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RESEARCH ARTICLE

Efficacy of phonemic training program in rehabilitation of Persian-speaking children with auditory processing disorder: a single subject study

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Abstract

Background and Aim: One of the most prevalent problems in auditory processing disorder (APD) is in decoding. This problem is at the phonemic level and can difficulties in spelling, reading, speech processing disorder, responding delay, phonemic identification, memory, and manipulation. One of the training approaches for decoding problems is the phonemic training program. Considering high prevalence of decoding problems and lack of evaluation of the Persian version of the phonemic training program, this study investigated its efficacy in a child with APD.

Methods: This is a single-subject interventional study. A child with APD was selected and evaluated with Persian version of Phonemic Synthesis Test and staggered spondee words test at baseline, training, and monitoring phase. Data were analyzed by single-subject study statistics.

Results: All results showed absolute efficacy of the training.

Conclusion: The phonemic training program was effective in a child with auditory processing disorder.

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Introduction

Auditory processing refers to the central auditory nervous system (CANS) ability in utilizing auditory information [1]. Katz in 1992 defined auditory processing simply and comprehensively as “auditory processing is what we do with what we hear” [2]. Auditory processing disorder (APD) is a quite prevalent disorder involving children and adults [3]. APD prevalence in children ranges between 2% to 5% [4]. APD is an inability in neural processing of auditory information that can lead to language perception disorder [5]. It can result from CANS disorders [6] or abnormalities in executive function skills needed for reception, perception, and interpretation of the auditory signal [7]. (Central) auditory processing disorder or (C)APD can be seen in children with speech-language impairment, as well as developmental, attentional, and learning disability [8]. This disorder interferes with effective communication, preliminary education, self-confidence, and many aspects of a normal life [2].

Auditory processing models have been introduced to develop a diagnostic test battery, determining disorder structure appropriately and establishing proper rehabilitation. One of the most famous and common auditory processing models is Buffalo model. This model comprises 4 categories, including decoding, integration, organization, and tolerance fading memory (TFM) [2]. In Buffalo model, there are six trainings. One of these trainings is phonemic training program (PTP). Katz maintains that phonemic training and phonemic synthesis training are key trainings in the auditory processing model. The main treatment for decoding deficit is making a gradual change in incorrect or ambiguous engrams that are assumed to be stored in auditory cortex in the temporal lobe. In this training program, patient's auditory system is stimulated repeatedly by individual speech sounds. The main objective is improving subjects' phonemic capabilities. PTP is simple to conduct in different age ranges, unsusceptible to peripheral auditory disorders, also with simple equipment, which consists of a cover for lips and mouth to hide lower half of the face. The other materials required for phonemic training are a deck of flash cards, on each, there is an alphabet letter representing a phoneme [2].

As decoding is one of the basic categories of APD and Farsi version of this training program has not been developed or evaluated, the present study was conducted to develop Persian version of PTP and evaluate the efficacy of this treatment in Persian-speaking children with APD.

Methods

To evaluate PTP for APD remediation, a single-subject experimental design with reverse method and convenience sampling was conducted. Hearing evaluation for octave and half-octave intervals between 250 to 8000 Hz for air conduction and bone conduction pure tones was implemented by Piano audiometer (Inventis Co, Italy), also the middle ear status and auditory reflex thresholds were evaluated by Clarinet Middle Ear Analyzer (Inventis Co, Italy). Inclusion criteria included having hearing threshold below 15 dB HL, with normal middle ear function and normal IQ, without acute visual abnormality, having right dominant hemisphere, and being monolingual (Persian).

For sampling, in addition to the complete history of academic and social status of children from parents, Persian Phonemic Synthesis Test (P-PST) and Persian staggered spondaic words (P-SSW) test were conducted. The scores below the normal value were considered as APD. In history taking, the chief complaints were taken, including child's spelling, reading, writing, math, speech, language articulation and speech disfluency, reaction to sounds, the speed of answering to the questions, handwriting ability to follow multiple instructions, etc.

The selected patient was included in the single-subject study after fulfilling the inclusion criteria and taking the informed consent form by her parents. The other simultaneous treatments of the subject including medical treatments and behavioral therapies were continued. Finally, one child (Sara) entered the study. Her history and the results of her evaluations are discussed in detail in the following section.

Sara was a 9-year-old girl at the third grade of an elementary school in Tehran. Parents' chief complaint was her spelling problem. She did not have any math problem based on parents' report and her math skills were as good as her peers. She had a history of chronic otitis media and speech development delay. She had nasal articulation, speech disfluency, and slow articulation. Parents claimed that she was disturbed by loud sounds. There were many phonemic errors in her notebook including omission and substitution of phonemes. Written sentences were usually incomplete and some words were missing. She has been under treatment for her speech delay and articulation disorder for six months when she was between 4 to 5 years old.

For evaluating her central auditory processing disorder, P-PST and P-SSW were selected based on Buffalo model. After fulfilling inclusion criteria, she was submitted to the research baseline phase (A phase). In this phase, she was tested twice a week for three weeks. To prevent any learning effect during phase A, one of the P-PST (out of six available lists) and P-SSW lists (out of three available lists) were used in each session. In addition, for filling phoneme error analysis (PEA) form, her qualitative and quantitive errors were recorded. Finally, the total errors were calculated based on three phonemic error subcategories; omission, substitution, and addition. After 6 evaluation sessions and forming a baseline, phase A was completed. In the next phase (B phase), PTP started as a treatment. Training included 13 sessions, each session lasted for 20 to 30 minutes. Her peripheral hearing and middle ear function were evaluated before training sessions to rule out otitis media. For tracking changes in her scores, P-PST, P-SSW, and PEA were evaluated every two sessions.

For PTP, Persian alphabet cards (9×10 cm) were used. We graphically modified cards to improve their identification. The training process was as follows: at the first session, she was taught four phonemes. At the second session, there was a brief review (BR) of four previous phonemes, and then four new ones were introduced to her. At the third session, there was a BR of four phonemes of the second session, then eighth phonemes of the first and second session were put together and a general review (GR) was done and finally, four new phonemes were introduced. This process was followed in the same way. To avoid any fatigue effect, after the eighth session, previous phonemes that Sara could easily identify were eliminated from GR. The process of introducing new cards was at the end of each session except for the first session. She received the following instruction: "I want to say a sound several times. Do not repeat it, just listen." After presenting the sound, the therapist would say: "Now listen to the next sound", and then "now listen to a more difficult sound". During training sessions, therapist hid the lower part of his face with a cover and pointed to the related card. Each sound for the first time was repeated 2-3 times with different time intervals, like /š/… /š/….that is *sh* sound in Persian. The therapist would say: this is /š/ such as *shir* and *shoor* (words starting with /š/ in Persian were given as examples while cards were in the front of her). For maintaining her attention, the therapist used this strategy: "If I say a sound which is not here and you do not see it, point to the desk to show that I could not deceive you." We tested child one or two times and then the first card was taken away temporarily. To introduce the second sound, the therapist would say: "Now I am going to say another sound. Listen." The process was the same as the first sound. Then the two cards were put on the table at a distance, the therapist said each one more time and after Sara correctly pointed to the related card, cards were taken away, and the third and fourth sounds were introduced in the same way. In the end, all four sounds were evaluated.

For GR, all trained sounds were blended and introduced randomly. Each time, four cards were before the child who selected them randomly. The therapist produced each sound once and Sara pointed to the related card. Then these cards were taken away temporarily and the therapist worked on 4 new cards. Now eighth cards in two rows were arranged in front of the child and she must identify each sound among eighth cards and so on. If Sara had any difficulty with several previous sounds, training process was modified and fewer new sounds would be introduced (even in one session). If the number of errors for some phonemes was high and training could not proceed, different strategies were used to improve her function. The first strategy was "focus" used when she made a mistake in differentiating two sounds. In this strategy, two phonemes were compared and their difference was highlighted to the child. If there was not a significant progress with this strategy, in the following session when she forgot the errors, itch cards were used. Itch cards are keyword cards that help to develop a more tangible relationship between the sound and the card. In this strategy, the child will listen to a sound like /m/…/m/…../m/. Itch card for /m/ is *moosh* (meaning mouse in Persian language and starts with /m/). The therapist would say: "every time I said /m/, I want you to point to the *moosh* card and repeat it". After repeating the process once or twice, the card was taken away and the next

Table 1. The trend of changes in Phonemic Synthesis Test results from 1st session of baseline phase to the last session of the monitoring phase

P-PST indices	TFM	DEC	1st	P	Rev	NF	QR	Q	XX	X	Qual	Quant
1st baseline session	3	13	2	3	0	4	2	1	1	3	4	11
Last monitoring session	0	0	0	0	0	0	0	0	0	0	23	23

P-PST; Persian Phonemic Synthesis Test, TFM; tolerance fading memory, DEC; decoding, 1st; 1st phoneme omission, P; preservation, Rev; reversal, NF; non fused, QR; quiet rehearsal, Q; quick, XX; extreme delay, X; delay, Qual; qualitative, Quant; quantitative

itch card was introduced and at the end, two cards were compared with each other. This process followed for one or two sessions to make sure the relation between sounds and itch cards is clear for the child.
To evaluate reversibility of disorder, after three weeks since the last training session, baseline phase evaluations were repeated. This evaluation lasted for 6 weeks. For data analysis, single-subject case study methods were used, including celebration line, C-statistics, effect size, percentage of non-overlapping data (PND), and percentage of all non-overlapping data (PAND).

Results

The present study was conducted to develop Persian version of PTP and evaluate the efficacy of this remediation in Persian-speaking children with APD. The first step was developing phoneme cards (9×10 cm), and then PTP efficacy was evaluated. For determining face validity, Persian alphabet cards were distributed among 10 audiologists, linguists, speech therapists and fifteen 7- to 9-year-old children. Finally, experts and children's comments were applied.

Comparing results of Sara's evaluations before and after training

In the Tables 1 to 4, Sara's performance in P-PST, P-SSW, and PEA are presented. Regarding P-PST qualitative and quantitative scores, unlike P-PST and P-SSW, the number of errors are considered for evaluation. In Table 1, the results of the first and the last session are presented and compared. Our findings showed score improvements in P-PST and P-SSW and a reduction in the errors in PEA.

Analytic statistics based on single-subject case study methods

a- Celebration line analysis

In order to analyze celebration-line, the most aligned line with the baseline phase scores in right non-competing (RNC), right competing (RC), left competing (LC) and left non-competing (LNC) conditions, was drawn and then extended to the intervention phase.
In RNC, RC, LC, and LNC in the baseline

Table 2. The trend of changes in Persian staggered spondaic words results (quantitative) from the first session of baseline phase to the last session of the monitoring phase

P-SSW indices (quantitative)	C	LE	RE	Rev	Total	LNC	LC	RC	RNC
1st baseline session	25	17.5	17.5	1	17.5	10	25	22	13
Last monitoring session	1	1	1	0	5	2	2	0	2

C; condition, LE; left ear, RE; right ear, Rev; reversal, LNC; left non-competing, LC; left competing, RC; right competing, RNC; right non-competing

Table 3. The trend of changes in staggered spondaic words results (qualitative) from 1st session of baseline phase to the last session of the monitoring phase

P-SSW indices (qualitative)	TTW	Sm	P	Q	BTB	Sm-2	IW	QR	XX	X
1st baseline session	4	0	6	4	1	4	1	4	1	2
Last monitoring session	0	0	0	0	0	0	0	0	0	0

P-SSW; Persian staggered spondaic words, TTW; tongue twister, Sm; smush, P; preservation, Q; quick, BTB; back to back, IW; intrusive word, QR; quiet rehearsal, XX; extreme delay, X; delay

phase, 50%, 16%, 33% and 33% of dots were respectively below the line, but after training 100% of dots in all the conditions were below the line. Regarding RC of the baseline phase, 16% of dots were below the line and after training 100% of dots were below the line. For the right, left, total and condition score in the baseline phase, 33% of dots were below the line but after training these scores reached to 100%. With respect to decoding (DEC) and tolerance fading memory (TFM) P-SSW score in the baseline phase, 33% of dots and after training 100% were below the line.

Regarding the quantitative and qualitative PS score in the baseline phase, 50% and 33% of the dots were above the line respectively but after training 84% and 100% of them were above the line. Regarding DEC PS qualitative score in the baseline phase, 33% of dots were below the line but after training 100% of them were below the line. Regarding TFM score of the baseline phase, 33% of dots were below the line, but after training 50% were below the line.

With regard to PEA substitution, omissi on and total errors of the baseline phase, 33% of the dots were below the line but after training, 100% of them were below the line. With respect to phonemic errors in the baseline phase, none of the dots were below the line, but in the training phase, 84% of them were below the line.

b- C-statistics analysis

None of Sara's P-SSW quantitative scores were significant in the baseline phase (Table 5). However, the difference between P-SSW quantitative scores at the baseline and training phase were significant.

The qualitative score of the P-SSW test based on Buffalo processing model subcategories is summarized in Table 6. None of the qualitative indices were significant in the baseline phase ($p>0.05$). However, after training, there was a significant change in the qualitative (behavioral) P-SSW indices.

P-PST results for the baseline and training phase are shown Table 7. As it is shown, none of the quantitative, qualitative, and behavioral indices were significant.

PEA findings for the baseline and training phases are summarized in Table 8. None of the phonemic errors including substitution, omission, addition and total errors were significant in the baseline phase. All of the mentioned indices

Table 4. The trend of changes in phonemic errors from 1st session of baseline phase to the last session of the monitoring phase

PEA	Total errors	Addition	Omission	Substitution
1st baseline session	68	19	24	25
Last monitoring session	10	3	2	4

PEA; phoneme error analysis, 1st; 1st phoneme omission

Table 5. C-statistics results in quantitative score of Persian staggered spondaic words

	RNC	RC	LC	LNC	Total	RE	LE	C
Baseline								
z	-0.36	-0.59	-0.14	0	0	0.26	0.14	-0.14
p	0.712	0.554	0.883	1	1	0.788	0.882	0.883
Baseline and training								
z	3.08	3.26	3.24	3.21	3.22	2.99	3.19	3.24
p	0.002	0.001	0.001	0.001	0.001	0.002	0.001	0.001

RNC; right non-competing, RC; right competing, LC; left competing, LNC; left non-competing, RE; right ear, LE; left ear, C; condition

showed significant changes after training.

c- Efficacy estimation based on the percentage of non-overlapping data

Best Sara's function (lowest error) in the baseline phase in RNC, RC, LC, and LNC were 13, 22, 23 and 10 errors, respectively. About 100% of findings in RNC, RC and LC and 84% of findings in LNC were below the horizontal line. Also, the best function (lowest error) of the right ear, left ear, total score, and condition score were 17.5, 16.5, 17 and 23, respectively and 100% of the findings were below the horizontal line. Her best function (lowest error) for REC and TFM subcategories were 18 and 7, respectively at the baseline phase. About 100% of the DEC and 84% of the TFM subcategory findings were below the horizontal line. The best functions (highest score) of the PS quantitative and qualitative findings were 11 and 6 respectively in the baseline phase. About 84% of quantitative and qualitative findings were above the horizontal line. Best function (lowest errors) in behavioral indices of the Buffalo model at PST was 10 for DEC and 1 for TFM in the baseline phase. Also, 100% of DEC findings and 16% of TFM findings were below the horizontal line. The best PS function (lowest error) in the baseline phase for substitution, omission, addition and total errors were 24, 24, 19 and 67, respectively. In addition, 100% of the substitution, omission and total errors and 66% of the addition errors were below the horizontal line.

Table 6. C-statistics results in qualitative score of Persian staggered spondaic words

	DEC	TFM
Baseline		
z	0.61	1.12
p	0.539	0.261
Baseline and training		
z	3.28	3.16
p	0.001	0.001

DEC; decoding, TFM; tolerance fading memory

d- Training efficacy based on PAND principle

PAND value was 100% for RNC, RC, and LC improvements and 92% for LNC improvements. This value for the right ear, left ear, total and condition score was 100%. DEC and TFM subcategories of the Buffalo model showed 100% and 92% improvement in P-SSW respectively. PAND value in PST was 92% improvement in qualitative and quantitative score. The total behavioral indices of DEC and TFM subcategories showed 100% and 16% improvements respectively. In PEA, PAND value in substitution, omission, and total errors showed 100%

Table 7. C-statistics results in quantitative, qualitative scores and behavioral indices of P-PS

	Quant	Qual	DEC	TFM
Baseline				
z	-0.14	0.73	-0.28	-1.07
p	0.883	0.459	0.773	0.282
Baseline and training				
z	3.14	3.24	3.16	0.8
p	0.001	0.001	0.001	0.420

Quant; quantitative, Qual; qualitative, DEC; decoding, TFM; tolerance fading memory

improvement but in addition error, this value was 92%.

e- Visual inspection of functional changes

One of the methods for evaluating the effects of training in the single-subject studies are checking functional changes of the patient in the baseline, training, and monitoring phases. As it is shown in Figures 1 to 6, there was a significant reduction in the errors of all the scores after training. In addition, after training and during monitoring phase, there was not any regression to the baseline indices.

Discussion

Training effects on P-SSW were promising. In the four main scores, i.e. total score, ear score, and condition score, training has shown to be effective. With respect to the total score, ear score and condition score, the training was 100% effective. This result is also seen in DEC subcategory and Sara showed complete improvement. Although treatment in TFM was considered as very good, it seems that this good improvement might be due to fewer errors in the baseline phase. Regarding the qualitative and quantitative score of P-PST, improvement was significant and treatment was very good (92%). Training effect on PST DEC subcategory was in agreement with other results and showed 100% improvement. Training effect on TFM subcategory of PST was 16% which was predictable. Sara's errors in TFM subcategory were low even before training (maximum error in the baseline phase was four errors). Therefore it is obvious that training changes are not going to be significant but this subcategory showed error reduction too.

Phonemic errors showed positive training effects except for "addition" because "addition" errors happened less than other errors in the baseline phase. Repeated monitoring showed no regression in any of the indices after training. Therefore training effects were persistent in Sara.

Lenz claimed that PAND analysis was more cautious and accurate than PND [9]. Therefore in cases like ceiling and floor effect dilemma in PND, PAND can be used for evaluation and

Table 8. C-statistics results in phonemic errors based on phoneme error analysis

	Substitution	Omission	Addition	Total
Baseline				
z	-1.21	-0.59	0.87	-0.59
p	0.223	0.554	0.384	0.554
Baseline and training				
z	3.22	3.23	2.95	3.16
p	0.001	0.001	0.003	0.001

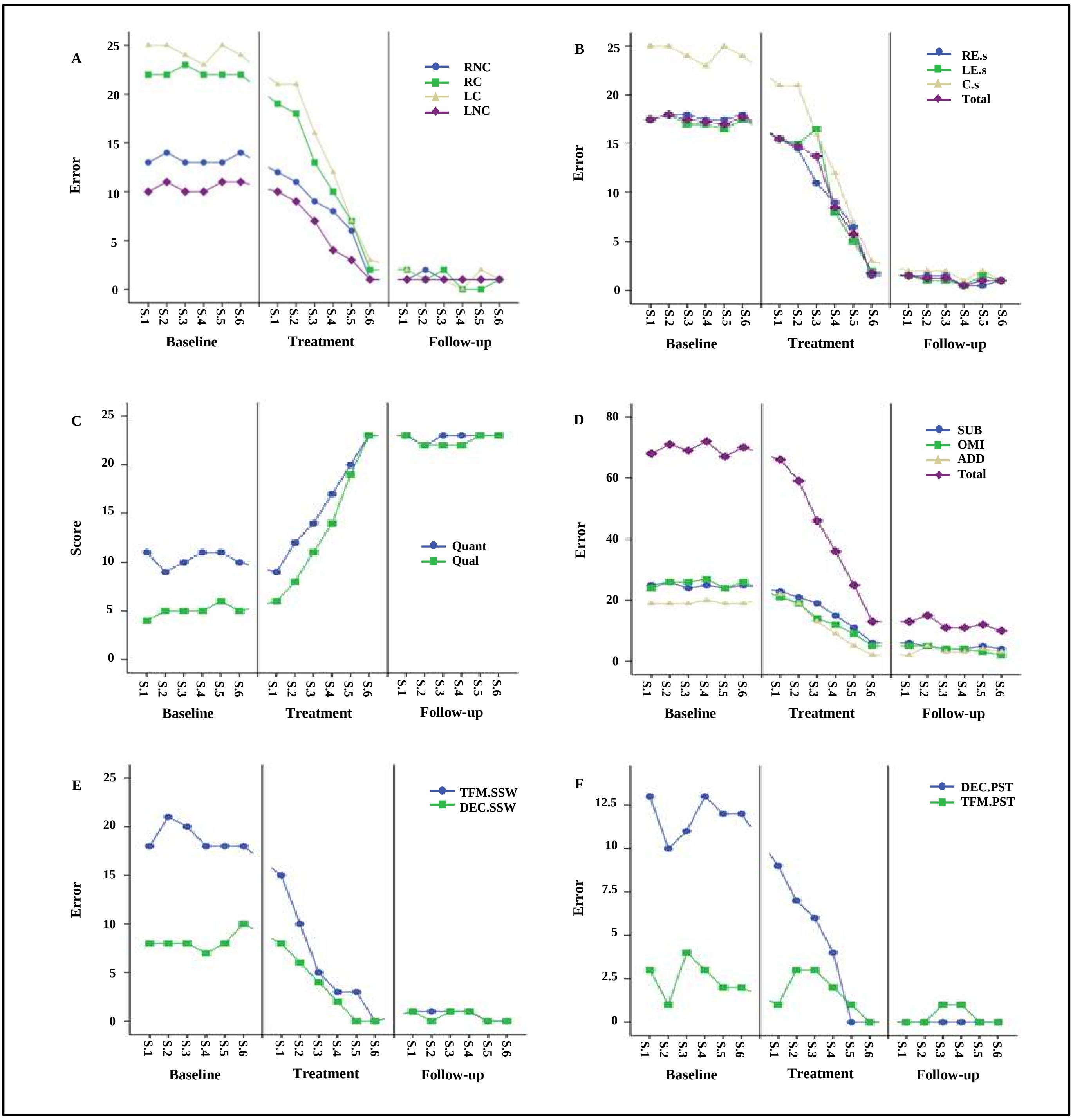

Fig.1. The trend of changes in the patient's A) scores in four main condition of P-SSW, B) scores of P-SSW, C) qualitative and quantitative scores of the P-PST , D) phonemic errors based on the P-PEA, E) behavioral indices of decoding, tolerance fading memory and organization based on P-SSW scores, and F) behavioral indices of decoding, tolerance fading memory and organization based on P-PST scores in the baseline, treatment, and follow up sessions. RNC; right non-competing, RC; right competing, LC; left competing, LNC; left non-competing; S; session, RE.s; right ear score, LE.s; left ear score, C.s; condition score, Quant; quantitative, Qual; qualitative, SUB; substitution, OMI; omission, ADD; addition, DEC; decoding, TFM; tolerance fading memory, P-SSW; Persian staggered spondaic words, P-PST; Persian Phonemic Synthesis Test.

Table 9. Guide for interpreting results of non-overlapping analysis

Training status	Percent of nonoverlapping results
Complete/definite treatment	Score over 90%
Appropriate treatment	Score 70-90%
Treatment is available but it should be used cautiously	Score 50-70%
No treatment	Score below 50%

analysis. PND and PAND are interpreted based on Scruggs and Mastropieri [10] findings. Table 9 shows PND and PAND findings and their relationship with training power and effectiveness.

Olive and Franco suggested that several statistical analyses are used in addition to visual inspection of change trend graph in single-case studies [11]. Lenz also suggested using multiple statistical analysis for evaluating training effects [9]. Nourbakhsh and Ottenbacher asserted that for a comprehensive evaluation of training effects, using multiple statistical analyses is mandatory [12].

Studies on phonemic based rehabilitation can be divided into two categories: one category includes studies that investigate PST effects and the other includes studies that assess PTP and PST effects together. Therefore the present study is the only study that evaluates phonemic training program independent of PST. In general, due to the common neurophysiologic base of two trainings (PST and PTP), the findings can be compared to both mentioned categories.

In a field study on 54 children, Katz studied increasing training repetitions from the first lesson to the last session and showed that PST would result in significant improvement in their function (comparing before and after training results) [2]. He mentioned that at first, the child has peak errors, therefore training would be lengthy. However, in the middle of the training program, this peak shows a steep decline in the number of errors and duration of the training needed for lesson completion. Our findings are in agreement with this study. In some of the visual graphs, it is shown that in some findings especially qualitative indices, at first, the number of errors were high.

Katz maintained that phonemic training aims to change patient's perception of language sounds. One of the main problems in children with DEC subcategory of APD is inaccurate phonemic engrams in the brain [2]. It can be inferred that inaccurate engrams are like wrong labeling of each phoneme. Therefore if a child cannot process a presented phoneme correctly and mislabel the phoneme, there will be many phonemic and qualitative errors in his responses. The present study is in agreement with this notion.

In the present study, Sara had significant academic difficulties especially spelling due to several phonemic errors before training. Spelling errors can happen as consequences for two main reasons. One is DEC difficulties and the other auditory-visual integration problems [2]. Firstly, effective phonemic training can resolve decoding problems. Secondly, for improving auditory-visual integration (that is necessary for spelling), organization training in addition to integration training is vital. In the present study, phonemic training was successful for correcting inaccurate engrams. Although PST unlike PTP has no emphasis on phonemes' place and order, this training was effective in organization subcategory, too. Therefore this training has led to phonemic error reduction and finally academic performance improvements such as spelling skill. Findings of the present study are in agreement with Luria who stated that middle-posterior portion of the superior temporal lobe is the phonemic region in charge of phonemic discrimination, memory, and blending [13]. Present findings showed that this training has positive effects on almost all indices mentioned at Luria study and more importantly all effects were persistent after training.

As it was mentioned, the second group of studies evaluates the effects of both PTP and PST. Katz studied the effects of these two trainings and compared the results of evaluations (PST and PEA) before and after training. He showed that qualitative score improved 7 points after 12.8 training sessions. He mentioned that after training, 31% of the patients had only one error or no error at all. Qualitative score improvement changed from 14 errors before training to 5 errors after training [2]. The present study is in agreement with Katz study and as it is shown in the result section, in PST, qualitative error reduction was more than quantitative error reduction. In Katz study, phonemic errors were evaluated and their improvement was 45% [2]. The present study even showed greater improvement in phonemic errors.

Conclusion

The present study was conducted to develop Persian version of PTP and then evaluate the efficacy of this remediation in Persian-speaking children with APD. Based on the results of this study with multiple analyses, phonemic training is a suitable remediation in patients with APD, especially for patients in DEC subcategory of the Buffalo model.

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Conflict of interest

The authors declared no conflicts of interest.

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