SUMMARY AND CONCLUSIONS

The prosodic/suprasegmental aspects of speech essentially consist of features of stress, intonation, junction, rhythm, among others and are manifested acoustically by fundamental frequency (F0), duration, and intensity. They serve numerous linguistic and affective functions (Lehiste, 1970; Streeter, 1978; Waibel, 1988; Hirschberg & Avesani, 1997; Schafer et al., 2000; Snedeker & Trueswell, 2003; Trueswell, 2003; Banziger & Scherer, 2005). At the discourse level, stress lends prominence to key words where as intonation serves to mark boundaries within and across topic units (Hirschberg & Pierrehumbert, 1986; Grosz & Hirschberg, 1992), express contrast between 'new' and 'given' information (Nooteboom & Kruyt, 1987), and signal speech acts (Geluykens, 1987). Some of the acoustic features that aid to structure discourse are onset and terminal F0, Peak F0, F0 range, pause duration, distribution of different types of boundary tones, and declination in F0 (Grosz & Hirschberg, 1992, Swerts & Geluykens, 1994; Swerts, 1997; Hirschberg & Nakatani, 1998).

Over the years, significant research was done to understand processing of prosody in clients with brain damage. Specifically the research aimed

a) to identify the neurological structures that govern processing of prosody

b) to describe prosody characteristics in individuals with specific brain damage

c) to identify the cause of dysprosody in individuals with specific brain damage

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Several hypotheses emerged concerning the neural processing of prosody. The contrasting evidence in support of these contentions have not allowed for consensus and complete understanding of the neural substrates of dysprosody in brain damaged individuals remains elusive. Many investigators have reported dysprosodic speech in clients with Broca's aphasia (Danly & Shapiro, 1982; Ryalls, 1982; Gandour et al., 1989). They exhibit difficulties in signaling stress contrasts (Vijayan & Gandour, 1997; Cappa et al., 1997; Laganaro et al., 2002), and in manipulation of intonation features such as F0 range and declination in longer sentences (Danly & Shapiro, 1982; Ryalls, 1982; Ryalls & Reinvang, 1986). Most often, the temporal deficits too have been reported to be more frequent in clients with Broca's aphasia, contributing in their own way to the stress and intonation aberrations (Gandour et al., 1989; Baum, 1992; Gandour et al., 1993; Gandour et al., 1994; Ouellette & Baum, 1994).

The basis for prosodic deficits in clients with Broca's aphasia has been proposed to be due to deficits in underlying linguistic processing. For instance, deficits in the production of lexical tone in tone languages such as Mandarin, Norwegian, and Thai revealed an underlying phonological impairment in individuals with aphasia (T' sou, 1978; Naeser & Chan, 1980; Packard, 1986; Gandour, Petty, & Dardarananda, 1988; Moen & Sundet, 1994; Moen & Sundet, 1996). At the sentence level, Danly and Shapiro (1982) reported that certain aspects of intonation such as F0 resetting were abnormal in LHD aphasics. They also observed frequent continuation rises which often did not occur at appropriate syntactic boundaries, suggesting that individuals with aphasia were unable to integrate syntax and prosody. Deficits in F0 to mark syntactically ambiguous
boundaries represent another level of linguistic processing problems which are often evidenced in aphasic individuals (Baum, Pell, Leonard, & Gordon, 1997; Walker, Daigle, & Buzzard, 2002). The conversation sample analysis too signifies the F0 modulation deficits in declarative sentences in these clients (Pietrosemoli & Mora, 2002). The findings are consistent with the results of a growing number of studies that indicate a close relationship between intonation and syntax in normal speech (O’Shaughnessy, 1979; Eady & Cooper, 1986; Nagel, Shapiro, & Nawy, 1994; Shapiro & Nagel, 1995; Taff & Wegelin, 1998).

Another assumption is that the dysprosody in clients with LHD aphasia is related to the phonetic-motoric impairment. The hypothesis has evolved from research findings of investigators such as Danly and Shapiro (1982), who in their study of LHD aphasics found that declination in short sentences were preserved, while it was impaired in longer stretch of utterances. Various types of F0 abnormalities were reported in LHD aphasics which varied from unusually large initial F0 peaks and peak-to-valley variations in F0 (Cooper et al., 1979), restricted F0 range (Ryalls, 1982), greater than normal F0 variability (Ryalls, 1984), and abnormally high F0 values (Cooper et al., 1984). These variable F0 aberrations suggest an underlying deficit that might be phonetic or motoric in nature (Seddoh, 2000). The idea is consistent with data on normal subjects which indicates that some components of the F0 contours associated with intonation may be determined physiologically (Ladd, 1983a, 1983b; Arvaniti et al., 1998; Ladd et al., 1999). Ryalls (1982) suggested that besides phonetic deficit, the reduction in F0 range in aphasic
clients may be due to either impaired ability to readjust breathing patterns that regulate phonation or to disturbed ability to control laryngeal muscles.

There are other views which suggest that the critical variable on which F0 production depends is the length of the utterance, and that abnormalities in F0 associated with intonation deficits in aphasics' speech result primarily from problems related to temporal control at the sentence level (Gandour et al., 1989; Gandour et al., 1992). In other words, there seems to be an intimate relationship between F0 control and timing. Based on acoustic-phonetic measures of intonation and rhythm in aphasics’ speech, Danly and Shapiro (1982) and Danly et al. (1983) demonstrated that programming of F0 crucially depends on sentence length, and that F0 programming may be less disrupted than temporal programming. They suggested that the programming of F0 necessarily intersects temporal programming in sentence production. Thus, disruption of F0 contours does not necessarily indicate malfunction in F0 mechanisms, but instead could be a secondary effect due to malfunction in timing (Gandour, Petty, and Dardarananda, 1988). However, specific impairments in temporal control with well preserved F0 control found by Seddoh (2004) do not suggest that timing deficits are responsible for F0 deficits in clients with aphasia. There may be dissociation in production of F0 and speech timing in individuals with aphasia (Seddoh, 2004).

Need for the study

Few studies have reported the features of stress and intonation in some Indian languages (Manjula, 1997; Geethakumary, 2002; Sadanand & Vijayakrishnan, 1998).
However, little attempt was made in any of the Indian languages including Kannada language to understand these features in the speech of individuals with aphasia, specifically those with Broca's aphasia. In comparison, extensive research has been carried out to investigate processing of prosody in clients with aphasia in languages like English (Baum & Pell, 1997; Seddoh, 2004) and other languages (Moen & Sundet, 1996; Laganaro et al., 2002; Packard, 1986). Despite these extensive studies, questions regarding the nature of dysprosody in the speech of individuals with Broca's aphasia and its cause have not been answered equivocally. In addition, the influence of length and complexity of linguistic unit and speech mode on the speech prosody in clients with Broca's aphasia is not clearly understood. These factors prompted the present study.

Objectives of the study

The study aimed to address 2 broad objectives:

3) To study some aspects of stress and intonation in the speech of individuals with Broca's aphasia in spontaneous narrative discourse mode in Mysore-Bangalore dialect of Kannada language.

4) To compare the results obtained in individuals with Broca's aphasia against those of normal control group.

Method

The experimental group included 10 male subjects in the age range of 45 – 60 years ($M = 54.00, SD = 5.23$). Fifteen normal male subjects in similar age range ($M = 52.67, SD = 5.05$) served as control group. In order to determine age related variations in
the selected acoustic measures, the experimental and control groups were further divided into three subgroups: 45 - 50 years, 51 - 55 years, and 56 - 60 years. This was also done to establish confidence intervals for the selected temporal and F0 measures in the normal control group against which the measures obtained by subjects in the experimental group were compared. All the experimental and control group subjects were native speakers of Mysore-Bangalore dialect of Kannada language. The subjects narrated a picture stimulus of a standardized test called the Linguistic Profile Test in Kannada language (Karanth, 1980). The subjects’ utterances were recorded on a digital tape recorder and later subjected to analysis.

Analysis

The intonation unit formed the basic unit of analysis of various features of stress and intonation. The analysis was carried out in two sections: (a) perceptual and (b) acoustic.

Perceptual analysis

The perceptual analysis for identification of intonation unit and nuclear stressed syllable was carried out independently by the investigator and another experienced Speech-language pathologist. The perceptual analysis formed the basis for later evaluation of acoustic correlates of stress and intonation. The parameters examined under perceptual analysis framework were:

5) Number of intonation units
6) Length of intonation units in terms of the number of syllables in intonation unit
7) Placement/position of nuclear stress in intonation unit
8) Occurrence of nuclear stress with respect to grammatical categories

*Acoustic analysis*

The acoustic analysis was carried out using Computerized Speech Lab (CSL) Model 4400 of Kay Elemetrics Corp. The acoustic analysis included measurement of temporal and fundamental frequency (F0) features that represented various aspects of stress and intonation.

*Temporal features*

1. Duration of intonation unit
2. Initial syllable duration of intonation unit
3. Final syllable duration of intonation unit
4. Duration of nuclear stressed syllable in intonation unit
5. Pause duration between successive intonation units

*Fundamental frequency (F0) features*

1. Onset F0 of intonation unit
2. Terminal F0 of intonation unit
3. F0 range in intonation unit
4. F0 of nuclear stressed syllable in intonation unit
5. Nuclear contour in intonation unit
6. Extent rise in F0 of nuclear contour in intonation unit
7. Extent fall in F0 of nuclear contour in intonation unit
8. Terminal contour in intonation unit
9. Extent rise in F0 of terminal contour in intonation unit
10. Extent fall in F0 of terminal contour in intonation unit
11. Declination gradient in intonation unit
12. Rate of declination in intonation unit
13. F0 reset across successive intonation units

The data obtained was subjected to 4-way comparison between

1) subgroups of clients with Broca's aphasia
2) subgroups of normal controls
3) corresponding subgroups of clients with Broca's aphasia and normal controls
4) combined experimental and control group

**Statistical analysis**

The statistical analysis was carried out using the SPSS 12.0 software. The statistical measurements applied in the study were Reliability coefficient - 'alpha', Oneway ANOVA, and Independent samples t-test.

**Results and Discussion**

The clients with Broca's aphasia were less proficient in narration of events depicted in selected picture card. The ability to narrate smaller details of the stimulus was not consistent in clients with Broca's aphasia compared to normal controls. There
difference in mean number of words found in the corpus speech sample of clients with Broca's aphasia \( (M = 61.00) \) and normal controls \( (M = 132.46) \).

**Perceptual measurements**

To determine the inter- and intra-judge reliability of identification of intonation units by the investigator and another Speech-language pathologist, reliability coefficient ‘Alpha’ was established. The item-by-item inter- and intra-judge reliability coefficient ‘Alpha’ revealed good correlation between and within the 2 judges.

- The mean number of intonation units in clients with Broca’s aphasia were found to be 37.30 \( (SD = 8.99) \) while in normal controls it was 38.73 \( (SD = 12.43) \).

- The mean length of intonation units in clients with Broca's aphasia \( (M = 4.17, SD = 12.42) \) was significantly less than normal controls \( (M = 9.57, SD = 10.24) \).

- The nuclear stress in either group of subjects occurred more frequently on first four syllables of intonation unit (75.51%), with higher probability of occurrence noted on second syllable (28.57%).

- The results concerning placement of nuclear stress with respect to grammatical categories revealed that content words were stressed more frequently than function words in both normal controls (content words = 22.67%; function words = 5.26%) and clients with Broca’s aphasia (content words = 52.77%; function words = 19.99%). Among the individuals content word categories, nouns and verbs received nuclear stress more frequently than others in both groups of subjects.
The similar number of intonation units in experimental and control group subjects suggests that clients with Broca's aphasia produced utterances equivalent to normal controls. However, the results should be read with caution because the increased number of intonation units in clients with Broca's aphasia was possibly due to production of shorter utterances compared to normal controls. Further, it is significant to note that despite the differences in length, the position of nuclear stress in intonation units by clients with Broca's aphasia was similar to normal controls. Even the ratio of occurrence of stress on content and function words in clients with Broca's aphasia was similar to normal controls.

*Acoustic measurements*

To determine the reliability of acoustic measurements, 20% of the speech sample was measured independently by another Speech-language pathologist with experience in instrumental analysis of prosody. The inter-judge reliability coefficient ‘Alpha’ for measurement of all acoustic features revealed good correlation between the 2 judges.

The acoustic analysis of temporal and F0 measurements revealed certain intact cues to stress and intonation in clients with Broca's aphasia.

- The clients with Broca's aphasia and normal controls demonstrated 5 types of nuclear contours - rise, fall, rise-fall, fall-rise, and level contour in intonation units. The complex nuclear contours including rise-fall-rise and fall-rise-fall were not found in any of the subjects of either experimental or control group.
• The terminal contour analysis revealed existence of 3 types of contours - rise, fall, and level in both groups of subjects. However, clients with Broca’s aphasia demonstrated relatively greater percentage of rising contours than falling and level types of contours. The frequency of rising contours in clients with Broca’s aphasia was even higher than normal controls.

• The mean F0 of nuclear stressed syllable, onset F0, terminal F0, mean extent rise/fall in F0 of nuclear contour and terminal contour were significantly higher in clients with Broca’s aphasia than normal controls.

• The mean rate of declination in clients with Broca’s aphasia was consistent with the findings in normal controls.

• The mean F0 reset cue to intonation unit boundary was not significantly different in clients with Broca’s aphasia compared to normal controls.

• The difference in relative lengths of final syllable length versus initial syllable length of intonation unit in clients with Broca’s aphasia suggested a preserved phrase final lengthening in these subjects, which is a useful cue to mark intonation unit boundaries (Cruttenden, 1997).

Nevertheless, significant deficits were noticed in some other features.

• The mean length of intonation unit when measured either in terms of the number of syllables or in time revealed significant reduction in clients with Broca’s aphasia than normal controls.

• The other temporal measures like initial and final syllable duration, duration of nuclear stressed syllable, and pause duration between intonation units were also shorter in clients with Broca’s aphasia than normal controls.
The mean declination gradient and F0 range in intonation unit were significantly less in clients with Broca’s aphasia than normal controls.

The temporal deficits observed in clients with Broca's aphasia suggests that they experience difficulties in utilizing temporal cues to prosody. The duration measures of final syllable lengthening and pause duration between intonation units are the known markers of prosodic boundaries (Cruttenden, 1997). On these temporal measures, clients with Broca’s aphasia differed significantly from normal controls. However, the ratio of final syllable duration to initial syllable duration was greater in these individuals, suggesting that they were able to effect phrase final lengthening similar to normal controls.

An important finding that emerged from the study is that the mean F0 of nuclear stressed syllable, onset F0, and terminal F0 were significantly higher than normal controls. The probable reason for increased F0 in these individuals is the increased effort in speaking put by these individuals (Ryalls, 1984). It should also be noted that onset F0 and terminal F0 serve as acoustic cues to intonation unit boundaries. Since the mean F0 of both these measures were greater in clients with Broca’s aphasia relative to normal controls, it can be explained that individuals with Broca’s aphasia were able to utilize these parameters to signal intonation unit boundaries.

It was also observed that F0 resetting were more common in clients with Broca's aphasia than normal controls. The short utterances in these clients could be responsible
for frequent resetting of F0. Moreover, there was significant difference in the pattern of F0 resetting in both groups of subjects. In normal controls, the resetting occurred at phrase boundaries or at sentence terminals. But in clients with Broca's aphasia, F0 resetting was observed within phrases, even often occurring at word boundaries. However, on a quantitative basis, the degree of F0 resetting in clients with Broca's aphasia revealed no significant difference from that of normal controls. The findings suggested that they were able to utilize this feature as cue to intonation unit boundaries.

Summary

The results point to evident differences in the manner of F0 resetting in clients with Broca's aphasia and normal controls. In normal controls the F0 reset occurred at genuine syntactic boundaries such as subject-predicate boundary, phrase boundaries, or the end of a statement. But clients with Broca's aphasia displayed frequent F0 resets that often occurred at word boundaries. The findings seem to suggest linguistic basis for dysprosody.

However, the clients with Broca's aphasia also produced unusually higher F0 which were not related to linguistic units. The mean F0 of nuclear stressed syllable, onset F0, terminal F0, mean extent rise/fall in F0 of nuclear contour and terminal contour were higher than normal controls. Further, clients with Broca's aphasia were able to formulate phrases and sentences but were unable to encode them in appropriate utterance units. The utterances were short, often extending over single words. It seemed like they were able to plan the sentence at the linguistic level but demonstrated difficulties in executing the linguistic plan. The notion of preserved linguistic planning is substantiated by
observation of pattern of terminal contours of intonation units within sentences. The clients with Broca's aphasia presented frequent rising terminal contours that were found in within-sentence intonation units whereas the final intonation unit witnessed a falling terminal contour signaling that the sentence is complete. They were probably using rising contours in within-sentence intonations units to indicate that the statement is not complete and there is something more to come. The phenomenon seems to suggest that they had planned the statement in advance but had difficulties in executing the motor plan effectively over larger segments. The results seem to suggest that phonetic-motoric impairment might be responsible for prosodic deficits in clients with Broca's aphasia in the present study. To support this fact, the manner of placement of nuclear stress with respect to grammatical categories in clients with Broca's aphasia was similar to those of normal controls. The results reflect to a certain extent about the preserved linguistic control in clients with Broca's aphasia.

The contention that F0 production depends on length of the utterance and that abnormalities in F0 associated with intonation deficits in aphasics' speech result primarily from problems related to temporal control at the sentence level (Gandour et al., 1988; Gandour et al., 1989; Gandour et al., 1992) may also be plausible. Especially the features such as declination in F0 occurring over smaller number of syllables as revealed by the shorter intonation units, declination gradient, and frequent F0 resets in clients with Broca's aphasia are related to short utterances of these clients. Unlike normal controls, clients with Broca's aphasia were unable to produce lengthy utterances. They frequently inserted pauses, thereby resetting the F0 baseline and causing reduction in declination
extent both qualitatively and quantitatively. The results however, are in contrast to the findings of Seddoh (2004), who found intact F0 patterns in the presence of impaired timing characteristics.

The results of the present study suggest that some measures of both duration and F0 are likely to be impaired in clients with Broca's aphasia. The results are not consistent with the hypothesis that right hemisphere is solely responsible for processing of prosody while the parallel linguistic processing occurs in the left hemisphere (Klouda et al., 1988). The results also do not favor the differential lateralization of acoustic cues hypothesis of Van Lancker & Sidtis (1992), which presumes that duration and pitch are independently lateralized. The assumption of subcortical processing hypothesis that prosodic functions are highly dependent on subcortical processing (Cancelliere & Kertesz, 1990) too does not receive support from the results of present study, since the brain damage did not include subcortical structures in Broca's aphasic subjects of present study. Since the study did not include the right hemisphere damaged subjects and affect based stimuli, definitive assumptions about the functional lateralization hypothesis cannot be made on the basis of results of present study.

Conclusions

The results of study suggest that temporal aspects such as duration of intonation unit, initial and final syllable duration of intonation unit, duration of nuclear stressed syllable, and pause duration between successive intonation units are prone to be impaired in clients with Broca's aphasia. In contrast, unusually higher than normal mean F0 of
nuclear stressed syllable, onset F0, terminal F0, mean extent rise/fall in F0 of nuclear contour and terminal contour are possible in these clients. Further, mean declination gradient and F0 range were found to be effectively less than normal controls. However, the magnitude of F0 reset and rate of declination were preserved. Thus, the dysprosody in clients with Broca's aphasia is contributed by impairment of temporal and some F0 features of prosody apart from shorter intonation units, frequent F0 resets, and shorter extent of declination.

**Further recommendations**

Future research needs to be undertaken in the area of prosodic analysis in clients with Broca's aphasia incorporating the following:

a) Inclusion of both males and female subjects.

b) Compare the stress and intonation features across other discourse modes like spontaneous monologue, dialogue, and read-speech.

c) Compare the stress and intonation features across other dialects of Kannada to verify if results similar to Mysore-Bangalore dialect would emerge in clients with Broca's' aphasia and normal controls.