

**PROTOCOL FOR ASSESSMENT OF SPEECH
INTELLIGIBILITY AND SPEECH NATURALNESS
IN DYSARTHRICS IN KANNADA**

Registration No. L048.006

A dissertation submitted in part fulfillment of
Master's Degree (Speech Language Pathology)
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ALL INDIA INSTITUTE OF SPEECH AND HEARING
MANASAGANGOTHRI
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*Dedicated with
Love, Joy & Thankful Heart to
those wonderful persons*

my life is blessed with

. My dearest Dada, Mamma

My liitle Sister Viyu

Certificate

This is to certify that this Dissertation entitled "**Protocol for assessment of speech intelligibility and speech naturalness in dysarthrics in Kannada**" is a bonafide work in part fulfillment for the degree of master of (Speech Language Pathology) of the student (Registration No.L0480006). This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysore

May, 2006



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Declaration

This Dissertation entitled "**Protocol for assessment of speech intelligibility and speech naturalness in dysarthrics in Kannada**" is the result of my own study in All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier in any other University for the award of any Diploma or Degree.

Mysore

May, 2006

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INTRODUCTION

What a curious thing speech is! The tongue is so serviceable a member (taking all sorts of shapes just as it is wanted) the teeth, the lips, the roof of the mouth, all ready to help; and so heap up the sound of the voice into the solid bits which we call consonants and make room for the curiously shaped breathing which we call words!

Oliver Wendell Holmes

Communication is a two-way process by which information is passed from one person to another. Three criteria are met in communication: first, there is some output from the initiating person; second, there is some means of transmitting and conveying the information; and third, the recipient can receive and interpret the information. Of all the modes employed for effective communication, oral communication is important because it is the primary means for interacting with others for expressing feelings and ideas, for venting anxieties and frustrations, for effecting change and for enabling one person to find out what another person is perceiving and thinking. Effective communication depends on how intelligible the speaker is, how well the speaker's speech meets the cultural standards, how much the listener perceives or understands of what the speaker conveys. Hence, nothing is more useful than to speak clearly, i.e., speech should be intelligible.

Speech intelligibility is defined as the degree to which the listener (Yorkston, Beukelman & Bell, 1986) understands the acoustic signal. It is simply and broadly defined as the understandability of speech. Implicit in the definition is a task in which a speaker produces a message and a listener who doesn't know the content of the

message attempts to comprehend and / or reproduce it. Articulation, rate, fluency, vocal quality and intensity mainly influence this measure. Reduction in speech intelligibility hampers/ impairs effective oral communication. This could have far reaching repercussions on the person's social, emotional well being, occupation, and inter personal relations. It is well understood that there is a very strong correlation between speech intelligibility and information transfer in the act of speech communication.

Speech is a very rapid and complex motor act, which requires very finely tuned neurological regulation (Kent & Forner, 1980; Netsell, 1984). For speech motor act to take place, good co-ordination in muscle strength, speed of movement, appropriate range of excursion, accuracy of movement, motor steadiness and muscle tone is required in the speech organs. Damage to the nervous system impairs one or more of these neuromuscular functions and this may affect speech motor production. Dysarthria results from a disruption of muscular control due to lesions of either the central or peripheral nervous systems. Dysarthria is a speech disorder that is caused due to weakness or in-coordination of the speech muscles. Speech is normal only when the respiratory, phonatory, resonatory and articulatory subsystems work together. Neuromuscular disorder in any one or a combination of these subsystems of speech result in dysarthria.

The errors in speech observed in dysarthria are consistent and predictable. There are no islands of clear speech; no matter what the speaking task or materials used, the person with dysarthria will exhibit the same types of errors. In most of the

dysarthric subjects, speech is slow, weak, imprecise or uncoordinated. Distortions and omissions dominate speech errors. Consonants are consistently imprecise, with the production of final and initial consonants being equally impaired. Vowels are not affected as much although, due to problems with tongue movement, they may sound too much alike. The client may distort or omit phonemes but syllables will be produced in the correct order. As the utterance complexity increases, the speech of a dysarthric client may become more unintelligible. All aspects of speech, including articulation, phonation, resonance, prosody, rate and respiration, may be affected by dysarthria. The movements of the soft palate, lips, tongue and jaw may be impaired not only during speech, but also in the context of vegetative functions. Disturbance in all these sectors of human system renders the speech of an individual with dysarthria to be unintelligible. Based on the severity of dysarthria, there will exist a variation in the speech intelligibility. Hence assessment of speech intelligibility is considered an important clinical measure in dysarthria.

Various clinical tools and tasks are employed by speech-language clinicians to assess the intelligibility of speech in dysarthrics. These are often used in the assessment of speech impairment before and after the rehabilitation procedures to maximize functional communication competence in this population (Coombes, 1986). The most common means of measuring speech intelligibility is to have a naive listener orthographically transcribe the recorded speech sample of a dysarthric individual. The number of words correctly identified by the listener, divided by the total number of words in a sample provides a percentage intelligibility score. Several factors influence the measurement of intelligibility: the speaking task, the type of analysis carried out by the judges, the training of the judges and the medium used for

judging the signal. (Yorkston, Beukelman & Bell, 1988). Although there is no 'ideal' technique proposed for the assessment of speech intelligibility, several techniques are advocated and employed for quantifying speech intelligibility. In spite of the drawbacks, each of these proposed scales / protocols / tests help as a handy tool in the treatment planning and assessment of progress in the dysarthric individual. In a practical clinical situation, it helps in deciding whether or not a program of remediation is required and in monitoring progress.

The common procedures adopted to assess the speech intelligibility in dysarthric clients include:

- Scaling procedure: wherein listener uses a rating scale procedure and assigns ratings of overall speech intelligibility (Darley, 1969; Platt, Andrews, young & Nelson, 1978; Yorkston & Beukelman, 1978; Platt, Andrews, Young & Quinn, 1980)
- Identification task wherein listener transcribes what the speaker says. Intelligibility of single words is measured by computing the percentage of correctly identified words (Tikofsky & Tikofsky, 1964; Platt, Andrews, young & Nelson, 1978; Yorkston & Beukelman, 1978)
- Acoustic analysis using instruments (analysis of acoustic waveforms) (Kent & Netsell, 1975).

There are a few standardized scales, tests and protocols developed to assess speech intelligibility in the Western countries. For example, "Assessment of intelligibility of dysarthric speech (AIDS)" given by Yorkston and Beukelman (1981), is a tool where word and sentence tasks are employed to assess the intelligibility of

speech. There are many other tests such as the sentence intelligibility tests and single-word intelligibility tests developed for the western population. These tests assess speech intelligibility of dysarthric speech based on the word / sentence task respectively. Percentage intelligibility scores are estimated for the word and sentence tasks. Apart from these standardized tests, various other tests are also employed in indigenous clinics, to meet the clinical demands and the clientele. In comparison to the Western scenario, there are no standard tests available in the Indian context to assess the intelligibility of speech in dysarthric individuals. Though Frenchay dysarthria assessment (FDA) is often used in many clinics in India, it only provides an overall speech intelligibility rating. It does not provide a clue to the clinicians as to the variations in speech intelligibility that are often observed in the dysarthric clients with increase in length of utterance and the complexity of the linguistic units which constitute the test material. There are also no standard procedures or tests available to test for the naturalness of speech in dysarthric individuals. Hence, a preliminary attempt is made here to develop a protocol for assessment of speech intelligibility and speech naturalness in the speech of dysarthric individuals speaking Kannada language. The protocol will:

- Aid in profiling the task specific influence on speech intelligibility and speech naturalness of the dysarthric individual.
- Aid in assessing the progress in speech after and/ during the intervention of a dysarthric individual in the form of a percentage score.
- Provide scope for improving inter clinician communication and understanding of the dysarthric individual.
- Provide scope for development of protocols to test the speech intelligibility and speech naturalness of dysarthric individuals in other major Indian languages, and

thus serve to meet the current clinical demands and needs in the speech-language clinics of India more aptly.

Aim and objectives:

- To develop a protocol for assessment of speech intelligibility and speech naturalness in Kannada speaking clients with dysarthria.
- To administer the protocol on selected individuals with different types of dysarthria such as spastic, flaccid, Hypokinetic and hyperkinetic.

The method consisted of preparation and development of a protocol for assessing speech intelligibility and speech naturalness. The protocol consisted of three tasks: word task, sentence task and narration task.

- The *word task* included all the sounds in Kannada language except the aspirated consonants. The length of the words varied from bisyllables to 4 syllables. The word task included 2 levels. Level 1 consisted of simple words and level 2 included complex words (in terms of the syllable length and syllable structure)
- The *sentence task* included sentences which varied from 2 -word length to 8-word length. Sentence task also included 2 levels. Level 1 included sentences constituted by words without any geminates and clusters and level 2 consisted of sentences made up of complex words i.e., words with geminates and clusters.
- For *narration task*, the picture of a 'market' was presented and the clients were asked to describe the picture.

Speech intelligibility scores in percentage was suggested for all the three tasks. The protocol is presented in Annexure A.

The protocol thus developed was administered on 5 dysarthric clients to check for the sensitivity of the protocol. The responses of the dysarthric subjects were audio recorded and subjected to perceptual analysis by three judges who were kept blind to the purpose of the study. From the perceptual judgement made, percentage intelligibility scores for words, sentences and narration sample were calculated for each subject. These judges also rated the speech naturalness after listening to the narrated speech samples of the subjects on a 2-point rating scale which included assessment for 5 factors: stress, intonation patterns, pauses in speech, rhythm patterns, rate of speech and articulatory proficiency. To see if the percentage speech intelligibility scores of the five subjects as judged by these judges matched with the perceived severity of speech in the selected dysarthric clients, three additional judges were selected who were also kept blind for the purpose of the study. The overall speech severity of the selected dysarthric subjects was rated by 3 judges who were not the same as those who assessed for the intelligibility of speech. They rated the severity of speech based on the narration sample of the subjects. The rating was done using 4 -point rating scale. Interjudge and intra judge reliability measures were computed.

Limitations of the study:

- Due to time constraints, only 5 dysarthric subjects were tested on the protocol. Clients with ataxic dysarthria were not tested on the protocol.
- This protocol can be administered only on literate subjects who can read Kannada and speak Kannada.

REVIEW OF LITERATURE

Speech is an extremely important and a unique human activity which sets us apart from other animals. The ultimate goal of the speakers is to maintain interpersonal communication and to make himself understood to the listener through speech. Hence speech serves as an important medium in bridging the thoughts, ideas, plans and action of the speaker and listener in a communication environment. The communication between a speaker and a listener is said to be effective if the speech of a speaker is intelligible. Intelligibility of speech of a speaker serves as an important yardstick in measuring communication effectiveness.

Intelligibility of speech is defined as recognition of words or utterances in natural communication situations (Smith & Nelson, 1985). This has been used as an important index or measure to assess the overall speech adequacy of individuals with speech-language disabilities by various researchers and clinicians (Beukelman & Yorkston, 1980; Yorkston & Beukelman, 1980; Weiss, Gordon, & Lillywhite, 1987; Bernthal & Bankson, 1998). Intelligibility of speech is broadly defined as the accuracy with which a listener is able to decode the acoustic signal of a speaker (Yorkston & Beukelman, 1980; Kent, Weismer, Kent, & Rosenbek, 1989; Yorkston, Strand, & Kennedy, 1996). Intelligibility of speech only reflects an interactive process (Connolly, 1986; Kent, 1993; Yorkston et al., 1996) that fluctuates for any given speaker depending on a host of variables pertaining not only to the acoustic signal produced by the speaker, but also to variables associated with the listener and the communicative context (Kent et al., 1989).

Intelligibility of speech in individuals with disordered speech-language is often represented in an objective manner. 'Speech intelligibility score' of an individual refers to how much of that subjects (deviant) speech is understandable to other listeners. Yorkston & Beukelman (1980), simply defined speech intelligibility as "the accuracy with which a message is conveyed." Decreased intelligibility of speech is commonly seen in several communicative disorders associated with neurogenic and structural anomalies.

Dysarthria is a neurogenic speech disorder with variable severity. Darley, Aronson, & Brown (1969) defined dysarthria as " A collective name for a group of related speech disorders that are due to disturbance in muscular control of the speech mechanism resulting from impairment of any of the basic motor processes involved in the execution of speech." The greater the severity of dysarthria, the poorer the intelligibility of speech. This is principally due to the impairments seen across several components of the speech production system, including the respiratory, phonatory, resonatory and articulatory mechanism. Reduced intelligibility of speech has been the chief concern in the assessment and management of speech disorders in individuals with dysarthria. It is considered to be the most relevant clinical tool and a socially important aspect of the disorder.

Nickerson and Stevens (1980) acoustically analyzed the speech of hearing impaired and discussed 7 approaches that could be used to investigate the relationship between physical properties of speech and the intelligibility of speech. Out of them 3 were elaborated for application to dysarthric speech.

- (1) Co-relational studies that attempt to show the relationship between speech intelligibility and one/more objective measurements of speech signal.

- (2) Studies of the effects of speech training.
- (3) Detailed phonetic analysis aimed at identifying the various aspects of an individual's speech that account for impaired intelligibility.

There is another index of speech which is equally well discussed as 'speech intelligibility' and that is 'speech naturalness' or 'Naturalness of speech'. Speech naturalness is generally defined as a perceptually derived overall description of prosodic adequacy. Speech is considered 'natural' if it conforms to the listeners' standards of rate, rhythm, intonation and stress among the suprasegmental features and the syntactic structure of utterance being produced as a segmental feature. (Yorkston, Beukelman & Bell, 1988). Many investigators contend that judgement of naturalness is made independent of speech intelligibility (Rosenbeck, 1984; Yorkston, Beukelman, Charles, 1988). There are others who support the notion that there is a mutual influence of speech intelligibility and speech naturalness.

Intelligibility of speech and speech naturalness in disordered population

Maasen and Povel (1985), showed that intelligibility of speech influenced the naturalness judgments of speech in hearing impaired. Southwood & Weismer (1996), reported that judgement of naturalness of dysarthric speech was based in part on speech intelligibility. They also found that intelligibility scores accounted for 61.8% - 64.8% of the variation in naturalness in speech. In addition, the contribution of speech intelligibility to naturalness judgement increased as the severity of dysarthria increased, suggesting that the naturalness judgments were based to some extent on the intelligibility of speech. This observation was made with limited

reference as the specific relationship of the speech intelligibility to speech naturalness was noted to be dependent in part, on the type of dysarthria studied.

Measures of speech intelligibility

Speech intelligibility measures are used in the clinical assessment and management of dysarthria and also for research on communication functions in this disorder. Speech intelligibility is a major factor in determining a speaker's communicative effectiveness and treatment decisions. It is a significant outcome measure suggesting the degree to which speech alone is effective as a means of communication.

In the evaluation of communicative impairments in speech and language disabilities, both subjective (perceptual), objective and acoustic analysis are often used. In the earlier days perceptual analysis was often used to test for phoneme intelligibility, word intelligibility and sentence intelligibility. The two most commonly used perceptual intelligibility measures are :

- (1) Interval scaling (IS)
- (2) Direct magnitude estimation (DME)

Interval scaling (IS): Listener assigns to each stimulus a number that represents a linear partition of a scale (Darley, Aronson, & Brown 1969).

Direct magnitude estimation(DME): Listener assigns to each stimulus a number representing the ratio of the stimulus to a standard that is either specified by the examiner or selected by the listener.

There are a few studies documented on the various measures employed to test intelligibility of speech and they are as follows:

Tikofsky (1970) recorded a 50 - word sample of dysarthric speakers and the same were transcribed by the naive listeners. Intelligibility of speech was objectively rated as the percentage of words correctly repeated or transcribed. Some subjective techniques are also employed where the listener's estimates of speech intelligibility are considered. There are other techniques, which employ objective scores from tasks other than transcriptions. Example of such technique is the rating scale system in which professional judges used a 7-point equal appearing interval scale to estimate speech intelligibility (Darley , Aronson & Brown 1975).

Keeping in line with these observations, various studies were conducted. Canter (1971) abandoned single word tests when the pilot data revealed that certain Parkinsonian individuals performed normally on such tests yet displayed obvious articulatory difficulty in connected speech. Flanagan (1972) measured speech intelligibility by counting the number of discrete speech units identified correctly by a listener. Schiavetti, Meet, and Setler (1981) studied the appropriateness of DME and IS procedures for assessing the speech intelligibility of hearing impaired (HI) adults. Intelligibility of 20 HI speakers were scaled using DME and IS. Results indicated better construct validity for DME than for IS of speech intelligibility.

Yorkston & Beukelman (1978) compared the various techniques employed in measuring intelligibility of dysarthric speech. Intelligibility scores derived from each method i.e., words correctly transcribed, percentage estimates, rating-scale estimates, multiple choice tasks and sentence completion tasks were compared across a wide range of severity levels and the relative reliability checked. They found that all except the word completion rank ordered speakers similarly to transcriptions. Results

indicated that the mean intelligibility scores derived from sentences were not different from scores derived from single word. But for transcription tasks, there was an interaction effect observed between severity and intelligibility scores in sentences vs. words. That is, the most intelligible speakers tended to score higher on sentences rather than on single words and the least intelligible speakers received higher scores on single words.

Measures of speech intelligibility are highly influenced by the subjective factors related to the speaker and the environment. This prompted Kent et al.(1989) to comment that "intelligibility is not an absolute quantity but rather a relative quantity that depends on variables such as test material, personnel training, test procedures and state of speaker".

A few studies done where no measures were used to test for speech intelligibility are also reported. Tikofsky and Tikofsky (1964) measured intelligibility in dysarthric speakers as the total number of correct responses made by listeners to three word lists spoken by subjects. Based on this, they concluded that speech intelligibility measure could be employed to evaluate dysarthric speech and to differentiate amongst dysarthria types.

Platt, Andrews, Young, & Neilson (1978) assessed the speech of 50 adults with Cerebral palsy (CP) using 2 assessment methods of articulatory impairment and 3 measures of speech intelligibility. Results indicated that athetoid CP were more impaired than spastic CP. Type of phonemic errors and degree of distortion of phonemes contributed to the reduced speech intelligibility in athetoids CP. They concluded that speech intelligibility measures could be used to infer on the speech

competence of the individual and for differential diagnosis. One another study on CP individuals by Platt, Andrews, Young & Quinn (1980) collected detailed information about the extent and nature of speech impairment of adults with spastic cerebral palsy and athetoid individuals. 50 subjects (32 spastic & 18 athetoids) were included in the study and the speech intelligibility and articulatory impairment were examined. Two estimates of speech intelligibility were obtained from naive listeners: single words correctly recognized and prose intelligibility rating. Diadochokinetic syllable rates and correct articulation of selected phonemes were employed as indices of articulatory impairment. The 50 subjects were on an average judged to be 50% intelligible on both intelligibility estimates. Group mean DDK rate was 2.9 syllables per second and 78% of phonemes were transcribed as correctly articulated. The mean scores of the spastic subject were superior to the athetoids on all speech measures, significantly for single word intelligibility and DDK rate.

A perceptual study on speech intelligibility in cerebral palsied was done by Mary, (1993). Speech intelligibility was assessed for reading, story narration, word intelligibility in Tamil speaking CP children. The rate of speech, voice, resonatory competence, stress, pitch, intensity and articulatory inadequacy were studied for their contribution in understanding speech. The subjects taken were spastics and athetoid CP children. Results showed that spastics had better intelligibility than athetoids. Both the groups had problem with consonants and athetoids also had problem in production of vowels. The results suggested variability in speech intelligibility indices in CP children belonging to different groups.

"Assessment of Intelligibility of Dysarthric Speech" (AIDS) is a scale developed by Yorkston & Beukelman (1981) which tests for intelligibility in word and sentence tasks respectively. In the single-word task, the 50 single word utterances of dysarthric individual is audio recorded. The recorded sample is perceptually judged by an examiner or listener in one of two response formats:- (a) multiple choice task or (b) transcription of the recorded speech. In the multiple choice format, the listener selects the word that has been spoken from a list of 12 similar sounding words. In the transcription format, the listener writes down the word that has been spoken. In both the formats, percentage correct identification of words are reported . In the sentence task, a series of sentences (varying from 5 to 15 words in length and a total number of 220 words) are spoken by the dysarthric individual which is audio recorded. The sentences are selected randomly from a master pool of 100 sentences for each sentence length. The responses are perceptually judged based on a word-by-word transcription. The results are reported as percentage correct identification. The speaking rate (as words per minute), rate of intelligible speech (number of intelligible words per minute), and communication efficiency ratio (rate of intelligibility of the dysarthric individual compared to that of normal speakers) are calculated from the Sentence Intelligibility task

Measures of speech intelligibility have long played a role in the description and evaluation of dysarthric speakers. Estimates (Darley, Aronson, & Brown, 1975; Enderby, 1983) and actual measures of intelligibility of connected speech (Yorkston & Beukelman, 1975, Yorkston, Beukelman, Hammen & Traynor 1990) have served as overall indicators of speech adequacy. The clinical utility of speech intelligibility assessment has also found support in the literature, as it is said to be related to

information transfer, articulatory function, fine motor control, posture and respiratory abnormalities. Stevens, Nickerson, Rollins (1983) proposed a set of measures for establishing a profile of deviant speech. The measures were grouped into the categories of timing, pitch, laryngeal configuration, tongue posture control and nasalization. This was used to measure intelligibility in dysarthric speakers.

Frenchay dysarthria assessment (Enderby, 1983) evaluated intelligibility in 3 tasks- word task, sentence task, and conversation. In this test, performance on a word task is graded on 5 levels of intelligibility, a-e wherein :

a : refers to 10 words correctly and easily recognized.

e : refers to 2 or fewer words correctly recognized

Sentence task: is similar to word task in administration and scoring. Sentence task is basically like a word recognition task using carrier phrase like "say the word".

Conversation task: involves about 3 minutes of conversation which is graded in 5 levels:

a : refers to no abnormality

e : speech is totally unintelligible

The speech intelligibility measures used to quantify dysarthric speech are found to be useful for a variety of reasons:

(a) It is used as an index of speaking proficiency: reduced speech intelligibility is a common characteristic of dysarthria and thus intelligibility measures are useful in studying different types and severity levels of dysarthria.

(b) It is used to determine compensatory adjustments: speech intelligibility provides an overall index of the disorder which takes into account many different

neuromuscular factors along with whatever compensatory strategies that the dysarthric speaker may have adopted

(c) It is used to assess everyday communicative adequacy: speech intelligibility measures give an index of functional communicative performance of dysarthric speakers which can be easily communicated to the speakers, his family members.

(d) It is used to monitor speech through treatment or the course of a disease (Barkmeier, Jordan, Robin, & Schum, 1991): the quantitative nature of speech intelligibility measures allows for monitoring the speakers performance during the course of treatment and recovery.

Several techniques have been traditionally used for the quantification of speech intelligibility and comparisons have been made. They appear to be sensitive and reliable measures of dysarthric speech intelligibility. However, no single technique appears to be applicable across different types of dysarthria.

There is no tool or a protocol developed for the Indian population to rate the speech intelligibility in adult dysarthric speakers. Study by Mary (1993) compared Tamil speaking spastics and athetoid children. No objective scores were used to delineate the intelligibility of speech.

This protocol is developed as a tool to obtain objective measures of speech intelligibility and speech naturalness in the speech of dysarthric speakers in Kannada language. The protocol will help as a clinical tool and majorly help in comparison of pre-therapy and post-therapy baseline of speech intelligibility and speech naturalness. Three tasks are included in the protocol and they are :

- (a) the word intelligibility tasks (in 2 levels of complexity)
- (b) the sentence intelligibility task (in 2 levels of complexity) and
- (c) the narration task

The 2 complexity levels in words and sentences and the narration task will help in understanding the breakdown in speech intelligibility of the dysarthric speakers as the complexity level increases.

It is known that communication occurs at a variety of linguistic levels, including word, sentence, and connected discourse. Speech intelligibility research has often focused on word (Miller, Heise, & Lichten, 1951; Giolas, Epstein & Owen 1963; Beukelman & Yorkston, 1977; Beliveau et al., 1995) levels, with little attention paid to sentences and discourse. However studies have shown the differential effects of stimulus length on speech intelligibility of speakers. For example, sentences tended to be more intelligible than words presented in isolation (Miller et al., 1951; Silter, Schiavetti, & Metz, 1983). One reason for this phenomenon may be that listeners are more readily able to apply intrinsic top-down linguistic contextual knowledge to sentences than to individual words in isolation. In contrast, when listeners are presented with isolated words, they may be forced to rely more heavily on bottom-up acoustic-phonetic information because there is reduced opportunity to apply intrinsic top-down linguistic-contextual information. In this framework, it may be expected that speech in narrated discourse is more intelligible than in both sentences and words. Narrative discourse differs from unrelated sentences in that meaning is cumulative, building from sentence to sentence in a cohesive fashion.

METHOD

The aim of the study was to develop a protocol for assessment of 'speech intelligibility' and 'speech naturalness' in Kannada speaking clients with dysarthria.

The protocol was developed in stages as follows:

- 1) Preparation/ selection of test material
- 2) Administration of the protocol on selected subjects
- 3) Analysis of responses of subjects
- 4) Test for reliability

/. Preparation/selection of test material: The test material included :

- (A) Word intelligibility test
- (B) Sentences intelligibility test
- (C) Picture description task (Narrative discourse task)

AJ Word intelligibility test:

A word list consisting of 2 sets with 30 Kannada words in each set was prepared. Set I consisted of simple words without geminates and morpho-phonemic clusters. The syllable length varied from bisyllables to 4 syllable words. Set II consisted of complex words with geminates and morpho-phonemic clusters, which added to the complexity of the word structure. Even in this set, the words increased in length from bisyllables to 4 syllables. The words belonged either to the noun or verb class. The words were selected such that:

- they could be easily produced by the subjects
- they were the frequently used words in the language

- they included all the consonants in Kannada language except the aspirated sounds.
- the selected consonants occurred in CV syllable structure in three different positions of the word i.e., initial, medial and final.
- they represented the syllable structures CV, CVCV, CCV, and CCCV which occur commonly in Kannada.

Familiarity check:

The core word list thus prepared was subjected to familiarity check by administering the same on 5 native Kannada speakers. A 3 - point scale was employed to rate the words as (a) most familiar (b) familiar, and (c) not familiar. The words rated as 'familiar' and 'not familiar' were not included in the final word list. Only the words rated as 'most familiar' were selected for the protocol.

B] Sentence intelligibility test:

A list consisting of 20 simple declarative sentences were prepared. The sentences were so chosen that the level varied in terms of length and complexity. Using words with geminates and morphophonemic clusters complex sentences were formed. It was ensured that the words used to form the sentences included all the phonemes of Kannada language and represented all the place and manner of articulation. The selection of sentences were based on the following factors:

- All the sentences were meaningful, declarative and non-emotional sentences with word length varying from 2-8.
- The words represented the syllable structures of Kannada
- The chosen sentences were not related to each other.

The sentences were chosen from sets of sentences in the book "Kannada vakyagalu-antharika rachane mattu artha vyavasthe (KannaDa vaakyagaLu - aantarika rachane mattu artha vyavasthe) by Bhat (1978).

C] Picture description task (Narrative discourse task):

A figure consisting of a 'market' scene, which was depicted through line drawing was selected. A pilot study was conducted on 5 normal adult subjects who were asked to narrate the selected pictures. Analysis of responses of these speakers revealed that:

- (a) the selected picture facilitated generation of more than 2 minutes speech sample.
- (b) it provided scope for the use of all consonants and vowels in Kannada .
- (c) it also provided scope for the use of words with different syllable structures in the sentences used.

The protocol consisting of the word intelligibility task, sentence intelligibility task and the picture description task is presented in APPENDIX A.

2. Administration of protocol on selected subjects:

Subjects: 5 clients with confirmed diagnosis of dysarthria (by a neurologist & speech language pathologist) due to acquired condition in the age range of 25-70 years whose native language was Kannada were included. Table 1 shows the demographic details of the subjects. The subjects selected did not have any hearing, visual or cognitive deficits as revealed by screening tests. All the subjects could express in sentences and they could read Kannada text material.

Table 1: Demographic details of the subjects

<i>Subjects</i>	<i>Age</i>	<i>Sex</i>	<i>Type of dysarthria</i>	<i>Severity of dysarthria</i>
Subject 1	70yrs	Male	Hypokinetic	Moderate
Subject 2	25yrs	Female	Spastic	Severe
Subject 3	65 yrs	Male	Flaccid	Mild
Subject 4	26yrs	Male	Hyperkinetic	Severe
Subject 5	70 yrs	Male	Hypokinetic	Mild

B) Recording of speech sample: Speech samples of the subjects were recorded using a portable tape recorder. Recording was done in a quiet room, away from external noise.

The task performed by each subject included:

- Reading the words (in the word intelligibility task) one at a time which were presented by the experimenter
- Reading the sentences (in the sentence intelligibility task) one at a time which were presented by the experimenter
- Description of a picture (Narration task)

The speech samples of subjects performing the 3 tasks was recorded separately for each individual. The words and sentences were presented on separate cards. Within the word and sentence tasks, each stimuli was presented in a random order within the set 1 and 2 and the subjects were asked to read them aloud one by one. The duration for recording all 3 tasks by each client was approximately 45 min. Before each task the clients were instructed as follows:

For word reading, *"You will be given a few words written on cards one by one. Read them as naturally as possible"*.

For sentence reading *"You will be given a few sentences which are written on separate cards one by one. Read the sentences as naturally as possible "*.

For narration, *"You will be shown a picture, you have to describe the picture in as much detail as possible using sentences. "*

3. *Analysis of responses of subjects:* The speech sample obtained from the subjects was scored for percentage correct responses in terms of intelligibility of speech and speech naturalness by 3 literate judges who were speech-language pathologists with a work experience with dysarthric clients for a minimum of 1 year. They were kept blind to the purpose of the study and their mother tongue was Kannada.

Word intelligibility task:

The words spoken by the 5 subjects were randomized within set 1 and 2 and a master tape was prepared for set 1 and 2. This was then subjected for perceptual judgement. The 3 judges carried out the task independently and without mutual consultation. The 3 judges were instructed as follows *"You will hear a series of words which will be presented one by one with a time gap of 10 seconds in between. You have to listen to each word carefully and write the word as you hear them. You may rewind and listen to the word again if you want to"*. Word intelligibility scores were calculated as the total number of intelligible words/ correct words transcribed by the judge, divided by the total number of words uttered by the subjects and multiplied by 100. This yielded the percentage score of speech intelligibility on word task.

$$\text{Word intelligibility score} = \frac{\text{No. of correct words transcribed by the listener}}{\text{Total no. of words in the sample}} \times 100$$

Sentence intelligibility task:

The sentences spoken by the 5 subjects were also randomized across subjects and within the two sets respectively and a master tape for 2 sets was prepared which was subjected for perceptual judgement. The 3 judges carried out the task independently and without mutual consultation. The judges were instructed to listen to each sentence and do a word-by-word transcription of sentences. From the transcribed data, the percentage error was calculated i.e., number of words correctly identified in the sentences by the judges from the subjects' utterance, divided by the total number of words present in the sentences uttered by the subject and multiplied by 100.

Sentence intelligibility score =

$$\frac{\text{No. of intelligible words identified in the sentences uttered by subjects}}{\text{Total number of words in the sentences}} \times 100$$

This calculation was done for each sentence in set 1 and set 2 respectively.

Picture narration task:

a) The verbal description of the picture by each subject in the narration task was listened to by the judges and transcribed. The total number and percentage of intelligible words in the narration was calculated. The 3 judges performed the task independently without mutual consultation. The percentage correct identification was calculated for the picture narration as:

$$\text{Narration intelligibility score} = \frac{\text{No. of intelligible words identified in the narrated sample}}{\text{Total number of words in the narrated sample}} \times 100$$

b) In order to check for correlation of the percentage scores offered by the judges in the word, sentence and narration intelligibility task with the overall perceived

intelligibility of the subjects speech, three additional judges who did not participate in the assessment of speech intelligibility tasks were chosen. They were speech-language pathologists with a minimum of one year clinical experience with dysarthric clients. They were kept blind to the purpose of the study. These judges were asked to listen to a 30 second sample of the narrated speech sample of the five subjects and rate the narrated speech of each of the subject on a 4 -point rating scale with '0' indicating 'normal speech' and 3 indicating 'Severely unintelligible speech':

- 0 = Normal speech
- 1 = Mild unintelligible speech
- 2 = Moderate unintelligible speech
- 3 = Severe unintelligible speech

c) Assessment of Speech naturalness: The narration task selected in the protocol served as stimuli for assessment of speech naturalness also. The speech samples collected from subjects for assessment of speech intelligibility was judged on a 2 point rating scale by the same 3 qualified judges who assessed the speech intelligibility in words, sentences and narration sample.

- *Use of stress:* appropriate stress = 0, reduced stress / excess stress = 1
- *Use of intonation :* normal intonation = 0, excessive rise-fall / monotonous = 1
- *Use of pauses :* appropriate = 0, inappropriate = 1
- *Use of rhythm :* appropriate = 0, dysrhythmic = 1
- *Rate of speech:* normal = 0, abnormal (slow / fast/ variable) = 1
- *Articulatory proficiency:* Good = 0, Poor (imprecise consonants / prolongation of phonemes / repetition of phonemes / distorted vowels/ irregular articulatory breakdown) = 1

It was hypothesized that a higher score in speech unnaturalness would be correlated with higher percentage scores obtained for speech unintelligibility and vice versa.

d) Correlation between speech intelligibility and speech naturalness:

Percentage correct identification in speech intelligibility tasks (word, sentence and narration) and weighted scores under speech naturalness assessment task were observed to see if the percentage intelligibility scores for speech intelligibility task of words, sentences and narration correlated with the weighted scores offered by judge for the various factors under speech naturalness.

4. Reliability testing:

Interjudge reliability. The percentage intelligibility scores offered by the 3 judges for the words, sentences and narration were tested for interjudge reliability.

Intrajudge reliability: To test for Intrajudge reliability, 10 words, 5 sentences and 5 sentences from narration of each subject were randomly selected and subjected to judgement by the same 3 judges after a time interval of 1 week. Word intelligibility score, sentence intelligibility score and narration intelligibility scores were calculated. These scores were compared across the subjects and tasks and with the intelligibility ratings obtained in the first instance.

The results of percentage intelligibility scores and speech naturalness assessment in the speech of the selected dysarthric subjects on various tasks of the protocol across judges is presented and discussed in the next chapter.

SUMMARY

Dysarthria is a speech disorder, which results from a disruption of muscular control due to lesions of either the central or peripheral nervous systems. Weak, in-coordinated and imprecise speech movements are seen due to neuromuscular involvement. Respiratory, phonatory, resonatory, articulatory and prosodic subsystems of speech mechanism are involved to varying degree and this is directly reflected in speech leading to reduced speech intelligibility. Reduced speech intelligibility affects verbal communication.

Speech intelligibility is defined as the degree to which the listener (Yorkston, Beukelman & Bell, 1986) understands the acoustic signal communicated as speech. A listener defines it as the understandability of speech. Various tasks, protocols and scales are advocated to record speech intelligibility of dysarthric speakers and most of these are limited to Western context. Poor speech intelligibility also reduces the naturalness of speech. Speech naturalness has been defined as a perceptually derived overall description of prosodic adequacy. Speech is natural if it conforms to the listener's standards of rate, rhythm, intonation, and stress patterning and if it conforms to the syntactic structure of the utterance being produced.

Measures of speech intelligibility and speech naturalness form an important aspect of management in speech therapy for dysarthria clients. In Indian languages, there is no tool available for assessment of speech intelligibility and speech naturalness in dysarthria clients. Hence a preliminary attempt was made to develop a protocol for the assessment of speech intelligibility and speech naturalness in

dysarthria clients speaking Kannada language. The protocol was administered on 5 dysarthria clients and subjected to perceptual judgement to comment on the sensitivity of the protocol in assessment of the speech intelligibility and naturalness.

The protocol consists of 3 sections. They are: (1) Word intelligibility task (2) Sentence intelligibility task and (3) Picture narration task. The word intelligibility task consists of two sets: (a) Level I: Simple & (b) Level II: Complex (controlled for syllable length and syllable complexity in terms of geminates and morpho-phonemic clusters). The sentence intelligibility task consists of two sets: (a) Level I: Simple & (b) Level II: Complex (controlled for syllable length and syllable complexity in terms of geminates and morpho-phonemic clusters of the words which constituted the sentences). A picture of a 'market' scene served as the cue card for elicitation of narration speech sample.

The protocol was administered on five subjects with confirmed diagnosis of dysarthria due to different neuropathologies. The age range of the subjects varied from 25 to 70 years and all of them were native speakers of Kannada language. The severity of the speech varied from mild to severe and the type of dysarthria included Hyperkinetic, Hypokinetic, Spastic and Flaccid varieties.

The speech samples of dysarthria subjects on the three tasks were subjected for perceptual judgement of speech intelligibility and speech naturalness. Three judges performed this and the percentage intelligibility scores for word, sentence and narration samples were obtained. Speech naturalness was assessed on a 5 point binary scale after listening to the narrated speech sample of the subjects. The scores obtained

from the perceptual judgement were subjected to interjudge reliability and intrajudge reliability checks. Alpha reliability co-efficient was calculated to test interjudge reliability and intrajudge reliability co-efficient was calculated to check for the intrajudge reliability. To test if the perceptual judgment scores tallied with the overall perceived severity of the disorder, 3 other judges rated the severity of speech of the dysarthric subjects on a 4 -point rating scale after listening to a 30 second narrated speech sample of the subjects. All the judges were kept blind to the purpose of the study and the demographic details of the subjects.

Table 2 shows the interjudge reliability scores for word, sentence and narration task respectively.

Table 2: Interjudge reliability scores for word, sentence and narration task

Judges	Reliability scores for Word task		Reliability scores for Sentence task		Reliability scores for Narration task
	Level-1	Level-2	Level-1	Level-2	-
Overall judge reliability	0.95	0.96	0.96	0.97	0.85
Judge 1 Vs. Judge 2	0.95	0.91	0.98	0.94	0.98
Judge 1 Vs. Judge 3	0.94	0.98	0.92	0.95	0.96
Judge 2 Vs. Judge 3	0.91	0.94	0.91	0.97	0.96

From Table 2, it is seen that the overall interjudge reliability across the judges for all 5 subjects, at both the level 1 and level 2 was good for the word task. The overall percent intelligibility scores varied from 72% - 95% between the judges across all 5 clients for level 1 and it from 57% - 90% for level 2. Similar to the word task, the percentage speech intelligibility scores for 5 subjects as scored by 3 judges showed good reliability for both the levels of sentence task. The overall percent score for level 1 varied from 82% - 95% and that for the level 2 was from 55% - 95%. For the

narration task too, the reliability scores obtained between judges was good and varied from 65%-95%.

Intrajudge reliability check:

The scores obtained for the intrajudge reliability are shown in Table 3 for each task between the judgement of judge 1, 2 and 3 respectively in the 1st instance and the 2nd instance (the judgement task was repeated after a gap of 1 week)

Table 3: Intrajudge reliability for word, sentence and narration task:

Judges	Intrajudge reliability scores for word task		Intra judge reliability scores for Sentence task		Intrajudge reliability scores for narration task
	Level - 1	Level - 2	Level - 1	Level - 2	
Judge 1 (1 st instance Vs. 2 nd instance)	0.71	0.89	0.95	0.86	0.99
Judge 2 (1 st instance Vs. 2 nd instance)	0.86	0.88	0.92	0.88	0.95
Judge 3 (1 st instance Vs. 2 nd instance)	0.77	0.90	0.84	0.92	0.98

From table 3 we can observe that the intrajudge reliability for judge 1 and judge 3 are much lower when compared to the reliability scores obtained for judge 2 for the 2 instances of level 1 in the word task. For the level 2 of the word task the reliability scores are almost similar across the judges. The relatively poor intrajudge reliability of Judge 1 and 3 for simple words could probably be due to deployment of too many guesses for the simple target words rather than depending on the acoustic cues to perceive the right target word. The poor scores also reflect the fact that these judges had not retained the target words and did not follow any pattern in their judgement as the two judgements were made after a gap of 1 week. For the sentence task, the scores indicated no significant difference across the judges scores for both the levels of the sentence task. For the narration task also there is a good intrajudge reliability.

The judges were practicing clinicians in speech-language pathology and had a working experience with the dysarthria clients. The overall high inter and intrajudge reliability scores suggests that the judgement responses for the speech intelligibility evoked from the protocol was reliable.

Table 4 shows the comparison of the speech naturalness rating of the subjects speech by the first three judges and the overall speech severity rating offered by second three judges.

Table 4: *Comparison of speech severity and speech naturalness rating*

Subjects	Speech severity rating by judges			Speech naturalness		
	Judge A	Judge B	Judge C	Judge A	Judge B	Judge C
S1	Severe	Severe	Severe	83%	66%	83%
S2	Mild	Mild	Mild	100%	100%	100%
S3	Severe	Moderate	Moderate	66%	66%	66%
S4	Mild	Moderate	Mild	83%	83%	100%
S5	Severe	Severe	Severe	50%	50%	66%

Table 4 shows a comparison of ratings made by two groups of three judges, one for the severity of speech in the subjects and another on the speech naturalness in the subjects. It is seen that the speech of subjects 1 and 5 have been rated as 'severe' degree of impairment and the percent scores for speech naturalness are also poor ranging from 66% - 83% and 50% to 66% respectively. The speech of subject 2 is rated as 'mild' degree of impairment and the percent scores for speech naturalness is high at 100%. The degree of speech impairment of subject 3 was rated as 'severe' by one judge and 'moderate' by two judges. The percent speech intelligibility was 66%. The degree of speech impairment of subject 4 was rated as 'moderate' by one judge and 'mild' by two judges. The percent speech intelligibility in this subject ranged from

83% to 100%. Overall, the speech severity rating offered by three judges matched with the speech naturalness judgement given by three other judges. It is of importance to note that both the groups of judges were kept blind for the purpose of the study and the judgement was based on listening to the narrated speech sample of the subjects and carried out independently by the judges in both the instances without mutual consultation.

Further, Spearman correlation test was run to verify the correlation of the 3 judges who rated the speech intelligibility scores for word, sentence and narration task and speech naturalness rating based on the narrated speech sample. This is shown in Table 5 and a significant correlation at a probability level of 0.05 is observed for the judgments made by all the three judges.

Table 5: *Correlation values for speech intelligibility and speech naturalness ratings of 3 judges.*

Judges	Intelligibility Vs. Naturalness	Level of significance
Judge 1	0.913	P<0.05
Judge 2	0.913	P<0.05
Judge 3	0.889	P<0.05

Conclusion:

From the reliability and correlation checks, it is observed that the protocol developed is sensitive to assess speech intelligibility and speech naturalness in adult subjects with different types of dysarthria due to different neuropathologies. Thus, protocol can be used as an clinical tool for assessing the level of speech intelligibility and speech naturalness in adult dysarthric subjects speaking Kannada language.

Future recommendations:

- It is recommended that the protocol be administered on larger group of subjects with different types of dysarthria and standardization of scores be attempted.
- This study has been carried out only on Kannada speaking clients, hence it cannot be used for other cultural and linguistically differing population. The method may be replicated and protocols for assessment of dysarthric individuals speaking other Indian languages needs to be developed and standardized.

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ANNEXURE A

**PROTOCOL FOR ASSESSMENT OF
SPEECH INTELLIGIBILITY**

&

**SPEECH NATURALNESS
IN DYSARTHRICS IN KANNADA**

ITE OF SPE

Word List-Part I

ಆಸೆ

ಗಾಳಿ

ಲಾರಿ

ಕಾಗೆ

ಶಾಲೆ

ಮೂರು

ಕೋತಿ

ಬಾಕು

ಟೋಪಿ

ಒಂಟೆ

ನೋವು

ದಿಂಬು

ನವಿಲು

ಎರಡು

ಚಮಚ

ರುಪಾಯಿ

ಆಹಾರ

ಬಾವುಟ

ಕೊಳಕು

ಆಯಾಸ

ಮೆಣಸು

ಕುದುರೆ

ಸಾಂಬಾರು

ಒಣಗಿಸು

ಗಡಿಯಾರ

ಅರಮನೆ

ಅವಮಾನ

ಬಾಚಣಿಗೆ

ಆಲೋಚನೆ

ಹದಿಮೂರು

ಸೋಮವಾರ

Word List-Part II

ಪೆನ್ನ

ಅಜ್ಜ

ಪಲ್ಯ

ಹಕ್ಕಿ

ರಕ್ತ

ಸದ್ದು

ಜ್ಞಾನ

ಹಣ್ಣು

ಡಬ್ಬಿ

ಹಳ್ಳ

ಬಣ್ಣ

ಕತ್ತರಿ

ಪುಸ್ತಕ

ಅಕ್ಷರ

ಇಟ್ಟಿಗೆ

ವ್ಯಾಪಾರ

ಆಶ್ಚರ್ಯ

ಉತ್ಸಾಹ

ಮೈಸೂರು

ತೊಟ್ಟಿಲು

ಇರುತ್ತದೆ



ಬಾಳೆಹಣ್ಣು

ಜವಾಬ್ದಾರಿ

ಉದ್ಗಟನೆ

ಅಜ್ಞಾಪಿಸು

ಹೋಗುತ್ತಾರೆ

ಆರಕ್ಷಕ

ಪುಸ್ತಕದ

ಹಾಡುತ್ತಾಳೆ

ಆಲುಗೆಡ್ಡೆ

Sentences List-Part I

೧. ಅದು ಮನೆ.

೨. ಅದು ಕಾಯಿ.

೩. ಅವರು ಬಂದರು.

೪. ಗುಹೆಯೊಳಗೆ ಒಂದು ಹುಲಿಯಿದೆ.

೫. ಮನೆಯ ಎದುರುಗಡೆ ಮರವಿದೆ.

೬. ಅವನು ಮೂರು ಗಂಟೆಗೆ ಶಾಲೆಯಿಂದ
ಬಂದನು.

೭. ಮರದ ಮೇಲೆ ತುಂಬಾ ಹೂವಿನ
ಗೊಂಚಲುಗಳಿವೆ.

೮. ಹುಡುಗರು ಶಾಲೆಯಿಂದ ಬಂದು ತಿಂಡಿ ತಿಂದು
ಆಡಲು ಹೋಗುವರು.

೯. ಬಾವಿಯೊಳಗೆ ಹಲವು ಹಾವುಗಳು ಹಾಗೂ
ವಿಧವಿಧವಾದ ಮೀನುಗಳಿವೆ.

೧೦. ಊರಿನ ಹುಡುಗಿಯರು ಮನೆಯ ಬಳಿ ಇರುವ
ಮರದ ಅಡಿ ಕುಳಿತುಕೊಳ್ಳುವರು.

Sentence List-Part II

೧. ಅವನು ಬರೆಯುತ್ತಾನೆ.

೨. ಅವಳು ಹಾಡುತ್ತಾಳೆ.

೩. ಅದು ಕಥೆ ಪುಸ್ತಕ.

೪. ಆ ಹುಡುಗ ಬುದ್ಧಿವಂತನಾಗಿದ್ದಾನೆ.

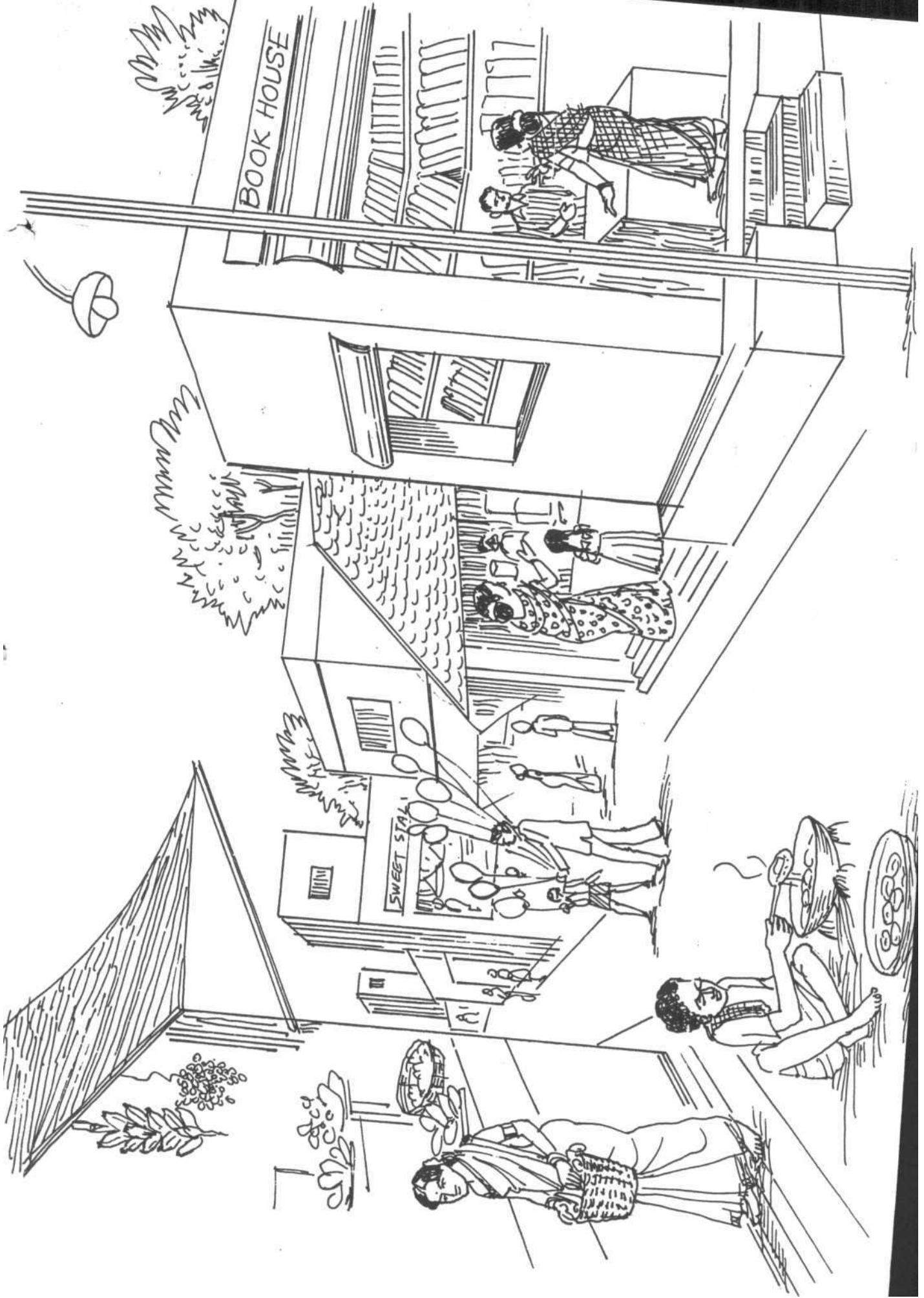
೫. ಬುಟ್ಟಿಯಲ್ಲಿ ಸ್ವಲ್ಪ ಅಕ್ಕಿಯಿದೆ.

೬. ಜಾನಕಿ ಬಹಳ ಸುಂದರವಾಗಿದ್ದಾಳೆ.

೭. ಪೇಟೆಗಳಲ್ಲಿ ಹಲವಾರು ಬಿಕ್ಷುಕರು ಇರುತ್ತಾರೆ.

೮. ಈ ಊರಿನಲ್ಲಿ ಎತ್ತರವಾದ ಕಟ್ಟಡಗಳನ್ನು

ಕಾಣುತ್ತೇವೆ.



೯. ಕಿತ್ತಳೆ ಹಣ್ಣು ಎಲ್ಲಾ ಹಣ್ಣುಗಳಿಗಿಂತ ಸಿಹಿಯಾಗಿ
ಇರುತ್ತದೆ.

೧೦. ಮಕ್ಕಳು ನಾಲ್ಕು ಗಂಟೆಯ ಮೇಲೆ ಆಟದ
ಮೈದಾನಕ್ಕೆ ಹೋಗಿ ಚೆಂಡಿನಲ್ಲಿ ಆಡುತ್ತಾರೆ.

Assessment of Speech Naturalness

The judges should listen to 1 minute narration sample and rate the client's speech on 2-point rating scale on the following factors:

Use of stress: appropriate stress = 0, reduced stress / excess stress = 1

Use of intonation: normal intonation = 0, excessive rise-fall / monotonous = 1

Use of pauses: appropriate = 0, inappropriate = 1

Use of rhythm: appropriate = 0, dysrhythmic = 1

Rate of speech: normal = 0, abnormal (slow / fast / variable) = 1

Articulatory proficiency: Good = 0, Poor (imprecise consonants / prolongation of phonemes / repetition of phonemes / distorted vowels / irregular articulatory breakdown) = 1