METHOD

The study aimed to evaluate features of stress and intonation in the speech of individuals with Broca’s aphasia in spontaneous narrative discourse in Kannada language.

Objectives of the study

Specific objectives of the study include evaluation of following features of stress and intonation in the speech of individuals with Broca’s aphasia and to draw comparison against those observed in the speech of normal subjects.

1) Number of intonation units
2) Length of intonation units
3) Temporal measurements within and across intonation units
4) Fundamental frequency (F0) measurements within and across intonation units
5) Tonal inventory of nuclear and terminal contours
6) Occurrence of nuclear stress with respect to grammatical categories
7) Placement/position of nuclear stress with respect to intonation unit

Subjects

Experimental group

The experimental group constituted 10 individuals with Broca’s aphasia. The diagnosis was based on neurological evaluation including neuro-imaging reports and test results of Kannada version (Karanth, Ahuja, Nagaraja, Pandit, & Shivashankar, 1990) of
Western Aphasia Battery (Kertesz, 1982). The subjects had undergone speech therapy for a minimum of 4 months to a maximum of 2 years. Table 2 delineates the clinical and demographic profile of experimental group subjects.

The following factors were considered for selection of subjects in experimental group:

- Absence of other associated neurogenic communication disorders such as dysarthria, apraxia of speech, or cognitive deficits. The Frenchay Dysarthria Assessment (Enderby, 1983) and Apraxia Battery for Adults (Dabul, 1979) were administered to rule out dysarthria and apraxia of speech. The Cognitive-Linguistic Assessment Protocol for Adults (Kamath, 2001) was used to rule out cognitive deficits.

- Native speakers of Mysore-Bangalore dialect of Kannada language.

- Subjects whose expressive speech consisted of at least phrases. The expressive speech ability was determined by results of ‘Spontaneous Speech’ sub-section of Kannada version of Western Aphasia Battery.

- All the subjects had right hemiparesis.

- All the subjects were right-handed individuals in the pre-morbid period and mostly used left-hand during post-morbid period due to right hemiparesis.

- All the subjects reportedly had normal visual acuity or had corrected vision.
Table 2.  
Clinical and Demographic Profile of Experimental Subjects

<table>
<thead>
<tr>
<th>Subject</th>
<th>Sex/Age (in years)</th>
<th>No. of years of formal education (pre-morbid)</th>
<th>Time post-onset at the time of recording (in years)</th>
<th>Therapy duration (in years)</th>
<th>WAB Aphasia Quotient</th>
<th>Etiology (CT scan findings)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GP</td>
<td>45/M</td>
<td>12</td>
<td>2.0</td>
<td>2.0</td>
<td>39.20</td>
<td>Left MCA territory infarct</td>
</tr>
<tr>
<td>RK</td>
<td>47/M</td>
<td>15</td>
<td>1.0</td>
<td>0.6</td>
<td>44.30</td>
<td>Left MCA territory infarct</td>
</tr>
<tr>
<td>MH</td>
<td>51/M</td>
<td>17</td>
<td>0.8</td>
<td>0.8</td>
<td>43.84</td>
<td>Left frontal and parietal infarct</td>
</tr>
<tr>
<td>NJ</td>
<td>52/M</td>
<td>7</td>
<td>1.1</td>
<td>0.5</td>
<td>47.08</td>
<td>Left frontal and parietal infarct</td>
</tr>
<tr>
<td>RS</td>
<td>55/M</td>
<td>5</td>
<td>0.8</td>
<td>0.8</td>
<td>41.84</td>
<td>Left MCA territory infarct</td>
</tr>
<tr>
<td>MG</td>
<td>55/M</td>
<td>15</td>
<td>0.6</td>
<td>0.4</td>
<td>44.64</td>
<td>Left MCA territory infarct</td>
</tr>
<tr>
<td>TN</td>
<td>56/M</td>
<td>12</td>
<td>1.4</td>
<td>0.6</td>
<td>49.12</td>
<td>Left frontal and parietal infarct</td>
</tr>
<tr>
<td>SD</td>
<td>59/M</td>
<td>12</td>
<td>1.3</td>
<td>1.0</td>
<td>45.84</td>
<td>Left MCA territory infarct</td>
</tr>
<tr>
<td>TR</td>
<td>60/M</td>
<td>19</td>
<td>2.6</td>
<td>1.2</td>
<td>38.62</td>
<td>Left MCA territory infarct</td>
</tr>
<tr>
<td>VK</td>
<td>60/M</td>
<td>10</td>
<td>2.2</td>
<td>1.5</td>
<td>40.12</td>
<td>Left MCA territory infarct</td>
</tr>
</tbody>
</table>

Note. WAB - Western aphasia battery, CT - Computerized tomography, MCA - Middle cerebral artery.
**Control group**

The control group consisted of 15 normal male subjects in the age range of 45 - 60 years. In order to determine age related variations in the selected acoustic measures, the control group was further divided into three subgroups: 45 - 50 years, 51 - 55 years, and 56 - 60 years. Five subjects were included in each of these age groups. This was also done to establish the 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. The subjects did not present any previous history of neurological damage, which was ascertained by information provided by the subjects and/or the caregivers. Subjects included right-handed individuals who were native speakers of Mysore-Bangalore dialect of Kannada language.

**Stimulus**

A picture description task was selected. The picture stimulus was a part of standardized test called the Linguistic Profile Test in Kannada language (Karanth, 1980). The picture depicted a 'market scene' (refer Appendix I). Initially, a pilot study was carried out to confirm:

(a) that expressive speech of minimum 3 minutes could be elicited from the subjects.

(b) the possible occurrence of different grammatical classes of Kannada language.

Five normal subjects narrated the events related to the selected picture stimuli. Analysis of the discourse content revealed that the subjects described the picture for about 3 to 5 minutes and there was sufficient scope for use of various grammatical classes such as
nouns, verbs, adjectives, adverbs, pronouns, postpositions, and conjunctions. There was also scope for repeated use of some of the grammatical categories. More importantly, the chosen stimulus facilitated generation of a significant number of sentences thus enabling collection of large corpus of speech sample. The affective load in the stimuli was very minimal and hence there was less scope for the occurrence of affective prosody. The intention of the experiment was to obtain narrated speech samples from subjects with minimal superposition of affective states.

Procedure

Recording procedure

Prior to recording of speech sample, informed consent in writing for participation in the study was obtained from all subjects. The subjects were tested individually either in home or clinic situations. Prior to actual recording of speech sample of subjects, the investigator demonstrated narration of picture using another stimulus to each subject. All subjects were given sufficient time to formulate the utterances and get familiarized about the picture to be narrated. The picture stimulus was placed in front of subjects. The subjects were instructed to observe the activities depicted in the picture and verbally describe as many events, things, activities etc. as possible about the picture. The speech sample was recorded in a single trial for normal control subjects but the recording had to be carried out in one or two sittings for subjects with Broca's aphasia, owing to difficulties in understanding instructions. Specifically, individuals with Broca's aphasia initially resorted to gross description of picture stimulus. They were asked to describe the picture giving finer details and the sample rerecorded. The recording was carried out with
minimal distraction in the recording room and in a quiet environment. The duration of
recording extended from 3 - 5 minutes across subjects. The subjects’ utterances were
recorded using Sony MZ R-55 digital tape recorder with a uni-directional microphone
placed at a distance of about 10 cm from the mouth.

Analysis

Perceptual analysis

The basis for perceptual analysis was to identify the intonation units that occurred
in the speech sample of subjects with Broca's aphasia and normal controls and to
determine the nuclear stressed syllable in each of these intonation units. The perceptual
identification of intonation units and nuclear stressed syllables was necessitated because
they formed the basis for further subjective and acoustic analysis of features of stress and
intonation.

The sequence of analysis was carried out in the following order

• The recorded utterances were transcribed by the investigator using The International

• The utterances were classified into separate intonation units by the investigator. The
  intonation units were identified by the investigator. An intonation unit (IU) was
  operationally defined as ‘a sequence of words combined under a single, coherent
  intonation contour’ (Chafe 1987). The perceptual criteria adopted for demarcating
  intonation units were: presence of atleast one stressed syllable, significant pause
  between intonation units, phrase final lengthening, anacrusis, and pitch reset
  (Cruttenden, 1986).
• Another judge who was a qualified Speech-language pathologist with experience in analysis of prosody in Kannada also identified the intonation units independently.

• The item-by-item inter-judge reliability coefficient ‘Alpha’ for identification of intonation units in the speech of individuals with Broca’s aphasia was found to be 0.9704 and in normal control subjects it was 0.9506. The judgment task was repeated after 3 weeks time by the investigator and other judge to establish intra-judge reliability. The item-by-item intra-judge reliability coefficient ‘Alpha’ for the investigator was found to be 0.9902 in the speech of individuals with Broca’s aphasia and 0.9807 in normal control subjects. For the other judge it was found to be 0.9804 in the speech of individuals with Broca’s aphasia and 0.9801 in normal control subjects. The intonation units that were not agreed upon by the two judges were not considered for final analysis.

• Later, the investigator and another Speech-language pathologist who had earlier classified intonation units also identified the nuclear stressed syllable in each intonation unit. The item-by-item inter-judge reliability coefficient ‘Alpha’ for identification of nuclear stressed syllable in intonation units of the speech of individuals with Broca’s aphasia was found to be 0.9405 and in normal control subjects it was 0.9203. The judgment task was repeated after 3 weeks time by the investigator and other judge to establish intra-judge reliability. The item-by-item intra-judge reliability coefficient ‘Alpha’ for the investigator was found to be 0.9804 in the speech of individuals with Broca’s aphasia and 0.9605 in normal controls, and for the other judge it was found to be 0.9708 in the speech of individuals with Broca’s aphasia and 0.9504 in normal controls.
The perceptual features analyzed were:

- **Number of intonation units**: The number of intonation units that occurred in the speech sample of each subject was computed.

- **Length of intonation unit**: The length of intonation unit was measured as number of syllables occurring in an intonation unit.

- **Placement/position of nuclear stressed syllable in intonation units**: The measure revealed placement/position of nuclear stress with respect to intonation unit. The percentage frequency occurrence of nuclear stress on specific syllable position with respect to intonation unit was obtained by noting the occurrence of nuclear stressed syllable with respect to the syllabic position in intonation unit which was mutually agreed by the 2 judges. It was calculated as

\[
\frac{\text{Total no. of occurrences of nuclear stress on specific syllable position in intonation unit}}{\text{Total no. of nuclear stress that occurred on all possible syllable positions in intonation unit}} \times 100
\]

- **Correlates of nuclear stress with grammatical classes**: Initially, the average percentage occurrence of grammatical categories in the speech sample of individuals with Broca's aphasia and normal control subjects was determined. The grammatical categories of nouns, verbs, adjectives, adverbs, pronouns, conjunctions, and post-positions are known to occur in Kannada language (Sridhar, 1990; Bhat, 2003). The average percentage occurrence of grammatical categories was calculated as

\[
\frac{\text{Total no. of occurrences of specific grammatical category}}{\text{Total no. of occurrences of all grammatical categories}} \times 100
\]
This was followed by measurement of average percentage occurrence of nuclear stress with respect to specific grammatical categories in the speech sample of clients with Broca's aphasia and normal controls. It was calculated as

\[
\frac{\text{Total no. of occurrences of nuclear stress on specific grammatical category}}{\text{Total no. of occurrences of nuclear stress on all grammatical categories}} \times 100
\]

This two-way measurement method revealed the percentage of nuclear stress on specific grammatical categories against the total percentage occurrence of specific grammatical categories.

**Acoustic analysis**

The utterances of subjects recorded on a digital tape recorder were transferred through line feeding to Computerized Speech Lab (CSL) Model 4400 (Kay Elemetrics) for the purpose of acoustic analysis. The speech signal was digitized at a sampling rate of 16000 Hz. The basic unit of analysis was intonation unit, within and across which all the temporal and F0 measurements were carried out. For the purpose of pitch analysis, F0 range was set between 70-350 Hz and the window frame length of analysis was 25 ms. The pitch contours were extracted using pitch extraction algorithm of CSL software. The F0 related measures were read directly from the pitch contour. In order to obtain accurate duration measurements and facilitate discernible boundaries of syllables and intonation units, the utterances were displayed on a wide-band spectrogram. The spectrographic display was obtained between 0-80% Nyquist frequency and was analyzed in Blackman window weighting. The pre-emphasis level was set at 0.80. The acoustic measurements of temporal and F0 cues to stress and intonation were carried out by the investigator. To
check for the reliability of measurement of temporal and F0 parameters, about 20% of the speech sample was measured independently by another Speech pathologist with experience in instrumental analysis of prosodic parameters. Eight intonation units were randomly selected from the speech sample of each subject of either group. The inter-judge reliability coefficient 'Alpha' for measurement of all acoustic features was found to be 0.9508. The inter-judge duration measurements had mean absolute differences of 2 ms (SD = 5) while for F0 measurements, the differences were found to be 10 Hz (SD = 6).

The acoustic measurements of duration and F0 were obtained for the parameters listed below. These parameters were selected as they represent the acoustic manifestation of aspects of stress and intonation.

**Acoustic measurements within and across intonation units**

**Temporal measures**

_A) Duration of intonation unit:_ It was measured as the time difference between onset and offset of each intonation unit (Figure 1).

_B) Initial syllable duration of intonation unit:_ It was measured as the time difference between onset and offset of first syllable of intonation unit (Figure 2).

_C) Final syllable duration of intonation unit:_ It was measured as the time difference between onset and offset of terminal syllable of intonation unit (Figure 2).
**Figure 1.** Intonation unit duration and pause duration between intonation units.

Note. IUD - intonation unit duration; PD – Pause duration between intonation units.

**Figure 2.** Initial and final syllable duration of intonation unit.

Note. ISD - Initial syllable duration; FSD – Final syllable duration.

**D) Duration of nuclear stressed syllable in intonation unit:** It was measured as the time difference between onset and offset of stressed syllable in intonation unit (Figure 3).
E) Pause duration between successive intonation units: It was measured as the time difference between offset of an intonation unit and the onset of subsequent intonation unit (Figure 1).

Figure 3. Duration of nuclear stressed syllable and extent fall in F0 of nuclear contour in intonation unit.

Note. DN - Duration of nuclear stressed syllable; EFN – Extent fall in F0 of nuclear contour

Fundamental frequency (F0) measures

A) Onset F0 of intonation unit: It was measured as the fundamental frequency associated with onset of intonation contour. It was read directly from F0 curve (Figure 4).

B) Terminal of intonation unit: It was measured as the fundamental frequency associated with offset of intonation contour. It was read directly from F0 curve (Figure 4).

C) F0 range in intonation unit: The F0 range was calculated as the difference between lowest and highest F0 in intonation unit (Figure 4).
Figure 4. Onset F0, terminal F0, and F0 range of intonation unit.

Note. OF - Onset F0; TF - Terminal F0; b – a = F0 range.

D) F0 of nuclear stressed syllable in intonation unit: It was measured as the fundamental frequency associated with peak F0 of nuclear stressed syllable in intonation unit. The F0 of nuclear stressed syllable was read by placing the cursor on peak F0 of stressed syllable in F0 contour of intonation unit (Figure 5).

Figure 5. F0 of nuclear stressed syllable in intonation unit.

Note. F0NSS - F0 of nuclear stressed syllable.
E) **Nuclear contour in intonation unit:** The nuclear contour is a distinct contour associated with nuclear stressed syllable in an intonation unit (Cruttenden, 1986). Based on the nuclear contour analysis of previous research by Palmer (1922), Kingdon (1958), O’Connor & Arnold (1961), Halliday (1967), and (Cruttenden, 1986), nuclear contours were analyzed in the present study in terms of rise, fall, rise-fall, fall-rise, rise-fall-rise, fall-rise-fall, and level contour. The operational definitions of these types of nuclear contours are given below:

1) The rise type nuclear contour was defined as the rising contour occurring on nuclear stressed syllable (Kingdon, 1958).

2) The fall type nuclear contour was defined as the falling contour occurring on nuclear stressed syllable (Palmer, 1922; Kingdon, 1958).

3) The rise-fall nuclear contour was defined as a contour consisting of a compound contour in which there is an initial rise followed by a falling contour on nuclear stressed syllable (O’Connor & Arnold, 1961).

4) The fall-rise nuclear contour was defined as a contour consisting of a compound contour in which there is an initial fall succeeded by a rising contour on nuclear stressed syllable (O’Connor & Arnold, 1961).

5) The rise-fall-rise nuclear contour was defined as a complex contour consisting of a rising, falling, and then rising contour on nuclear stressed syllable (Halliday, 1967).

6) The fall-rise-fall contour was defined as a complex contour consisting of a falling, rising, and falling contour on nuclear stressed syllable (Halliday, 1967).

7) The nuclear level contour was defined as a contour occurring on nuclear stressed syllable whose contour was relatively flat.
F) Extent rise in F0 of nuclear contour in intonation unit: It was measured as the rise in F0 from beginning to the peak of nuclear stressed syllable (Figure 6).

Figure 6. Extent rise in F0 of nuclear and terminal contour in intonation unit.

Note. ERN - Extent rise in nuclear contour; ERT - Extent fall in terminal contour.

G) Extent fall in F0 of nuclear contour in intonation unit: It was measured as the fall in F0 from peak to the lowest point of the contour of nuclear stressed syllable (Figure 3).

H) Terminal contour in intonation unit: The terminal contour is a distinct contour occurring on terminal syllable of an intonation unit (Cruttenden, 1986). Based on previous studies in Kannada language by Nataraja (1981), Patil (1984), and Manjula (1997), terminal contours were analyzed in terms of rise, fall, and level contour. The operational definitions of terminal contours were defined as follows based on the criteria given by Cruttenden (1986):

1) The rise type of terminal contour was characterized by a rising tonal pattern.
2) The fall type of terminal contour was characterized by a falling tonal pattern.

3) The level type of terminal contour was characterized by a relatively flat tonal pattern.

I) Extent rise in F0 of terminal contour in intonation unit: It was measured as the rise in F0 from beginning to the peak of terminal syllable contour (Figure 5).

J) Extent fall in F0 of terminal contour in intonation unit: It was measured as the fall in F0 from peak to the lowest point of the terminal syllable contour (Figure 7).

Figure 7. Extent fall in F0 of terminal contour in intonation unit.

Note. EFT - Extent fall in F0 of terminal contour.

K) Declination gradient in intonation unit: The ‘regression line’ method (Thorsen, 1979; Cooper & Sorenson, 1981; Vaissiere, 1983; Bruce & Garding, 1978) connecting the selected peaks of pitch contour, was followed to measure declination gradient in each intonation unit. This method was preferred because of its proven feasibility in measurement of declination in Kannada language (Manjula, 1997). The declination
gradient was operationally measured as the difference between the first peak F0 appearing in the pitch contour and the terminal peak F0 of the intonation contour (Figure 8).

Figure 8. Declination gradient in intonation unit.

![Graph of intonation unit showing gradient](image)

Note. a - b = Declination gradient.

**L) Rate of declination in intonation unit:** It was operationally defined as the decline in F0 with respect to unit time from first peak to last peak F0 in intonation unit and was measured in terms of Hertz/second i.e.

\[
\text{Extent of declination in intonation unit (Hz)} \quad \frac{\text{Hz}}{\text{sec}}
\]

**Time in seconds**

**M) F0 reset across successive intonation units:** The F0 reset across successive intonation units was calculated as the difference in F0 between ‘onset F0’ of intonation unit and ‘terminal F0’ of a preceding intonation unit (Figure 9).
The data obtained was compared among and across the 3 subgroups of experimental and control group individuals i.e. 45-50 years vs. 51-55 years vs. 56-60 years. This was followed by combined group comparison of various acoustic parameters between individuals with Broca’s aphasia and normal controls.

**Statistical analysis**

The statistical analysis was carried out using the SPSS 12.0 software. The following statistical measurements were applied:

- Reliability coefficient – ‘alpha’ was applied to determine
  1) inter-judge and intra-judge reliability for identification of intonation units
  2) inter-judge and intra-judge reliability for identification of nuclear stressed syllables
3) inter-judge reliability for measurement of various acoustic features using CSL 4400 software

• Oneway ANOVA: This measure was employed to check significance of difference in mean of the various acoustic measures between the
  1) three subgroups of clients with Broca’s aphasia
  2) three subgroups of normal controls

• Independent samples t - test: This measure was employed to check significance of difference in mean of the
  1) number of intonation units between experimental and control group
  2) length of intonation units (number of syllables in intonation unit) between experimental and control group
  3) various acoustic measures between corresponding subgroups of clients with Broca’s aphasia and normal controls
  4) various acoustic measures between combined experimental and control group

The results are presented and discussed in the next section.