Behavioral Temporal Auditory Processing Tests in Adult Stutterers

Original Article

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ABSTRACT

Purpose: To assess the temporal processing function in adults stutterers and compare the results with non-stutterers.
Patients and Methods: Eighty adults: forty with stuttering as the study group and forty without stuttering as controls, whose age ranged between 18-45 (27.7±7.53) and 18-55 (29.88±10.56) respectively, were compared regarding selective behavioral temporal auditory processing tests: Pitch Pattern Sequence Test (PPST), Duration Pattern Test (DPT), Time Compressed Sentences Test (TCST) for adults and Auditory Fusion Test-Revised (AFT-R). The severity of stuttering was evaluated by using Stuttering Severity Instrument (SSI-3).
Results: Scores of the AFT-R was statistically significantly higher (worse) in the study group than the control group in both ears and at all frequencies. PPST, DPT and TCST showed statistically significant lower values (worse) in the study group than the control group in both ears. No correlation was found between stuttering severity assessed by (worse) index score and either AFT-R, PPST, or DPT, while there was a statistically significant negative correlation between stuttering severity and TCST at 40%, and 60%.
Conclusion: This study helped to underline how crucial it is to evaluate a person's auditory temporal processing abilities when providing speech, language, and hearing care to someone whose fluency has been altered.

Key Words: Adults, auditory temporal processing, hearing, stuttering.

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INTRODUCTION

Fluent speech is distinguished by the uninterrupted flow of sounds, syllables, and information; the rate of speech; the ease with which speech is produced; and rhythmical patterning in terms of temporal sequencing of similar events[1]. A lapse in this fluency is referred to as a fluency disorder or stuttering[2]. Stuttering is a multidimensional, as it is considered a complex, genetic, and neurofunctional disorder with diverse and it may have complex etiologic factors[3].

Central auditory processing (CAP) is our nervous system's ability to detect, understand, and process auditory stimuli. Sound localization and lateralization, auditory discrimination and temporal resolution, ordering, and masking are all auditory skills that contribute to recognize acoustic information[4].

The neurocognitive characteristics of stuttering entail biological factors, with auditory temporal processing, which is the cornerstone of the auditory processing. Since speech fluency includes the synchronic communication between the acoustic aspects of speech development and perception related to time, numerous auditory information aspects are affected by time, which plays an important role in hearing and fluency[5].

The ability of a person to identify abnormalities in temporal features of sounds, like duration, intensity, frequency, and pauses between stimuli, is referred to auditory temporal processing[6]. Various methods are used to assess temporal processing aurally, like the frequency pattern (FPT) and duration pattern (DPT) tests with pure tone[7].

Temporal resolution can detect rapid variations in sound stimuli in very short duration of time to identify two acoustic stimuli. It is a useful method for precise auditory processing and speech development[8]. Auditory Fusion Test Revised (AFT-R) was designed to measure the temporal resolution skills[9].

Time compressed sentence test (TCST) for adults was designed by Wingfield *et al*,[10] to measure auditory closure skills[11]. Time compressed sentences has no changes in frequency but is developed by deleting short durations of the signal and mixing the other parts together. So, the 60% compressed sentence would contain 60% of the original sentence omitted[12].

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Aim of the work:

To study the temporal processing function in adult stutterers and compare the results with non-stutterers and correlate these results with the degree of stuttering severity.

PATIENTS AND METHODS:

This is a case control study. Forty stuttering adults of both genders were included in this study. Another forty adults of both genders were included as a control group. Informed written consent was taken from both groups before starting the study, after explaining the purpose of the study. All participants were above 18 years old. Stuttering adults were collected from patients who attended the Phoniatric Outpatient clinic, Kasr Al-Ainy Hospital, Cairo University. The control group adults were selected to have no speech or hearing disorders. The study was carried out between October 2019 and June 2022. The study was performed during a period of 12 months. The ethical committee of the Faculty of Medicine, Beni-Suef University approved this study.

All individual had bilateral within normal peripheral hearing detected by using pure tone audiometry (air conduction from 250 Hz to 8 KHz, bone conduction from 500 Hz to 4 KHz) at octave intervals, Speech Reception Threshold (SRT) using Arabic spondaic words[13], and word discrimination score (WDS %), using Arabic phonetically balanced (PB) words[14]. A selective behavioral temporal auditory processing tests were performed: Pitch Pattern Sequence Test (PPST), Duration Pattern Test (DPT), Time Compressed Sentences Test (TCST) for adults, Auditory Fusion Test-Revised (AFT-R). The audiological evaluation was done at the Unit of Audio-Vestibular Medicine in Kasr Al-Ainy Hospital.

The severity of stuttering was evaluated by using the protocol of assessment used in Phoniatric Unit, Cairo University[15] and by using Stuttering Severity Instrument (SSI-3)[16].

Statistical analysis:

Statistical analysis was done using statistical package for social science (SPSS version 25; SPSS Inc.,Chicago, Illinois,USA). Student t-test, Mann-Whitney U Test, Chi-square test (χ^2): Wilcoxon Test were computed. A P-value of < 0.05 was considered statistically significant & <0.001 for high significant result for two tailed tests.

RESULTS:

This study included 80 adult patients distributed into two groups: the study group was composed of 40 adults stutterers (28 (70%) males and 12 (30%) females). Their age ranged from 18-45 years (with a mean of 27±7.53). The control group was composed of 40 non-stutterers adults (22 (55%) males and 18 (45%) females). Their age ranged from 18-55 years (with a mean of 29.88±10.56). There was no statistically significant difference between the two groups as regards age or gender ($p>0.05$).).

AFT-R was statistically significantly higher in study group than control group in both ears and at all frequencies. While, PPST, DPT and TCST show statistically significant lower values in the study group than the control group in both ears (Table 1) and Figures (1, 2, 3 and 4).

Table 1: Comparison between study group and control group as regards Auditory Fusion Test – Revised (AFT-R) in msec, Pitch Pattern Sequences Test (PPST), Duration Pattern Test (DPT) and Time Compressed Sentences Test (TCST).

	Mean ± SD Min. - Max	Mean ± SD Min. - Max	*P-value*
AFT-R			
250Hz	18.38 ± 5.27 10.00 - 30.00	13.44 ± 4.69 2.50 - 20.00	*0.00***
500Hz	16.69 ± 6.19 7.50 - 37.50	12.24 ± 4.45 2.50 - 17.50	*0.002**
1000Hz	16.56 ± 5.09 7.50 - 27.50	12.69 ± 3.81 5.00 - 17.50	*0.001**
2000Hz	17.25 ± 4.83 5.00 - 25.00	12.63 ± 4.67 2.50 - 20.00	*0.00***
4000Hz	16.88 ± 5.63 5.00 - 35.00	11.06 ± 3.66 2.50 - 17.50	*0.00***
PPST			
Right ear	74% ± 16% 44% - 96%	83% ± 5% 70% - 88%	*0.038**

Left ear	74% ± 13%	83% ± 4%	*0.00***
	36% - 96%	76% - 88%	
	74% ± 16%	83% ± 5%	
DPT			
Right ear	69% ± 15%	83% ± 7%	*0.00***
	43% - 93%	70% - 93%	
Left ear	67% ± 15%	81% ± 6%	*0.00***
	30% - 93%	70% - 90%	
	69% ± 15%	83% ± 7%	
TCST			
0%	98% ± 4%	100% ± 0%	*0.011**
	87% - 100%	100% - 100%	
40%	85% ± 7%	91% ± 4%	*0.00***
	65% - 98%	83% - 98%	
60%	69% ± 8%	83% ± 4%	*0.00***
	58% - 83%	77% - 95%	

SRT: speech reception threshold **WDS:** word discrimination scores **AFT-R:** Auditory Fusion Test - Revised **PPST:** Pitch Pattern Sequence Test **DPT:** Duration Pattern Test **TCST:** Time Compressed Sentences Test **P:** *p value* for comparing between the studied groups by Mann Whitney U test ***:** *p value <0.05* is significant ****:** *p value <0.001* is highly significant

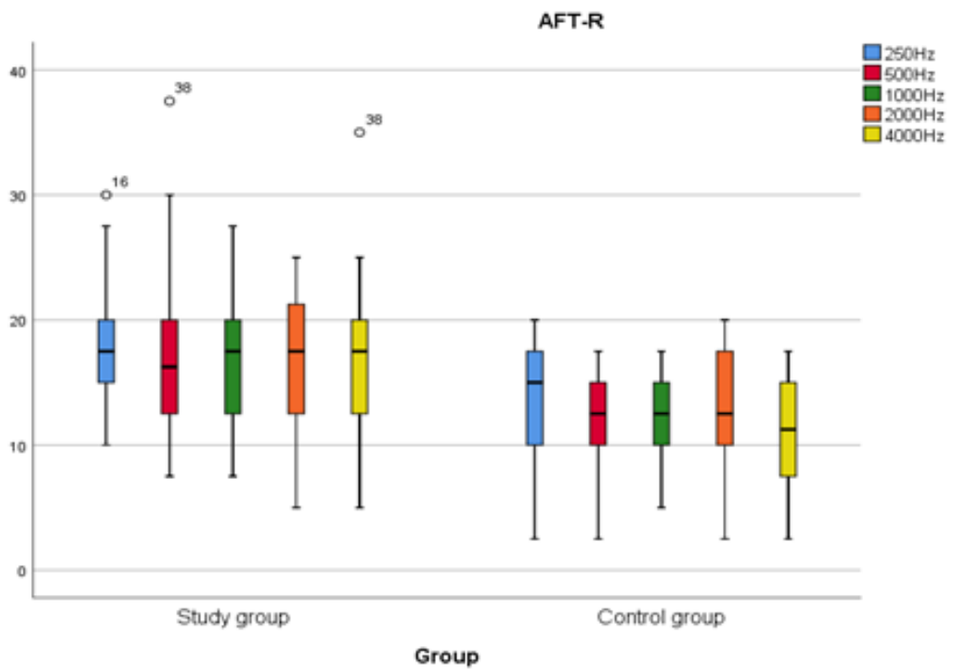

Fig. 1: comparison between study group and control group as regards Auditory Fusion Test – Revised (AFT-R)

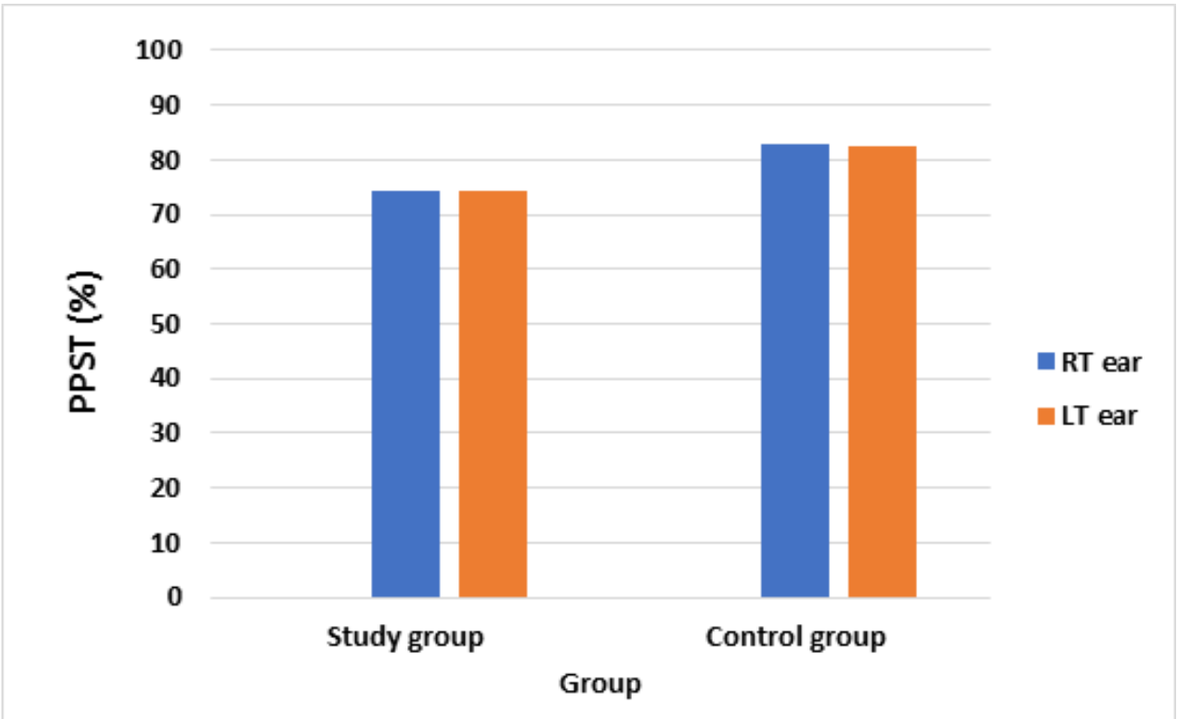

Fig. 2: Comparison between study group and control group as regards Pitch Pattern Sequence Test (PPST)

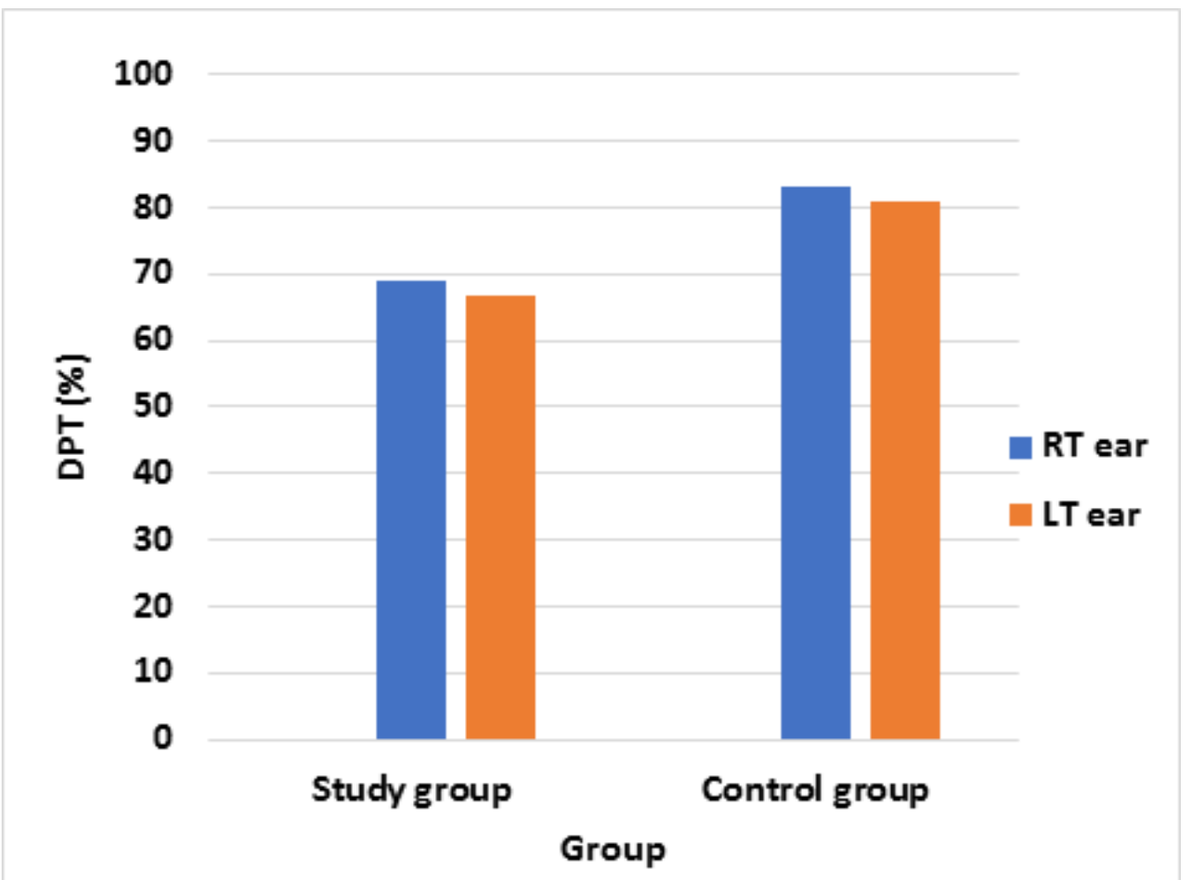

Fig. 3: Comparison between study group and control group as regards Duration Pattern Test (DPT).

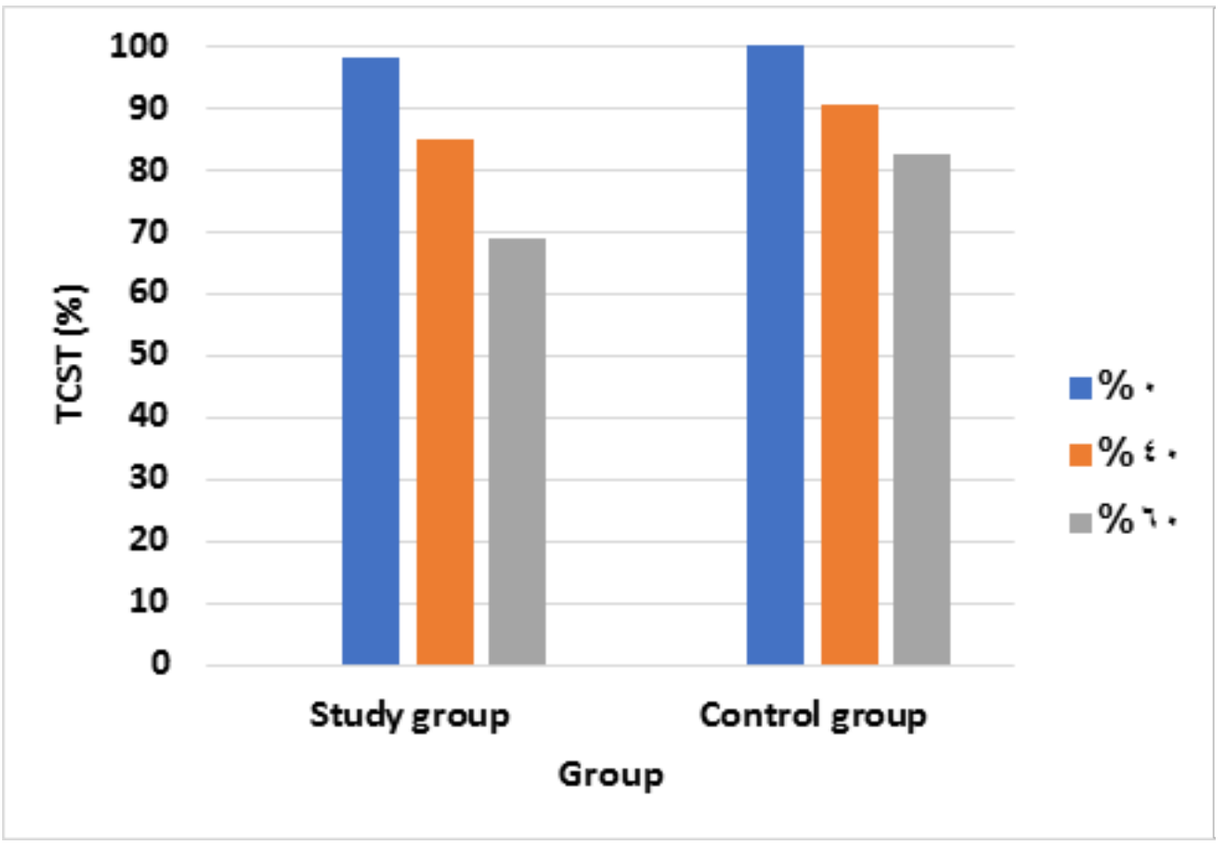

Fig. 4: Comparison between study group and control group as regards Time Compressed Sentences Test(TCST)

Figure (5) shows the distribution of patients as regards stuttering severity according to stuttering severity index, where stuttering severity was very mild in 10 (25%), mild in 19 (47.5%), and moderate in 11 (27.5%).

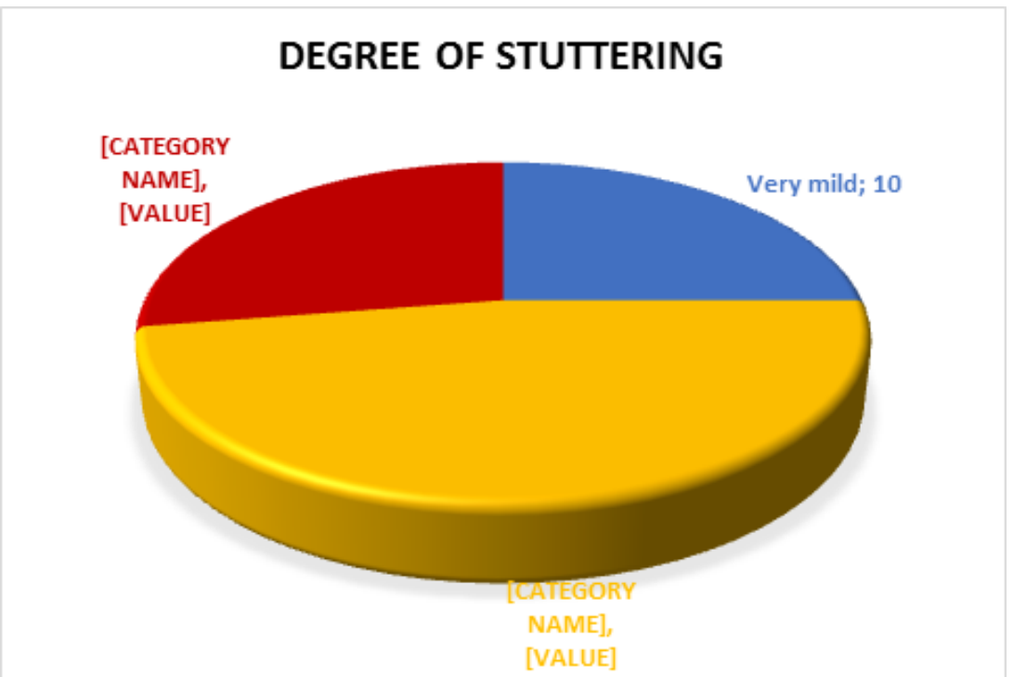

Fig. 5: Distribution of degree of stuttering in the study group.

Table (2) shows that there was no statistically significant correlation between temporal auditory processing results and age. There was no statistically significant correlation between temporal auditory processing results and stuttering severity as regards AFT-R, PPST, and DPT, while there was statistically significant negative correlation between TCST at 40%, and 60% with stuttering severity index score. As the severity of stuttering increased, the scores of TCST-40%, TCST-60% decreased. There was no statistically significant correlation between temporal auditory processing test results and duration of stuttering of the study group but as regards Time Compressed Sentences Test (TCST). There was a statistically significant negative correlation between TCST-40%, TCST-60% and duration of stuttering of the study group. As the duration of stuttering increased, the scores of TCST-40%, TCST-60% decreased.

Table 2: Correlation between temporal auditory processing results with age of the study group, severity and duration of stuttering.

	Age		Stuttering severity		Duration of stuttering	
	r	p	r	p	r	P
AFT-R						
250Hz	0.133	0.241	0.21	0.194	0.045	0.784
500Hz	0.152	0.178	0.075	0.644	0.106	0.515
1000Hz	0.146	0.196	0.058	0.722	0.093	0.569
2000Hz	0.046	0.684	0.038	0.816	-0.006	0.971
4000Hz	0.121	0.285	0.035	0.83	0.141	0.387
PPST						
PPST Rt%	-0.035	0.755	0.081	0.621	-0.178	0.272
PPST Lt%	-0.032	0.779	0.191	0.237	-0.237	0.141
DPT						
DPT Rt%	0.106	0.35	0.009	0.956	0.139	0.391
DPT Lt%	0.004	0.973	-0.092	0.571	0.065	0.688
TCST						
0%	0.109	0.335	-0.246	0.126	0.161	0.322
40%	0.149	0.187	-0.459	0.003*	-0.437	0.005*
60%	0.179	0.112	-0.467	0.002*	-0.457	0.003*

AFT-R: Auditory Fusion Test - Revised **PPST:** Pitch Pattern Sequence Test **DPT:** Duration Pattern Test **TCST:** Time Compressed Sentences Test **r:** spearman's correlation coefficient

Table 3: Comparison between degrees of stuttering of the study group regarding Pitch Pattern Sequence Test (PPST), Duration Pattern Test (DPT), and Time Compressed Sentences Test (TCST).

		Study group degree of stuttering			F	P	Post hoc test
		Very mild (n=10)	Mild (n=19)	Moderate (n=11)			
PPST Rt%	Mean	72%	75%	75%	0.141	0.869	
	SD	17%	15%	16%			
PPST Lt%	Mean	71%	74%	77%	0.321	0.728	
	SD	17%	11%	12%			
DPT Rt%	Mean	70%	68%	70%	0.150	0.862	
	SD	18%	13%	14%			
DPT Lt%	Mean	67%	68%	64%	0.703	0.501	
	SD	11%	18%	14%			
TCST- 0%	Mean	100%	98%	97%	1.290	0.287	
	SD	0%	5%	5%			

TCST-40%	Mean	90%	84%	81%	5.486	0.008*	*P1=0.015*
	SD	7%	7%	4%			*P2=0.003*
							P3=0.289
TCST-60%	Mean	74%	69%	64%	5.201	0.010*	*P1=0.113*
	SD	8%	9%	3%			*P2=0.003*
							P3=0.051

PPST: Pitch Pattern Sequence Test **DPT:** Duration Pattern Test **TCST:** Time Compressed Sentences Test **P:** *p value* for comparing between the studied groups by ANOVA test * significant *p-value <0.05*. **P1:** Very mild vs Mild **P2:** Very mild vs Moderate **P3:** Mild vs Moderate.

There was no statistically significant difference among the degrees of stuttering in the study group as regards Pitch Pattern Sequence Test (PPST), Duration Pattern Test (DPT), but as regards Time Compressed Sentences Test (TCST) 0%. But there was a statistically significant difference among the degrees of stuttering in the study group as regards TCST-40% and TCST-60% (Table 3). Post -hoc test revealed that this difference was found between Very mild and Mild (*p=0.015*) and very mild and Moderate (*P=0.003*) as regards TCST 40%, and difference was found between Very mild and Moderate (*P=0.003*) as regards TCST 60%.

There was no statistically significant difference between males and females as regards AFT-R, PPST, DPT in either ear or TCST at any compression level (data not shown).

DISCUSSION

Recent speech production models stated that there is a strong link between sensory and motor processing in explanation of stuttering[17]. It has been proposed that stuttering is caused by issues with the acquisition and updating of internal sensorimotor processing models[18].

Auditory processing is a neural function that has been highlighted in many theories as playing a role in stuttering[19]. Auditory information processing is linked to the temporality of the sounds, rhythm, and prosody, all of which can change in stutterers. Disorders in these areas have been considered as the immediate cause of stuttering, especially when the degree of stuttering is severe[20].

In the present study, we found that AFT-R was statistically significant higher (worse performance) in the study group than the control group in both ears and at all frequencies (Table 1 and Fig 1). This reflected a disorder at the level of the cortex regarding temporal processing related to temporal resolution. Temporal resolution disorders can result in serious abnormality in the detection of rapid changes in speech, resulting in speech and reading impairments particularly in children[21]. As a result of disability in identification of rhythm, stress, and intonation, individual with temporal patterning deficits can suffer from inability to understand and use prosody of speech. These deficits may hinder the auditory feedback mechanism which is essential for achievement the fluency of speech[22].

PPST, DPT, TCST scores were statistically significant lower (worse performance) in the study group than control group in both ears (Table 1 and Fig 2, 3). These results are indicative of stuttering being associated with a disorder of temporal processing related to ordering, pattern recognition, auditory memory, and pitch discrimination[23].

In agreement with our results **Asal and Abdou**[24] who studied a group of children with stuttering, found a poorer performance than their counter nonstutterers in PPST While they found no difference in performance regarding AFT-R in both groups. They explained their results of PPST as follow, the temporal ordering skills necessitates contour recognition, which takes place in the right hemisphere and is then transferred through the corpus callosum ending in the left hemisphere where linguistic labelling occurs[9]. Also, they stated that the normal results of the AFT-R are due to poor temporal processing abilities detected when the task is more difficult and need additional requirements of attention and auditory memory, as in the PPST[24].

As a result of disability in identification of rhythm, stress, and intonation, individual with temporal patterning deficits can suffer from inability to get understand and use prosody of speech. These deficits may hinder the auditory feedback mechanism which is essential for achievement the fluency of speech[22].

Similar to our findings, **Prestes *et al***.[25] who compared a group of adults stutterers with a group of non-stutterers demonstrated that DPT test was underperformance in stutterers group compared to non-stutterers .They refer that to people who suffering from stuttering found difficulty in distinguishing sound patterns related to their duration[26].

Ferreira *et al*.[22], who studied a group of adults stutterers and a group of volunteers with normal communicative abilities, found lower scores of DPT and PPST tests in stutterers group. According to the

literature, the auditory information features are affected by time, which is connected to speech perception. It also claims that disorders of central auditory processing results in difficulties with sound pattern comprehension[27]. Temporal ordering allows the individuals to distinguish between the real incidence of sounds in terms of duration and frequency[28].

In accordance with our results, **Lotfi *et al***.[30] and **Andrade *et al***.,[30] in their study of a group of children who are stutterers; reported a deficit as regards DPT and PPST tests. They contended that stuttering is caused by difficulty to create stable and true neural representations of sounds in childhood or to maintain them over time[8].

In the present study, TCST scores were statistically significant lower (worse performance) in the study group than control group in both ears (Table 1 and Fig 4). This reflected a disorder of auditory processing specifically in the ability of the cases to understand acoustically distorted or rapid rates of speech hence may yield insights into cases with slow reaction times and speed of mental processing at the brainstem and cortical lesions[12].

In accordance with our results, **Peñaloza-Lòpez *et al***.[31], conducted a study on a group of 25 stutterers and 25 controls their ages ranging between 8-36 years using TCST found that at 75% the average score of correct answers was 60.98% in stutterers patients and 82.04% in the control group ,while at 100% the sores were 56.56% and 73.16%,respectively.They advised using the TCST in stutterers people to detect temporal processing auditory disorders.

Correlation of Behavioral Temporal Auditory Processing Tests with severity of stuttering:

In the present study, the very mild degree showed significantly better result than Mild and Moderate as regards TCST 40%, and the mild degree showed significantly better result than Mild and Moderate as regards TCST 60% (Table 3). As the stuttering severity increased, the TCST scores at 40%, and 60% of the stuttering group were worse. **Weber *et al***.,[32] stated that auditory processing is a neural function that has been highlighted in many theories as playing a role in stuttering Auditory information processing is linked to the temporality of the sounds, rhythm, and prosody, all of which can change in stutterers. Disorders in these areas have been considered as the immediate cause of stuttering, especially when the degree of stuttering is severe[32].

In the present study, there was no statistically significant correlation between AFT-R, PPST, and DPT results and stuttering severity. In accordance with our results **Andrade *et al***.,[30] demonstrated no correlation between DPT and stuttering severity.

Our study results reflected that as the stuttering duration increases, temporal auditory processing test based on speech material gets worse by time, unlike those not involving speech.

In contrast to our findings **Lotfi *et al***.[29] and **preste *et al***.[25] found negative correlation between DPT and stuttering severity, explained that by abnormalities detected in temporal patterns tests, like duration pattern leads to difficulty in the interpretation of suprasegmental parts of speech and results in speech dysfluency.

• Correlation of Behavioral Temporal Auditory Processing Tests with duration of stuttering:

In the current study, there was no statistically significant correlation between other temporal auditory processing test results AFT, PPT or DPT and duration of stuttering of the study group. This reflected that as the stuttering occurs no matter how long it lasted, the Cortical Auditory processing is affected.

But as the stuttering duration increased, the TCST scores at 40%, and 60% of the stuttering group were worse. This reflected that as the stuttering duration increases, temporal auditory processing test based on speech material gets worse by time, unlike those not involving speech.

The auditory information features are affected by time, which is connected to speech perception. Temporal ordering allows the individuals to distinguish between the real incidence of sounds in terms of duration and frequency[34]. Disorders of central auditory processing results in difficulties with sound pattern comprehension[27].

• Correlation of Behavioral Temporal Auditory Processing Tests Findings with age and gender:

There was no statistically significant correlation between temporal auditory processing results and age of the study group (Table 2). And there was no gender difference regarding test results.

In agreement with our results, **Ferreira *et al***.,[22] also concluded that temporal resolution and ordering changes were observed in the people presented with stuttering, regardless of sex or chronological age.

Temporal ordering tests allow persons to distinguish the correct occurrence of stimulus according to their

duration and frequency, furthermore, abnormalities throughout the information transfer between the programming of the speech motor plan and carrying out its movement[8].

CONCLUSION

This study helped to underline how crucial it is to evaluate a person's auditory temporal processing abilities when providing speech, language, and hearing care to someone whose fluency has altered. Further research can look into the relationship between temporal processing skills and stuttering severity, including more severe degrees of stuttering. It is possible to research the impact of therapy on temporal processing. Comparison regarding central auditory processing test results between stuttering and other speech dysfluencies such as cluttering is recommended in futures studies.

CONFLICT OF INTEREST

There are no conflicts of interest.

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