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Manuscript

Background

Speech perception is the process of imposing a meaningful perceptual experience (Massaro, 2001). It is a sophisticated process of transforming distinctly encoded physical stimuli into an explicit abstract neural representation.Despite decades of research in the discipline of speech perception, a significant complication still remains unresolved,is the lack of invariance between the speech signal and perceptual categories.The issue of lack of invariance becomes much more intricated considering the variability in speaking rate and talker as these constituents present auxiliary sources for several mappings. Although there is a significant likelihood for a phoneme produced bya single talker to be diverse acoustically, the same speech acoustic configuration can be in agreement with different perceptual categories(Peterson & Barney, 1952; Dorman, Studdert-Kennedy& Raphael, 1977).

Mental representations of speech are often comprehensiveandexhaustive. They include various sources of details about the talker's speech characteristics. The effect of speech variability is found to be present in speech processing and also its representation(McLennan&Luce, 2005). Furthermore, it assists in word recognition by maintaining detailed representations of discrete talker information, especially for known talkers (Nygaard, Sommers&Pisoni, 1994). When stimuli are presented with different speaking styles or rates or when multiple speakers are included, the accuracy in word recognition and memory task diminishes. Consequently, both inter-talker and intra-talker variability tends to affect the performance (Mullennix, Pisoni& Martin, 1989; Nygaard, Sommers&Pisoni, 1995; Uchanski&Braida, 1998; Bradlow, Nygaard&Pisoni, 1999; Sommers&Barcroft, 2006; Magnuson &Nusbaum, 2007).

Spoken word recognition and speech perceptionaccuracy depend on a vast scale of utterance, talker, and listener related characteristics that can differ across interactive situations.Speech signals are variable for numerous factors due to the differences in various aspects such as the

production of spoken language, inter and intra-talker variability, rate of speech, dialect, social context,semantic, syntactic, and pragmatic effects. Besides, the impact of the ambient environment that includes reverberation, background noise, and microphone characteristics cannot be neglected (Klatt, 1986). In one experiment, Sommers, Nygaard&Pisoni(1992) stated that words were identified better when they were produced at a single rate compared to the words produced at heterogeneous rates (i.e., fast, medium and slow). The present word recognition models emphasize more on factors such as lexical structure, word frequency andits effects on spoken word recognition performance using numerous experimental paradigms (Landauer& Streeter, 1973; Eukel, 1980; Luce, 1986).

Creelman (1957) conducted a study to discern the effect of talker variability in recognition of phonetically balanced (PB).In the presence of background noise, the author presented the monosyllabic words to a group of five listeners represented by 1, 2, 4, 8, and 16 speakers. The results revealed that the words were identified much more precisely when the stimuliwere from a single talker comparedto a multi-talker stimuli. Also, there were relatively small differences in the order of 7% - 10% between theirrecognition performances.

Mullennix et al. (1989) investigated spoken word recognition in continuation of the Creelman (1957) research, where the study included thirty-seven undergraduate students who volunteered as participants from introductory psychology courses at Indiana University. Fifteen participants produced stimulus materials, and the other twenty participants served as listeners in the perceptual experiment. All participants werenative speakers of English and reportedno history ofany sort of communication disorders. The stimulus included 68 spoken words (CVC monosyllabic English words withwideconsonant variations) obtained from each 15 different talkers of the same language with signal-to-noise ratios (SNRs) +10, 0 and -10 dB as background noise variation and other 22 participants were guided to type the word corresponding to what they listen and thought on each trails. Two minutes resting period was maintained between each block

and at different SNR in each particular block. Results revealed that word recognition accuracy decreased across the SNR from +10 to -10, and better word recognition was reported for single talker than the multi talker's conditions.

Spoken word recognition and speech perception were reported to be affected by variability in the rate of speech (Miller &Liberman, 1979; Summerfield, 1981; Miller &Volaitis, 1989; Volaitis&Miller, 1992). There is a relative decline in word recognition scores when the speaking rates were variable (Sommers, Nygaard&Pisoni, 1994).Although, when the amplitude of the words was varied, the word identification scores did not decline as expected. This implies that variations in speaking rate and talker characteristics require resources and time.When the speech rate or talker characteristics varied, there was less phonetic processing on each word, which in turn resulted in increasederror rates andhigh response times rather than low variability contexts.

Recall can also be defined as a process where information can be recollected or retrieved from storage at will. Precise encoding functions are carried out to determine perception, retrieval cues, and memory storage that helps in recalling words (Tulving& Thomson, 1973). Serial recallis recalling the events or items in the presented order. Primacy and recency effects are generally seen in serial order recall. An individual recalls the items that were presented in the beginning better than the last items due to the primacy effect. In contrast, another person recalls the items that were presented at the end of the sequence because of recency effect.

Nygaard, Sommersand Pisoni (1992) reported that individuals were able to recall words betterwhen the stimulus was presented at an indifferent speaking rate compared to the same stimulus produced at altered speaking rates.Transferring items into long-term memory were difficult, which was implied by the variations observed in the initial section of the serial position curve.

Goldinger, Pisoni, and Logan (1991)conducted a serial recall task of spoken word lists where the rate of presentation of items was varied in order tounderstandthe effects of talker variability. It was speculated that the listener's capacity to encode discrete talker related particulars for multi-talker lists would be affected by the rate of presentation.It was observed during the rehearsal period that the multi-talker lists were accurately recollected than the lists that was produced by a single speaker. Clearly, the talkerspecific information served as additional retrieval cues for the listeners while recalling words from a multi-talker list. Words in the initial portion of the sequence were remembered better when the presentation rate was faster (words per 250 msec) for single-talker lists compared to multi-talker lists. In contrary, the differences in recall abilities were reversed when the items were presented at a slower rate (words per 4,000 msec). It is evident that the speakers' distinctive details can be used as an effective cue to retrieve information that has been encoded into the long-term memory of the listeners (Goldinger et al. (1991) and is utilized in recognition memory (explicit) tasks andperceptual recognition (implicit) tasks (Goldinger, 1996).

Serial recall ability tasks on spoken wordlistswas determined by Martin, Mullennix, Pison& Summers (1989) and Goldinger et al. (1991). The evaluated tasksare indicative ofencodedinformation about speakers' voices in the long-term memory of the listeners. Even on a continuous recognition memory procedure, the voice characteristics of episodic speakers were still encoded in the listeners' memory and was presented in the test sequence for explicit judgments despite significant competition from distinct voices (Palmeri et al., 1993).

Conventionally, speech perception for an individual occurs from several different talkers (Hager, & Amanda, 2013).In order to perceive speech, listeners integrate auditory cues for interacting in both favorable and compromised listening situations. Characteristics of the talker, listener, and the speech signal itself comprise for the success of communicative interactions. Studies need to be carried out to examine the effect of stimulus variability on memory and further on spoken

word recognitiontodecidewhetherthe perceptual effects of stimulus variance are due to the increased encoding time for perceptual information or due to a time-consuming process of normalization.This demonstrates that talker variabilitystands as one of the prime factors in speech perception that is required to be assimilated into the abstract concept of spoken word recognition.Published empirical studies in Indian context/literature is meager in this line where most of the languages are syllable based and it would be very much tedious for listeners to recognize and memorize each phonemes of the word in ongoing speech in a noisy background for better speech perception.

The present study aimedto determine the effect of talkers' variability on spoken word recognition and recall in adult neuro-typical individuals whose native language is Kannada.

The major objectives of the study were;

1. To evaluate the spoken word recognition and recall abilities under single and multi-talker variations.
2. To determine gender differences (if any) on spoken word recognition and recall abilities.
3. To examine the serial position effect using single and multi talkers as one of the variable for spoken word recognition and recall.

Methods

Participants

A total of 30 neuro-typical adult individuals were considered for the study and wereclassifiedinto two groups as Group 1 consisted of 15 males and Group 2 included 15 females.All the participants were within the age range of 18-21 years with mean age of 19.4 years (group 1) and 19.3 years (group 2).All the participants were native speakers of Kannada language who reported no history of speech, language, hearing, cognitive and communication disorders during the study.

Stimulus material

Test material consisted of two sets of word lists as List A and List B in which both had 15 tri-syllabic meaningful Kannada words each (see Appendix A). Words in both the lists were semantically unrelated to each other and were of different categories of words. List A was composed of a single talker and List B on other hand; it was prepared by multi talkers' utterances.

Words in the first list (List A) were uttered by a male of 21 years of age whose native language was Kannada. His speech clarity was assessed by 3 SLP's where they rated his speech as 100% intelligible. Whereas, words in the second list (List B) were uttered by 15 different individuals (both males and females) age ranged between 18-23 years who were of native Kannada speakers. Similarly, the multi talker's speech was assessed by 3 SLP's and out of fifteen words, only one word which had 100% intelligible was considered for preparation of stimuli for List B from each different individual's word production.

All these recordings were carried out in a sound treated room using CSL software (CSL 4500 Model, Kay Pentax, New Jersy, USA) and with 'Shure' microphone, where the input signal was digitized online via a 16 bits analog to digital convertor at 44.1 KHz sampling rate and saved in .wav format. Both List A and B recorded stimuli was edited to maintain a 3 seconds inter-word interval duration and the whole stimulus was superimposed with speech babble as a background noise using Aux Viewer Version 1.41 (Win 64) software. Both the signal/target words and speech babble noise were presented at 0 dB SNR. The final version of the recorded stimuli for the study, thusformed the stimulus material, List A (spoken by a male speaker) and List B (fifteen different speakers uttered 15 different words).

Procedure

Presentation of stimuli

The aim and objective of the study were explained and took a written consent from the participants. The participants were made to sit comfortably in noise free room. The stimulus was controlled online using laptop and presented through head phones (ZEB-100HM) binaurally at a comfortable loudness (50 dB SPL). With no possibility of repetition,each word was presented only once and order of list presentation (List A and List B) was counter-balanced across listeners and a break of 3 - 5 minutes duration was provided between the presentations of two lists. After the experiment, participants were given a questionnairethathadfive questions (4 close ended and 1 open ended) to answer about their feedback on the experimental procedure and performance (see Appendix B).

Instruction

Participants were instructed to listen to the words presented from each of the lists and write the words by recollecting them immediately after each list presentation. Upon completion of the task, participants were asked tofilla post experiment questionnaire, majorly to check the experience and feedback of their performance in the spoken word recognition and recall task.

Statistical analysis

Number of words recollected was measured and for each recollected word, a score of one was assigned and words which were not related to lists had not been scored. Also, responses closed to the target words were scored as one. Statistical analysis was carried out using SPSS software Version 20, to analyze the statistical difference between lists (List A versus List B) and gender (males versus females) on spoken word recognition using Mixed ANOVA.

Results

To test the normality, Shapiro-Wilk's test was carried out where it showed that the data fulfilled the normality assumption. Hence, Mixed ANOVA was performed to check the significant difference within subject effect (Lists), between subject effect (Gender) and any interaction effects.

The mean (M) number of words recollected by the two groups (Group 1 and Group 2) across the two tasks of single (list A) and multiple talkers (list B) with corresponding standard deviation (SD) values were shown in table1. Descriptive statistics revealed that the mean number of words recollected was relatively more by participants for list A compared to list B. The same was observed in both group 1 (males) and group 2 (females). The SD values were higher in list B than list A indicating more variability in performance by participants for multi-talker list. Also, females (group 2) recollected more number of words in list A& B compared to males (group 1). Further, SD values were higher in females in list A& B indicating wider variability in performance.

Table 1: Mean and standard deviation of words recollected between lists and gender

No. of words recollected	**Single Talker** (List A)		**Multi Taker** (List B)	
	Group1 (Males)	**Group2** (Females)	**Group1** (Males)	**Group2** (Females)
Mean	7.46	8.06	6.53	7.2
SD	0.91	1.86	1.72	1.89

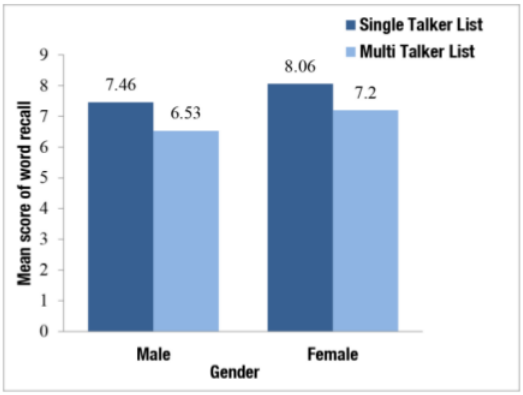


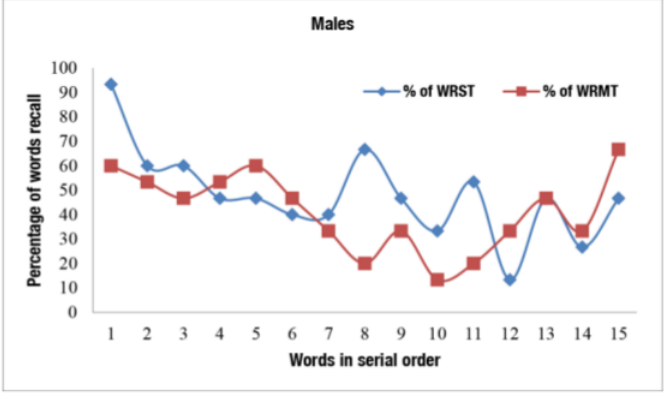
Figure 1: Mean scores of word recollected between two groups from list A&list B.

Within subject comparison, there was a significant difference between the single talker (List A) and multi talker list (List B), $F(1, 28) = 4.837$, $p < 0.05$. The graphical representation of the mean differences on word recall between the groups is depicted in figure 1. Also, results of Mixed ANOVA revealed that there was no significant interaction effect [$F(1, 28) = 0.07$, $p > 0.05$] found for lists (tasks) and groups (gender). Table 2 showed the results of Mixed ANOVA. Further, between subject comparison revealed no statisticalsignificantdifference between group 1 and 2 [$F(1, 28) = 2.043$, $p > 0.05$], that is, no gender difference found.

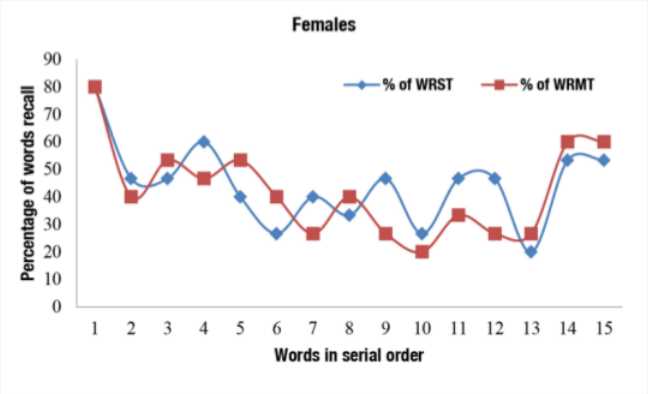
Table 2: Results of Mixed ANOVA for different variables

Variables	df	F	sig.
Lists	1	4.83	0.03
Gender	1	2.04	0.16
Lists * Gender	1	0.07	0.93
Error	28		

In analyzing the serial order position effect on word recall ability, most of the participants have increased percentage of word recall at the initial position (primacy effect) and the final position (recency effect) compared to the middle position of words in both the lists (List A & B).Figure 2 depicted the 'serial order position' effect for males (a) and females (b) between list A and list B. From figure 2, it can be observed that the retain ability of words were superior in the initial and final position of list of words when it was read by multi-talker rather than a singer talker. Both the primacy and recency effects were clearly noticed in group 2 (females) than group 1 (males).



2 (a)



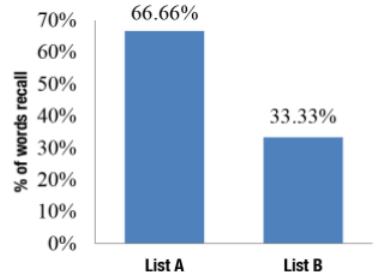
2 (b)

Figure 2: Percentage of correctly recalled words for both single and multi-talker lists as a function of serial order position effect in males (a) and in females (b).

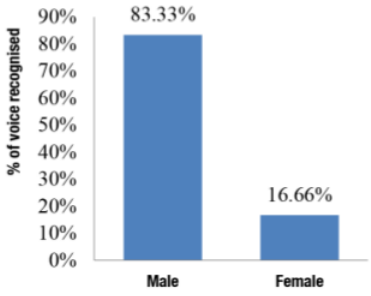
(WRST – Word Recall in Single Talker List; WRMT – Word Recall in Multi Talker List)

The post experimental questionnaire responses or feedbackobtained from participants were tabulated and analyzed. The obtained data was analyzed into percentages and the results revealed the following points;

66.66% of participants reported that list A was easier compared to list B [figure 3(a)].83.33% of participants reported words read by male voice was easier to recollect than female voice [figure 3(b)]. 60% of participants had mentioned that they required more time to recall words from list B compared to list A [figure 3(c)].93.33% of participants had mentioned that they can recall the word in the initial position of the list comfortably compared to other positions [figure 3(d)] and 26.66% of participants reported that they had recalled approximately 8 words correctly (out of 15 words) from lists [figure 3(e)].

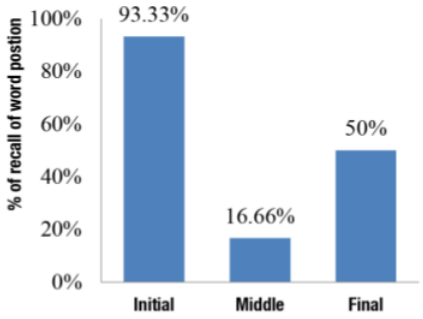


3(a)



3(b)

3(c)



3(d)

3(e)

Figure 3: (a) Percentage of words recollected easily between lists; (b) Percentage of word recollected based on voice; (c) percentage of time required for word recall; (d) Percentage of recall of word concerning position in the list; (e) Percentage of the perceived correct number of words recollected.

Discussion

Spoken word recognition is one of the major components in speech perception, which would be affected by various factors like talker's variability, stimulus variance, environmental parameters, and perceptual recall ability of an individual. The results of the present study found that participants recognized and recollected the target words better froma single talkers list compared to the multi talkers list. That is, participants recalled significantly more words from list A than list B, which indicated that participants might form relatively an acoustic vowel space for a single talker that influence them to encode, process, store and retrieve words more quickly than creating multiple acoustic vowel spaces for different speakers as in case of list B (Multi-talkers). The present study findings support the findings of Mullennix et al. (1989), who reported that better word recognition for single talker than multi talkers. This is also correlating with the feedback of the study participants' that 66.66% of them recognized the target words efficiently and correctly from list A compared to list B and further found that 60% of participants neededa longer time torecollect words from list B (multi-talker list).

Group 2 (females) in the present study recollected relatively more words than group 1 (male) participants, albeit the difference is not statistically significant. Hence, the present study did not find any gender difference in spoken word recognition and recollect task. The present finding is contradicting with the fMRI investigation of Schirmer, Zysset, Kotz, and Cramon (2004), who reported with evidence that the left inferior frontal gyrus repeatedly implicates in semantic processing in women than in men, which is more susceptible to influences from emotional prosody. More participants warranted in each of the groups in the future for gender-related differences in spoken word recognition investigation.

The serial order position effect in the present study revealed that most of the participants were able to recall the initial and final words compared to the middle position words in both

lists.Further, group 1 showed that the percentage of initial and final words recall ability of the multiple talkers list (list B) was higher compared to the words in the middle position. The exclusive details provided by every distinct voice in the word list apparently helped listeners recall both the item and its temporal location in the list. Features of distinctive talkers and linguistic content of spoken words were encoded in the memory representation of listeners that aided for serial recall positioning. These resultsare in consonance with the study findings of Goldinger et al. (1991), Palmeri et al. (1993) and Nygaard et al. (1994) who has mentioned that distinctive talker information is stored in long-term memory and can be utilized not only to support recognition memory but also to promote subsequent perceptual analysis of the phonetic structure of the novel utterance of a speaking person.For each stimulus dimension examined in this study, the distinct results indicate that each source of variation experienced in the speech signal may involve specific adaptive mechanisms in the perceptual system and may affect different processing levels.

Conclusion

The present study found spoken word recognition was better in single talker than multi talkers. Also, the present study found no gender difference in spoken word recognition and word recall ability as a factor of talker variability. Further, the present study added the evidence on to the literature of speech perception in Indian language/context in general and Kannada language in particular. The output of the results can be generalized to understand how speech perception is delicate in a typical scenario where multiple speakers involved (example, in marriage halls).

Further studies can be planned in individuals with Hearing Impairment (HI) whether they can recognize and process the spoken words of multi-talkers easily. Further, individuals with hearing

impairment require tunings of their speech perception system or improving their meta-cognitive skills for better spoken word recognition and recall ability that's needs to be exploredin a multi-talkers conditions.

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Appendix A

List of tri-syllabic words used in the study (in Kannada)

List A	List B
ಅಳಲು	ಈರುಳ್ಳಿ
ಕಾನನ	ಕವಡೆ
ಸಾಹಸ	ಪಿಂಗಾಣಿ
ಕನ್ನಡಿ	ಪವಿತ್ರ
ಗಿಡುಗ	ಶಿರ್ಶಿಕೆ
ತೊರಣ	ಪೀಠಿಕೆ
ಅಶ್ಚರ್ಯ	ಸಿನಿಮಾ
ಚಮಚ	ತಕ್ಕಡಿ
ಸುಶೃಷ	ಅಮೃತ
ಪ್ರಥಮ	ಚಪ್ಪಾಳೆ
ಬಿಂದಿಗೆ	ಸಂಪಿಗೆ
ಬಾವುಟ	ನಕ್ಷತ್ರ
ವೈಷ್ಣವ	ಗೊಡಂಬಿ
ಕುವರಿ	ಬೆಳಕು
ಬೈರವ	ಮಾಧ್ಯಮ

Appendix B

POST-EXPERIMENT QUESTIONNAIRE

Which list of words you were able to recall easily? ನಿಮಗೆ ಯಾವ ಪಟ್ಟಿಯ ಪದಗಳು ಜ್ಞಾಪಕವಿಡಲು ಸುಲಭವಾಯಿತು?	List A or List B ಪಟ್ಟಿ ಎ ಅಥವ ಪಟ್ಟಿ ಬ
Which person's voice you were able to recognize and recall easily in this task? ನಿಮಗೆ ಯಾರಧ್ವನಿಯ ಪದಗಳು ಗುರಿತಿಸಲು ಆಗು ಜ್ಞಾಪಕವಿಡಲು ಸುಲಭವಾಯಿತು?	Male or Female ಗಂಡಸುಅಥವ ಹೆಂಗಸು
Which list of words you feel you require more time to recall? ನಿಮಗೆ ಯಾವ ಪಟ್ಟಿಯ ಪದಗಳನ್ನು ಜ್ಞಾಪಕಮಾಡಿಕೊಳ್ಳಲು ತುಂಬಾ ಸಮಯ ಬೇಕು?	List A or List B ಪಟ್ಟಿ ಎ ಅಥವ ಪಟ್ಟಿ ಬ
Which all word in the list (position) you were able to recognize easily? ನಿಮಗೆ ಪಟ್ಟಿಯಯಾವ ಸ್ಥಾನದ ಪದಗಳನ್ನು ಜ್ಞಾಪಕಮಾಡಿಕೊಳ್ಳಲು ಸುಲಭವಾಯಿತು?	Initial/ Middle/ Final ಮೊದಲನೆಯ/ಮಧ್ಯದ/ಕೊನೆಯ
How many words you think you recollected correctly in any of the list? ಯಾವುದೆ ಪಟ್ಟಿಯಾಗಲಿ ನಿಮಗೆ ಅಂದಾಜಾಗಿ ಎಷ್ಟು ಪದಗಳನ್ನು ಜ್ಞಾಪಕಮಾಡಿಕೊಳ್ಳಲು ಸಾಧ್ಯವಾಯಿತು?	

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