysfunction (PGI-BBD), Agra: National Psychological Corpration.

Pichora- Fuller, M. K., Schneider, B. A., & Daneman, M. (1995). How young and old adults listen to and remember speech in noise. *The Journal of the Acoustical Society of America*, *97*(1), 593-608.]

Pichora-Fuller, M. K., & Souza, P. E. (2003). Effects of aging on auditory processing of speech. *International journal of audiology*, *42*(sup2), 11-16.

Preetha, S. (2015). Speech-in-Speech Recognition: Effect of Language Uncertainty (Unpublished Master's Dissertation), University of Mysuru, Mysuru.

Prosser, S., Turrini, M., & Arslan, E. (1991). Effects of different noises on speech discrimination by the elderly. *Acta Oto-Laryngologica*, *111*(sup476), 136-142.

Rajan, R., & Cainer, K. E. (2008). Ageing without hearing loss or cognitive impairment causes a decrease in speech intelligibility only in informational maskers. *Neuroscience*, *154*(2), 784-795.

Raja, S., (2018). Influence of Proficiency of Non-native Background Language on Speech Recognition of Native Language (Unpublished Master's Dissertation), University of Mysuru, Mysuru.

Rhebergen, K. S., Versfeld, N. J., &Dreschler, W. A. (2005). Release from informational masking by time reversal of native and non-native interfering speech. *The Journal of the Acoustical Society of America*, *118*(3), 1274-1277.

Rönnberg, J., Rudner, M., Foo, C., & Lunner, T. (2008). Cognition counts: A working memory system for ease of language understanding (ELU). *International journal of audiology*, *47*(sup2), S99-S105.

Rosen, S., Souza, P., Ekelund, C., & Majeed, A. A. (2013). Listening to speech in a background of other talkers: Effects of talker number and noise vocoding. *The Journal of the Acoustical Society of America*, *133*(4), 2431-2443

Ross, B., Schneider, B., Snyder, J. S., & Alain, C. (2010). Biological markers of auditory gap detection in young, middle-aged, and older adults. *PLoS One*, *5*(4), e10101.

Rudner, M., Rönnberg, J., & Lunner, T. (2011). Working memory supports listening in noise for persons with hearing impairment. *Journal of the American Academy of Audiology*, *22*(3), 156-167.

Savithri, S., R., & Jayaram, M. (2005). 300 words reading passages in Dravidian languages. *AIISH Research Fund Project*, Done at AIISH, Mysuru.

Schoof, T., & Rosen, S. (2014). The role of auditory and cognitive factors in understanding speech in noise by normal-hearing older listeners. *Frontiers in aging neuroscience*, *6*, 307.

Shashank, N. (2017). Linguistic Release of Masking in Juveniles and Adults – an Indian language perspective (Unpublished Master's Dissertation), University of Mysuru, Mysuru.

Sheft, S., Shafiro, V., Lorenzi, C., McMullen, R., & Farrell, C. (2012). Effects of age and hearing loss on the relationship between discrimination of stochastic frequency modulation and speech perception. *Ear and hearing*, *33*(6), 709.

Shinn-Cunningham, B. G. (2008). Object-based auditory and visual attention. *Trends in cognitive sciences*, *12*(5), 182-186.

Simpson, S. A., & Cooke, M. (2005). Consonant identification in N-talker babble is a nonmonotonic function of N. *The Journal of the Acoustical Society of America*, *118*(5), 2775-2778.

Smith, S. L., & Pichora-Fuller, M. K. (2015). Associations between speech understanding and auditory and visual tests of verbal working memory: effects of linguistic complexity, task, age, and hearing loss. *Frontiers in Psychology*, *6*, 1394.

Snyder, J. S., & Alain, C. (2007). Toward a neurophysiological theory of auditory stream segregation. *Psychological bulletin*, *133*(5), 780.

Stibbard, R. M., & Lee, J. I. (2006). Evidence against the mismatched interlanguage speech intelligibility benefit hypothesis. *The Journal of the Acoustical Society of America*, *120*(1), 433-442.

Tremblay, K. L., Piskosz, M., & Souza, P. (2003). Effects of age and age-related hearing loss on the neural representation of speech cues. Clinical Neurophysiology, 114, 1332–1343.

Tun, P. A., Wingfield, A., Rosen, M. J., & Blanchard, L. (1998). Response latencies for false memories: Gist-based processes in normal aging. Psychology and Aging, 13, 230–241

Tun, P. A., O'Kane, G., & Wingfield, A. (2002). Distraction by competing speech in young and older adult listeners. *Psychology and aging*, *17*(3), 453.

Van Engen, K. J., & Bradlow, A. R. (2007). Sentence recognition in native-and foreign-language multi-talker background noise. *The Journal of the Acoustical Society of America*, *121*(1), 519-526.

Van Engen, K. J. (2009). Informational masking in first- and second- language speech recognition. *The Journal of the Acoustical Society of America*, *125*(4), 2772-2772.

Van Engen, K. J. (2010). Similarity and familiarity: Second language sentence recognition in first-and second-language multi-talker babble. *Speech communication*, *52*(11-12), 943-953.

Vermeire, K., Knoop, A., De Sloovere, M., Bosch, P., & van den Noort, M. (2019). Relationship between working memory and speech-in-noise recognition in young and older adult listeners with age-appropriate hearing. *Journal of Speech, Language, and Hearing Research*, *62*(9), 3545-3553.

Vineetha, C. V., Suma, R., & Nair, S., P. (2013). Effect of Biligualism on Speech in Noise Perception in Young Adults. *Language in India, 13(6),* 799 – 811.

WHO. 2008. World Health Organization. Grades of Hearing Impairment. Prevention of Blindness and Deafness. World Health Organization. Retrieved May 9, 2015,from

Wong, P. C., Jin, J. X., Gunasekera, G. M., Abel, R., Lee, E. R., & Dhar, S. (2009). Agingand cortical mechanisms of speech perception in noise. *Neuropsychologia*, *47*(3), 693-703.

Yathiraj, A., & Vijayalakshmi, C., S. (2005). Phonetically Balanced Word List in Kannada. *Departmental Project*, Developed in Department of Audiology, AIISH, Mysore

Yathiraj A., Jain S. N., & Amruthavarshini B. (2018). Modified Language Proficiency Questionnaire. Student research at AIISH Mysore.

Zobel, B. H., Wagner, A., Sanders, L. D., & Başkent, D. (2019). Spatial release from informational masking declines with age: Evidence from a detection task in a virtual separation paradigm. *The Journal of the Acoustical Society of America*, *146*(1), 548-566.