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Original Research Article

Development of time compressed sentence test in Bengali (TCST-B)

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ABSTRACT

Background: Auditory processing of speech involves sound localization, auditory discrimination, and auditory pattern recognition, audition of temporal aspects, auditory performance in competing acoustic signals, and auditory performance with degraded acoustic signals. Time compressed sentence test is mono aural low redundancy test which helps to identify person with APD as well as neurological deficit accompanying cortical and subcortical lesion. The purpose of the present study was to develop Time Compressed Sentence Test in Bengali and establish normative data on young adults along with investigating the effect of ear, gender, reliability and the level of compression of time compressed sentence in Bengali.
Methods: 50 sentences were developed and compressed with 100% intelligibility. 100 young adults, native Bengali speaker (50male, 50 female) having normal hearing were selected for the study. The task involved repetition of monotically presented Time Compressed Sentences. The compression levels used in the present study were 0%, 40%, 50% 60% and 70%. The compressed material was administered three times (baseline, after 15 min break and after 1 week) to measure test-retest reliability.
Results: Statistical analysis revealed speech identification score (SIS) decreased with increase in compression level. There was no significant gender effect or ear difference on performance. The reliability is good for 40%, 50%, 60% and acceptable for 70% compression.
Conclusions: The study provides the normative values of Time compressed sentence test in Bengali for young adults. Understanding the effects of the temporally degraded stimulus in Bengali will help in better utilization of the test in clinical population.

Keywords: Gender, Compression, Auditory processing disorder, Speech perception, Bengali

INTRODUCTION

The complex process of hearing starts as soon as sounds strike the ear drum. The acoustic signals are then passed from the ear through complicated neural networks to various parts of the brain for additional analysis, and recognition. This neurological phenomenon is termed central auditory processing.[1] The anatomical network and redundancies of the auditory neural pathways work as an intricate mechanism to perform functions like ability to attend to spoken conversation, to comprehend, remember and respond appropriately.[2] Our brain detect the features of the incoming acoustic cues of the speech sounds in terms of frequency, intensity and temporal aspect and integrate those features to perceive the sound. The cues differentiate speech sounds belonging to different phonetic categories. Speech perception ability differs based on subject, region, language, and environment. It also varies based on the hearing threshold and neuronal richness of auditory system. Day to day communication requires the ability to understand speech in varying

degrees of noise. Therefore assessment of speech perception ability in background noise should be done in routine Audiological testing. Speech perception ability variation happens on the basis of dialect.[3] Listeners show better perception in native language.

Besides, the auditory system speech perception requires an intact cognitive skill which includes memory, learning, categorization and attention.[4] Central auditory processing disorder (CAPD) is a complex and heterogeneous group of disorders associated with a range of listening and learning deficits despite normal hearing sensitivity.[5] The audiologist assesses the peripheral system and central auditory system using a battery of tests, which includes both electrophysiological and behavioral tests. Assessment of the central auditory system evaluates the person's ability to respond under different conditions of auditory signal distortion and competition. Time-compressed speech includes electronically compressed speech by systematic sampling and discarding segments of the signal without distorting the frequency.[6,7] Time compressed speech is not altered in frequency but is created by removing short durations of the signal and splicing the remaining parts together. Hence 60% compressed signal would therefore have 60% of the original signal removed.[8]

Bengali is an Indo Aryan language. Broadly it is evolved from the eastern middle Indo Aryan languages approximately in 1000-1200 AD.9 Bengali is the native language of West Bengal, Tripura and Assam among the Indian state and in Bangladesh. There are about 230 million native Bengali speakers and it is the 7th most spoken language worldwide. Since performance in native language is better and there is no tool in Bengali, this brings us to the need to investigate the effects of temporally degraded speech on speech perception of normal hearing young adults in Bengali. This would also help establish normative data for a Time Compressed Sentence Test in Bengali.

The aim of the present study is to develop Time Compressed Sentence Test in Bengali (TCST-B). The objectives of the study are:

To develop and standardize the sentence for Time Compressed Sentence Test in Bengali. To measure the speech recognition ability to 0%, 40%, 50%, 60% 70% compressed speech condition. To Measure the reliability of The Time Compressed Sentence Test in Bengali. To establish the best compression level of Time Compressed Sentence Test in Bengali (TCST-B) for clinical use.

METHODS

Study design

The present study was prospective and exploratory. The study was carried out at Ali Yavar Jung National Institute of Speech and Hearing Disability (AYJNISHD), Kolkata, India from April 2019 to March 2020.

Selection criteria

A total of 100 subjects (mean age 23.5years, SD +2.89), native speaker of Bengali were taken for the study, out of which there were 50 female 18- 30 years (mean age 23.7 years, SD +2.94) and 50 males 18- 30 years (mean age 23.3years, SD +2.84) were included in the study. The subjects who had any history of ear discharge, ear infection, hearing loss, neurological impairment, and perceptual cognitive impairment were excluded. Individuals having poor academic performance were also excluded.

Procedure

Written consent was taken from all the participants. After that all the participants were made to undergo pure tone audiometry at 250 Hz to 8000Hz and individuals having auditory sensitivities across the total auditory range (hearing threshold between 0.25 Hz to 8 KHz ≤25 dBHL), were taken for study. A routine immittance audiometry and otoscopic examination were done to exclude any external ear and middle ear pathology. Speech Audiometry was done to obtain Speech Recognition Threshold (SRT) and Word Recognition Score (WRS). Subjects who had scored 100% on WRS and their Speech recognition thresholds correlated with the pure tone threshold were taken for the study. All the subjects were assessed using Edinburgh Handedness Inventory for right and left handedness. The questionnaire was asked to the subjects and rating was given accordingly. The mean score of the 100 participants was +90.1 % with standard deviation of 7.84. Only right handed subjects were taken for the study.

Material

Resonance r37a Dual Channel Diagnostic Audiometer (Calibrated with reference to ANSI S3.6-2004) was used for Pure Tone Audiometry and Speech Audiometry.

GSI tympstar Pro Aural acoustic immittance instrument (ANSI S3.39-1987 Type I) and Otoscope was used to rule out external ear, middle ear pathologies. To record sentences for TCST-B Shure SM 50A Recording microphone was used. All the sentences were recorded and edited in PRAAT version 6.0.49. The sentences were time compressed by shortening them digitally using C Programming algorithm. Stimulus were routed to DELL Vostro 15 3000 series i5 laptop to Resonance r 37a calibrated audiometer via 6.5mm audio cable. Stimulus was presented through TDH 39 Circumaural Headphones.

Test environment

The testing was done in a sound treated room, with the ambient noise levels within permissible limits as

recommended at Ali Yavar Jung National Institute of Speech and Hearing Disabilities (Divyangjan), RC, Kolkata-90 (ANSI S 3.1-1999).

The test was executed in two phases. In 1st phase Bengali sentences were developed and in 2nd phase standardization of the time compressed sentences in Bengali were done.

Ethical clearance

Ethical committee clearance was obtained from the ethical committee of research of AYJNISHD, Kolkata.

Phase I: Development of sentence material.

A set of 131 sentences were selected from the daily conversation, newspaper, and magazine.

Sentences had the following criteria:

The total number of words ranged from five to seven. Conversational speech was included in sentences. Sentences were syntactically correct. Proverbs, exclamations, questions, proper name was excluded.

These 131 sentences were linguistically examined by a Linguist. The 100 sentences out of 131 were selected that were syntactically correct and were recorded in a sound treated room. The microphone was placed at a distance of 4-6 cm from the speaker's mouth. Recording was done at a sampling frequency of 44,100 Hz and 16 bit analog to digital converter was used to digitize the signal. These sentences further endured for intelligibility testing. PRAAT version 6.0.41 was used to record the sentences.[10] For intelligibility testing, 8 subjects with normal hearing was asked to rate the intelligibility of the sentences in a seven point rating scale (6= unintelligible and 0= intelligible). The subjects were given the recorded sentences through laptop and asked to rate the intelligibility. Only the sentences rated 100% intelligible were included in the list. 50 sentences scored 100% intelligibility and were taken for editing. The 50 sentences were time compressed digitally by using Epoch-Synchronous Overlap-Add (ESOLA) method. The algorithm for the computation was developed by Center For Development of Advanced Computing (CDAC). ESOLA segmented speech signals into overlapping Short- time frames and then the adjacent frames were aligned with respect to the epoch and the frames were overlapped to synthesize time-scale modified speech. The ESOLA synthesis scheme involved three steps. These were: generation of short-time signals from original speech waveform, epoch synchronous modification brought to the short-term signals, and finally, the synthesis of the modified signals.[11] Sentences were compressed in time at different compression ratio that is 0%, 40%, 50%, 60% and 70% time compression levels. These compression ratios were selected on the basis of previous studies on time-compressed speech.[12,13]

Phase II: Standardization of the time compressed sentences

Written consent was taken from each participant included in the study. The recorded stimuli were presented to the participants from a computer through a calibrated audiometer (Resonance r37a) at 40 dB SL (Ref: speech recognition threshold) monaurally. 50 sentences were compressed in to 5 compression levels and presented to each subject monaurally. Thus all subjects heard all five levels of compression. The list was randomized to avoid the order in which the subject heard all five different compression levels. 50 subjects were given stimuli to their right ear first and the other 50 were given the stimuli to their left ear first in order to avoid ear biasness. The subjects were asked to repeat what they heard and the responses were recorded. The responses were scored in terms of number of correct words repeated per sentences at different compression levels. The scoring was done on Microsoft Excel 2013 professional version. The test was administered thrice in 40 participants – baseline condition, immediately after a 15-min break (intra-session) and after 1 week (inter-session). The scores were obtained compared across all the three trials and the test–retest reliability was determined.

Statistical analysis

One way ANOVA was carried out to evaluate the differences in compression ratio in Time Compressed Sentence Test in Bengali. Interclass difference was obtained by Cronnach alpha to check the test-retest reliability of the developed stimulus. Pairwise comparison for ear and gender was done using paired t-test.

RESULTS

The 50 sentences selected and edited at 0%, 40%, 50%, 60%, 70% compression levels were presented monotically and the speech identification score was calculated for mean and standard deviation. The percentage score was identified for each compression levels.

It was observed from table that the performance decreased when the compression level was increased. The variation increased gradually at high compression level.

On the basis of above data, there is a significant difference (*$p<0.05$) in scores at 70%, 60%, 50% compression levels when compared with 0% compression level. However, there is no significant difference (*$p>0.05$) in scores of 0% and 40% compression levels.

One way ANOVA was done to evaluate the significant difference of each compression levels.

The Table 3 suggested there was significant difference ($p<0.05$) between each compression level. The result

revealed there is significant difference in scores in 50%, 60%, and 70% compression level.

Table 1: The percentage mean and standard deviation in scores.

Compression ratio	40%	50%	60%	70%
Speech identification score in percent	99.136 %	97.317 %	83.995 %	29.427 %
Mean	6.1075	5.9725	4.9862	1.9237
SD	0.880007	1.068021	1.880287	2.175167

Table 2: Difference in scores of different compression ratio in time compressed sentence test in Bengali.

Test pair	P vale	At 5% level of significance	Interpretation
0% and 70%	0	<0.05	Significant
0% and 60%	9.2893E-93	<0.05	Significant
0% and 50%	0.0015	<0.05	Significant
0% and 40%	0.3339	>0.05	Not significant

*p<0.05 significant

Table 3: The performance between each compression levels and within each compression levels.

ANOVA					
Performance	**Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
Between each compression levels	26258	4	6565	3027	$<2e^{-16}$
Within each compression level	21677	9995	2		0

Test-retest reliability of the developed Time Compressed Sentence test in Bengali was measured. 40 out of 100 subjects were selected in randomization. For that, the test was administered thrice in baseline condition, immediately after a 15-min break (intra-session) and after 1 week (inter-session). The scores obtained were compared across all the three trials and the test–retest reliability was determined. The interclass correlation was determined using Cronbach's alpha. Results showed the alpha value more than 0.7 which suggests good test retest reliability across all compression ratios.

Table 4: Cronbach alpha values across compression ratios for time compressed sentence test.

Compression ratios	Cronbach's alpha	Interpretation
70 %	0.7618	Acceptable reliability
60%	0.9173	Excellent Reliability
50%	0.9816	Excellent Reliability
40%	0.9888	Excellent Reliability

Table 5: Pairwise comparison using t tests with pooled SD.

	70% compression	60% compression	50% compression	40% compression
60% compression	$<2e^{-16}$	–	–	–
50% compression	$<2e^{-16}$	$<2e^{-16}$	–	–
40% compression	$<2e^{-16}$	$<2e^{-16}$	0.0233	–
0% compression	$<2e^{-16}$	$<2e^{-16}$	0.0015	0.3339

P<0.05 level of significance

Table 6: The p value of t-test on the basis of Ear effect.

Sl. No.	Effect of Ear (P value)	Significance value
1	0.599	p>0.05

From the table 4 it can be stated that the test retest reliability is very high across all compression level except 70% which is acceptable.

To establish best compression level for Time compressed sentence test in Bengali pairwise comparison of different compression level in R programming was done.

No significant (*p>0.05) change in 40 % and 0% compression level. But significant change in performance

was present at 50% compression on comparison with the performance of 0% and 40%. At 60% and 70% compression level, there were significant differences (*p<0.05).

Table 7: P value of t-test across all compression levels for gender effect.

Compression ratio	Effect of gender (P value)	Significance value
70%	0.926139324	p> 0.05
60%	0.231281849	p> 0.05
50%	0.528842907	p> 0.05
40%	0.706195283	p> 0.05

p<0.05 level of significance

From the above mentioned Tables 2 and 5 it was concluded: there was high test-retest reliability (Cronbach alpha score above 0.85) on 40%, 50% and 60% compression levels. From the table 3 it was observed there was no significant difference in score of 0%, 40% compression levels. Hence 40% compression level may be excluded. But the significant difference started from 50% compression level. From table 1 the SD was less at 50% compression level among the 50%, 60%, 70% compression level. Hence it is concluded that 50% compression is the best for future study.

The overall ear effect was determined across all compression levels. The result of t-test showed that there was no significant difference between the right and the left ear.

The Table 6 showed *p>0.05 which indicated there was no significant difference between right ear and left ear performance.

The gender effect was determined using paired t test at each compression levels.

The Table 7 showed p value greater than 0.05 suggesting no significant difference found in all compression level across gender.

DISCUSSION

An essential function of the human auditory system is the neural encoding of speech sounds. The ability of the brain to translate the acoustic events the speech signal into meaningful linguistic constructs rely in part on the way the central nervous system represents the acoustic structure of speech. Consequently, an understanding of how the nervous system accomplishes this task would provide important insights into the basis of language function and Auditory-based cognition. From table 2 there was a significant difference (p<0.05) in 70%, 60%, 50% compression levels on comparison with 0% compression level. As the compression level increased the speech identification scores decreased. The speech identification score was deteriorating after 50% of the performance but huge difference found after 60% compression level. Hence the score was found to be poor at 70% compression level. A possible reason for this could be at higher compression level auditory closure cures are much affected. But there is no significant difference in performance between 0% and 40 % compression levels. This suggests that under lower compression level, the subjects were able to use auditory closure abilities to guess the sentence correctly.[14] In accordance with the present study is a study in which the mean scores obtained by 18-28 years old adults decreased from 92.7% to 73.7% for 0% compression to 60% compression.[15] Another study revealed similar findings where the scores reduced from 97.5% to 89.9% for 0% compression to 60% compression conducted on adult aged 18-26 years.[16] While the scores for the 0% compression is not very different from the scores of the present study and that of another study, their scores for the 60% compression were much higher. A possible reason for this discrepancy at 60% compression level could be attributed to segmental cues which were deleted during time compression. Foltner et al also found that responses were significantly different at different levels of compression.[17] Studies have shown similar results with increase in compression level, the amount of external redundancy decreases, making it difficult for the listener to perceive the speech signal.[12,13] As a consequence, perception scores decrease with increasing compression level. Thus, the results of the present study indicated that the performance of time compressed words was significantly different across levels of compression Hence during clinical application of a time compression test, it is essential that the scores obtained on a client be compared with norms of appropriate levels of compression. Study on Time compressed speech in Malayalam in children and adults was done where they used PB words and monosyllables at 50%, 60%, 70%, 80% compression level for the test. The result showed at 50% compression level the SIS was 85-90% for both the groups. For 60% compression level 65 % to 80% SIS score was found. For 70% compression level 45%- 70% SIS was obtained, for 80% compression level 25%- 55% approximately SIS was obtained. Young adults performed better than children. The standard deviation is high in higher compression levels.[13] The same study showed scores were significantly higher for monosyllables than for PB words by using Paired sample t-test. The results suggest compression ratio of 50% can be used in clinical population as SIS was high (around 85-90%) and had lower standard deviation at 50% ratio for both monosyllables and PB words.[13]

Another study found significant difference between conditions of time compression with substantial greater number of errors for the 60% time compression compared to 40% time compression for each age group for sentences.[18]

The test retest reliability revealed that the Cronbach Alpha value was greater than 0.7 which suggested the test retest reliability was good for all four compression levels i.e. 70%, 60%, 50%, and 40%.

Test-retest reliability was measured by Prabhu et al for time compressed speech test in Kannada using PB words and monosyllables. They tested 30 normal hearing individuals at 50%, 60%, and 70% compression for PB words and 50%, 60%, 70%, and 80% compression for monosyllables. They administered the test three times (baseline, after 15 min break and after 1week) at all the compression ratio for PB words and monosyllables. They found that scores were reliable at 60% compression level for both PB and Monosyllables.[12] In present study the findings showed the test-retest reliability is good for all four compression levels 40%, 50%, 60% and 70%. The result of this study showed the performance was improved when tested after 15 min but after one week the performance became stable. One possible reason could be the memorization or familiarization effect on the stimulus.

There were no significant difference in right ear and left ear performance. The performance of right ear (mean score 5.13) and left ear (mean score 5.03) was similar. This is in compliance with the study conducted on the western population which reported no difference between right and left ear scores at several conditions of time compression.[7]

Under dichotic listening conditions, right ear superiority was found for speech whereas for non-speech stimuli, the left ear performance was found to be better.[19] This is because dichotic tests checks for hemisphere dominance. However, studies of monotic listening tasks have failed to reveal clinically utilized in a monotic listening task without being confounded by ear laterality effects.[20] A contradictory finding was illustrated in study by Keith in which Time compressed Sentence Test was administered on 117 children aged between 6 and 11 years at 40% and 60% compression levels. The study revealed there was significant difference between right ear and left ear performance.[18]

The difference in the scores of male and females was determined for all compression levels and there was no gender difference across all compression levels which are in consonance with another study.[21] Another study reported similar finding which was conducted by Konkle et al.[22] They measured the speech discrimination ability in adults (54-84 years) at different sensation levels and different levels of compression. They found that within age groups there was essentially no difference in performance across gender under different compression and sensation level conditions. They also found no significant difference in the performance of males and females at different levels of compression. It has also reported been that performance on time compressed speech did not vary across gender for Cantonese Time Compressed Speech test.14 Similar findings were reported by other studies.[23-25] Study by Prabhu et al on effect of time compressed speech by using phonetically balanced word lists in Kannada showed results that did not vary across gender for all the compression ratios for both the stimuli.[12] Another study done on factors affecting the perception of time compressed speech with monosyllables and PB words in Malayalam language done in children and adults is conforming to the present study.[13]

Thus the results of the present study are in agreement with earlier studies, indicating that there exist no significant difference between the performance of males and females at different compression levels. Hence it can be constructed that males and females have similar temporal processing skills.

Limitation

The developed time compressed sentence test in Bengali was not assessed in pediatric and geriatric population and not administered on CAPD population hence the validity of the test was not done.

CONCLUSION

There is no significant difference in right and left ear scores for monotically presented Time Compressed Sentences in Bengali as well as no difference across gender. There is significant difference across different levels of compression. There is decrease in performance with increase in the level of compression. When time is a constrain, testing can be done with 0% and 50% compression level for adults, as distinctly different scores within normal hearing person were obtained with these two levels of compression. Also in literature, 50% compressed words has been recommended to be used as a clinical tool for differential diagnosis of different clinical population.13 Freeman and Beasley have stated that the procedure of comparing the discrimination scores obtained at 0% and 60% time compression thus might provide more diagnostic information.26 While using the Time compressed sentence test in Bengali as a clinical tool the norms for the appropriate levels of compression should also be referred to. Time compressed sentence test can be used in the identification of potential cortical lesion (temporal lobe lesion). Hence, the time compressed sentence test in Bengali can be incorporated as a part of the Central Auditory Nervous System evaluation battery, to evaluate the central auditory nervous system in the elderly population and in the disordered population. Results of this test would also provide clinician guidelines regarding the manners that need to be taken while providing client rehabilitation. Clients with deviant time compression scores could be provided a temporal based rehabilitation. Further, the test could be used to monitor progress of therapy.

Recommendations

The developed test could be used for further research. For example the developed test could be used to: develop norms for children, check the effect of temporal based training on time compressed scores, the time compressed sentence test in Bengali can be validate with hearing impaired and auditory processing disorder population, the test will help to evaluate the measurement of hearing aid benefit.

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