RHYTHM PERCEPTION AND EAR PREFERENCE IN PERSONS WITH STUTTERING

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Register No.: 11SLP021

A Dissertation Submitted in Part Fulfilment for the Degree of

Master of Science (Speech - Language Pathology)

University of Mysore

Mysore

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May, 2013

Certificate

This is to certify that this dissertation entitled **"Rhythm Perception and Ear Preference in Persons With Stuttering"** is a bonafide work in part fulfilment for the degree of Master of Science (Speech-Language Pathology) of the student (Registration No. 11SLP021). This has been carried out under the guidance of a Faculty of this institute and has not been submitted earlier for the award of any other Diploma or Degree to any other University.

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Declaration

This dissertation entitled **"Rhythm Perception and Ear Preference in Persons With Stuttering"** is the result of my own study under the guidance of **Dr. S. R. Savithri**, Prof. in Speech Sciences and Director, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier for the award of any Diploma or Degree to any other University.

Mysore

May, 2013 Register No. 11SLP021

ACKNOWLEDGEMENTS

First, I would like to thank GOD Almighty for showering His blessings on me and for supporting and helping me. Without You, nothing would have been possible.

I express my deepest gratitude to my guide Dr. S. R. Savithri for her guidance and support. Thank you ma'am for helping me a lot and for patiently correcting my mistakes, inspite of your busy schedule.

I would also like to thank Papa, Mummy, Sherry chetan and Merry chechi for their support. You mean a lot to me. Thank you for the love and care that you give me. Thank you for making me what I am.

I thank Dr. Vasanthalakshmi and Mr. Santhosh for all the help given to me for the statistical analysis.

I also thank Ms. Anjana, Ms. Sahana, and Mr. Jayakumar for helping me in preparing the stimuli

I thank all the participants of the study for their cooperation and for spending their time for the study

Lastly, I thank all my classmates and my friend Suma, for being with me and for all the good times that we had together

Dedicated to…

AMMA

(My grandmother)

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CHAPTER I

INTRODUCTION

Stuttering can be defined as an abnormally high frequency or duration of stoppages in the forward flow of speech affecting its continuity, rhythm, rate and effortfulness. (Guitar,1998). The various dysfluencies observed in stuttering given by Hegde and Davis (1992) includes repetition, silent pauses, incomplete phrases, revisions, interjections, prolongation. Repetitions seen in stuttering can be whole word repetition, part word repetition and phrase repetition. Silent pauses or unfilled pauses can be seen before a word is told or in between a word. Incomplete phrases are where the person with stuttering fails to complete a phrase or sentence due to the fear that he may stutter on a particular word. Revisions are those where the person tells a phrase and then change the phrase by substituting other words. Interjections are where the person uses schwa vowels or uses sound like 'mm', in between before the sentence or in between the sentence. Prolongations are where the duration of a sound is increased.

Wingate (1985) hypothesised stuttering as a prosodic disorder. Brown (between 1935 and 1945) conducted a series of studies to investigate the sounds on which stuttering occurred more. Johnson and Brown (1935, 1939) found that not all stutterers had difficulty on the same sounds. Furthermore, the data did not indicate any specific group of sounds which was difficult for stutterers. However, the frequency with which the various sounds were stuttered could be arranged in rank order, and from this ranking, those sounds whose rank order value was above the average was identified as difficult. The results indicated that words beginning with vowels and four easy consonants were less frequently associated with stuttering. Thus the authors reported that words beginning with some consonants, words from grammatical classes of nouns, verbs, adjectives and adverbs (content words) were stuttered more often than function words. Also, long words were more often stuttered than short words; words in the initial position of a sentence and stressed syllables were more frequently stuttered than others. These findings were investigated and corroborated by subsequent research. Hahn (1942a, 1942b), Quarrington (1963), Lanyon (1968, 1969) Schlesinger, Forte, Fried and Milkman (1965), Soderberg (1962, 1966, 1967), and Taylor (1966b) addressed some of Browns' findings, especially the grammatical factor and corroborated his findings. The last variable, stress, was compromised, till Wingate (1979) looked into it. In English, words of certain grammatical classes are typically spoken only with certain levels of stress. Word stress in English falls mostly on the first syllable and if not on the second syllable (data from Brown, 1937; Voelker, 1942; Hejna, 1955; Berger, 1967).

Wingate (1967) conducted a study where he constructed two lists of words: one 30 two syllable words and another list containing 30 pairs of single syllable words. Both the lists were phonemically matched, where each pair of the single syllable words was phonemically the same as that of a word in the two syllable list, although all the words differed in Standard English spelling. (For example fan sea fancy; bay bee baby; not whole knothole).

Persons with stuttering were taken as participants for the study. The participants were initially made to read the first list containing the single syllable pair of words and then to read the second list containing the single two syllable words. It was found that there was more stuttering when the participants read the first list containing two syllable words when compared to the single syllable words. Also, it was seen that stuttering was mainly in the initial part of the word. This study supported that word length plays a role in stuttering. In this study, the major dimension of the word length difference was that long words had prosodic pattern which can be seen by the variations in stress over the two syllables. In contrast, the single syllable words were spoken as separate syllabic units. This study hence showed that prosodic factors influence stuttering occurrences even at the level of individual words. Further, the results of two studies by Wingate (1979, 1984a) showed that grammatical class and early sentence position were not separate factors in their influence on stuttering.

It has been known for a long time that stuttering can be markedly reduced if a stutterer speaks under certain circumstances or in certain manners. These include singing, speaking rhythmically, choral speaking, speaking under reduced hearing acuity, speaking under delayed auditory feedback etc. The beneficial influences of these have been explained in several ways. However Wingate based on his experiments (1969, 1970, 1976) indicated that there is a change in the manner of speaking in all these circumstances and manners, which is the ***change in prosody***.

"Stuttering is characterized by an impairment of speech rhythm or fluency (Bloodstein and Ratner, 2008). Speech disruptions typically include blocks, repetitions, or prolongations of speech segments (WHO, 2007b), and may be accompanied by movements of face and limb muscles and by negative emotions such as fear or embarrassment. About 5% of the population stutters at some point during childhood (Mansson, 2000). Although spontaneous recovery rate is high, stuttering without obvious neurological origin persists after puberty in about 1% of adults (Andrews and Harris, 1964; Bloodstein and Ratner, 2008; Craig et al., 2002). Exploring the underlying neural mechanisms of this disorder provides insights into mechanisms of dysfluent speech production and into models of speech planning and production in general. These insights into the physiology of stuttering may ultimately serve to improve treatments enhancing speech fluency. Temporal patterns in speech occur on multiple timescales (i.e., subsegmental, segmental and suprasegmental, Levelt, 1989). In adults who stutter (AWS), acoustic-temporal and spatio-temporal characteristics are affected in stuttered and fluent speech on all these timescales (Jancke, 1994; Kleinow and Smith, 2000; Max and Gracco, 2005; Prins and Hubbard, 1992). Most consistent are the observations of increased variability of duration and relative timing of acoustic and kinematic features. Additionally, stuttering has been associated with altered auditory feedback control mechanisms (Max et al., 2004; Tourville et al., 2008). Altogether, these facts underline a deficit of speech motor timing and the impact of the timing of auditory information during speaking in AWS.

Alterations of timing abilities in AWS exceed the domain of speech and affect the motor control of non-speech movements as well. For example, AWS performed poorly in reproducing varying rhythmic patterns (Hunsley, 1937) or unpredictable digit sequences (Webster, 1986). Additionally, AWS exhibit prolonged initiation and execution times in finger movement sequencing tasks (Smits-Bandstra et al., 2006; Webster, 1997) and increased manual reaction times (Bishop et al., 1991; Webster and Ryan, 1991). Phase variability is greater during bimanual coordination of auditory paced movements (Zelaznik et al., 1997) and movement variability is increased during simultaneous synchronization of speech and hand movements (Hulstijn et al., 1992). However, studies on auditory paced isochronous finger movements did not find differences of timing accuracy and timing variability between AWS and controls (Hulstijn et al., 1992; Max and Yudman, 2003; Melvine et al., 1995; Zelaznik et al., 1994). Two separate processes have been related to timing accuracy: a neural clock mechanism (Rao et al., 1997; Ivry and Spencer, 2004), and an emergent property of the kinematics of movements itself (Ivry and Spencer, 2004; Mauk and Buonomano, 2004). This dissociation between event timing and emergent timing has been corroborated by previous findings (Spencer et al., 2003; Zelaznik et al., 2005, 2002). Timing in the sub- and supra-second range involves dissociable neural networks (Gibbon et al., 1997; Lewis and Miall, 2003; Wiener et al., 2010). Sub-second timing engages cerebello-thalamocortical network (Pollok et al., 2005), whereas supra-second timing tasks were more prone to activate cortical structures such as supplementary motor area (SMA) and prefrontal cortex (Wiener et al., 2010). For an event timing task like self-paced finger tapping, Wing and Kristofferson (1973) indicate a dichotomy between central clock and motor execution by suggesting that a central timekeeper supplies intervals of the adequate length and drives motor commands at the end of each interval. The original Winge-Kristofferson model was concerned with the special case of self-paced finger tapping and therefore neglected the process of integrating external cues. This contrasts with finger tapping in synchrony with an acoustically presented pacer, a timed motion task that additionally involves the integration of the external event and the monitoring of the synchrony of the pacer and the tapping. Theoretical frameworks on stuttering suggest an aberrant timing of neural activity in different brain regions that are relevant for speech processing (Alm, 2004; Howell, 2004; Ludlow and Loucks, 2003). Specifically, the basal gangliacortical route might be impaired in providing internal cues for the exact timing of movements, while the PMd in concert with the cerebellum successfully utilizes external time cues resulting in enhanced fluency for example during metronome speaking (Alm, 2004). Interestingly, in AWS even a non-speech motor task like externally paced finger tapping mirrored an irregular right-shifted activation (Morgan et al., 2008). This increased right pre-central activation suggests that the cortical contribution to the process of timed movements is less left lateralized" (Nicole, Jung, Rothkegel, Pollok, Gudenberg, Paulus and Sommer , 2010).

Prosodic features are features that extend beyond the segmental features and include intonation, stress, rhythm, and quantity. According to Lehiste (1970) "Suprasegmental features are features whose arrangement in contrastive patterns in the time dimension is not restricted to single segments defined by their phonetic quality". Intonation can be defined as "the distinctive use of patterns of pitch or melody" (Crystal, 1985). Intonation is the melodic pattern of an utterance. Intonation serves a grammatical function, distinguishing one type of phrase or sentence from another (Britannica encyclopedia). Rhythm is the systematic patterning of timing, accent and grouping in sequences of events (Patel, 2008).

Rhythm is considered to enhance fluency by shortening the unstressed syllables, and anticipating upcoming movements, hence aiding in rapid speech production. Further listener actively enters into the speaker's tempo and the movements of listeners tend to be in synchrony with the speech rhythm produced by the speaker (Martin, 1972). It is seen that rhythm is affected in persons with stuttering when compared with normal individuals. Van Riper (1982) also considered stuttering to be, at its root, "a disorder of timing," and suggested that "when a person stutters on a word, there is a temporal disruption of the simultaneous and successive programming of muscular movements required to produce one of the word's integrated sounds...". Kent (1984) suggested that "a primary difference between stutterers and nonstutterers lies in their capacity to generate temporal programs, or time structures of action".

A temporal misalignment or improper temporal alignment of one variable to another implies a mismatch. The rapidity which instances of stuttering come and go strongly suggest that whatever processes underlie instances of stuttering must also come and go rapidly. Sometimes the processes are temporally aligned and the resulting speech behavior is smooth and fluent. Other times, the processes are subtly to not- so- subtly misaligned and the resulting speech is hesitant, repetitious or actually stopped until the underlying processes are temporally aligned (Manning, 1996).

The above studies suggest that stuttering may be a prosodic disorder. If stuttering is a prosodic disorder then there is ample evidence to believe that persons with stuttering will behave differently on prosody – intonation, stress and rhythm. In this context the present study examined the perception of rhythm in persons with stuttering (PWS) and compared it with persons with no stuttering (PWNS).

Specifically the objectives of the study were multifold and as follows:

- To compare the accuracy of tapping for the different ta:las in diotic and dichotic conditions in PWS and PWNS,
- To compare the percent accuracy for each ta:la in PWS and PWNS,
- To compare the ear preference for the perception of ta:la in PWS and PWNS,
- To compare the ta:la preferred by PWS and PWNS, and
- To compare the reaction time in PWS and PWNS.

CHAPTER II

REVIEW OF LITERATURE

Prosody or suprasegmentals refer to features superimposed on segments and include intonation, stress and rhythm. Intonation refers to the pitch movement in a sentence, stress refers to the extra effort and rhythm refers to repeated movements. Stuttering has been considered as a disorder of prosody (Wingate, 1984a). Wingate examined studies on grammatical variables on stuttering and conducted several studies and proposed stuttering as a prosodic disorder.

Johnson and Brown (1935, 1939) found that not all stutterers had difficulty on the same sounds. Furthermore, the data did not indicate any specific group of sounds which was difficult for stutterers. However, the frequency with which the various sounds were stuttered could be arranged in rank order, and from this ranking, those sounds whose rank order value was above the average was identified as difficult. The results indicated that words beginning with vowels and four easy consonants were less frequently associated with stuttering. Thus the authors reported that words beginning with some consonants, words from grammatical classes of nouns, verbs, adjectives and adverbs (content words) were stuttered more often than function words. Also, long words were more often stuttered than short words; words in the initial position of a sentence and stressed syllables were more frequently stuttered than others. These findings were investigated and corroborated by subsequent research. Hahn (1942a, 1942b) Quarrington (1963), Lanyon (1968, 1969) Schlesinger, Forte, Fried and Milkman (1965), Soderberg (1962, 1966, 1967), and Taylor (1966b) addressed some of Browns' findings, especially the grammatical factor and corroborated his findings. The last variable, stress, was compromised, till Wingate (1979) looked into it. In

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Studies has been done regarding the perception of rhythmic patterns since the nineteenth century (Hall & Jastrow, 1886; Bolton, 1894). Bolton (1894) conducted a psychophysical experimental study on the perception of rhythm. The stimulus used was clicks. When asked to reorganize the clicks, the subjects at first reported of hearing a steady, unchanging beat, but after a short period of time, the clicks became organized into groups which had the requested number of clicks. Most of the subjects were not able to maintain the requested organization of groups for a longer duration, and soon went back to their preferred organization. Few of the subjects were not able to hear any organization at all and kept on hearing a steady, unchanging series of clicks even when they were asked to count and tap their finger at every second or fourth click. The inter–click interval was varied and it was noted that as the rate of the click was varied, the number of clicks per group also changed, which was normal for the subjects. It was also noted that the length of time per group remained relatively constant, although it did tend to decrease as the number of clicks per group increased.

Woodrow (1934) had done a study on the perception of duration between sequences of clicks in terms of his concept of the indifference interval. Individual differences were found such that for each subject, i, there was a time interval, Ti such that the subjects tend to say that the interval between the first pair of clicks was longer when t

< Ti seconds and the interval between the second pair of clicks was longer when t > Ti seconds.

Studies by Cameron, Potter, Wiggins and Pearce (2010), done on musicians and non musicians states that musical training provides an advantage in processing rhythmic information. It was also found that Clapping Music's (starting with the first 2 rhythmic figures, up to the full 12 figures) compositional process of rhythmic transformation can provide additional information used by listeners to distinguish rhythms, and that the perceived similarity of rhythms can depend on the order in which they are presented.

A study was done by Odekar (2001) to examine the perception of rhythm in normal individuals. She took 32 right handed subjects of the age range 18-25 yrs for the study. Four ta:las of Carnatic music were used as the stimuli which were Tisra, Misra, Caturasra and Khanda ta:las. She presented the ta:las in monoaural condition where each ear was separately tested for each ta:la and in a dichotic condition where two ta:las were sent to each ear simultaneously. The subjects were asked to tap according to the rhythm. It was found that there were no ear advantages in the monoaural condition. There was a right ear advantage found in dichotic condition.

Reicker, Wildgruber, Dogil, Mayer, Ackermann and Grodd (2002) used fMRI and reported that left subcortical and right cortical structures play an important role during rhythmic syllable production. Jeffries, Fritz and Braun (2003) had done a study where they compared the patterns of activation during speech with the pattern during song with words. It was seen that speech occurs mainly due to activation of the left hemisphere, while singing had a widespread activation of the right hemisphere. It was also noted that during speech there was increased activation in the left dorsal putamen (the basal ganglia motor circuit) but singing did not result in any activation of the right or left putamen. This result indicated that normal speech requires timing cues from (the left) basal ganglia system, while singing is based on a different strategy for timing of syllables, which mainly involves the structures of the right hemisphere.

A study was done by Gauri (2004) where the perception of rhythm was studied in both stutterers and non stutterers. The stimuli were presented monoaurally to each ear during the first experiment and the time taken for perception of the rhythm was noted. It was found that, in general stutterers identified rhythms better compared to non stutterers. It was also seen that normals identified rhythms presented to the right ear better than those presented to the left ear and stutterers identified rhythms presented to the left ear better than those presented to the right ear.

Limb, Kemeny, Ortigoza, Rouhani, and Braun (2006) used MRI, where 12 non musicians and 12 non musicians participated. Conjunction analysis revealed a shared network of neural structures which are mainly the bilateral superior temporal areas, left inferior temporal lobe, right frontal operculum irrespective of the musical background. The left hemisphere lateralization was seen more in musicians compared to non musicians. The results indicated that musical training leads to the involvement mostly of the perisylvian areas in the left hemisphere which are otherwise active during language comprehension. The mechanism of cerebral control of singing differs from the control of speech. Grahn and Brett (2007) investigated the perception of rhythm and beats, in musicians and non musicians by using fMRI scans and observed that there was a higher activity in the basal ganglia and supplementary motor area. Musicians showed increased activation unrelated to rhythm type in the premotor cortex, cerebellum, and supplementary motor areas (pre-supplementary motor area and supplementary motor area). It was concluded that in addition to their role in movement production, the basal ganglia and supplementary motor areas may mediate beat perception.

Hampton and Fox (2008) had done a study in adults with and without stuttering using an odd ball paradigm of tones. It was seen that adults with stuttering performed less accurately compared to the other group. Also, the P300 was found to be reduced in the stuttering group which suggests that in adults with stuttering, there is a possibility of having a weaker update in the short term memory for representing the target tone stimuli.

Vuust, Ostergaard, Pallesen, Bailey and Roepstorff (2009) conducted a study using MEG where sequences of rhythm was investigated, which contained greater salient violations of the expectancy of the rhythm. The error term was predicted to be shown by the mismatch negativity component (MMNm).A mismatch negativity (MMNm) and a subsequent P3am component were noted, and they were strongest for the condition with the biggest expectancy violation. Musicians had a greater sensitivity, when compared to non-musicians, to milder violations, by having larger MMNm peaks which were found to occur slightly early. The authors suggest that this indicates that musicians have a better internal representation of the metrical structure, which enables them to make more precise predictions about the incoming stimuli. The brains of the musicians therefore respond more strongly and more quickly than non-musicians to any slight changes from their predictions.

Neef, Jung, Rothkegel, Pollok, Gudenberg, Paulus and Somme (2009) investigated rhythm in persons with and without stuttering. Subjects were asked to perform paced finger tapping using right and left hand according to the beats heard in a metronome. It was seen that in individuals with no stuttering, there was an inhibition of left dorsal precortex which affected synchronization accuracy of left hand. In individuals with stuttering, trans magnetic stimulation over right dorsal premotor cortex increased the asynchrony of left hand. This result supports the earlier studies confirming a particular role of the left dorsal premotor cortex in auditory paced rhythmic finger tapping (Pollok, Rothkegel, Schnitzler, Paulus & Lang, 2008). The study indicates an altered functional connectivity in individuals with stuttering in which the right dorsal premotor cortex seems to be important for the control of timed non speech movements. Moreover, a shift in the laterality suggests a compensatory role of the right dorsal premotor cortex to successfully perform paced finger tapping. In this study the subjects were asked to perform paced finger tapping using right and left hand according to the beats heard in a metronome. The beats presented had been constant with no change in the rhythm. However, the reaction time was not noted. The beats were presented to both the ears simultaneously where the hemisphere which was activated first could not be found out.

In a study by Kaganovich, Wray and Fox (2010), event related potentials were used and 18 children with stuttering and 18 children without stuttering participated in the study. An odd ball paradigm was used as the stimulus where 1 kHz tones were given more often and 2 kHz tone was presented rarely in between these 1 kHz tones. It was seen that the event related potentials were almost the same in both the groups. There was no change in the peaks P1 and N1 which indicates that the encoding of pure tones is unimpaired in children with stuttering. The P300 was found to be less robust in children with stuttering. In the above study, the behavioural responses of the clients were not assessed. Also only one type of auditory change was noted since only two frequencies were used for the study.

The above studies suggest that stuttering may be a prosodic disorder. If stuttering is a prosodic disorder then there is ample evidence to believe that persons with stuttering will behave differently on prosody – intonation, stress and rhythm. In this context the present study examined the perception of rhythm in persons with stuttering (PWS) and compared it with persons with no stuttering (PWNS).

CHAPTER III

METHOD

Participants: Two groups of subjects participated in the study. Group I consisted of 15 persons with stuttering ranging from moderate to severe degree, as diagnosed by a speech pathologist. Group II consisted of 15 age and gender matched normal individuals. All the subjects selected were non- musicians with normal hearing and with no psychological, sensory, motor or cognitive impairments on observation by the experimenter. The details of the participants in group I are in table1.

Participant	Age in years	Severity of stuttering
1.	18	Severe
2.	19	Moderate
3.	19	Moderate
4.	21	Moderate
5.	21	Mod- Severe
6.	21	Moderate
7.	23	Moderate
8.	23	Mod- Severe
9.	25	Severe
10.	26	Moderate
11.	26	Moderate
12.	27	Moderate
13.	29	Severe
14.	29	Mod- Severe
15.	30	Severe

Table 1: Details of participants in group I.

Stimuli: Four ta:las of Carnatic music - Tisra, Caturasra, Khanda, and Misra – were selected. Tisra ta:la has three beats with stress on the first beat; Caturasra ta:la has four beats with stress on the first beat; Khanda ta:la has five beats with stress on first and third beat and Misra ta:la has seven beats with stress on first, fourth and sixth beat. Table 2 shows the beats of the ta:las.

Tisra	Iii sariga sariga 3
Caturasra	Iiii sarigama sarigama 4
Khanda	Ii Iii sarisariga sarisariga 5- 2,3
Misra	IiiIiIi sarigasarisari sarigasarisari – 7 – 3,2,2

Table 2: Beats of the ta:las (Capitalized I indicates stress on the beat).

These ta:las in Ma:ya:ma:lavagaula ra:ga were sung five times by a female musician aged 59 years with an experience of 51 years in music. The ta:las were audio-recorded using Omega digital tape recorder. From the recordings the best singings in each ta:la were selected and displayed as waveform using PRAAT software (Boersma & Weenink, 2011). Silence if any was deleted and each ta:la was repeated twice. Two experiments were conducted. Experiment I involved diotic listening and experiment II involved dichotic listening.

Stimuli for experiment I: Using Adobe Audition (Adobe Systems, 2003) multitrack, same ta:las were aligned in two channels. Thus the participant would hear the same ta:la in both ears. A total of four stimuli were generated in this manner. Figure 1 shows an example of diotic stimuli.

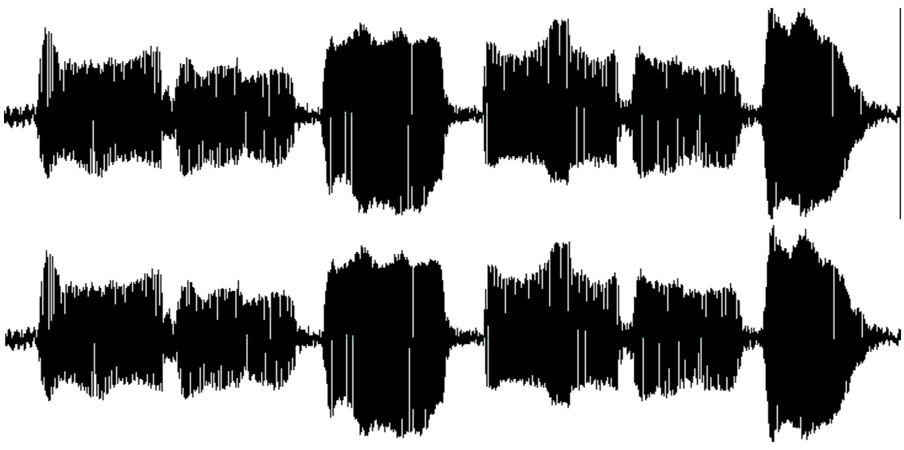

Figure 1: Diotic stimuli /sariga sariga/.

Stimuli for experiment II: The duration of the ta:las differed. For example, Tisra was short and Misra was long. Hence in order to minimize the effect of duration on rhythm perception the ta:las were loaded on to PRAAT software. The duration of each ta:la was measured from the waveform display. Using PSOLA, the duration of Tisra (which was the shortest) was lengthened to be equal to Misra. Similarly, the duration of the other two ta:las was lengthened to be equal to Misra. Following this, dichotic stimuli were generated so that all possible combinations were obtained. For example, Tisra was in the first track and Caturasra was in the second track of the multitrack recording of Adobe Audition; Tisra was in the first track and Khanda was in the second track; Tisra was in the first track and Misra was in the second track. In the same manner combinations of other ta:las were also generated. Table 3 shows the combinations of ta:las and the ears to which they were supposed to be presented.

Ear	
Right	**Left**
Tisra	Caturasra
Tisra	Khanda
Tisra	Misra
Caturasra	Tisra
Caturasra	Khanda
Caturasra	Misra
Khanda	Tisra
Khanda	Caturasra
Khanda	Misra
Misra	Tisra
Misra	Caturasra
Misra	Khanda

Table 3: Dichotic presentation of ta:las.

Stimuli were randomized and presented thrice. Thus a total of 12 and 36 stimuli were generated in diotic and dichotic conditions, respectively.

Procedure: Participants were seated comfortable and were tested individually. The stimuli were presented using the Adobe Audition software (Adobe Systems, 2003) through headphones diotically and dichotically. Before the actual experiment subjects were familiarized with the task using three diotic and dichotic stimuli. A loud speaker was connected with the computer which was kept on the table in front of the participant. Further, the digital tape recorder was kept close to the loud speaker. The purpose of the loud speaker was to enable recording the stimuli and the response in the Omega tape recorder so that reaction time could be measured.

Procedure for experiment I: Participants were instructed to listen to the stimuli carefully and tap the rhythm on the table in front of them as soon as they perceive it. The tapings and the stimuli from the loud speaker were audio- recorded using the Omega tape recorder placed on the table in front the participant.

Procedure for experiment II: Participants were instructed to listen to the stimuli carefully and tap the rhythm on the table in front of them as soon as they perceive it irrespective of the ear in which they heard the ta:la. The tapings and the stimuli from the loud speaker were audio- recorded using a microphone placed on the table in front the participant.

The audio-recorded stimuli and taps were listened to by the experimenter and the accuracy of the taps was decided. Only accurate tappings were used for further measurements. The audio-recorded stimuli and taps were displayed on PRAAT as waveform and reaction time was measured as the time difference between the onset of the stimuli to the onset of the tapping. Figure 2 illustrates the measurement of reaction time.

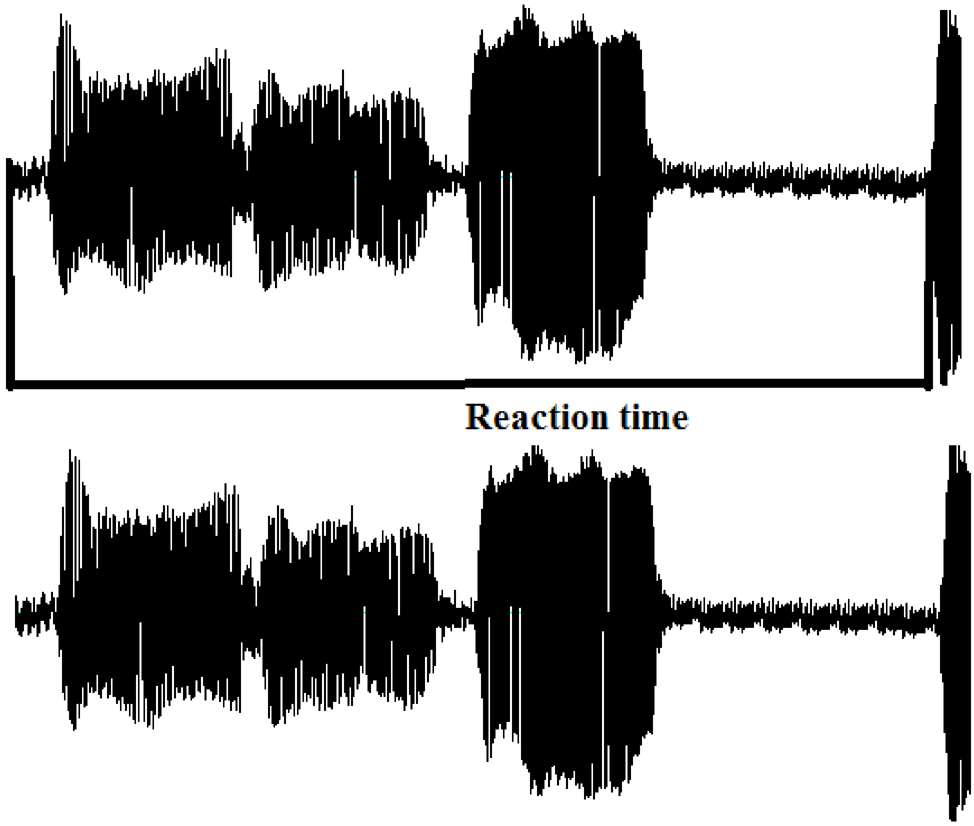

Figure 2: Illustration of measurement of reaction time.

Statistical analyses: Commercially available SPSS software (version 17.0) was used statistical analyses. The percent accuracy for diotic and dichotic stimuli for each ta:la was calculated. Equality of proportions was used to find out significant difference between groups. Chi-square test was used to find significant difference between groups on ear preferences for each ta:la. Mixed ANOVA, Repeated measures ANOVA and Independent sample t- test were used to find the significant difference in reaction time across and within group in the diotic condition. A graph was plotted to find the differences in reaction time of the ta:la pairs in dichotic condition across and within groups.

CHAPTER IV

RESULTS

The results are discussed under the following headings:

1) Accuracy of responses in PWS and PWNS,
2) Percentage accuracy for each ta:la in PWS and PWNS,
3) Comparison of ear preference in PWS and PWNS,
4) Comparison of ta:la preferences in PWS and PWNS, and
5) Comparison of reaction time in PWS and PWNS.

1) Accuracy of responses in PWS and PWNS

The results indicated that the overall accuracy of responses in PWS was 51.5% (Diotic – 67.7; dichotic – 46.1) and 67.6 in PWNS (Diotic – 83.3; dichotic – 62.4). Accuracy was better in diotic condition compared to dichotic condition. Further, results of equality of proportions indicated significantly poorer accuracy in PWS compared to PWNS (Diotic condition - $|z| = 3.4$, $p<0.05$; dichotic - $|z| = 5.37$, $p<0.05$; Overall - $|z| = 6.2$, $p<0.05$). Table 4 shows the percent accuracy of ta:las in PWS and PWNS.

Groups	**Diotic**	**Dichotic**	**Overall**
I	67.7	46.1%	**51.5**
II	83.3	62.4	**67.6**

Table 4: Percent accuracy of ta:las in PWS and PWNS.

2) Percentage accuracy for each ta:la in PWS and PWNS

Accuracy was best for Tisra ta:la followed by Catusra, Khanda and Misra ta:las in both groups in diotic condition. Results of equality of proportions indicated significantly poorer accuracy in PWS compared to PWNS on Khanda and Misra ta:las in diotic condition. Table 5 shows percent accuracy, Z values and p values for four ta:las in diotic condition.

Ta:la	Group I	Group II	Z value	p value
Tisra	100	100		-
Catusra	84.4	88.8	0.62	>0.05
Khanda	64.4	86.6	2.45	<0.05
Misra	22.2	60	3.64	<0.05

Table 5: Percent accuracy of ta:la in both groups, Z and p values in diotic condition.

3) Comparison of ear preference in PWS and PWNS

Results of chi-square test indicated significantly better response in right ear for T-C, T-K, T-M, C-K, C-M, C-T. K-M ta:las; significantly better response in left ear for M-C,M-T ta:las and equal preference for K-T ta:la in dichotic condition in PWS. Table 6 shows the number of times the ears were preferred and the Z and p value on chi-square test.

Stimuli	Ear		Total	Z value	p value
	Right	Left			
T-C	22	7	29	3.38	**<0.05**
T-K	18	5	23	3.14	**<0.05**
T-M	17	2	19	3.87	**<0.05**
C-K	25	2	27	5.29	**<0.05**
C-M	18	2	20	4.05	**<0.05**
C-T	25	9	34	3.47	**<0.05**
K-C	9	15	24	1.43	>0.05
K-M	11	2	13	2.69	**<0.05**
K-T	12	12	24	0.0	>0.05
M-C	2	9	11	2.25	**<0.05**
M-K	3	3	6	0.0	>0.05
M-T	4	15	19	2.8	**<0.05**
Total	166	83	249		**<0.05**

Table 6: Ear preference, Z and p values on Chi-square test in PWS (T – Tisra, C – Caturasra, K- Khanda, M – Misra).

Results of chi-square test indicated significantly better response in right ear for C-K, C-M, C-T, K-M, T-M ta:las and significantly better response in left ear for M-C ta:las in dichotic condition in PWNS. Table 7 shows the number of times the ears were preferred and the Z and p value on chi-square test.

Stimuli	Ear		Total	Z value	p value
	Right	Left			
T-C	15	19	34	0.86	>0.05
T-K	17	12	29	1.12	>0.05
T-M	19	6	25	3.05	**<0.05**
C-K	28	7	35	4.54	**<0.05**
C-M	14	6	20	2.02	**<0.05**
C-T	37	6	43	6.54	**<0.05**
K-C	13	24	37	2.35	**<0.05**
K-M	18	3	21	3.73	**<0.05**
K-T	19	12	31	1.55	>0.05
M-C	3	19	22	3.92	**<0.05**
M-K	7	11	18	1.05	>0.05
M-T	12	10	22	0.49	>0.05
Total	202	135	337		

Table 7: Ear preference, Z and p values on Chi-square test in PWNS (T – Tisra, C – Caturasra, K- Khanda, M – Misra).

Both the groups preferred right ear compared to left ear for most of the stimuli.

4) Comparison of ta:la preferences in PWS and PWNS

Results of chi-square test indicated no significant difference between groups on ta:la preferences. However, Group I had significantly lower preference for C-T and M-T in right ear. Table 8 shows the number of times groups preferred each ta:la in right year, Z and p values on Chi-square test.

Stimuli	PWS	PWNS	Z value	p value
T-C	22	15	1.49	>0.05
T-K	18	17	0.21	>0.05
T-M	17	19	0.43	>0.05
C-K	25	28	0.64	>0.05
C-M	18	14	0.88	>0.05
C-T	25	37	2.70	**<0.05**
K-C	9	13	0.98	>0.05
K-M	11	18	1.50	>0.05
K-T	12	19	1.55	>0.05
M-C	2	3	0.46	>0.05
M-K	3	7	1.30	>0.05
M-T	4	12	2.20	**<0.05**

Table 8: Ta:la preference between groups, z and p values in right ear (T – Tisra, C – Caturasra, K- Khanda, M – Misra).

Results of chi-square test also indicated no significant difference between groups on ta:la preferences. However, Group I had significantly lower preference for T-C and M-C in left ear. Table 9 shows the number of times groups preferred each ta:la in right year, Z and p values on Chi-square test.

Stimuli	PWS	PWNS	Z value	p value
T-C	7	19	2.79	**<0.05**
T-K	5	12	1.88	>0.05
T-M	2	6	1.48	>0.05
C-K	2	7	1.75	>0.05
C-M	2	6	1.48	>0.05
C-T	9	6	0.04	>0.05
K-C	15	24	1.90	>0.05
K-M	2	3	0.46	>0.05
K-T	12	12	0.0	>0.05
M-C	9	19	2.2	**<0.05**
M-K	3	11	2.32	<0.05
M-T	15	10	1.17	>0.05

Table 9: Ta:la preference between groups, z and p values in left ear (T – Tisra, C – Caturasra, K- Khanda, M – Misra).

5) Comparison of reaction time in PWS and PWNS

The reaction time was 164.69 ms and 125.60 ms in PWS and PWNS, respectively. Results of ANOVA showed that reaction time was significantly longer in PWS compared to PWNS [F = 17.865, p<0.05]. However, SD was high in both groups. Table 10 shows the mean, SD and N of reaction time in both groups for each ta:la.

Ta:la	Groups	Mean	SD	N
Tisra	1	179.00	46.709	14
	2	129.00	29.211	15
	Total	153.14	45.674	29
	1	171.00	35.117	14
Caturasra	2	134.80	16.891	15
	Total	152.28	32.467	29
	1	144.07	22.023	14
Khanda	2	113.00	22.181	15
	Total	128.00	26.849	29

Table 10: Mean, SD and N of reaction time in both groups for each ta:la.

Results of Mixed ANOVA showed significant difference between reaction times of Tisra and Khanda ta:las and Tisra; Khanda and Caturasra ta:las; Khanda and Tisra ta:las in both groups. Misra tala was not considered in the statistical analyses since there was less number of observations. Table 11 shows the mean difference and p values between ta:las in both groups.

Ta:la	Ta:la	Mean Difference	p value
Tisra	Caturasra	1.100	>0.05
	Khanda	25.464	**<0.05**
Caturasra	Tisra	-1.100	>0.05
	Khanda	24.364	**<0.05**
Khanda	Tisra	-25.464	**<0.05**
	Caturasra	-24.364	**<0.05**

Table 11: Mean difference and p values between ta:las in both groups.

Results of repeated measure ANOVA indicated significant difference within the groups in the diotic condition. Comparison of Tisra, Caturasra and Khanda ta:las indicated that reaction times significantly differed between Tisra and Khanda, and Caturasra and Misra ta:las in PWS. However, in PWNS significant difference was noticed between Caturasra and Khanda ta:las. Table 12 shows the mean difference and p values within groups for ta:las.

		Group I		Group II	
Ta:la	Ta:la	Mean difference	p value	Mean difference	p value
1	2	8.000	>0.05	-5.800	>0.05
	3	34.929	**<0.05**	16.000	>0.05
2	1	-8.000	>0.05	5.800	>0.05
	3	26.929	**<0.05**	21.800	**<0.05**
3	1	-34.929	**<0.05**	-16.000	>0.05
	2	-26.929	**<0.05**	-21.800	**<0.05**

Table 12: Mean difference and p values within groups for ta:las for reaction time (1 = Tisra, 2 = Caturasra, 3 = Khanda).

Results of Independent sample t-test showed significant difference [t (18) = -3.199, p<0.05] between groups on the reaction time of Misra ta:la with other ta:las in diotic condition. Within group II significant difference between Caturasra and Misra ta:las was noticed. Table 13 shows t, df and p values for reaction time between Misra and other ta:las in both groups.

	Group I			Group II		
Pair	T	Df	p value	t	df	p value
Tisra-Misra	1.691	6	>0.05	1.83	12	>0.05
Caturasra-Misra	1.142	6	>0.05	3.02	12	**<0.05**
Khanda- Misra	-1.052	6	>0.05	-0.543	12	>0.05

Table 13: t, df and p values for reaction time between Misra and other ta:las in both groups.

In the dichotic condition all the tal:a pairs were compared within and across groups. Significant differences were seen within and across groups. Misra-Tisra pair and Caturasra- Tisra pairs had the longest reaction time in PWS and PWNS, respectively. Figure 3 shows the reaction time for ta:la pairs in both groups.

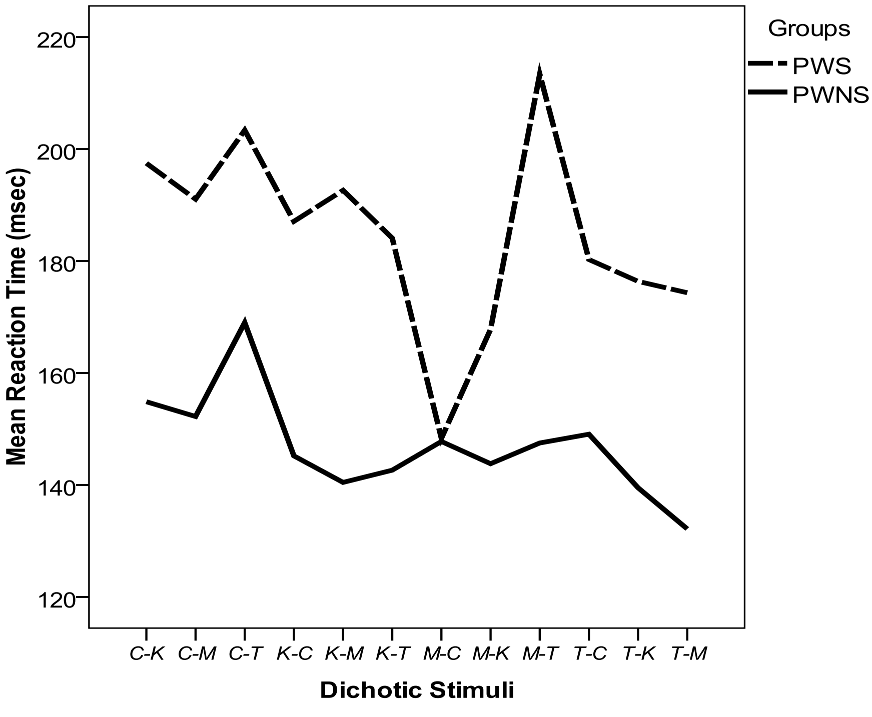

Figure 3: Reaction time for ta:la pairs in both groups.

CHAPTER V

DISSCUSSION

The results indicated several points of interest. First of all the ***overall accuracy of responses was significantly lower in PWS compared to PWNS***. Accuracy was better in diotic condition compared to dichotic condition. Further, results of equality of proportions indicated significantly poorer accuracy in PWS compared to PWNS. This result is in consonance with the study done by Gauri (2004), where it was found that the accuracy of the response was less in PWS compared to PWNS and it was also found that the accuracy of both the groups decreased in dichotic condition with PWS having lesser accuracy than PWNS. These results indicate that there is some impairment in the perception of the rhythm or in the motoric abilities in PWS. This result is also in consonance with the study done by Hampton & Fox (2008) where odd ball paradigm of tones were used and it was seen that PWS had poorer accuracy in identifying the tones compared to PWNS. According to Bloodstein & Ratner (2008)"Stuttering is characterized by an impairment of speech rhythm or fluency". Rhythmic speech is impaired in PWS, there may be an impairment at the level of rhythm perception as well. Further, the lower accuracy scores in the dichotic presentation might have been due confusions. This greater confusion can be due to impairment in perceiving and in focusing and responding to only one stimulus.

Second, ***accuracy was best for Tisra ta:la followed by Caturasra, Khanda and Misra ta:las in both groups in diotic condition***. Results of equality of proportions indicated significantly poorer accuracy in PWS compared to PWNS on Khanda and Misra ta:las in diotic condition. This is expected as Tisra was the simplest ta:la and Misra was the most complex ta:la among the four ta:las. This result is in consonance with the study done by Odekar (2001) where it was seen that the subjects were able to correctly identify Tisra and Caturasra ta:las compared to Khanda and Misra ta:las. The increase in the number of beats in Khanda and Misra ta:las leads to increase in the complexity of the ta:las. Tisra ta:la has three beats and Caturasra ta:la has four beats, wheareas Khanda ta:la has five beats and Misra ta:la has seven beats. Hence, the accuracy of Tisra ta:la was the best followed by Caturasra, Khanda and Misra ta:las. The result is not in consonance with the study done by Gauri (2004), where it was found that Tisra ta:la and Khanda ta:la were more easily identified when compared to the other ta:las. This may be because of the similarity in the stress of these two ta:las. Tisra ta:la has stress in the first beat wheareas Khanda ta:la has stress on the first and the fourth beat. So the pattern of stress is almost similar. Moreover, the presentation of the ta:las were different in these two studies. In the former study, the presentation was in a monotic condition whereas in the present study, the presentation is in a diotic condition. This might have also lead to variation in the responses, as the subjects might have concentrated more on the stress patterns and hence might have perceived Tisra ta:la and Khanda ta:la as similar and easy.

Third, ***results of chi-square test indicated significantly better response in right ear*** for T-C, T-K, T-M, C-K, C-M, C-T. K-M ta:las; significantly better response in left ear for M-C,M-T ta:las and equal preference for K-T ta:la in dichotic condition in PWS. Also, significantly better response in right ear for C-K, C-M, C-T, K-M, T-M ta:las and significantly better response in left ear for M-C ta:las in dichotic condition in PWNS was noticed. The results indicated a right ear preference in both groups. Thus no differences between groups on ear preferences were noticed. This result where PWNS preferred right ear is in consonance with the study done by Gauri

(2004). The results are not inconsonance with the study done by Odekar (2001), where PWS had a left ear preference. In the present study, it appeared that simple ta:las were preferred when presented in right ear. However, when simple ta:las like Tisra and Caturasra were presented in the left ear along with complex ta:la in right ear, left ear was preferred. Thus it appears that ta:las were preferred rather than ears.

Fourth, ***reaction time was significantly longer in PWS compared to PWNS***. The results are in consonance with those by Cross & Luper (1979) and Reich, Till & Goldsmith (1981). Cross & Luper (1979), reported a significantly longer reaction time in voicing /^/ to each stimulus for PWS compared to PWNS. Reich & Goldsmith (1981) noted reaction time for subjects for button pressing, inspiratory phonation, expiratory throat clearing and also production of isolated vowel and word and reported that the reaction time for PWS was significantly longer than for PWNS for all the tasks. It was interesting to note that reaction time decreased from Tisra to Caturasra to Khanda in PWS and from Khanda to Tisra to Caturasra in PWNS. Ludlow and Loucks (2003) indicate that studies of dynamic inter-relationships among brain regions during normal speech and in persons who stutter (PWS) suggest that the timing of neural activity in different regions may be abnormal in PWS. “The symptoms of stuttering are compared with basal ganglia motor disorders like Parkinson's disease and dystonia. It is proposed that the basal ganglia-thalamocortical motor circuits through the putamen are likely to play a key role in stuttering. The core dysfunction in stuttering is suggested to be impaired ability of the basal ganglia to produce timing cues for the initiation of the next motor segment in speech. Similarities between stuttering and dystonia are indicated, and possible relations to the dopamine system are discussed, as well as the interaction between the cerebral cortex and the basal ganglia. Behavioral and pharmacologic information suggests the existence of subtypes of stuttering" (Alm, 2004). Further, Andrade, Sassi , Juste, and Mendonça (2008) examined the rest muscle tension and speech reaction time of fluent (G1) and stuttering (G2) adults. They reported that the groups were significantly different considering rest muscle tension (G2 higher recordings) and did not differ when considering speech reaction time and muscle activity during speech. There was a strong positive correlation between speech reaction time and speech muscle activity for G2--the longer the speech reaction time, the higher the muscle activity during speech.

Last, ***Misra-Tisra pair and Caturasra- Tisra pairs had the longest reaction time in PWS and PWNS***, respectively. It is interesting to note that Misra is a complex ta:la and Tisra is a simple ta:la and that PWS had longest reaction time on this pair. Probably they had confusion in detecting ta:la presented in the right ear. Or it may be that since Tisra ta:la was very slow compared to Misra ta:la, they had a tendency to tap for Tisra ta:la. However, PWNS did not have this confusion. It might be because that they did not have much difficulty tapping to Misra ta:la. They had confusion only in two simple ta:las (Caturasra and Tisra) presented dichotically. It might be because of the similarity between these two ta:las. Tisra ta:la has three beats, Caturasra ta:la has four beats, Khanda ta:la has five beats and Misra ta:la has seven beats. There is a difference of only one beat between these two ta:las, whereas there is a difference of more than one beat in all the other ta:la combinations. Hence, the similarity between these two ta:las might have caused confusion and a longer reaction time to choose one ta:la and respond according to it.

The results indicate some differences between PWS and PWNS. However, these are not strong to support any model on the cause of stuttering. Future studies are warranted which could more specifically investigate the responses of PWS to rhythm along with rhythm production tasks.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Wingate (1985) hypothesised stuttering as a prosodic disorder. A study was conducted by Wingate where PWS were asked to read two syllable words and pairs of single syllable words which were phonemically same. It was observed that PWS were able to read the single syllable pairs with dysfluencies compared to the single two syllable words. This study hence showed that prosodic factors influence stuttering occurrences even at the level of individual words. Studies have proven that the perception of rhythm is affected in stuttering (Odekar 2001;Gauri 2004; Hampton & Fox,2008).

The present study examined the perception of rhythm in PWS and PWNS. 15 PWS with a severity range from moderate to severe as diagnosed by an SLP, and 15 age and gender matched PWNS participated in the study. The age range of the participants was from 18-30 years. All the participants were right handed, non-musicians and did not have any psychological, cognitive, sensory or motor impairments, on an informal assessment by the experimenter. Four ta:las of Carnatic classical music- Tisra, Caturasra, Khanda and Misra were considered for the study. A 59 year old female musician with 51 years of experience in music sung the ta:las in Ma:ya:ma:lavagaula ra:ga which was audio recorded using a digital tape recorder. Two conditions- diotic and dichotic - were considered. Using the Adobe audition software the same ta:las were copied in the two channels of multitrack recording which were saved for diotic condition. Thus, there were four files for diotic condition. The duration of all the ta:las was equalized using PSOLA software of PRAAT. Following this a ta:la was copied on track one and another ta:la on track two. In this manner twelve files were generated and saved for dichotic condition. The four files in diotic condition and twelve files in dichotic condition was iterated thrice and randomized. Thus, a total of twelve files and thirty six files formed the stimuli for diotic and dichotic conditions, respectively.

Participants were seated comfortably and tested individually. They were audio-presented with the stimuli through headphones and were instructed to tap for the stimuli on the table in front of them as soon as possible. Further, they were instructed to tap to the stimuli, they perceived in the diotic condition. The stimuli through a loudspeaker, and the taps were audio- recorded using a digital tape recorder. The recordings were listened to and the accuracy of the taps was determined. Recordings which had accurate taps only were considered for further analysis. The reaction time was calculated for the accurate responses, by calculating the duration from the onset of the stimulus to the onset of the response.

A commercially available SPSS (version 17.0) was used for statistical analysis. Percent accurate taps for groups, ears, and ta:las were calculated. Equality of proportions and Chi- square test were used to find significant difference between groups, ears, ta:las.

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Last, ***Misra-Tisra pair and Caturasra- Tisra pairs had the longest reaction time in PWS and PWNS***, respectively. It is interesting to note that Misra is a complex ta:la and Tisra is a simple ta:la and that PWS had longest reaction time on this pair. Probably they had confusion in detecting ta:la presented in the right ear. Or it may be that since Tisra ta:la was very slow compared to Misra ta:la, they had a tendency to tap for Tisra ta:la. However, PWNS did not have this confusion. It might be because that they did not have much difficulty tapping to Misra ta:la. They had confusion only in two simple ta:las (Caturasra and Tisra) presented dichotically. It might be because of the similarity between these two ta:las. Tisra ta:la has three beats, Caturasra ta:la has four beats, Khanda ta:la has five beats and Misra ta:la has seven beats. There is a difference of only one beat between these two ta:las, whereas there is a difference of more than one beat in all the other ta:la combinations. Hence, the similarity between these two ta:las might have caused confusion and a longer reaction time to choose one ta:la and respond according to it.

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