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Article

Impact of central auditory processing rehabilitation on literacy and phonological awareness skills in dyslexic children with central auditory processing disorder: a quasi-experimental interventional study

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Abstract:

Background: (Central) auditory processing disorder (C)APD and learning disorders such as dyslexia are common comorbidities. Furthermore, there is extensive evidence that rehabilitation of (C)APD disorder might improve reading and phonological skills. *Methods*: In a quasi-experimental interventional study assessment pre-therapy and post-therapy was done using the Arabic dyslexia assessment test and phonological awareness assessment. The children received the Arabic version of "differential processing training program" as a form of comprehensive auditory processing disorder training. *Results*: Children demonstrated better scores on assessment tools post-therapy. *Conclusions*: (Central) auditory processing remediation has an impact on phonological awareness, literacy and hence academic achievement.

Keywords: central auditory processing disorder, dyslexia, rehabilitation, children

Introduction

Poor performance in one or more of the auditory and temporal skills is a sign of auditory processing disorder, which is characterized by difficulties with the CNS (Central Nervous System) perceptually processing auditory information (sound localization and lateralization, auditory discrimination, auditory pattern recognition, temporal aspects of audition).(1)

One of the most widespread learning disabilities is dyslexia. It is believed to be a disorder with unclear causes up until today. Theories focus primarily on genetic and neurological factors, as well as the impact of environmental factors.(2, 3)

Different methods of evaluation were used to assess auditory training for the treatment of dyslexia. There are only a few reports of effects on reading and spelling ability, despite the fact that effectiveness with regard to the auditory symptoms was observed.(4-6)

Wether APD can be considered a separate diagnosis is an area of debate due to overlapping symptoms between APD and other language/learning disorders.(7-9)

Moore et al. (2013) present three hypotheses for the association between APD and other developmental disorders: (1) The distinction between some disorders is not always possible; more so than by the symptoms, a child's diagnosis is influenced by the reference route; (2) APD contributes to SLI and dyslexia; (3) The underlying cause of the various disorders is a more general neurodevelopmental deficit.(9)

It is postulated that some dyslexic children' reading difficulties are caused by distorted acoustic perception, and that correcting this deficiency can enhance children' literacy.

The identification of potential precursors to the learning of written language skills in recent years has drawn particular attention to auditory perception and processing, — in particular phonological awareness.(10)

Objectives

To determine the impact of (central) auditory processing remediation on literacy and phonological awareness.

Methods

Study design, setting and participants

In a quasi-experimental interventional study; 26 dyslexic children with central auditory processing disorder were enrolled after obtaining informed consent from the primary caregiver of these children. The study was conducted in the outpatient clinic of the Phoniatrics unit; Alexandria main university hospitals. (C)APD diagnosis was based on behavioral tests and scores were compared to norms; subnormal values on at least 2 tests was mandatory. Dyslexia diagnosis was based on an at risk quotient (ARQ) 1 or higher on the Arabic dyslexia assessment test (ADAT).(11) which includes 11 subtests rapid naming, bead threading, one-minute reading, two-minute spelling, phonemic segmentation, backward digit span, nonsense passage reading,

one-minute writing, semantic fluency and verbal fluency. Subjects received (central) auditory processing remediation using the Arabic version of the "differential processing training program".(12) at a frequency of 1-hour sessions per week for 3 months. Reassessment was done after therapy using the ADAT.(11)

Statistical analysis

Data were collected and fed to the computer using Statistical Package for Social Science (SPSS) program for statistical analysis (ver 21).(13) Kolmogorov-Smirnov test of normality revealed significance in the distribution of the age, other variables were non-normally distributed.(14) Data were described using minimum, maximum, mean, standard deviation, standard error of the mean, and 95% CI of the mean.(15) Data were described using minimum, maximum, median, 95% CI of the median, 25th to 75th percentile and inter-quartile range for non-normally distributed data. Categorical variables were described using frequency and percentage. Comparisons were carried out between two studied related non-normally distributed subgroups using Wilcoxon Signed Ranks test.(16) Accordingly, Box and Whiskers plots were employed. During sample size calculation, beta error accepted up to 20% with a power of study of 80%. An alpha level was set to 5% with a significance level of 95%. Statistical significance was tested at p value <0.05.(17)

Results

The ages of children ranged from 6.75 to 12.00 years with a mean of 9.74 years and standard deviation ±1.39 while the male: female ratio was approximately 2:1 1,8 males (69.23%) and 8 females (30.77%) which was consistent with the generally reported over-representation of boys shown in table (1).

Table (1): Distribution of the studied group according to age and sex

	(n=26)
Age (years)	
- **n**	26
- **Min. – Max.**	6.75-12.00
- **Mean ± SD**	9.74±1.39
- **SEM**	0.27
- **95% CI of the mean**	9.18-10.30
Sex	
- **Male**	18 (69.23%)
- **Female**	8 (30.77%)

n: number of patients

Min-Max: Minimum to Maximum

SD: Standard deviation

SEM: Standard error of the mean

CI: Confidence interval

***: Statistically significant (p<0.05)**

NS: Statistically not significant (p≥ 0.05)

The analysis of the data revealed statistically significant decrease of the ARQ of ADAT with a median of 1.90 and an IQR of 0.70 pre-therapy and a median of 1.25 with IQR of 0.88 post-therapy (p<0 .001) shown in table (2).

Table (2): Comparison between ARQ of ADAT pre-therapy and post- therapy in the studied group

ADAT	DPTP (n=26)
ARQ (Pre)	
- **n**	26
- **Min. – Max.**	1.00-3.00
- **Median**	1.90
- **95% CI of the median**	1.70-2.20
- **Percentile 25th – Percentile 75th**	1.50-2.20
ARQ (Post)	
- **n**	26
- **Min. – Max.**	0.40-2.70
- **Median**	1.25
- **95% CI of the median**	0.90-1.50
- **Percentile 25th – Percentile 75th**	0.80-1.60
Test of significance	$Z_{(WSR)}$=4.471
***p* value**	p<0.001*

n: number of patients

Min-Max: Minimum to Maximum

CI: Confidence interval

WSR: Z test of Wilcoxon Signed Ranks Test

***: Statistically significant (p<0.05)**

NS: Statistically not significant (p>0.05)

Subtests of the ADAT showed statistically significant improvement when pre-therapy and post-therapy scores were compared with p< 0 .001 in all subtests demonstrated in **fig. 1.**

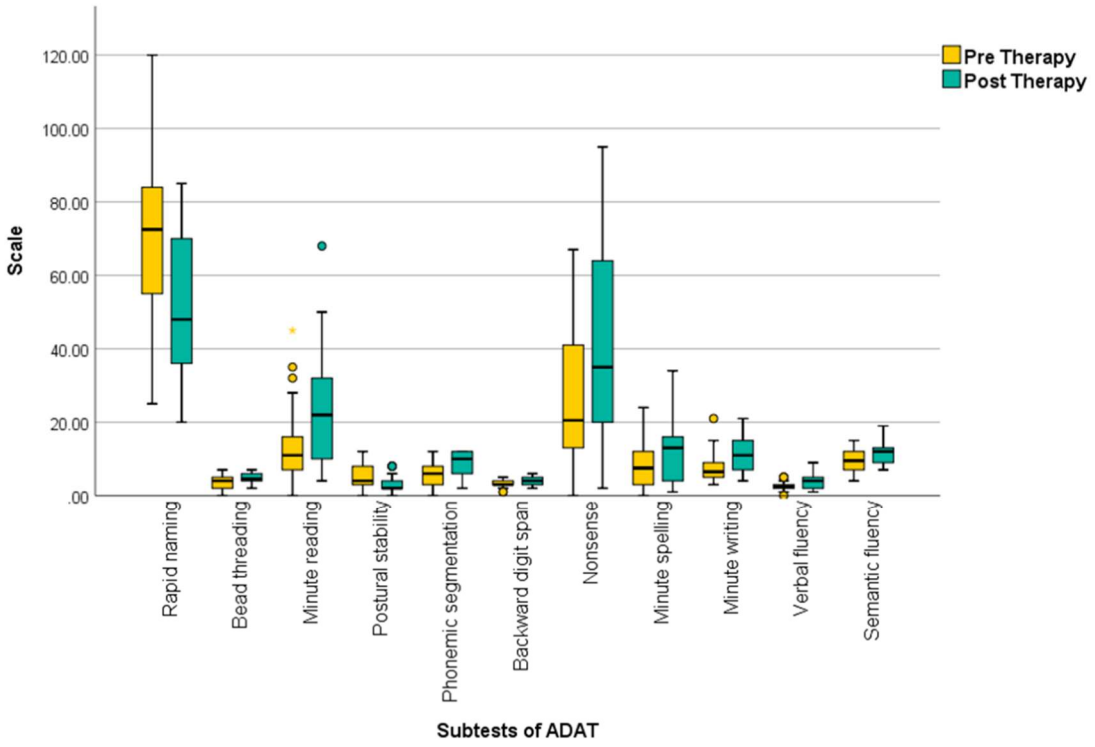

Figure (1): Box and whisker graph of Scale of Sub-tests of ADAT pre and post-therapy, the thick line in the middle of the box represents the median, the box represents the inter-quartile range (from 25th to 75th percentiles), the whiskers represents the minimum and maximum after excluding outliers (circles) Number(s) attached to the circle indicate(s) patient serial number in the original master table.

PAA scores showed statistically significant difference with a median of 74.50 and an IQR of 38 pre-therapy and a median of 96 with IQR of 23 post-therapy ($p<0$ .001) shown in **table (3).**

Table (3): Comparison between PAA scores pre-therapy and post- therapy in the studied group

	PAA
	DPTP (n=26)
PAA (Pre)	
- **n**	26
- **Min. – Max.**	32.00-105.00
- **Median**	74.50
- **95% CI of the median**	60.00-90.00
- **Percentile 25th – Percentile 75th**	56.00-94.00
PAA (Post)	
- **n**	26
- **Min. – Max.**	45.00-105.00
- **Median**	96.00
- **95% CI of the median**	85.00-105.00
- **Percentile 25th – Percentile 75th**	82.00-105.00
Test of significance	$Z_{(WSR)}$=4.109
***p* value**	p<0.001*

Discussion

The positive results of the current study demonstrated by the improvement in reading and phonological awareness can be explained by improved speed, auditory processing and speech-sound discrimination.

The addition of rapid auditory processing training can significantly boost the effectiveness and speed of language and phonologically-based interventions, which is perhaps the most exciting finding of the most recent neurophysiologic and neuroimaging studies. This is because auditory processing, language, and reading impairment are neurologically intertwined.(18)

Improvements in reading skills directly accountable to auditory training and language interventions with acoustically modified speech were studied by Temple and colleagues in two studies implemented using functional magnetic imaging, (fMRI) with a follow-up study by Gaab and colleagues (2007) looking at changes in rapid temporal processing in relation reading effects among children with dyslexia.(19) It was observed that despite no direct reading intervention, the

dyslexic group showed significant improvements in language and reading after only 6 weeks of this combined auditory processing and language training. The finding that reading decoding scores, which are directly correlated with phonemic awareness skills, improved from one standard deviation below the mean before training to within normal limits after training was particularly intriguing. (20)

Several studies using auditory processing interventions in language- and reading-impaired children have shown improvements in a variety of cognitive domains, most notably reading, after treatment aimed at increasing auditory processing speed and speech-sound discrimination, which is consistent with the findings of our current study.(21-24)

Contrastingly, Strehlow et al. reported that the capacity to improve phonological awareness after training for auditory processing impairment did not translate to reading performance.(25)

The study had several limitations such as the lack of a control group which would have added a better insight about the effect of training on literacy, and follow up to determine the long term effects and maintenance of results.

Conclusions

Auditory processing skill training has positive effects on phonological awareness and reading achievement and is an accepted form of therapy for dyslexic children.

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The project received no funding.

Conflict of interest

None

Statement of Ethics

The research was conducted in the time interval between March 2020 and March 2022 after approval by the ethics committee of the Faculty of Medicine, Alexandria University (IRB No :00012098). The trial is registered at www.clinicaltrials.gov NCT04708899.Written informed consent was taken from parents and/ or legally caring surrogates of all children participating in the study.

References

1. Sharma M, Purdy SC, Kelly AS. Comorbidity of auditory processing, language, and reading disorders. J Speech Lang Hear Res. 2009;52(3):706-22.
2. Plume E, Warnke A. Definition, Symptomatik, Prävalenz und Diagnostik der Lese-Rechtschreib-Störung. Monatsschr Kinderh. 2007;155(4):322-7.
3. Schulte-Korne G, Remschmidt H. Legasthenie-Symptomatik, Diagnostik, Ursachen, Verlauf und Behandlung. Dtsch Arztebl Int. 2003;100(7):333-8.
4. Bischof J, Gratzka V, Strehlow U, Haffner J, Parzer P, Resch F. Reliabilität, Trainierbarkeit und Stabilität auditiv diskriminativer Leistungen bei zwei computergestützten Mess- und Trainingsverfahren. Z Kinder Jugendpsychiatr. 2002;30(4):261-70.
5. Fischer B. Studien zur sprachfreien auditiven Differenzierung bei Legasthenie. Forum Logopaedie. 2007;21:30-5.
6. Schmidt R, Winter K, Tesch-Roemer C, Behrndt SM, Steffen M, Nawka T. Lassen sich auditive Verarbeitungs- und Wahrnehmungsstörungen (AVWS) bei Kindern mit Lese-Rechtschreib-Störungen nachweisen? Laryngo Rhino Otol. 2007;86:22-6.
7. Levy S, Parkin CM. Are We Yet Able to Hear the Signal Through the Noise? A Comprehensive Review of Central Auditory Processing Disorders: Issues of Research and Practice. Can J Sch Psychol. 2003;18(1-2):153-82.
8. Cacace AT, McFarland DJ. Current Controversies in Central Auditory Processing Disorder (CAPD). San Diego, CA: Plural Publishing, 2009.
9. Moore DR, Rosen S, Bamiou DE, Campbell NG, Sirimanna T. Evolving concepts of developmental auditory processing disorder (APD): a British Society of Audiology APD special interest group 'white paper'. Int J Audiol. 2013;52(1):3-13.
10. Schneider W. Entwicklung der Schriftsprachkompetent vom fruehen Kindes- bis zum fruehen Erwachsenenalter. In: Schneider W, (ed). Entwicklung von der Kindheit bis zum Erwachsenenalter. Befunde der Muenchner Laengsschnittstudie LOGIK. Weinheim: Beltz Verlag, 2008. 167-86.
11. Aboras Y, Abdou R, Kozou H. Development of an Arabic test for assessment of dyslexia in Egyptian children. Bull Alex Fac Med. 2008;44(3):653-62.
12. Winget K. Differential processing training program. East Moline, IL: LinguiSystems, 2007.
13. IBM Corp. IBM SPSS Statistics for Windows, Version 25.0. Data were entered as numerical or categorical, as appropriate. Armonk, NY: IBM Corp, 2017.
14. Field A. Discovering Statistics Using IBM SPSS Statistics. London: SAGE Publications Ltd, 2013.
15. Greenland S, Senn SJ, Rothman KJ, et al. Statistical tests, P values, confidence intervals, and power: a guide to misinterpretations. Eur J Epidemiol. 2016;31(4):337-50.
16. Wilcoxon F. Individual Comparisons by Ranking Methods. In: Kotz S, Johnson NL, (eds). Breakthroughs in Statistics: Methodology and Distribution. New York, NY: Springer New York, 1992. 196-202.

17. Curran-Everett D. Evolution in statistics: P values, statistical significance, kayaks, and walking trees. Adv Physiol Educ. 2020;44(2):221-4.
18. Burnsr MS. APDs and literacy edito. In: Geffner D, Ross-Swain D, (eds). Auditory processing disorder assessment, management and treatment. 3rd ed. San Diego, CA: Plural Publishing, 2019. 233-50.
19. Gaab N, Gabrieli JD, Deutsch GK, Tallal P, Temple E. Neural correlates of rapid auditory processing are disrupted in children with developmental dyslexia and ameliorated with training: an fMRI study. Restor Neurol Neurosci. 2007;25(3-4):295-310.
20. Temple E, Deutsch GK, Poldrack RA, et al. Neural deficits in children with dyslexia ameliorated by behavioral remediation: evidence from functional MRI. Proc Natl Acad Sci U S A. 2003;100(5):2860-5.
21. Heim S, Keil A, Choudhury N, Thomas Friedman J, Benasich AA. Early gamma oscillations during rapid auditory processing in children with a language-learning impairment: changes in neural mass activity after training. Neuropsychologia. 2013;51(5):990-1001.
22. Edwards VT, Giaschi DE, Dougherty RF, et al. Psychophysical indexes of temporal processing abnormalities in children with developmental dyslexia. Dev Neuropsychol. 2004;25(3):321-54.
23. Improved Early Reading Skills by Students in the Springfield City School District who used Fast ForWord® Products. MAPS Lear Educat Rep. 2011;9(25):1-5.
24. Agnew JA, Dorn C, Eden GF. Effect of intensive training on auditory processing and reading skills. Brain Lang. 2004;88(1):21-5.
25. Strehlow U, Haffner J, Bischof J, Gratzka V, Parzer P, Resch F. Does successful training of temporal processing of sound and phoneme stimuli improve reading and spelling? Eur Child Adolesc Psychiatry. 2006;15(1):19-29.