

Measurement of Stuttering Severity-A Comparison between Subjective and Objective Methods

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Abstract

Introduction

Stuttering is a communication disorder, characterized by repetition of sounds, syllables, or words; prolongation of sounds; and interruptions in speech known as blocks which may be accompanied by struggle behaviours, such as rapid eye blinks or tremors of the lips.

Methodology: This study investigated the correlation of 2 stuttering measurement tools: an objective measurement of different behaviours of stuttering assessed using a computer and the subjective severity assessment done by the clinician. The number of different stuttering behaviours and their duration were calculated using a computer. Three experienced speech pathologists rated stuttering severity by listening to the audio recording of reading and spontaneous speech samples of 10 stuttering and 10 nonstuttering participants.

Results: Results showed very high intra-judge and inter-judge agreement for both measures. There was a strong linear correlation between subjective stuttering severity assessment done by the judges and stuttering severity scores calculated by the computer. The finding of this study suggests that the two measures can be regarded as interchangeable. Hence the results of the current study can be used to develop an algorithm to measure severity assessment which will be more objective measure than the traditional perceptual evaluation by clinician.

Introduction

Stuttering is a fluency disorder affecting communication , characterized by repetition of sounds, syllables, or words; prolongation of sounds; and interruptions in speech known as blocks which may be accompanied by struggle behaviours, such as rapid eye blinks or tremors of the lips(1). The exact causes for stuttering are not precise.

Various measures of assessing the severity of stuttering are available. These are either (1) perceptual rating, where the clinician rates the severity of the behaviours according to a scale, or (2) counting instances of specific stuttering behaviours or measuring the duration of specific behaviours.

Subjective Perceptual rating scales have been widely used for overall estimation of the severity based on the perception of the clinician, for example Martin et al. (1988) proposed a scale with satisfactory intra-judge reliability and inter-judge reliability, which has a 9-point scale, where one is labelled "mild," and nine is labelled "severe." There are no descriptions of any symptoms (2).

Another measurement method of stuttering severity is calculating the percentage of stuttered syllables/ words whereby the number of stuttered syllables/words is related to overall spoken syllables/words (3). The percentage duration of different stuttering behaviours has also been used to find stuttering severity (4).

Different stuttering behaviours like part-word repetitions, whole-word repetitions, phrase repetitions, prolongation, pauses, and interjections with their frequency of occurrence have been tabulated to describe the severity by some researchers(5). The Stuttering Severity Index

(SSI-IV) was developed to assess the severity of stuttering based on frequency, duration, and physical concomitants combined into one stuttering severity score (6). However, doubts have been raised about the test's inter and intra-judge reliability (7).

There are also rating scales where the patient marks severity based on his/her difficulty. The Overall Assessment of the Speaker's Experience of Stuttering is a self-reported measure with 100 items across four sections (I General information, II Reactions to stuttering, III Communication in daily situations, and IV Quality of life), scored against a 5-point Likert scale (8).

Computer programs like CASPER, Video Voice, and Bakker's program have been developed to count stressed syllables and voice initiations automatically. (9) The Institute for Stuttering Treatment and Research, Edmonton, has developed an electronic button-press event recorder to facilitate the manual counting of syllables and manual registration of stuttering events or disfluencies (10)

The present study aimed to compare subjective clinician-based judgment of severity by calculating the number of different stuttering behaviours and their duration assessed using a computer.

Objectives of the Study

The aim of the study was to find the correlation between different stuttering behaviours assessed using a computer and the subjective severity assessment performed by the clinician.

Methodology

Consents were taken concerning the participation in the study after explaining the details of the study.

Participants

Two groups of subjects were included in the study. The first group consisted of 10 stutterers between the age range of 15 to 25 years and the mean age of 20, who were diagnosed clinically by a speech-language pathologist. The second group consisted of 10 normal speakers matched for age and sex.

Procedure

The subjects were seated comfortably in a sound-treated recording room with an average noise level of around 40 dB. The subjects' reading of the Rainbow Passage as well as spontaneous speech were audio recorded using a digital recorder (Sony IC Recorder, ICD-PX440). The Rainbow Passage is a standard, phonetically balanced oral reading passage used by speech-language pathologists(11). The microphone was held approximately 10 cm from the mouth of the subjects during the recording. The speech samples were recorded at a sampling rate of 44,100 Hz and with 16-bit quantization.

The following Questions were asked to elicit spontaneous speech

- 1) What is your name?
- 2) Which is your native place?
- 3) How old are you?
- 4) What are you doing?
- 5) What is your problem?

The Vaghmi software (Speech and Voice Systems, Bangalore, India)(12) was used to analyse the data. Speech fluency of the recorded samples produced by the subjects were quantified using two measures:

1. Subjective rating by judges - three Speech Language Pathologists (SLP) served as judges to perceptually rate the severity of stuttering after listening to the recorded sample on a five-point scale as 0-normal, 1-mild, 2 - moderate, 3-moderate-severe, 4-severe. The average of the scores by the three judges was calculated.
2. Objective measurement using computer - The samples were fed to the computer and digitized. The digitized samples were then visually displayed on the computer screen as a waveform (time intensity function) in the program "VAGHMI" developed by VSS-Bangalore(12). Then, the experimenter identified the instances of stuttering and the duration of each instance based on listening to the audio sample and the looking at the visual display simultaneously. The core stuttering behaviours considered for identification were repetitions, prolongations, blocks and interjections based on Teesson et al.'s (2003) dysfluency taxonomy (13). On identifying the stuttering moments as repetitions, prolongations, blocks and

interjections, the duration of each stuttering moment was measured by moving the cursor on the computer. The program facilitated the measurement of the duration of each of the stuttering moments. The type, number, and duration of a particular stuttering moment were registered and stored in the computer memory. The data was processed regarding the number of stuttering moments, the duration of the stuttering moments, and the rate of speech (number of syllables/second).

Criteria for Counting Core Behaviours of Stuttering:

- 1. Repetitions-** Both syllable and word repetitions were counted. A syllable repetition as pa-pa was marked as a single repetition. Each word repetition was marked separately.
- 2. Prolongation** was considered when airflow continued but movement of the articulators stopped, producing a vowel or consonant for longer duration than beyond its appropriate duration. Eg “I fffffeel saaad”
- 3. Interjections-** when there was a break in speech by a filler word or sounds like Ummm, Uhhh, Like, But, Mmmm, You know. eg. “I, ummm, like to eat”
- 4. Blocks** involved stopping of both airflow and sound during the production of speech due to fixed articulatory posture for subsequent sound.

Rate of speech was calculated by dividing the total number of syllables by total time in seconds

Results

1. Subjective Judgement of Severity of Stuttering by Speech Pathologist.

Three Speech Language Pathologists (SLP) served as judges to perceptually rate the severity of stuttering after listening to the recorded sample on a five-point scale as 0-normal, 1-mild, 2 - moderate, 3-moderately severe, 4-severe. For intra-judge reliability calculation, rating of the recorded speech samples of all the subjects were blindly done twice by the same judges (SLP). For inter-judge reliability, the same sample was blindly rated by two other judges (SLP). The ratings were done independently and were blinded to the other clinicians' ratings and their own prior ratings.

A high intra-judge reliability was found where Judge II showed maximum reliability (correlation coefficient was 0.97), and Judge III showed minimum reliability (correlation coefficient was 0.88).

	Judge I	Judge II	Judge III
Intra judge reliability	0.92	0.97	0.88

Table- 1: The intra-judge reliability of judgement of severity of stuttering.

	Judge I & II	Judge II & III	Judge I & III
Inter judge reliability	0.98	0.88	0.89

Table- 2: The inter-judge reliability of judgment of severity of stuttering.

The inter-rater reliability results indicated a strong level of agreement between the raters. Correlation coefficient was 0.98 between Judge I & II, 0.88 between Judge II & III, 0.89 between Judge I & III.

2. Objective Measurement Using Computer

Tables 3 & 4 show total number of repetitions, prolongations, Interjections, and blocks as measured using the computer and the average severity judgment by the SLP's for stuttering subjects and normal subjects respectively

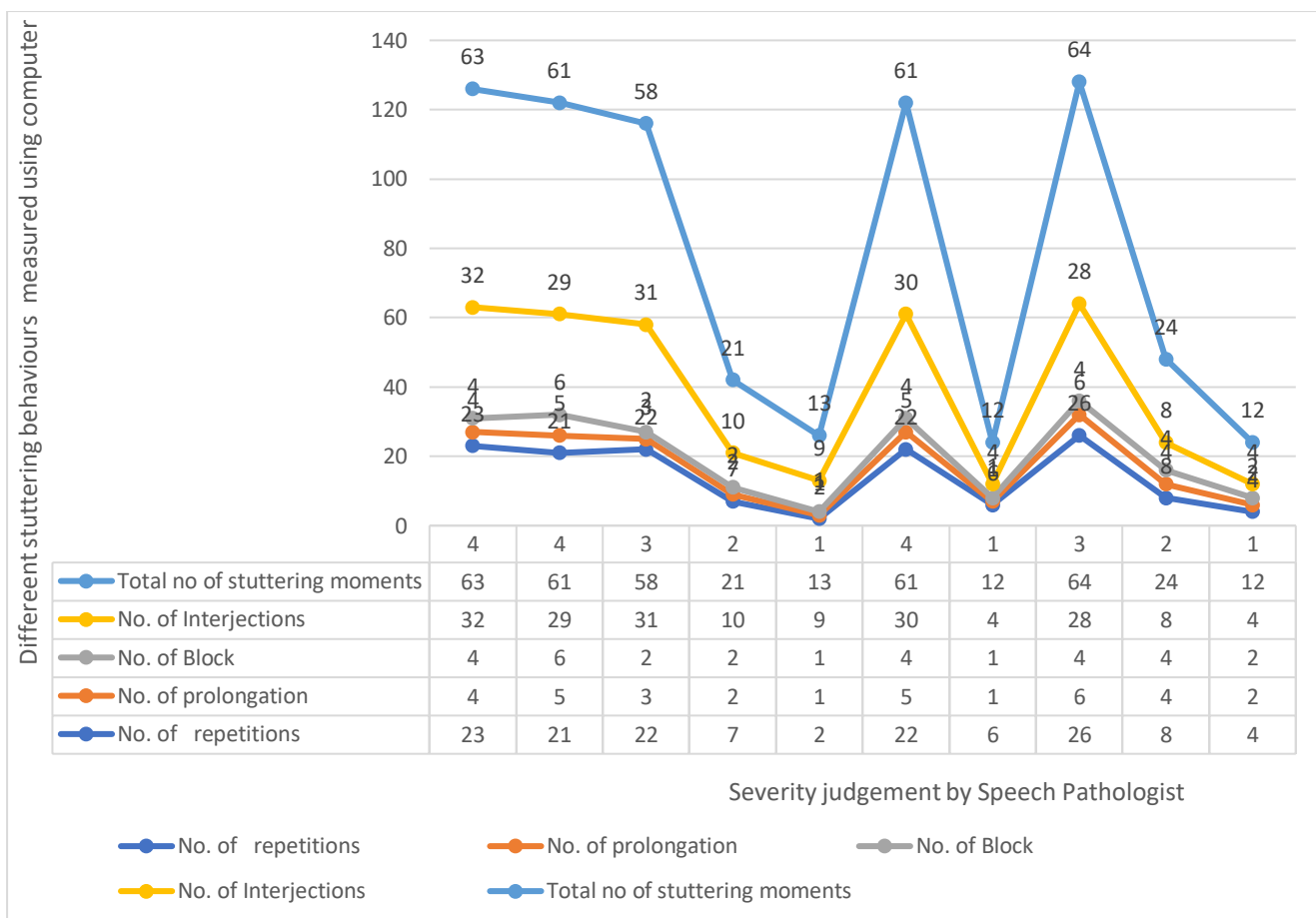


Table- 3: Total number of repetitions, prolongations, Interjections, and blocks as measured using the computer and the average severity judgment by the SLP's for the stuttering subjects

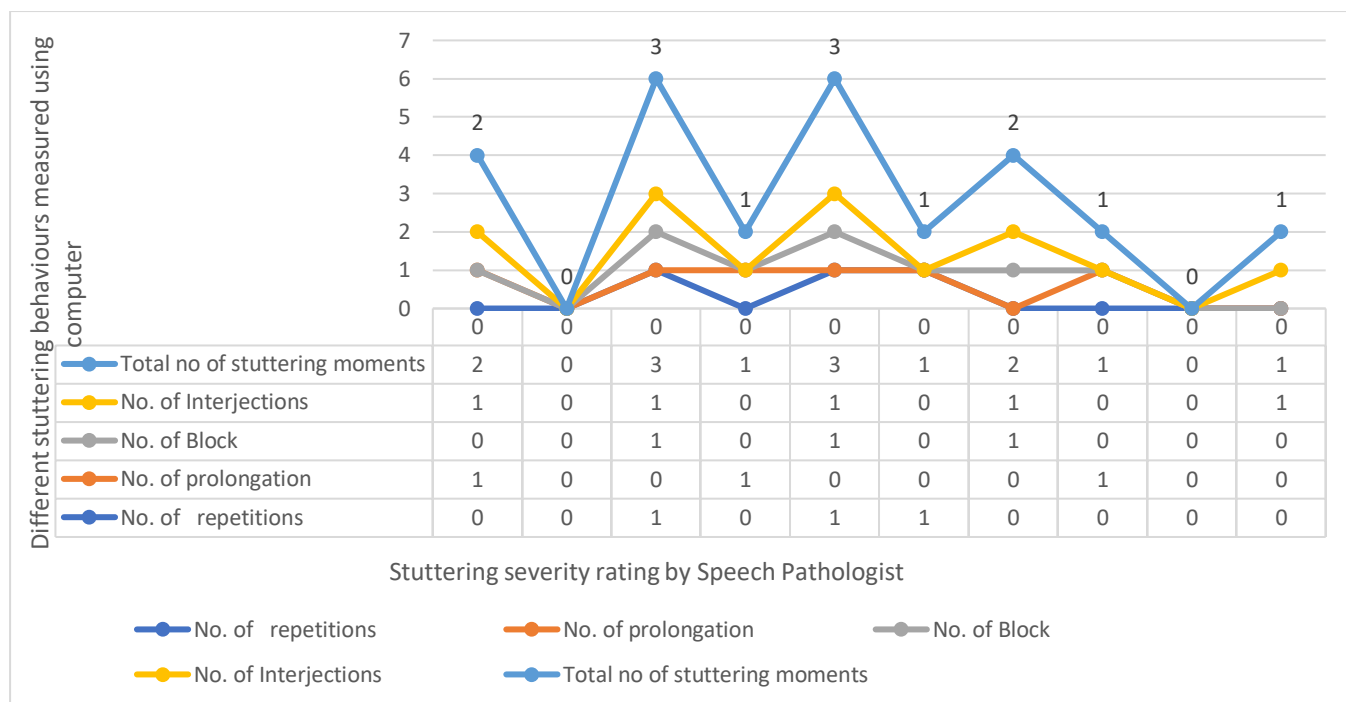


Table- 4: Total number of repetitions, prolongations, Interjections, and blocks as measured using the computer and and the average severity judgment by the SLP’s for the normal subjects

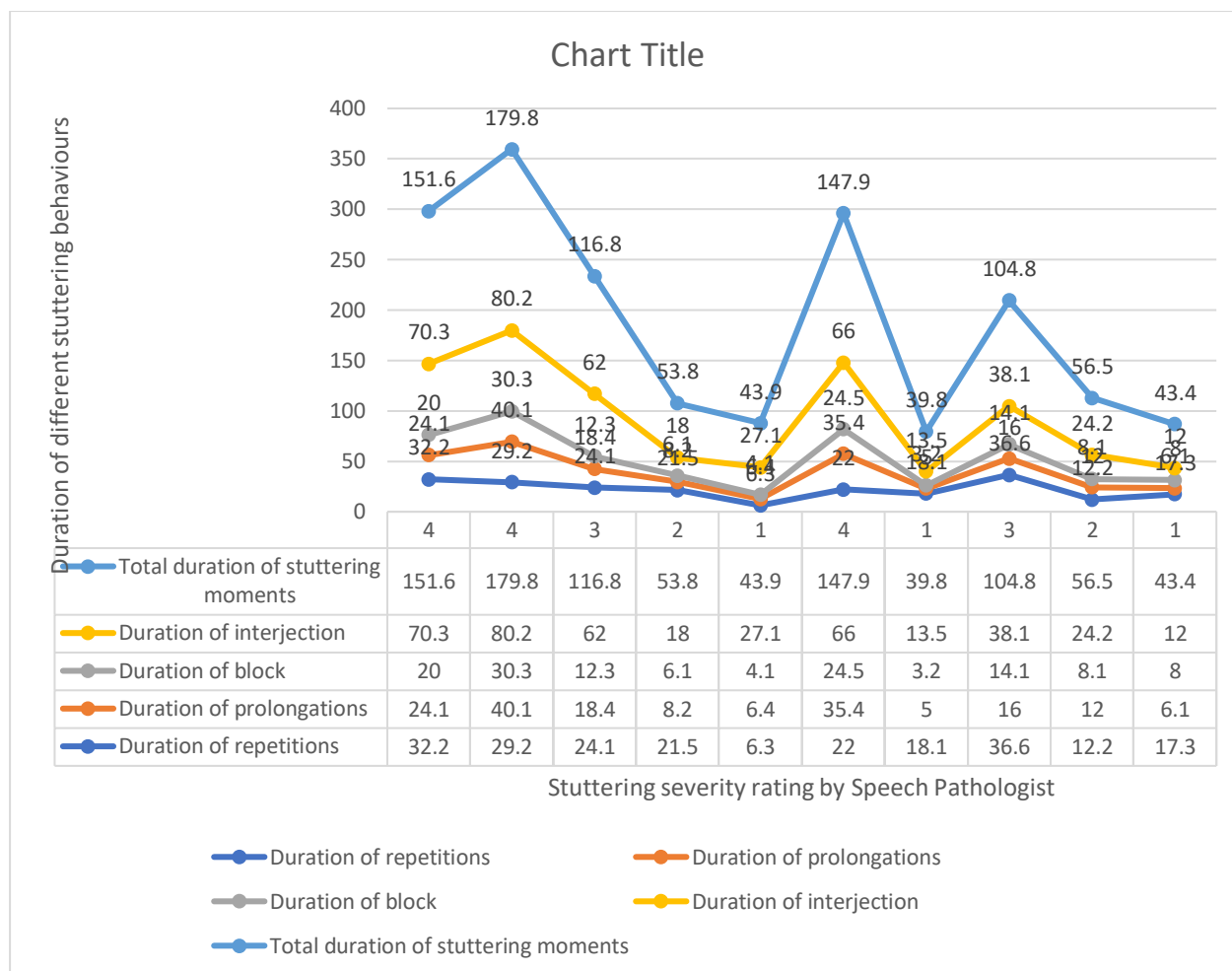


Table 5 shows total duration of repetitions, prolongations, Interjections, and blocks as measured using the computer and the average severity judgment by the SLP's for stuttering subjects.

Table- 5 and 6 shows total duration of repetitions, prolongations, Interjections, and blocks as measured using the computer and the average severity judgment by the Speech Pathologists for stuttering subjects and normal subjects respectively

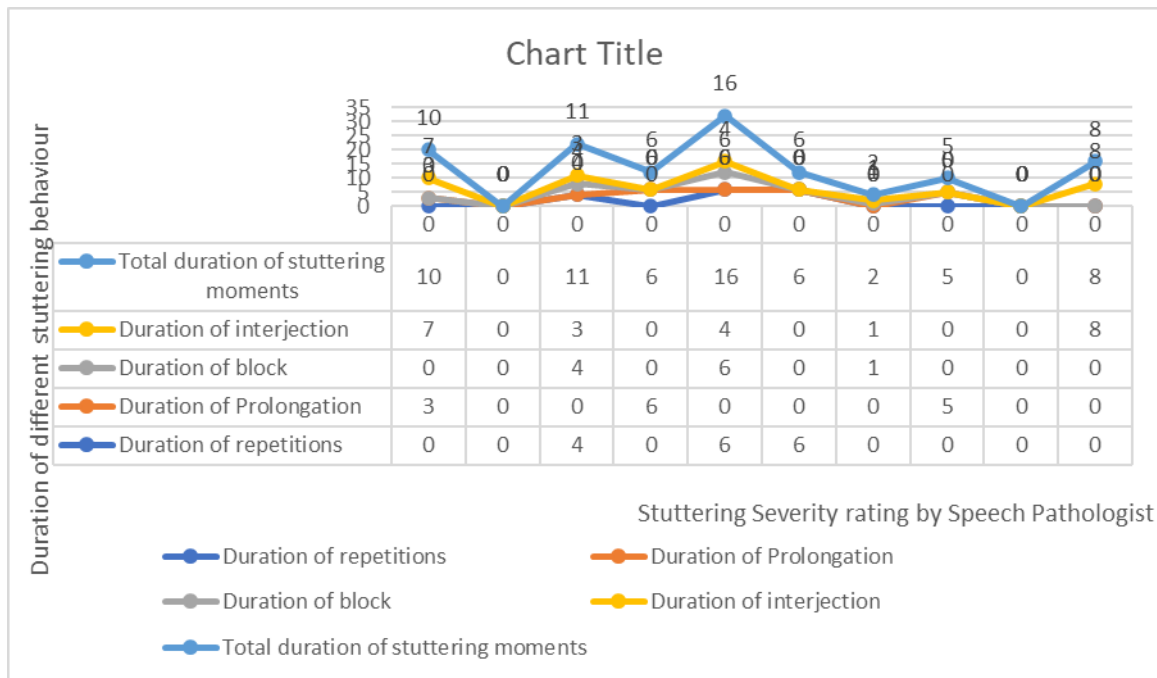


Table- 6: Total duration of repetitions, prolongations, Interjections, and blocks as measured using the computer and the average severity judgment by the SLP's for normal subjects.

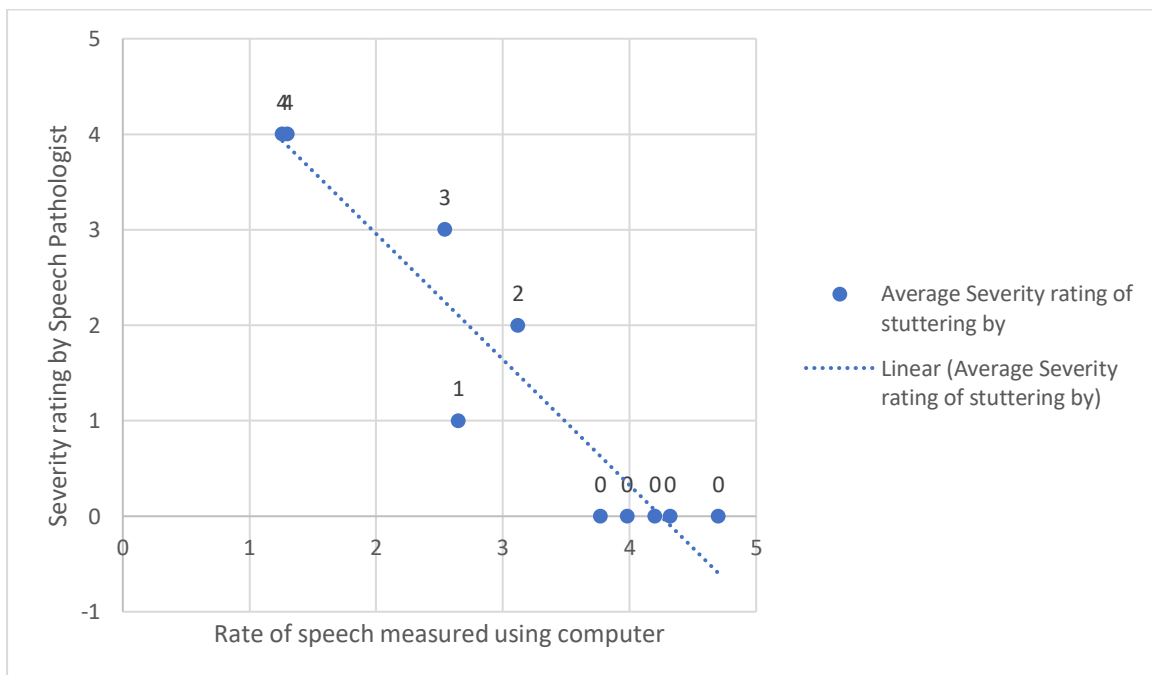


Fig 1. Rate of speech in terms of number of syllables per second as measured by the computer and the average severity judgment by the SLP's.

Spearman's coefficient of correlation was applied to find out the correlation between the severity ratings of judges and severity judgments made using computer measurements.

	Correlation between stuttering moment and rating of severity by SLP's	Correlation value (v)
1	Number of repetitions vs. rating by SLP	0.832
2	Duration of repetition vs. rating by SLP	0.815
3	No of blocks vs. rating by SLP	0.81
4	Total no of stuttering moments vs. rating by SLP	.799
5	Duration of blocks vs. rating by SLP	0.79
6	Duration of prolongation vs. rating by SLP	0.732
7	Number of prolongations vs. rating by SLP	0.612
8	Number of interjections vs. rating by SLP	0.591
9	Duration of interjections vs. rating by SLP	0.532
10	Total duration of stuttering moments vs. rating by SLP	0.501
11	Rate of speech (syllable/sec) measured using computer vs. rating by SLP	-0.821

Table 8: Correlation between different stuttering behaviours assessed using a computer and the subjective severity assessment performed by the SLP's.

Positive Correlation between different stuttering behaviours and severity rating by Speech Pathologist

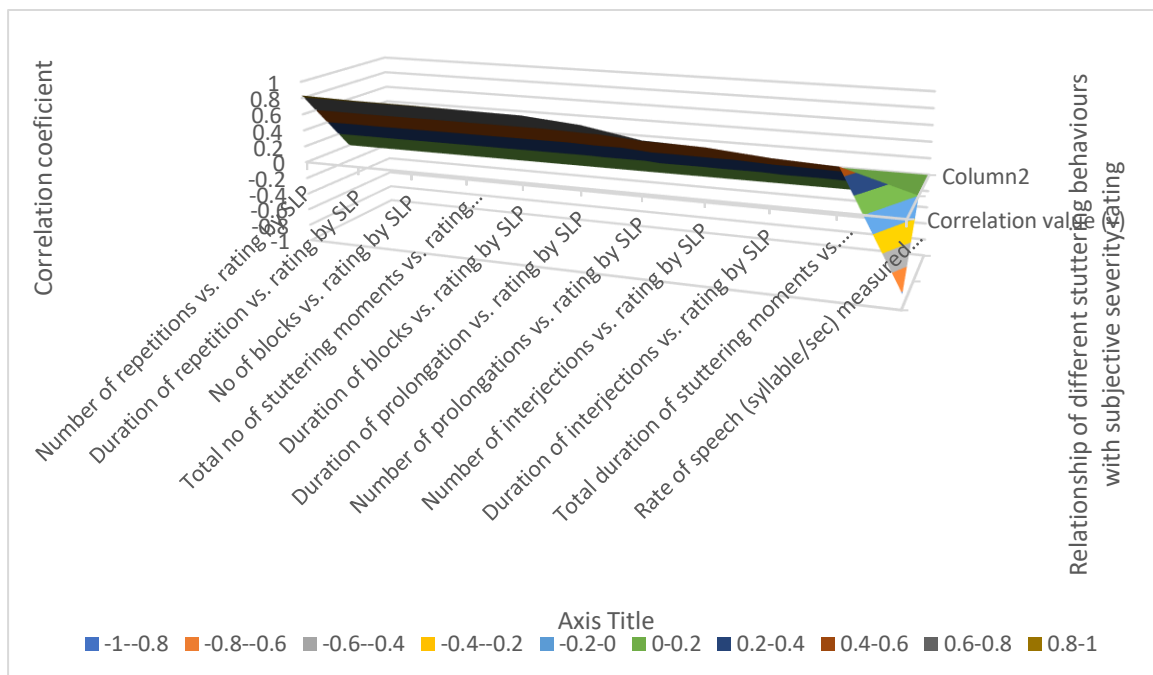
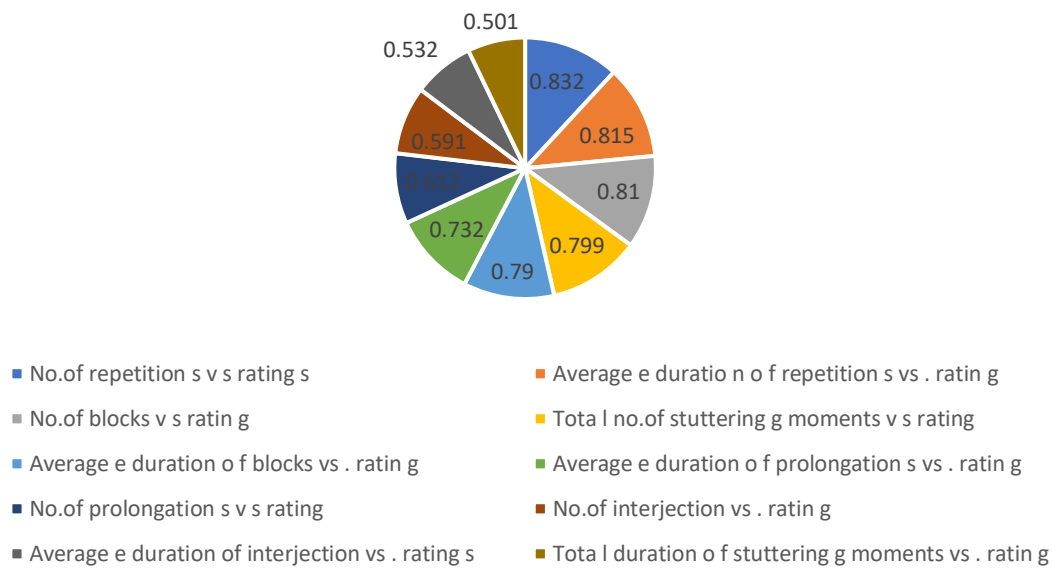


Fig 2. Correlation coefficient value for the relationship between different stuttering behaviours assessed using a computer and the subjective severity assessment performed by the SLP's.

Discussion

Clinically, perceptual evaluation of stuttering is usually done using severity rating-scales, where numerical value is assigned on an ordinal scale or marks a rating on visual-analog scale to represent the perceived overall stuttering severity (14,15), which are simple to use, and does not require any equipment. To reduce judgement bias, rather than relying on a single judge, it is desirable to have multiple judges. In our study, three Speech Pathologists served as judges to perceptually rate the severity of stuttering after listening to the recorded sample on a five-point scale as 0-normal, 1-mild, 2 - moderate, 3-moderately severe, 4-severe.

All the three judges were consistent in their judgments, as demonstrated by the high correlations between their repeated ratings (Table 1).

Results also demonstrated that the three judges evaluated stuttering severity similarly using the perceptual rating scale as indicated by high correlation between the ratings of the three judges (Table 2)

The study aimed to find the correlation between the severity of stuttering, as judged by speech-language pathologists, and the severity of the stuttering, as measured using a computer program. The number of stuttering moments, the average duration of stuttering moments, and the rate of speech (number of syllables/second) were measured using computer. The core behaviours identified as stuttering behaviour vary slightly from one author to another (16) Van Riper identified repetitions, prolongations, and blocks as the basic core behaviours of stuttering (3) and according to Wingate the behaviours included repetitions, hesitations, prolongations, interjections, and broken words during speech (17). Johnson's classification system focuses on interjections, repetitions, revisions, broken words, incomplete phrases, and prolonged sounds (18). The terms used in this labelling by different authors are almost synonymous but is vaguely defined (e.g., "tense pause" and "blocks," or "broken words" and "part-word repetition").

Teesson et al opined that reducing the number of categories into limited number of self-defining categories would enhance inter- and intra-judge agreement (13). Teesson et al.'s (2003) dysfluency taxonomy has three main categories: repeated movements, fixed postures, and superfluous behaviours. (13).

The core stuttering behaviours considered by us in our study were repetitions, prolongations, Interjections, and blocks, based on Teesson et al.'s (2003) dysfluency taxonomy (13).

Repetitions come under the category of repeated movements, prolongations and blocks come under the category of fixed postures and interjections under superfluous behaviours.

Among the different stuttering behaviours that was taken under study, interjections and repetition were found to be the most frequently observed stuttering behaviours followed by blocks and prolongations (Table 3). Blocks have been attributed to inappropriate tensing of muscles at the level of the glottis (19) or due to obstruction either at the respiratory, laryngeal, and/or articulatory levels of speech production (20).

Table 6 shows that all the stuttering behaviour assessed using computer had a positive correlation with the subjective severity assessment performed by clinician except rate of speech, which showed a high negative correlation (-0.82).

Rate of speech of normal subjects varied from 3.7 to 4.7 syllables per second and 1.3 to 2.65 syllables per second for stuttering subjects. We have found that the rate of speech reduced with increase in severity among stutterers. A high negative correlation of 0.82 was found between rate of speech in syllables/second as measured using computer and severity of rating of stuttering by the Speech Pathologist. Speech rate can reflect the severity of an individual's stuttering, with reduction in speaking rate with increase in severity(21,22). Speaking rate can be measured as the number of either syllables or words produced per minute, with syllable counts being the preferred method(20,21). We had measured speaking rate as syllable per second. The speaking rate for a normal person is around four syllables per second / 160-230 syllables per minute/ 150 words per minute (14,15) and can vary between 3.3 and 5.9 syllables per second (16). The rate of speech is reduced in stutterers because stuttering behaviours like repetitions, prolongations, blocks, and pauses naturally slow down the rate of speech.

Among the behaviours which showed positive correlation, number of repetitions (0.83) , duration of repetition (0.81), number of block (0.81) had more effect on judgement of severity of stuttering when compared to duration of block (0.79), duration of prolongations (0.73), number of prolongations (0.61), number of interjections (0.59). Total number of stuttering

moments (0.79) correlated more than total duration of stuttering moments (0.50) towards severity rating of stuttering by judges.

The high correlation between the measurement of severity using computer and the listeners' subjective evaluation of stuttering severity suggests that they provided same results and can be used interchangeably. Hence the results of the current study can be used to develop a computer assisted severity assessment which will be more objective measure than the traditional perceptual evaluation by clinician. Algorithms can also be developed for automated segmentation and calculation of severity which can be used as smartphone application where an ongoing assessment of fluency in natural speaking environments can be done by the clinician.

Conclusion

The study provides consensus guidelines on two different methods of stuttering severity assessment, first one using perceptual evaluation of stuttering severity and second one using computer. There was a strong linear correlation between subjective stuttering severity assessment done by the judges and stuttering severity scores calculated by the computer. The finding of this study suggests that the two measures can be regarded as interchangeable.

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