5. DISCUSSION

Behavioral measurement of speech characteristics: SSI was one of the tools of our study to measure the changes in speech characteristics of persons with stuttering (PWS) after the therapy. Both pre and post therapy measurements were carried out using SSI. The improvement in the speech among PWS was indicated by the change in SSI score after the therapy, which would be contributed to the efficacy of the therapy. In pre assessment out of 100 PWS 28 had moderate stuttering, 56 had severe stuttering while 16 had normal fluency while 15 had mild stuttering on post assessment. Similarly, out of 56 PWS with severe stuttering in pre assessment, 9 had normal fluency 43 had mild stuttering and 4 had moderate stuttering on post assessment. Also, out of 16 PWS who had very severe stuttering in pre assessment, 6 had mild stuttering, 8 had moderate stuttering and 2 had severe stuttering on post assessment. Thus the analysis of pre and post assessments revealed improvement in terms of stuttering severity in the majority of PWS.

In a study by Cristiane and Pereira, 2014, regarding the assessment made after the applied therapeutic program, there was a significant improvement in fluency profile, as most of the analyzed measurements (speech disruption, stuttering-like disfluencies, flow of syllables per minute and stuttering severity) showed statistically significant differences. The findings indicated that there was a quantitative reduction in disruptions, which led to an increased flow of syllables per minute and decreased stuttering severity. These results confirm the therapeutic efficacy of applied therapy program.

Electrophysiological measurements: Hearing seems to play a definite role in speech fluency: stuttering can be made to essentially disappear, e.g. by applying a masking noise or metronome pacing, or by making the stutterer read in chorus with another person (Alm, 2004). Delayed auditory feedback makes stutterers more fluent, but, conversely, disrupts speech production in normally fluent subjects (Lincoln et al., 2006; Van Borsel et al., 2005).
There is emerging evidence that auditory-evoked potentials can be used as an objective, noninvasive tool to investigate auditory processing and plasticity of auditory function in humans (Jirsa, 1992; Tremblay, 2007). ABR, MLR and LLR were used in our study in accordance with these studies to find out their utility in the study of auditory processing and neural plasticity as a result of speech therapy in the population with stuttering.

In general, the observed results showed that, PWS showed anomalies in one or more measures of ABR, AMLR and LLR. Already on the first electrophysiological evaluation, abnormal AEP measures were observed in fifty three (53%) participants, being that five same adult subjects presented alterations on ABR and AMLR and one same child subject presented alteration on ABR and LLR. No participant in the control group showed abnormal findings (> ±3SD of mean values). Therefore, a higher occurrence of altered results on AEP is verified in PWS when compared to PWNS.

**ABR measures:** In ABR test absolute latencies of wave I, wave III and wave V, interpeak latencies of wave I-III, III-V and I-V and amplitude ratio of V/I were measured. In pre assessment there was no significant difference between PWS (SG, G1 and G2) and PWNS (CG, G3 and G4) on any ABR measures. Findings of the present study are similar to those obtained by Dietrich et al. (1995), who found no statistically significant differences on ABR latencies and amplitudes and on the AMLR Pa wave latency in PWS when compared to the control group.

Analysis of individual data showed there was increase (> ±3SD of mean value in PWNS) in peak I latency among nine subjects (9%). Out of these nine subjects six subjects were adults with stuttering (4 males and 2 females) and three were children with stuttering (2 males and 1 female). Alteration was seen for both the ears. Thus there was increase in wave I latencies in total 18 ears.

Such findings are in accordance with a study conducted by Blood and Blood (1984), who compared the ABR of PWS and fluent subjects, with predominance of altered responses in the SG. Khedr et al. (2000) found a statistically significant increase in latencies of waves I, III and V and interpeaks I-III and I-V in the ABR of PWS.
The present study supports, in part, the previously mentioned one. Although ABR alterations were predominantly found, these were not statistically significant.

In a similar study on children with phonological disorder (Leite RA et al., 2014) there was significant delay in latencies of wave III and interpeak I-III and I-V in children with phonological disorder compared with control group. Some studies have demonstrated different results when comparing click ABR results between normal children and those diagnosed with language disorders (i.e., lower amplitudes for waves I, III, and V compared with the control group) (Mason & Mellor, 1984), learning difficulties (i.e., shorter latencies for wave V and interpeak III-V than the control group) (Purdy et al., 2002), and specific language impairments (i.e., increased waves III and V latencies compared with the control group) (Basu M et al., 2010). Among these findings, longer latencies and reduced wave amplitudes were more frequently observed. The slow neural conduction time at this level was linked with disordered feedback in PWS as suggested by Stager (1990).

In ABR measures between assessments (pre and post speech therapy), in PWS (SG, G1 and G2) and PWNS (CG, G3 and G4) there was no significant change in post therapy ABR measures. Lack of significant difference on ABR measures is similar to findings obtained in a similar study by Hayes et al. (2003). They examined the plasticity of the central auditory pathway in children with learning problems using a standard ABR paradigm and cortical potentials. They employed an auditory training program for a group of students with learning problems and compared them to a group of normal control students using brainstem and cortical-evoked potentials. The results demonstrated that the trained group improved and exhibited changes in cortical responses and exhibited no changes in the classical ABR in comparison to the control group. Thus ABR may not be efficient tool to assess neuroplasticity as a result of therapy in persons with stuttering.

In a related study Leite RA et al. (2014) used AEP in 23 children with phonological disorders to predict speech therapy outcome. It was found that the group of children with phonological disorder who received the regular speech therapy demonstrated
significantly shorter wave I latency in the first electrophysiological evaluation in comparison to the second evaluation which was done after the therapy program was over. Another study indicated correlations between the temporal aspects of brainstem-evoked responses and cortical asymmetry for the processing of speech sounds (Abrams, 2006). These results reinforced the idea that the timing deficits reflected by electrophysiological brainstem measurements could affect cortical acoustic information processing.

**AMLR measures:** AMLR measures included absolute latencies of waves Pa, Na, Pb, and Nb and wave amplitude NaPa. In pre therapy assessment there was no significant difference in mean values between PWS (SG, G1 and G2) and PWNS (CG, G3, and G4) on any measures. Among SG however, examination of individual data revealed that wave Pa and Nb latencies were prolonged (> ±3 SD of mean value of AMLR measures of PWNS) for 40 subjects (40%) in SG. Out of these 40 subjects 24 were adults with stuttering (14 males and 10 females) and 16 were children with stuttering (10 males and 6 females). Similar AMLR studies in PWS have shown varied results including decrease of Pb wave latency (Dietrich et al, 1995) and increase of Pb wave latency (Hood, 1987).

Abnormality in AMLR suggests an anomaly in the Thalamo-Cortical projections and the reticular formation which are proposed to activate the AMLR from the primary and secondary auditory cortex (Shi Di and Barth, 1992). These thalamo-cortical projections form a part of the cortico-striato-cortical loop. This loop performs the function of internal feedback to result in the final execution of language in the form of internal feedback to result in the final execution of language in the form of speech. Stuttering could occur in the subjects as a result of dysfunction in this loop (Mazziotta, Phelps and Wapenski, 1985).

In comparative study of AMLR between assessments (before and after speech therapy), post therapy there was significant decrease (p value .008) in wave Pa latencies in right ears in SG. In adults with stuttering (G1) the decrease in wave Pa was significant in right ears (p value .047). Gender based analysis revealed significant difference between pre
and post assessments of Pa wave latencies in right ears of male participants in PWS (SG) (p=.008) and right ears of male participants in adults with stuttering (G1) (p=.035).

A similar study was carried out by E. Schochat et al (2010) on effect of auditory training on MLR in children with CAPD. They reported a significant increase in AMLR amplitude in post assessment after the auditory training was given to children with CAPD.

**LLR measures:** LLR measures included latencies of waves P1, N1, P2, and N2 and wave amplitude N1P2. In pre therapy assessment there was no significant difference in mean values between PWS (SG, G1 and G2) and PWNS (CG, G3, and G4) on any measures. Among SG however, examination of individual data revealed an increase (> ±3 SD of mean value of LLR measures of PWNS) in N2 wave latencies for 10(10%) subjects. Out of these 10 subjects 7 subjects (4 males and 3 females) were adult with stuttering while 3 subjects (2 males and 1 female) were children with stuttering.

In a related study, Finitzo et al (1991) tested twenty adult stutterers and examined P1, N1 and P2 components of the auditory evoked responses. They found no significant differences in terms of latency; however amplitude was reduced in mild to moderate stutterers as compared to normals but not reduced for the severe stutterers. In a similar study on children with phonological disorder by Leite RA et al (2010), it was observed that on comparison with the control group, P2 wave latency was significantly decreased in children with phonological disorder.

In comparative study of LLR between assessments (before and after speech therapy) there was significant decrease in wave P2 (p value .005) and N2 (p value .004) in right ears in SG. The decrease in wave P2 and N2 latencies was significant in right ears of adults with stuttering (G1) (p value for P2 wave .048 and N2 wave .047) and for children with stuttering(G2) the decrease was significant in P2 wave latency (p value .045) and in N2 wave latency (p value .04) in right ears. Comparisons based on side of ears showed Significant difference (p=.023) between the pre and post assessments for N2 wave
latency measure between right ears in persons with stuttering (SG) and persons with no stuttering (CG). When findings were analyzed based on gender there was significant decrease in P2 wave significant only for right ears in males in SG (p value .027) while significant difference was seen in N2 wave latency in male as well as female participants in SG (p value .042 for male and p value .041 for female respectively).

Fujioka et al. (2006) studied auditory long latency potential before and after musical training in children aged 4 to 6 years. They observed higher P1 amplitudes in children after musical training, which suggested an improvement in the neuronal circuit after this training regime.

Although it cannot be ascertained that aberrations in the AEP measures in pre assessment are related to stuttering in these subjects, yet the results do give an indication of a central auditory processing problem in PWS. In related literature a subtle deficiency in central auditory function of stutterers has been suggested, based on a variety of linguistic tasks. For example, in dichotic presentation of meaningful linguistic stimuli, a large proportion of stutterers fail to show the normally observed right-ear advantage. Such findings could reflect a fairly high-level language-related dysfunction (Salmelin et al., 1998).

Also, the variety of anomalies exhibited by some stutterers and not by all the stutterers supports the proposition that the stutterers form a heterogeneous group (Stager, 1990; Clutter and Freeman, 1984). The anomalies seen in Auditory evoked potentials in stutterers show that findings are scattered. This highlights the importance of inspecting individual data in PWS and that relying only on group statistics in a population with high inter subject variability, may lead to erroneous conclusions. Hence even among the group of stutterers demonstrating a central auditory processing disorder, the site of dysfunction can be anywhere along the auditory pathway. However the results of this study weigh more towards the cortical area being the site of dysfunction.

The decrease in the wave latencies in AEP measures (AMLR and LLR waves) after therapy in PWS indicates the improvement in the auditory processing at different levels in the auditory system. This finding indicates the occurrence of functional
neuroplasticity, which occurred as a consequence to the speech therapy, reflecting better neuronal promptness for auditory stimuli. According to the literature, three plasticity types can occur in the auditory pathway, including developmental plasticity, compensatory plasticity (resulting from an injury to the auditory pathway), and learning-related plasticity (Musiek et al. 2002). In our study there was significant decrease in AMLR and LLR measures only in the PWS given speech therapy. This suggests that the plasticity type evidenced in the present study was learning related.

It was also observed that there were significant changes in AMLR and LLR waves as a result of speech therapy in right ears only. This may provide evidence towards the left cerebral dominance phenomena for speech and language tasks. This may indicate that after speech therapy there was more activation in left hemisphere in comparison to right hemisphere. This information may be useful for speech language pathologist to plan the therapy sessions to incorporate more activities to stimulate left hemisphere.

In a related study results of the robust electromagnetic response of the auditory cortical neurons (peaking at about 100 ms) indicated the left hemisphere as the major locus of discrepancy between fluent individuals and stutterers (Salmelin et al., 1998). The left auditory cortex may thus have a special role in stuttering. In terms of functional neuroanatomy of persons with stuttering is characterized by an abnormal recruitment of right-sided cortical regions during speech preparation and production (Blomgren, Nagarajan, Lee, Li, & Alvord, 2003; Braun et al., 1997; De Nil, Kroll, Kapur, & Houle, 2000; Fox et al., 1996, 2000; Ingham et al., 2004). Fluency-inducing maneuvers have been found to reduce the predominantly right hemispheric motor-system overactivations and left temporal deactivations (Fox et al., 1996, 2000; Ingham et al., 2003, 2004). Andrade et al. (2007) conducted a pilot study aiming to investigate the relationship between stuttering improvement and brain activity, using the assessment of P300 in three PWS. They concluded that this population could show different patterns of inter-hemispheric activity in a task with P300 after speech therapy.
A few studies of functional neuroimaging (Ingham et al., 1996; Wu et al., 1995) have investigated neural activation under fluency-enhancing techniques such as choral speech, pacing or automatic speech. Although these techniques often demonstrated to improve speech dramatically, characterized by the normalization or decrease in activity of many cortical and subcortical areas, the fluency-enhancing effect is linked to the immediate presence of the external stimulus and have little, if any, carry-over in time or space once the stimulus is removed. These functional imaging studies have not documented any long-term effects of the fluency-enhancing condition. De Nil, Kroll, Lafaille, and Houle (2003), (Andrade, Sassi, Juste, & Mendon, a, 2008). Hence there is need to study the long term effects of speech therapy on cerebral activation in PWS.