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Impact of 'Be Clear' Treatment on Speech and Functional Communication Outcomes in Adults with Post-Stroke Dysarthria

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ABSTRACT

Background: Dysarthria is a neurogenic speech disorder characterized by dysprosody and distinguished by deficits in speech understandability. Clear speech is a compensatory treatment approach that has gained traction in recent years. Studies investigating the impact of 'Be Clear' treatment are limited, particularly in post-stroke dysarthria.
Objectives: The study aimed to investigate the effect of 'Be clear' speech treatment on speech intelligibility, speech naturalness, prosodic characteristics, and communication participation in adults with post-stroke dysarthria.
Methods: Eight Kannada-speaking participants aged between 30 to 66 years with post-stroke dysarthria were recruited for the study. 'Be clear' treatment was practiced over the duration of sixteen one-hour sessions across four weeks. Assessments of narrative intelligibility, overall speech naturalness, and functional communication were carried out. Acoustic measures included measurements of mean fundamental frequency, standard deviation of fundamental frequency, mean intensity, and standard deviation of intensity.
Results: Participants demonstrated significant improvements in narrative intelligibility, and overall speech naturalness, between pre-versus post and pre-versus follow-up (FUP) conditions. In acoustic variables, significant changes were observed in mean intensity between pre-post and pre-FUP conditions. Speech handicap was reduced and improvements in overall communication partner ratings were noticed following the treatment.
Conclusions: 'Be clear' treatment led to improvements in narrative intelligibility, enhanced speech naturalness, reduced speech handicap, increased communication participation, and increased vocal intensity in the participants. Future studies could incorporate a broader range of parameters with a larger sample size.

Keywords: Post-stroke dysarthria, 'Be clear', speech intelligibility and naturalness, fundamental frequency and intensity

INTRODUCTION

Dysprosody, manifested by reduced pitch, reduced loudness, monotone (restricted pitch and loudness variability), and slow rate are observed as the most frequently occurring biomarkers in post-stroke dysarthria.[1,2] Dysarthria is also distinguished by disruptions in speech intelligibility, particularly in connected speech, which consequently hinders an individual's capacity to engage in effective communication,[3] reduces communicative participation,

leading to social isolation, decline in psychosocial functioning, and reduced quality of life.[4] Clear speech is a compensatory speaking strategy that requires individuals to use 'exaggerated articulation' or 'overenunciation' to improve speech understandability. Immediate effects of clear speech have been documented in the previous literature showing increments in fundamental frequency, vocal loudness, and alterations in variabilities of fundamental frequency and intensity. These effects have been thoroughly examined, particularly in Parkinson's disease.[5-9] Limited studies have delved into the impact of clear speech as an approach to intervention. Efficacy of the 'Be Clear' and other clear speech treatment programs are conducted largely in the Western context,[10-14] and stroke representation in these studies was minimal, despite stroke being the highly prevalent cause of dysarthria.[1,15]

Thus far, perceptual measurements are considered gold standard.[13] It is crucial to incorporate acoustic measurements since they can potentially capture subtle alterations in the speech signal after treatment, which may go unnoticed through conventional intelligibility evaluations. The current study was a pioneering research on investigating the effects of clear speech treatment on fundamental frequency, intensity, variations in fundamental frequency and loudness in post-stroke dysarthria. Examining suprasegmental acoustic adjustments following a clear speech treatment provides a deeper understanding of monitoring the treatment outcomes on the speech intelligibility and naturalness in individuals with dysarthria.

The study aimed to investigate the effect of 'Be clear' speech treatment on speech intelligibility, speech naturalness, prosodic characteristics, and communication participation in adults with post-stroke dysarthria. The objectives of the study were (1) To investigate changes, if any, in narrative speech intelligibility and speech naturalness before the treatment, following the treatment and one month following the treatment, (2) To evaluate the changes, if any, on mean fundamental frequency (Mean f0), standard deviation of fundamental frequency (f0SD), mean intensity and standard deviation of intensity (IntSD) before the treatment, following the treatment and one-month following the treatment, and (3) To assess any changes, if any, on the functional communication outcomes before the treatment, following the treatment and one-month following the treatment.

MATERIALS & METHODS

Research Design

A single-group time series design was adopted in the study to evaluate the effects of 'Be clear' treatment program.

Participants

Eight Kannada-speaking males between 30 to 66 years of age (Mean age: 48 ±14.3 SD) were recruited through convenience sampling from the rehabilitation caseloads of the Department of clinical services, AIISH, Mysuru, and the major hospitals in Mysuru. Participants with a confirmed diagnosis of cerebrovascular accident (CVA), supported by neurological scan findings were screened for the presence of dysarthria using the Kannada version of the National Institute of Health stroke scale (Ka-NIHSS) [16] indicated by a score of '1 or above' for the presence of dysarthria. Severity of dysarthria was evaluated using the 9-point rating scale of the Frenchay Dysarthria Assessment-2 (FDA-2).[17] The demographic details of the study participants are depicted in table 1.

Table 1: Demographic details of the participants, stroke types, and severity of dysarthria

Participants	Age [Years]	Sex	SPO*	Stroke type[a]	Dysarthria type	Severity[b]
P1	32	Male	2 years	Ischaemic	UUMN*	Mild
P2	46	Male	3 years	Haemorrhagic	Mixed	Moderate
P3	66	Male	2 years	Ischaemic	Mixed	Moderate
P4	30	Male	3 years	Haemorrhagic	UUMN	Mild

P5	42	Male	5 years	Haemorrhagic	Flaccid	Moderate
P6	62	Male	6 months	Ischaemic	UUMN	Mild
P7	64	Male	>5years	Ischaemic	UUMN	Mild
P8	42	Male	1 year	Ischaemic	UUMN	Mild

***Abbreviations: SPO- Stroke post-onset; UUMN- Unilateral upper motor neuron dysarthria;**
[a] Stroke type determined based on MRI/CT scan findings
[b] Severity of dysarthria determined by Frenchay dysarthria assessment-2 (FDA-2)

Informed consent and ethics

Informed consent was obtained from all the participants. All procedures in this study complied with the ethical guidelines of bio-behavioral research involving human subjects.[18]

Treatment program

'Be clear' treatment was carried-out over a course of sixteen one-hour sessions for four weeks aimed to establish clear speech production. The treatment program comprised of pre-practice and intensive practice phases. In the pre-practice phase, clear speech discrimination task was employed in which the participants observed two video recordings of a native female Kannada speaker reading a standard Kannada passage in normal and clear speech. Participants were given the task to differentiate between the two speeches and evaluate which of the speech samples was clear, and compare alterations made by the speaker (exaggerated articulation) that might have resulted in the enhancements in speech clarity.

In the intensive practice phase, the participants were made to spontaneously modify their habitual speech in order to improve speech intelligibility. This technique depends extensively on 'purposeful enunciation' (exaggerated articulation) of all the sounds. To accomplish this, participants were required to practice structured speech drills such as functional phrases, service requests, and functional speech tasks using the same effort of enunciation. Speech drills for functional phrases and service requests included a 10-minute practice of ten phrases and service requests used in daily functional living.

Speech drills of functional speech tasks included a 30-minute practice of tasks alternating between reading, picture description, and conversations with the practice of 2-3 minutes per stimulus item. The tasks were gradually increased in length and complexity across weeks, tailored to each participant's goals (Ex: Communicating at the workplace/caregivers) and interests (Ex: speaking about topics about cricket or cooking). In addition, fifteen-minute practice of homework assignments of all the practiced speech tasks was provided to carry out clear speech practice in real-world communication situations (e.g., telephone conversation).

PROCEDURE

The participants were seated in a quiet room with minimal environmental noise and the samples were recorded individually. The speech samples were recorded using a unidirectional dynamic microphone (Maono AU-HD300T) by keeping the microphone 10 cm away from the mouth of the participant.

Perceptual measures

Narrative intelligibility and overall speech naturalness was measured using the Protocol of speech intelligibility and naturalness for Dysarthrics in Kannada [19] using a picture description task that consisted of a picture depicting a "market scene" represented through line drawing. The speech samples obtained by the participants in narrative intelligibility were analysed by scoring the percentage of correct responses using the following formula:

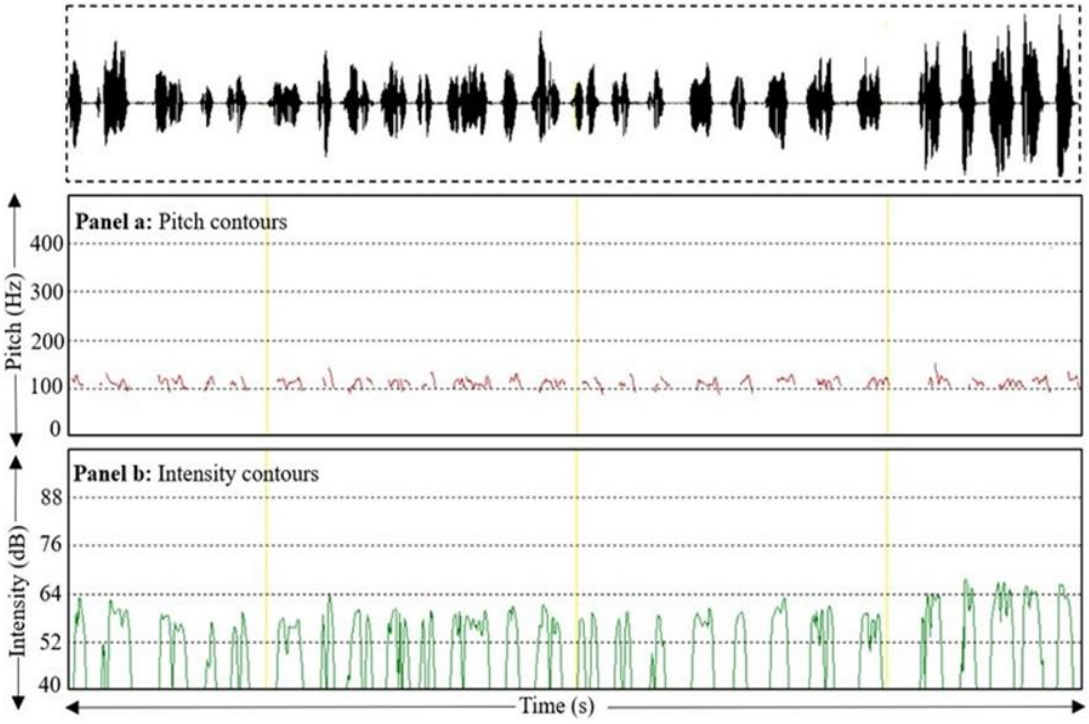
$$\text{Narrative intelligibility} = \frac{\text{Number of intelligible words in the narrated sample}}{\text{Total number of words in the narrated sample}} \times 100 \qquad (1)$$

The narration task selected in the protocol was used for the assessment of speech naturalness [19]. The speech samples of the participants were rated on a '2-point' rating scale in the following parameters: use of stress (0=appropriate stress, 1= reduced stress/excess stress), use of intonation (0= normal intonation, 1= excessive rise-fall/ monotonous), use of pauses (0= appropriate, 1= inappropriate), use of rhythm (0= appropriate, 1= dysrhythmic), rate of speech (0= normal, 1= slow/fast/variable), articulatory proficiency (0= good, 1= poor-imprecise consonants/prolongation of phonemes/ repetition of phonemes/ distorted vowels/irregular articulatory breakdown).

Acoustic measures

Secondly, acoustic stimuli comprised a standard Kannada passage [20] encompassing six sentences that included both voiced and voiceless phonemes in all places and manner of articulation. The stimuli was presented through Microsoft PowerPoint 2007 on a white background (Lenovo 82H8). Participants were instructed to read the passage in their habitual speech. The acoustic samples were analysed using the PRAAT software version 6.0.23 [21]. The analysis was focused on the second to fifth sentence in the reading passage, excluding the first and last sentences due to acoustic variabilities. Mean f0, f0SD, Mean intensity, and standard deviation of intensity (IntSD) were measured by extracting the pitch contours and intensity contours from the reading passage using corresponding functions in PRAAT. The extraction of pitch contours and intensity contours have been illustrated in figure 1.

Fig 1. Illustration of extraction of pitch contours (panel a- indicated in red) and intensity contours (panel b- indicated in green) from the standard Kannada passage using PRAAT software in a participant with post-stroke dysarthria



Functional communication outcomes

In addition to this, the Kannada version of Speech Handicap Index [22] was administered to evaluate the speech-related quality of life in individuals with dysarthria. The questionnaire consisted of 30 statements involving speech related difficulties experienced by the individuals during different communicative situations. The participants were made to self-rate their speech difficulties on a '5-point' rating scale indicating: '0'-never, '1'- rarely, '2'-

sometimes, '3'- almost always, and '4'- always.

In order to rate the everyday communication abilities of the participants with dysarthria, a set of five questions developed by Park et al. [13] were given to the primary communication partners of the participants in Kannada. The questions were based on these parameters namely: Item 1: Ease of understanding the speaker; Item 2: How frequently the participants are requested to repeat themselves;

Item 3: How frequently the participants initiate conversation with familiar individuals; Item 4: How often the participants initiate conversation with strangers; Item 5: Overall rating of communication. The primary communication partners were instructed to rate each question of communicative effectiveness and participation on a scale from 1 to 7 where a rating of '7'indicated very good ability and '1' indicated poor ability. Perceptual and acoustic samples were recorded and analysed at three time points namely: pre-treatment (Pre), post-treatment (Post), and one month following the treatment (FUP).

STATISTICAL ANALYSIS

The data from all the participants were tabulated and appropriate statistical analysis was done using Statistical package for social sciences (SPSS) version- 26. Descriptive statistical analysis was performed to obtain the median and interquartile range (IQR) of the dependent variables. As the obtained data were not in normal distribution based on the Shapiro-Wilk test of normality, non-parametric Friedman's one-way analysis of variance was carried out to perform the pair-wise comparisons of the outcome measurements across the three time-points.

RESULT

The present study compared the intelligibility, certain prosodic measures and functional communication outcomes in adults with dysarthria across pre, post, and FUP time intervals. Table 2 presents the descriptive statistics and multiple pairwise comparisons of narrative speech intelligibility and overall speech naturalness among the participants across the three-time points. Descriptive statistics revealed that participants demonstrated improvements in median and IQR scores in narrative intelligibility and in overall speech naturalness, between pre-post and pre-FUP conditions. Post-hoc Bonferroni corrected multiple pairwise comparisons of Friedman's test indicated significant differences in narrative intelligibility and overall speech naturalness between pre-post and pre-FUP conditions.

Table 2: Median, Interquartile range (IQR), Friedman's test, and pairwise comparisons of narrative intelligibility measures and overall speech naturalness in participants with post-stroke dysarthria across three treatment conditions

Intelligibility scores	Median (IQR)			Friedman's test statistic (χ^2)	Pairwise comparison |Z|		
	Pre	Post	FUP		Pre-Post	Post-FUP	Pre-FUP
Narrative intelligibility	80.08 (7.72)	93.02 (11.82)	92.09 (13.27)	14	2.4*	1.25	3.62*
Overall speech naturalness	5 (3)	3 (4)	3 (4)	14	2.6*	-	2.6*

***Indicates statistically significant change at p<0.05 with Bonferroni correction.**

Table 3 presents the descriptive statistics and multiple pairwise comparisons of mean f0, f0SD, mean intensity and standard deviation of intensity (IntSD) among the participants across the three-time points. Among the acoustic variables, median and IQR scores increased for mean f0, Mean intensity and IntSD across post and FUP conditions.

Pairwise comparisons indicated significant differences only in mean intensity between pre-post and pre-FUP conditions. Significant differences were not observed for Mean f0, f0SD, and IntSD across the three-time points.

Table 3: Median, Interquartile range (IQR), Friedman's test, and pairwise comparisons of mean f0, f0SD, mean Int, and IntSD in participants with post-stroke dysarthria across three treatment conditions

Acoustic variables	Median (IQR)			Friedman's test statistic (χ^2)	Pairwise comparison |Z|		
	Pre	Post	FUP		Pre-Post	Post-FUP	Pre-FUP
Mean f0	143.89 (58.11)	149.71 (44.9)	147.07 (42.78)	1	-	-	-
f0SD	25.68 (15.47)	19.74 (7.29)	18.42 (10.81)	0.75	-	-	-
Mean Int	57.18 (10.01)	63.3 (8.49)	61.42 (6.27)	9.25	2.5*	0.25	2.7*
IntSD	11.23 (5.7)	15.17 (5.4)	13.25 (3.47)	0.41	-	-	-

***Indicates statistically significant change at p<0.05 with Bonferroni correction**

Figure 2 demonstrates individual participant scores of the acoustic variables across three time-points. It revealed that the highest proportion of participants, specifically 7 out of 8, displayed an increase in mean intensity across three treatment conditions. Subsequently, 4 out of 8 participants exhibited an increase in mean f0 across three-time conditions, while 3 out of 8 participants demonstrated f0 variability across the three-time points. However, there were no changes in IntSD among the participants across the pre, post, and FUP conditions.

Fig 2. Individual data points depicting a: mean f0, b: f0SD, c: mean Intensity, and d: IntSD across pre, post, and follow-up (FUP) conditions in participants with post-stroke dysarthria

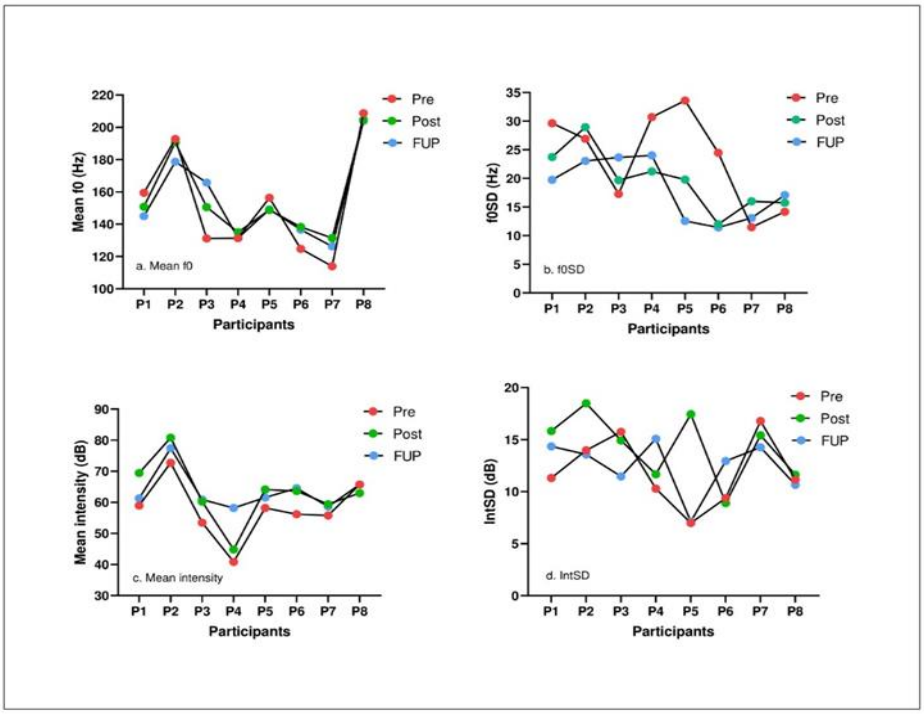


Table 4 demonstrates functional outcome measures in the participants across three-time intervals. Descriptive statistics indicated that median and IQR scores of SHI-K decreased across pre- post, and FUP conditions. Post-hoc Bonferroni corrected multiple pairwise comparisons of Friedman's test indicated significant

differences for SHI-K only between pre-FUP condition. Median and IQR scores of communication partner rating (CPR) increased across pre, post, and FUP conditions. Post-hoc pairwise comparisons revealed that significant differences were observed in CPR item 3 (how often the participants initiate conversation with familiar speakers) in pre-post conditions only, and significant differences were observed in 2 out of 5 CPR items, specifically, the CPR 4 (how frequently the participants initiate conversation with strangers), and CPR 5 (overall rating of communication) between pre-post and pre-FUP conditions.

Table 4: Median, Interquartile range (IQR), Friedman's test, and pairwise comparisons of SHI-K and communication partner ratings (CPR) in participants with post-stroke dysarthria across three treatment conditions

Functional communication outcomes	Median (IQR)			Friedman's test statistic (χ^2)	Pairwise comparison |Z|		
	Pre	Post	FUP		Pre-Post	Post-FUP	Pre-FUP
SHI-K	57 (40.2)	43 (45)	18.5 (50)	7.75	1.75	1	2.75*
CPR item 1	4.5 (2.5)	5.5 (1.75)	6 (1)	9.39	2.2	-	2.2
CPR item 2	4.5 (3)	6 (1.5)	6 (1.75)	4.17	-	-	-
CPR item 3	3.5 (2)	5.5 (3)	5.5 (2.75)	10.17	2.6*	0.8	1.8
CPR item 4	2.5 (1.75)	4.5 (2.75)	4.5 (2.5)	13.45	2.7*	0.2	2.5*
CPR item 5	4.5 (1.75)	5.5 (1)	6 (0.75)	13.13	2.4*	0.5	2.8*

***Indicates statistically significant change at p<0.05 with Bonferroni correction**

DISCUSSION

Effects on intelligibility and speech naturalness

Narrative intelligibility and speech naturalness significantly improved between pre-post and pre-FUP conditions and the present study aligns with the research of Park et al. [13] indicating that employing 'Be clear' enhances speech intelligibility. Within the literature on clear speech treatment, the majority of researchers have primarily monitored the effects of treatment on single-word intelligibility and sentence intelligibility. [10,11,13,14] The present study is in line with a single case study that investigated the impact of clear speech treatment on speech naturalness in post-stroke dysarthria.[12] Consequently, there is a notable scarcity of research examining the effects of clear speech treatment on speech naturalness in dysarthria, in general, within the existing literature. This study stands out as the inaugural investigation to demonstrate enhancements in narrative intelligibility and speech naturalness following clear speech intervention in adults with post-stroke dysarthria, a previously unexplored area in the literature.

Effects on Fundamental Frequency and Intensity

In the acoustic variables, although scores increased for mean f0, Mean intensity and IntSD, however, based on pairwise comparisons, the only significant difference was documented in the mean intensity (dB) between pre-post and pre-FUP conditions. Prior research has shown that clear speech is typically linked to modifications in speech production, including, acoustical alterations such as increased mean f0, mean intensity, and variations in fundamental frequency, and intensity. [7-9] Previous research on clear speech has associated increased vocal intensity along with enhancements in intelligibility.[8] This study pioneers the examination of the treatment effects of clear speech on suprasegmental adjustments and has revealed a significant increase in vocal intensity following clear speech treatment.

Effects on Functional Communication Outcomes

Improvements in the narrative intelligibility were also reflected in results of the SHI-K and communication partner ratings. Speech handicap significantly reduced following the treatment. This study marked the first investigation of SHI-K to monitor the treatment effects both speech and psychosocial functions. However, reduction in the handicap indicated improvements in the psychosocial well-being, improved self-perception of speech difficulties, and improved performance in social activities aligning with the previous research findings of Park et al. [13] However, significant improvements were not observed immediately post-treatment, a factor that could be attributed to the smaller sample size in the study.

Participants showed improvements in their ability to be understood by their communication partners following the treatment. Additionally, they displayed proficiency in communicating with unfamiliar individuals and showed improvement in overall communication abilities post-treatment. The current study's outcomes align with the earlier findings of Park et al. [13] in which the participants successfully extended their clear speech capabilities beyond their usual communication settings. However, participants struggled when prompted to repeat themselves and initiate conversations with familiar individuals. This limited communicative participation might be attributed to the fact that the primary communication partners were already accustomed to their participants' speech despite their speech difficulties.

Limitations and Future Directions

The current study utilized narrative intelligibility to evaluate treatment outcomes in participants with post-stroke dysarthria because narrative tasks resemble natural speech and can provide better insights into the functional evaluation of the participants' communication abilities in real-world communication situations. However, it is important to employ conversational speech tasks to capture a wide range of information on different aspects of speech production. Secondly, participants demonstrated increments in mean intensity following 'Be Clear' treatment. The minimal acoustic variations observed in the fundamental frequency (f0) parameters post-intervention can be ascribed to functional differences in the laryngeal subsystems among the participants.

A majority of the dataset comprised individuals with unilateral upper motor neuron (UUMN) dysarthria, exhibiting varying laryngeal conditions. Specifically, some participants presented strained-strangled voice qualities indicative of laryngeal hypotonia, while others demonstrated with hoarseness and breathiness associated with laryngeal hypertonia. These distinct laryngeal profiles might have influenced the measured f0 parameters. However, by conducting a detailed subgroup analysis (hypertonia vs hypotonia), it is possible to understand the specific impact of f0 parameters among the participants.

CONCLUSION

'Be clear' treatment led to improvements in narrative intelligibility, enhanced the speech naturalness, increased communication participation, reduced speech handicap and increased mean intensity. To further investigate the effectiveness of this treatment, future studies could incorporate a broader range of perceptual and acoustic parameters with a larger sample size.

Declaration by Authors

Ethical Approval: Participants had given their written informed consent. The ethical clearance according to the declaration of Helsinki was obtained from the Institutional Review Board, AIISH Ethics Committee (AEC), Approval number: No.DOR.9.1/Ph. D/SS/919/2021-2022 dt 10th February, 2023.

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