The study of central auditory processing in stuttering children

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Background
There are evidences that indicate a relationship between auditory processing disorders and stuttering.

Aim
The aim of the study was to evaluate central auditory processing in stuttering children and to compare the findings with those of normal fluent children.

Patients and methods
Twenty stuttering school-age children of both sexes were included in the study. A control group included 20 age-matched and sex-matched nonstuttering children. Full informed consent from all participants was taken before initiating the study. All participants were subjected to the following central auditory processing tests: pitch pattern sequence test (PPST), dichotic digit test (DDT), speech in noise test (children version) (SPIN), auditory fusion test revised (AFT-R), and binaural masking level difference (MLD) test. All patients were subjected to stuttering severity instrument III to assess their stuttering and its severity.

Results
The stuttering group scored significantly poorer in the PPST, DDT, and SPIN, whereas they scored similar to the control group in MLD and AFT-R. There was no correlation between the severity of stuttering and the performance on the central auditory processing tests.

Conclusion
Stuttering children have an intact brain stem integrity shown by the normal MLD and an intact right hemisphere as signified by the normal right and left ear difference in the DDT and by the improvement in the PPST on humming. Left hemisphere deficit appears in more complicated tasks such as PPST, DDT, and SPIN, but not in simple tasks such as AFT-R. We can conclude that the deficit is within the left cerebral hemisphere.

Recommendation
The effect of the usage of central auditory processing disorder rehabilitation programs on those children should further be assessed.

Keywords:
auditory processing, left hemisphere, stuttering

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Introduction

Stuttering is a developmental disorder affecting speech fluency. It is present in 5% of preschool-age children and in 1% of the adult population [1].

Stuttering is an involuntary disruption in fluency; it is characterized by abnormal frequency or duration of interruptions in the flow of speech, namely repetitions, prolongations, and blocks [2]. Although a variety of etiologies have been proposed to explain its etiology, the cause of stuttering is still unknown [2]. Many current models of stuttering incorporate atypical neurophysiology, genetic factors, a person's environment, personality, learning ability, auditory processing, language processing, and the correlation of speech and stuttering [1,2]. Smith and Kelly [3] propose a nonlinear multifactorial model of stuttering, which incorporates the complex relationship of many factors that can influence stuttering and their compounded and interactive effects on the speech motor system. It is hypothesized that the contribution level of each factor determines distinctive behavior patterns that emerge among individuals.

Central auditory processing (CAP) disorder is a condition involving listening difficulties caused by impaired bottom-up processing of sounds by the brain [4]. It is characterized by poor perception of both speech and nonspeech sounds, which is not attributable to intellectual problems or peripheral hearing loss. It commonly impacts listening, spoken language comprehension, and learning [5].

The present experiment focuses on one factor hypothesized to play a role in stuttering, which is auditory processing [1,2].

Aim

The aim of the study was to evaluate CAP in stuttering children and to compare the findings with those of normal fluent children to detect the relationship between auditory processing and stuttering.

Patients and methods

Twenty stuttering school-age children of both sexes were included in the study. Another group of 20 nonstuttering age-matched and sex-matched children were included as control. Full informed consent from all participants was taken before initiating the study. All participants were subjected to complete history taking and to stuttering severity instrument III to assess their stuttering and its severity. Later, a selective CAP test battery was run on children to assess the different auditory processing abilities; pitch pattern sequence test (PPST), dichotic digit test (DDT), speech in noise test (children version) (SPIN), and masking level difference (MLD) test were performed before their admission to speech therapy. The study was carried out during a time period of 6 months.

Statistical analysis

Statistical analysis was performed using statistical package for the social sciences (SPSS, version 15; SPSS Inc., Chicago, Illinois, USA) software, and mean (X), SD, Student's t-test, and analysis of variance or F-test were computed.

Results

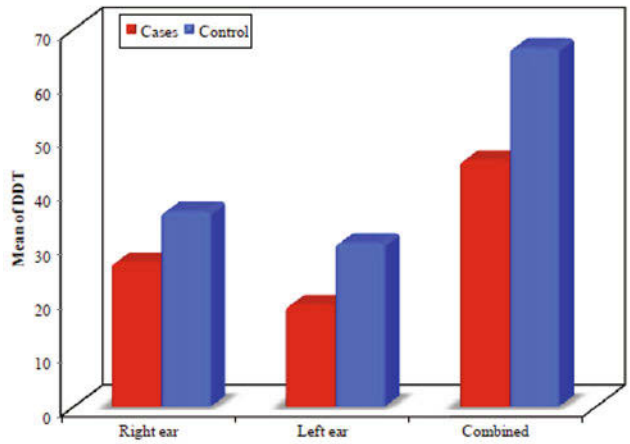
In this study, all students were of matched age and sex, with no significant difference between both groups (Table 1). The stuttering group was found to score significantly poorer in the DDT (Fig. 1), PPST (Fig. 2), and SPIN (Fig. 3) (Table 2). There was no statistically significant difference in performance between both groups in the right ear–left ear DDT scores. Significantly lower PPST results improved whenever the stutterers were asked to respond by humming (Table 2). As for the auditory fusion test revised (AFT-R) (Fig. 4) and MLD (Fig. 5), both groups showed no significant differences in performance across all the tested frequencies (Table 2). The stuttering severity index III (SSI) showed that 30% of stutterers had mild stuttering, 40% had moderate

Table 1 Comparison between the studied groups according to demographic data

Demographic data	Cases	Control	P
Age	7.80 ± 0.79	8.60 ± 1.84	0.222
Sex			
Male	10 (100.0)	10 (100.0)	–
Female	0 (0.0)	0 (0.0)	–

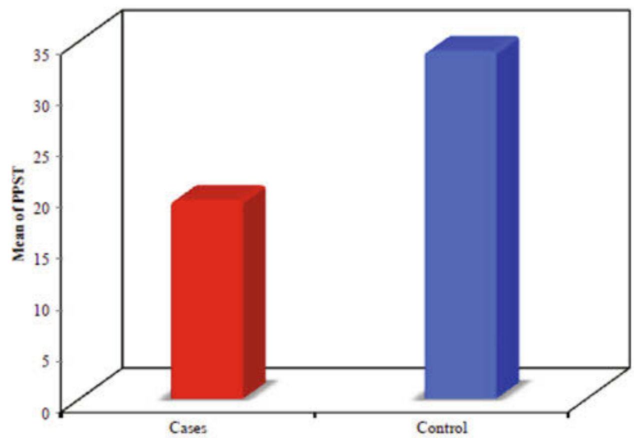
P value for Student's t-test for comparing the two studied groups.

Figure 1



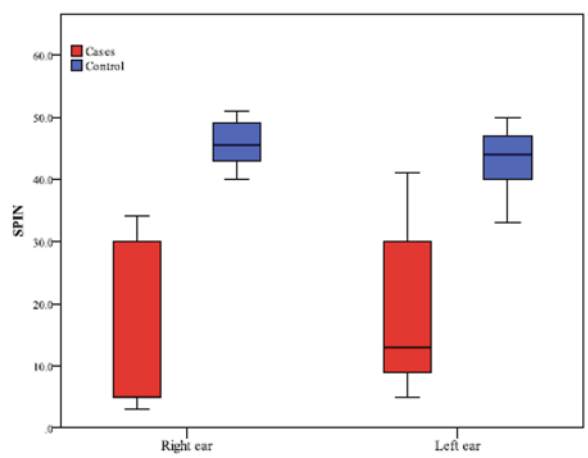
Comparison between the studied groups according to dichotic digit test (DDT).

Figure 2



Comparison between the studied groups according to pitch pattern sequence test (PPST).

Figure 3



Comparison between the studied groups according to speech in noise test (children version) (SPIN).

stuttering, and 30% had severe stuttering (Table 3 and Fig. 6). There appeared to be no correlation between the degree of severity in stuttering and the performance on CAP tests (Table 4).

Discussion

In this study, school-aged stutterers showed a significantly lower performance than their counter nonstutterers in DDT, PPST, and SPIN. The age-matched performance of both groups shows that any discrepancy in performance is not attributable to the differences of neuromaturation, which is very important because of the continuous emphasis of the literature on the variability in performance with age [6–8].

MLD functionally provides a measure of binaural interaction. Anatomically, it assesses integrity at the level of the brain stem. It has been proposed that the MLD

Table 2 Comparison between the studied groups according to dichotic digit test, pitch pattern sequence test, auditory fusion test revised, masking level difference, and speech in noise test (children version)

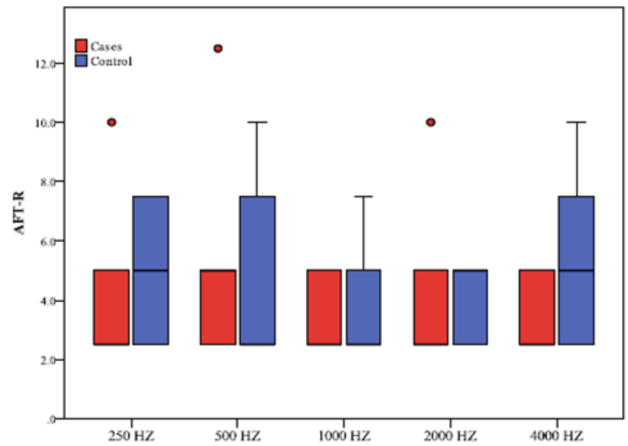
CAP test battery	Cases	Control	Test of significance
DDT			
Right ear	26.80 ± 7.22	36.10 ± 2.13	$^{t}P = 0.003$*
Left ear	18.80 ± 6.34	30.40 ± 7.95	$^{t}P = 0.002$*
Combined	45.60 ± 10.72	66.50 ± 8.76	$^{t}P < 0.001$*
PPST	19.40 ± 8.07	34.0 ± 6.36	$^{t}P < 0.001$*
AFT-R (Hz)			
250	2.50–10.0 (2.50)	2.50–7.50 (5.0)	$^{MW}P = 0.375$
500	2.50–12.50 (5.0)	2.50–10.0 (2.50)	$^{MW}P = 0.514$
1000	2.50–5.0 (2.50)	2.50–7.50 (2.50)	$^{MW}P = 0.861$
2000	2.50–10.0 (2.50)	2.50–5.0 (5.0)	$^{MW}P = 0.737$
4000	2.50–5.0 (2.50)	2.50–10.0 (5.0)	$^{MW}P = 0.185$
MLD	2.0–9.0 (8.0)	4.0–10.0 (8.0)	$^{MW}P = 0.697$
SPIN			
Right ear	3.0–34.0 (5.0)	40.0–51.0 (45.5)	$^{MW}P < 0.001$*
Left ear	5.0–41.0 (13.0)	33.0–50.0 (44.0)	$^{MW}P = 0.001$*

P value for comparing the two studied groups; AFT-R, auditory fusion test revised; DDT, dichotic digit test; MLD, masking level difference; MW, Mann–Whitney test; PPST, pitch pattern sequence test; SPIN, speech in noise test (children version); *t*, Student's *t*-test; *Statistically significant at $P \leq 0.05$.

Table 3 Distribution of studied patients according to SSI-3 in the patients group

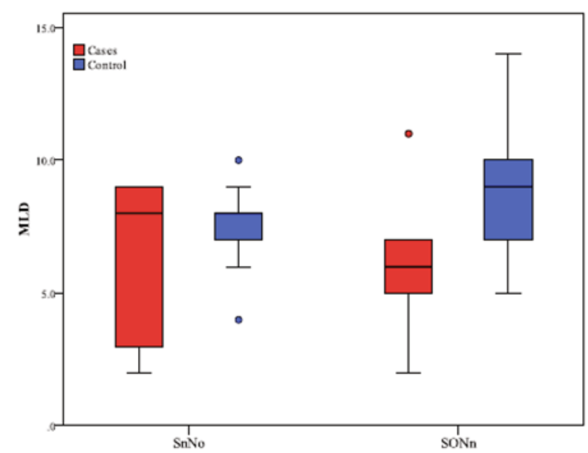
SSI-III battery	Mean ± SD
% Syllable stuttered	15.40 ± 2.72
Length of stuttering moment	3.70 ± 0.82
Associated movements	4.90 ± 3.78
Total score	24.0 ± 6.98
Equivalent to [*N* (%)]	
Very mild	3 (30.0)
Moderate	4 (40.0)
Severe	3 (30.0)

Figure 4



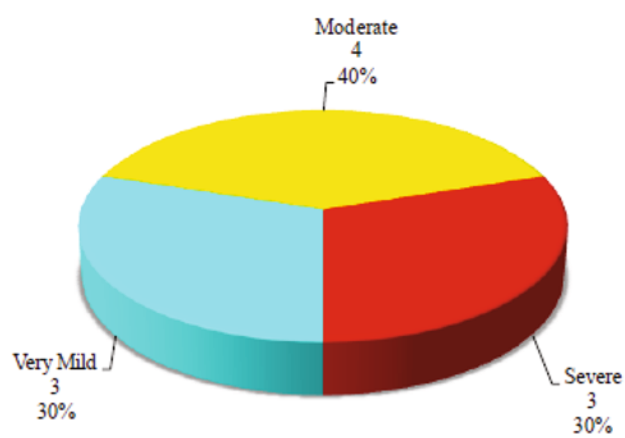
Comparison between the studied groups according to auditory fusion test revised (AFT-R).

Figure 5



Comparison between the studied groups according to masking level difference (MLD).

Figure 6



Distribution of studied patients according to SSI-3 in the patients group.

Table 4 Correlation between total score with different studied parameters in cases group

CAP test battery	r (P)
DDT	
Right ear	0.020 (0.957)
Left ear	−0.342 (0.334)
Combined	−0.189 (0.602)
PPST	−0.065 (0.858)
AFT-R (Hz)	
250	−0.078 (0.831)
500	−0.041 (0.910)
1000	−0.401 (0.251)
2000	−0.143 (0.694)
4000	0.216 (0.549)
MLD	
SIINO	0.005 (0.989)
SONII	0.087 (0.876)
SPIN	
Right ear	−0.242 (0.501)
Left ear	−0.345 (0.329)

AFT-R, auditory fusion test revised; DDT, dichotic digit test; MLD, masking level difference; PPST, pitch pattern sequence test; *r*, Pearson's coefficient; SPIN, speech in noise test (children version) SIINo, Signal is 180° out-of-phase between the two ears; SoNII, Noise is 180° out-of-phase between the two ears.

reliably tests the brain stem integrity and represents the brain stem ability to extract signal from background noise [6]. The nonsignificant difference of the mean performance in both tested conditions of the patients group relative to the control group signifies a normal brain stem. Literature is conflicting in this matter, where studies have centered on the brain stem as a possible site of central auditory system dysfunction in stutterers. Depressed performance by stuttering patients on different central auditory batteries has been reported by several investigators [9–11]. More recent studies show that functional stutterers problem is not within the brain stem as shown by our current study [12].

The dichotic digit ability depends on the integrity of the right and left hemispheres as well as on the interhemispheric transfer [13]. The patients group poor performance on the DDT individual as well as combined ear scores with no significant difference in the right–left ear score assumes that the deficit is within the left hemisphere.

PPST is a pitch-ordering task that is designed to examine a number of central auditory functions: temporal ordering, pattern recognition, auditory memory, and pitch discrimination [14,15]. Physiologically, temporal ordering task requires contour recognition, which occurs in the right hemisphere then transfer through the corpus callosum. Finally, linguistic labeling occurs in the left hemisphere [8]. Significantly poor performance of the stuttering group relative to the control group, which significantly improved on humming, further signifies an intact right hemisphere. PPST ability with required verbal response is impaired in stutterers.

AFT-R is a test of temporal integrity at the level of the cortex designed to measure the temporal resolution [8]. The patients group performed normally within AFT-R task, which signifies that a poor performance in temporal processing abilities is met whenever the task is complicated with further prerequisites of attention and auditory memory, as in PPST.

SPIN is a test of auditory closure ability and selective attention. The performance scores finding points out that the stuttering group may have such impaired abilities relative to normal fluent individuals.

Thus, from the entire CAP test battery, we are able to conclude that the processing deficit lies within the left hemisphere and is reflected on the abilities testing that area. In fluent speakers, the left language-dominant brain hemisphere is most active during speech and language tasks [16]. An important PET study [17] reported increased activation in the right hemisphere in a language task in developmental stutterers instead. Another PET study [18] confirmed this result but added an important detail to the previous study where they found that activity in the left hemisphere was more active during the production of stuttered speech, whereas activation of the right hemisphere was more correlated with fluent speech. Thus, the authors concluded that the primary dysfunction is located in the left hemisphere and that the hyperactivation of the right hemisphere might not be the cause of stuttering but rather a compensatory process [19]. Right hemisphere hyperactivation during fluent speech has been more recently confirmed with functional MRI [20].

Conclusion

In this study, we can conclude that the stuttering children have intact brain stem integrity and an intact right hemisphere as signified by the normal right and left ear difference in the DDT and by improvement in the PPST on humming. Left hemisphere deficit appears in more complicated tasks such as PPST, DDT, and SPIN but not in simple tasks such as AFT-R.

Recommendations

It is recommended from the previous findings that CAP profile of stuttering children should be assessed and the effect of CAP disorder rehabilitation program should be further studied.

Acknowledgements

Conflicts of interest

None declared.

References

1 Bloodstein, O. A handbook of stuttering. 5th ed. San Diego, CA: Singular Publishing Group Inc.; 1995.

2 Guitar B. Stuttering: an integrated approach to its nature and treatment. Philadelphia, PA: Lippincott, Williams, & Wilkins; 1998.

3 Smith A, Kelly E. Stuttering: a dynamic, multifactorial model. In: RF Curlee, GM Siegel, editors. Nature and treatment of stuttering: new directions. 2nd ed. Boston, MA: Allyn and Bacon; 1997. 204–217.

4 ASHA. (Central) auditory processing disorders. The role of the audiologist; 2005. Available at: http://www.asha.org/policy/PS2005-00114/. [Last accessed on 2010 June 14].

5 Chermak GD, Musiek FE. Comprehensive intervention. Handbook of (central) auditory processing disorder. 2. San Diego, CA: Plural Publishing; 2007.

6 Musiek FM, Geurkink K, Baran JA. Myelination of the corpus callosum and auditory processing problems in children: theoretical and clinical correlates. Semin Hear 1984; 5:31–40.

7 Bellis TJ. Central auditory processing disorders. San Diego, CA: Singular Publishing Group Inc.; 1996.

8 Musiek F, Pinheiro M. Dichotic speech tests in the detection of the central auditory function. In: Musiek F, Pinheiro M, editors. Assessment of central auditory dysfunction: foundation and clinical correlates. 12th ed. Baltimore, MD: Willians & Wilkins; 1985. 201–218.

9 Andrade AN, Gil D, Schiefer AM, Pereira LD. Behavioral auditory processing evaluation in individuals with stuttering. Pro Fono 2008; 20:43–48.

10 Peñaloza-López YR, Téllez G, Pérez-Ruiz S, Silva MJ, García-Pedroza F. Results from applying the monaural compressed speech test in Spanish at 75% and 100% in cases of stuttering and controls. Rev Neurol 2008; 47:363–368.

11 Jutras B, Lagacé J, Lavigne A, Boissonneault A, Lavoie C. Auditory processing disorders, verbal disfluency, and learning difficulties: a case study. Int J Audiol 2007; 46:31–38.

12 Liebetrau RM, Daly DA. Auditory processing and perceptual abilities of 'organic' and 'functional' stutterers. J Fluency Disord 1981; 6:219–231.

13 Bitan T, *et al.* Bidirectional connectivity between hemispheres occurs at multiple levels in language processing, but depends on sex. J Neurosci 2010; 30:11576–11585.

14 Strouse A, Grantham D. Temporal processing in aging auditory system. J Acoust Soc Am 1998; 104:2385–2399.

15 Schow R, Seikel J. Screening for (central) auditory processing disorder. In: Chermak G, Musiek F, editors. Handbook of central auditory processing disorder: auditory neuroscience and diagnosis v.1. San Diego, CA: Plural Publishing Inc.; 2007. 137–161.

16 Moore WH, Haynes WO. Alpha hemispheric asymmetry and stuttering: some support for a segmentation dysfunction hypothesis. J Speech Hear Res 1980; 23:229–247.

17 Fox PT, Ingham RJ, Ingham JC, Hirsch TB, Downs JH, *et al.* A PET study of the neural systems of stuttering. Nature 1996; 382:158–161.

18 Braun AR, Varga M, Stager S, Schulz G, Selbie S, *et al.* Altered patterns of cerebral activity during speech and language production in developmental stuttering: an H_2(15)O positron emission tomography study. Brain 1997; 120:761–784.

19 Weiller C, Isensee C, Rijntjes M, Huber W, Muller S, *et al.* Recovery from Wernicke's aphasia: a positron emission tomographic study. Ann Neurol 1995; 37:723–732.

20 Neumann K, Euler HA, Gudenberg AW, Giraud AL, Lanfermann H, *et al.* The nature and treatment of stuttering as revealed by fMRI: a within- and between-group comparison. J Fluency Disord 2003; 28:381–410.