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Original Article

Preliminary Results of the Adaptation of Developmental Test of Auditory Perception (DTAP) to Turkish with Normal Hearing Children and Adolescents

Normal İşiten Çocuklarda ve Adölesanlarda İşitsel Algının Gelişimsel Testi'nin Türkçeye Uyarlanmasının Preliminer Sonuçları

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ABSTRACT

Objective: Auditory perception, which is the recognition and interpretation of auditory stimulus, forms the basis of verbal communication skills. Evaluating auditory perception in children is very important. Developmental Test of Auditory Perception (DTAP) is a battery that measures different aspects of auditory perception. This study aimed to present the Turkish adaptation of the DTAP battery.

Material and Methods: A total of 80 individuals (40 girls, 40 boys), aged between 8 and 18 years with normal hearing, were recruited in this study. The DTAP consists of 5 subtests, including environmental sounds, word discrimination, phonemes in isolation, tonal pattern, and rhyming sounds. All of these subtests were adapted to Turkish.

Results: The participants were found to have a greater difficulty in tonal pattern and rhyming sounds subtests. Negative correlation was found between age and the subtests of tonal pattern and rhyming sounds ($P < .05$). According to these results, as the age of the participants increases, the probability of making mistakes in these subtests decreases. However, a positive correlation was found between tonal pattern and rhyming sounds subtests, with both the number of incorrect items in tonal pattern and rhyming sound subtests increased.

Conclusion: It is concluded that auditory perception of tonal patterns and rhyming sounds is challenging for children in the young age group. The DTAP is an adaptable tool for the Turkish population. Further studies are needed with greater populations of Turkish children.

Keywords: Adolescent, audiology, auditory perception, child, hearing

ÖZ

Amaç: İşitsel uyaranın tanınması ve yorumlanması olan işitsel algı, sözlü iletişim becerilerinin temelini oluşturmaktadır. Çocuklarda işitsel algının değerlendirilmesi, oldukça önemlidir. İşitsel Algının Gelişimsel Testi (DTAP), işitsel algının farklı yönlerini değerlendiren bir bataryadır. Bu çalışmanın amacı, DTAP bataryasının Türkçeye uyarlanmasını sunmaktır.

Gereç ve Yöntem: Bu çalışmaya 8-18 yaşları arasında normal işiten 80 birey (40 kadın, 40 erkek) dahil edilmiştir. DTAP; çevresel sesler, kelime ayırt etme, fonem izolasyonu, tonal patern ve uyaklı sesler olmak üzere 5 alt testten oluşmaktadır. Tüm alt testler, Türkçeye uyarlanmıştır.

Bulgular: Katılımcıların tonal patern ve uyaklı sesler alt testlerinde daha fazla zorluk yaşadıkları belirlenmiştir. Yaş ile tonal patern ve uyaklı sesler alt testleri arasında negatif korelasyon bulunmuştur ($P < ,05$). Bu sonuçlara göre katılımcıların yaşı arttıkça, bu alt testlerde yanlış yapma olasılığı azalmaktadır. Ayrıca, tonal patern ile uyaklı sesler alt testleri arasında pozitif korelasyon bulunmuştur. Tonal patern alt testindeki yanlış madde sayısı arttıkça, uyaklı sesler alt testindeki yanlış madde sayısı da artmıştır.

Sonuç: Tonal paternlerin ve uyaklı seslerin işitsel algısının küçük yaş grubundaki çocuklar için zor olduğu sonucuna varılmıştır. DTAP, Türk popülasyonu için uyarlanabilir bir bataryadır. Daha geniş popülasyonlar ile yapılacak çalışmalara ihtiyaç vardır.

Anahtar Kelimeler: Adölesan, odyoloji, işitsel algı, çocuk, işitme

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Introduction

Auditory perception, which is the recognition and interpretation of auditory stimulus, forms the basis of verbal communication skills.[1] Development of auditory perception is directly related to the maturation of auditory neural pathways.[2-4] It begins with auditory awareness and continues with discrimination, identification, and comprehension.[5,6] This process, which is directly related to all developmental areas, is important, especially for speech and language development in children.[7] Therefore, evaluating auditory perception in pre-school and school-age children is very important.[8] Owing to the complicated functions of auditory perception, the skills are evaluated one by one.[9] Auditory discrimination, one of the components of auditory perception skills, is evaluated with speech identification and discrimination tests.[10]

There are many test batteries to evaluate auditory perception skills, which are applied to different age groups. Auditory perception tests are screening tests or diagnostic assessment tools used particularly for auditory discrimination skills.[11-13] The results of these tests were closely related to individual factors like auditory memory and attention.[12,14-16] The skills measured in test batteries administered to children are auditory discrimination, auditory memory, auditory integration, and audiovisual integration. The basis of all of these skills lies in central auditory processing (CAP).[3,17] These auditory skills are important for reading and writing skills.[16,18] According to researchers, auditory discrimination tests must be a component of educational programs because poor auditory discrimination skills could result in a child being unable to read successfully.[11]

Developmental test of auditory perception (DTAP) is a comprehensive tool for assessing auditory perception. Unfortunately, in Turkey, test batteries that are used to evaluate auditory perception skills are limited. This study aimed to present the preliminary results of Turkish version of DTAP for Turkish children and adolescents with normal development and hearing aged 8-18 years. Our long-term target is to establish the first step of a comprehensive test battery for evaluating auditory perception abilities.

Material and Methods

This study was conducted as a dissertation thesis between January and November 2017. The ethics committee approval for this study was received from İstanbul University-Cerrahpaşa Faculty of Medicine clinical research center. Because the participants were under the age of 18 years, their families signed an informed consent form. Adaptation permission was obtained from the manufacturing company of DTAP (PRO-ED, Incorporated, an international publisher, Austin, Texas). The study was designed using a correlational model of quantitative research methods. Per our purpose, data analysis was intended to answer the following 5 questions:

1) What are the correct answer percentages (%) of the test items in the test battery?

2) What is the number of minimum and maximum incorrect items for each subtest in the test battery?

3) Is there any difference in the number of incorrect items between sexes in the subtests?

4) Is there any difference in the number of incorrect items in the subtests according to age groups?

5) Is there a correlation between subtests or between age groups and subtests?

Participants

The participants of the study were 80 children (40 girls, 40 boys) with normal development, aged 8-18 years (11.50 ± 2.84) who had normal hearing. Normal development in these children was determined according to family history, observational experiences, and support of a clinical psychologist. The clinical psychologist evaluated the development of these children by Wechsler Intelligence Scale for Children-R and Wechsler Adult Intelligence Scale tests. Audiologic evaluation was conducted in all children (tympanometry, pure tone and speech audiometry, and transient evoked otoacoustic emission), and 0-15 dB HL (125-8,000 Hz) range in pure-tone average (PTA) was classified as normal hearing. PTA is 4 frequency averages as 500-1,000-2,000-4,000 Hz. All children were attending public or private schools in the Istanbul region. Children were grouped in 8 age groups with 5 boys and 5 girls in each group. Age groups are shown in Table 1.

Developmental test of auditory perception

DTAP is a comprehensive tool for assessing auditory perception in children. It was developed by Cecil R. Reynolds, Judith K. Voress, and Nils A. Pearson in 2008. It uses a simple response format that can be easily accommodated for children aged 6-18 years. DTAP includes 5 subtests (environmental sounds, word discrimination, phonemes in isolation, tonal pattern, and rhyming sounds). Each subtest evaluates a different aspect of auditory perception. In environmental sounds subtest (30 items), the child hears 2 non-speech sounds from the environment and has to indicate whether they are the same or different. In word discrimination subtest (30 items), the child hears 2 words and has to indicate whether they are the same or different. In the phonemes in isolation subtest (31 items), the child hears 2 phonemes and has to indicate whether they are the same or different. In tonal pattern subtest (31 items), the child hears 2 patterns of pure-tone sounds and has to indicate whether they are the same or different. In the rhyming sounds subtest, (31 items), the child hears 2 words and has to indicate whether they rhyme.

Table 1. Age Groups of the Participants

Age groups (y; m)	8;0-8;11	9;0-9;11	10;0-10;11	11;0-11;11	12;0-12;11	13;0-13;11	14;0-15;11	16;0-18;11
Mean	8;5	9;6	10;4	11;6	12;5	13;7	14;1	17;5
n	10	10	10	10	10	10	10	10

Abbreviations: y, year; m, month; n, number of participants

Turkish DTAP (TR-DTAP)

Adapting DTAP to Turkish

In TR-DTAP, the 5 subtests were examined. In the "environmental sounds" and "tonal pattern" subtests, no changes were made. They remained the same as in the original version of the battery. "Word discrimination," "phonemes in isolation," and "rhyming sounds" subtests were reorganized. The morpho-syntactic rules of Turkish were not taken into consideration, and only the sound matches were used. Changes were made according to the Turkish phonetic and phonotactic rules, which are described in the International Phonetic Alphabet (IPA). For example, in word discrimination subtest, the word "tree" was used as "tren" (train) in the Turkish version. In the rhyming sounds subtest, the pair of words "how-now" were used as "haz-naz." There were some sound combinations which did not exist in the Turkish phonologic system. For these sounds, the closest sound in the IPA chart was chosen. For example, "kul" was used instead of "foul." In this process, words and phonemes were formed according to the children's most familiar words to provide easy pronunciation. This was based on the 1,000-word list, which is taught to school-age children, as determined by the Turkish Language Institution and the Turkish Republic-Ministry of National Education. Adaptation of the battery was made by a speech-language pathologist and 2 linguists. TR-DTAP is given in Appendix A. A pilot study of TR-DTAP was conducted with 20 children aged 6-18 years. In this trial, the children aged 6-8 years had difficulty with the testing instructions, especially in rhyming sounds and with some of the unfamiliar words in word discrimination subtest. These words were changed to more familiar words. For the rhyming subtest, extra information was added to the instructions.

Sound recordings

A professional male voice actor vocalized the sounds of the TR-DTAP. For the recording of the sounds, Computerized Speech Lab (PENTAX Medical, New Jersey, USA) and a high-quality condenser microphone (Shure SM48) were used in a soundproof room. The microphone was located 15 cm away from the speaker's mouth during recording. The voice recordings were edited using the Adobe Audition CC 2017 software program (Adobe Systems, USA). Sound editing was done according to the Radiocommunication Sector of International Telecommunication Union Sound Broadcasting recommendations (ITU-R BS.1770-3–08/2012). Background noises, environmental sounds, and stimuli of tonal pattern subtest used inside the DTAP were taken from the original version of DTAP.

Test procedure

Testing was conducted inside a soundproof room with background noise below 35 dBA. During the testing period, the child and the researcher were seated comfortably. The child listened to the recordings from a computer (Apple MacBook Air). All items were presented at the most comfortable level for each listener. The items which were presented in noise were presented in a randomized manner as in the original DTAP. Signal-to-noise ratios were edited to be the same as the original content. Before beginning, output of the computer sound was analyzed from the child's listening position using a sound level meter (Bruel & Kjaer, 2270-S hand-held SLM, Denmark) to ensure that the output stayed the same across all trials. Identical protocols were used in the administration of the TR-DTAP as in the original test. It took 45-60 minutes to administer. Sufficient time was scheduled so that the entire test could be administered in 1 session. The test presentation order was not randomized and administered in the same order for each child. A 5-minute break was given at the end of each item set. After the instructions were given by the researcher, the child discriminated the sound and marked 1 of the checkboxes (same or different) on the test sheet. During the administration of the test, the examiner stayed neutral so as to not affect the examinee's response.

Statistical analysis

Statistical analysis was performed using The Statistical Package for Social Sciences version 21.0 software (IBM Corp.; Armonk, NY, USA). The first research question was addressed by carrying out descriptive statistics; number and percentage values for categorical variables. In other research questions, the Shapiro-Wilk test was used to test if the parameter had a normal distribution. According to the Shapiro-Wilk test results, the number of incorrect items by sex did not show a normal distribution as $P < .05$ for each subtest. Therefore, the Mann-Whitney U test, which is one of the nonparametric tests, was performed to analyze the relationship between sex and the incorrect items. In the analysis of the relationship between age groups and the number of the incorrect items, the data did not show normal distribution for environmental sounds, word discrimination, and phonemes in isolation subtests; however, for tonal pattern, rhyming sounds subtests, and the total test, the data showed normal distribution. Therefore, the Kruskal-Wallis test was used for non-normally distributed data, and one-way analysis of variance test was used for normally distributed data. Post-hoc Tukey test was also performed, because the data showed a homogeneous distribution. Spearman test was performed for correlation analysis between subtests. A value of $P < .05$ was considered statistically significant. In data analysis, the cutoff point for interpreting the correct answer percentages of the test items was determined statistically by expert opinion. This value was determined by the phonemes in isolation subtest, which contained the highest percentage of test items in the battery. When this subtest's scores were examined, it was seen that the lowest percentage was 85%. The cutoff point of 85% was applied in this study.

Results

The phonemes in isolation subtest had the highest percentage, and tonal pattern subtest had the lowest percentage of correct answers (Table 2). In environmental sounds subtest, item 6 (82.5%) and item 16 (80%) had the lowest percentage of correct answers. In word discrimination subtest, item 21 (73.8%) had the lowest percentage of correct answers. In this item, the difference between "file and fire" were examined, and 73.8% of all participants answered correctly. In the phonemes in isolation subtest, item 3 ("fiil-fil") ("ii-i" pairs) (85%) had the lowest percentage of correct answers. In tonal pattern subtest, 4 consecutive tones were used in 4 items (8, 23, 24, 29), and 3 consecutives tones were used in 1 item (10) with background noise.

Table 2. Correct Answer Percentages (%) of the Test Items

	Correct answer percentages (%)				
Test items	**Environmental sounds**	**Word discrimination**	**Phonemes in isolation**	**Tonal pattern**	**Rhyming sounds**
1	100	97.5	97.5	90	97.5
2	98.8	100[BN]	100[BN]	95[BN]	100
3	98.8	92.5	85	95	90[BN]
4	98.8	100	100	96.3	100
5	95	98.8	100	91.3[BN]	93.8
6	82.5[BN]*	98.8[BN]	100[BN]	92.5	92.5
7	96.3	98.8[BN]	100	97.5	65*
8	93.8	100	100[BN]	83.8[BN]*	98.8[BN]
9	98.8	98.8[BN]	100	96.3	96.3
10	96.3	90	100[BN]	72.5[BN]*	88.8
11	92.5[BN]	96.3	98.8	88.8	86.3[BN]
12	96.3	100	100	96.3[BN]	91.3
13	92.5[BN]	100[BN]	100[BN]	85	90[BN]
14	98.8[BN]	98.8	100[BN]	47.5*	93.8
15	98.8[BN]	97.5[BN]	100	90	85
16	80*	93.8	100[BN]	96.3[BN]	90[BN]
17	100	98.8	100	67.5*	70[BN]*
18	100[BN]	100	100[BN]	93.8[BN]	96.3
19	98.8	98.8[BN]	97.5	87.5	85[BN]
20	91.3	100	97.5	88.8	90
21	96.3[BN]	73.8[BN]*	97.5	86.3[BN]	90
22	100	100	97.5[BN]	61.3*	87.5
23	100	97.5[BN]	100	73.8[BN]*	96.3[BN]
24	95	100	98.8	76.3*	98.8
25	97.5	98.8	96.3[BN]	86.3	96.3
26	98.8	93.8	96.3	87.5[BN]	97.5[BN]
27	97.5[BN]	98.8[BN]	100	83.8*	53.8*
28	90	95	97.5BN	85	93.8
29	95[BN]	100	100	75[BN]*	92.5
30	97.5[BN]	100[BN]	100	83.8*	95

[BN]Background noise (+); *Scores under 85% (<85%)

In a quiet environment, 4 consecutive tones were presented in 3 items (14, 22, 27), 3 and 4 consecutives tones were used in 1 item (17), and 3 consecutives tones were used in 1 item (30). In the rhyming sounds subtest, the participants performed poorly in items 7 (kist-jest), 17 (tost-test), and 27 (üst-ast).

Tonal pattern and rhyming sounds subtests were observed to be more difficult than other subtests for the participants (Table 3).

There was no statistically significant difference between male and female participants in each of the subtests ($P > .05$) (Table 4). In addition, there was no statistically significant difference between the age groups according to the total number of incorrect items in environmental sounds, word discrimination, and phonemes in isolation subtests ($P > .05$). Table 5 shows that there was a statistically significant difference between the age groups. Table 6 shows that there was a negative correlation between the age groups in tonal pattern subtest, rhyming sounds subtest, and the total test. As age increased, the number of incorrect items decreased. The majority of the incorrect items in the total test included incorrect items in tonal pattern and rhyming sounds subtests. A positive correlation was found between tonal pattern and rhyming sounds subtests. Both the number of incorrect items in tonal pattern subtest and the number of incorrect items in rhyming subtest increased. As expected, there was a positive correlation between both tonal pattern and rhyming sounds subtests and the total test.

Discussion

This study aimed to present the preliminary results of adapting the DTAP to Turkish. When the correct answer percentages were examined; in environmental subtest, the lowest correct answer percentages were items 6 and 16. In item 6, there were 2 different forms of the closing sound of a postbox with background noise. It may not be familiar for Turkish children for cultural reasons, and they could have been distracted by the background noise. In item 16, a machine sound (acoustically complex with long duration) and a door closing sound were presented consecutively in quiet. Because of the complexity of the stimulus in item 16, the participants could not focus on the sounds. In our study, the percentages of the items in environmental subtest ranged from 80% to 100%, which corelates with a study that used the sound effects recognition test on 141

Table 3. Number of Minimum and Maximum Incorrect Items in the Subtests

	Mean ± SD	Minimum	Maximum
Environmental sounds	1.19 ± 1.3	0.00	5.00
Word discrimination	0.82 ± 0.9	0.00	4.00
Phonemes in isolation	0.37 ± 0.8	0.00	5.00
Tonal pattern	4.29 ± 3.4	0.00	14.00
Rhyming sounds	2.89 ± 2.3	0.00	11.00
Total test	9.56 ± 5.4	1.00	22.00

Abbreviations: SD, standard deviation

Table 4. Comparison of the Number of Incorrect Items in the Subtests According to Sex and Age Groups

	P	
Subtests	**Sex**	**Age groups**
Environmental sounds	0.49	0.164
Word discrimination	0.796	0.238
Phonemes in isolation	0.464	0.514
Tonal pattern	0.934	0.001*
Rhyming sounds	0.88	0.040*
Total test	0.798	0.001*

*According to the results of one-way analysis of variance ($P < .05$)

Table 5. Comparison of the Number of Incorrect Items in Tonal Pattern, Rhyming Sounds Subtests and Total Test According to the Age Groups

Subtests	**Age groups (year; month)**		*P*
Tonal pattern	8;0-8;11	13;0-13;11	0.029*
	9;0-9;11	13;0-13;11	0.024*
Rhyming sounds	9;0-9;11	14;0-15;11	0.032*
Total test	9;0-9;11	13;0-13;11	0.005*
	9;0-9;11	14;0-15;11	0.003*

*According to the results of the post-hoc Tukey test ($P < .05$)

Table 6. Correlation Among Subtests or Between the Age Groups and Subtests

Age groups	*P*	<0,001	0.005*	<0,001
	r_s	−0.472*	−0.308*	-0.452*
Tonal pattern	*P*		0.006*	<0,001
	r_s		0.302*	0.791*
Rhyming sounds	*P*	0.006*		<0,001
	r_s	0.302*		0.720*

Abbreviations: r_s, Spearman's rank. $P < .05$; *Correlation was significant at 0.01 level (2-way);

preschoolers with normal hearing and found a mean score of 90.5%.[19]

In another study, speech recognition scores for children with normal hearing, aged 5-7 years, varied between 96% and 98%. In the 10-12 years age group, these scores varied between 93% and 94%, similar to adults.[20] In our study, the percentages of the items in word discrimination subtest ranged from 73.8% to 100%, which was similar to these findings. The lowest correct answer percentage (73.8%) was in "file-fire" (filing-firing) word pair (item 21). Because of the phonetic similarities in the articulation pattern of the phonemes /l/ and /r/, the possibility of making a mistake may increase.

In phonemes in the isolation subtest, the lowest percentage of correct answer was in item 3 (fiil-fil). It might have also been affected by the absence of long /i/ or short /i/ in the Turkish alphabet. The ability to complete the missing components of the auditory stimulus in auditory processing skills has been shown to be very effective.[21] It is known that phoneme discrimination is acoustically more difficult than words owing to the short duration and less auditory cues in phonemes. The pitch movements of speech sounds depend on the frequency characteristics of the voice of the individual. As the speech intonation increases and decreases, the frequency changes in speech sounds can also make it difficult to identify.[12] However, in this study, the intonations in our sound records varied greatly because of the vocalization of the theater actor. The intonations affected the numbers of incorrect items, especially in phonemes in isolation subtest.

Tonal pattern subtest was the most difficult subtest according to the participants. They mostly made mistakes in 3 or 4 consecutive tonal patterns in different combinations. In tonal pattern subtest, the participants were asked to indicate whether the consecutive tonal stimuli were the same or different. Cognitive activity is important in tonal pattern which is related to pitch perception, auditory processing, temporal integration, attention, and auditory memory capacity.[17,22,23] The errors made could have been owing to the difficulty of the task and related to selective attention and auditory memory capacity.

The rhyming sounds subtest was the second most difficult subtest for the participants. They particlularly made mistakes with words that ended with "-st." Rhyme awareness is taught in the pre-school period for foreign educational systems. However, it is taught in the 6th grade (12-13 years age group) according to the Turkish teaching curriculum in Turkey. This might be the reason for more mistakes in this subtest.

Tonal pattern subtest had the most incorrect items, and the highest mean and standard deviation. The stimuli presented in tonal pattern subtest were long, and there were no known or predictable sounds such as environmental sounds. Because at least 3 tones were given consecutively, it required long-term working and auditory memory capacity. In these 2 aforementioned subtests, high-order cognitive and auditory functions are required.

There was no significant difference found between female and male participants for all subtests. Auditory perception is a skill developed on the basis of auditory experiences, which is closely related to individual factors.[8] In many studies, there was no significant difference between girls and boys in auditory perception abilities.[24]

The neuroplasticity of the sensory and cognitive systems develops with experience, and learning is rapid in early childhood. The increase in neural transmission, synaptic synchronization,

and myelinization with age also has an effect on the auditory neural system.[3,25] There was no significant difference in the incorrect items of environmental sounds, word discrimination, and phonemes in isolation subtests between age groups. A study found that the performance of children with normal hearing in the 10-12 years age group was better than those in the 5-7 years age group and similar to adults.[20] These findings suggest that children older than 10 years have better auditory perception abilities, including tonal and speech perception. These abilities depend on cognitive development and auditory neural maturation. This auditory experience increases with age.[3,20,25] The explanation that will support these ideas and findings is made in the original DTAP Examiner's Manual as follows: "The performance on 5 DTAP indexes is strongly related to age for students ages 6 through 11 years; the remaining index is moderately related to age for this group." The performance of students aged 12-18 years shows a small relationship with age; this is expected as auditory perception skills are fully developed in a normally achieving population by the teen years.[26] Although we found some vague differences, because our study did not use the aforementioned indexes, it may explain the statistically insignificant differences between age groups.

A negative correlation was found between age groups in tonal pattern subtest, rhyming sounds subtest, and the total test. As age increased, the number of incorrect items decreased. It was thought that the reason for this result may be owing to the increase in cognitive capacity, auditory memory, and central auditory processing skills with age.[3,25] The negative correlation between the age groups in tonal pattern subtest, which is affected by the temporal ordering skills and auditory memory, support that temporal integration, ordering ability, and auditory memory increase with age.[27] In the literature, the relationship among auditory perceptions, prosodic processing of speech, and vocabulary development was examined in 100 pre-school children. Notably, tonal awareness was found to be closely related to language development, and 36% of vocabulary development was associated with tonal sensitivity. Auditory frequency discrimination correlates significantly with lexical tonal sensitivity, discrimination of syllable duration, and awareness of intonation in early childhood.[28] In a study with 1,102 pre-school children with normal hearing, the auditory processing skills of the children showed a significant correlation with phonological awareness skills and the decision of time-sequence, temporal gap detection, and discrimination of complex tonal patterns constituted 32% of the variance in phonological awareness.[29] These findings are clear evidence that there is a strong influence of tonal perception and phonological awareness. Supporting these findings, we found a positive correlation between tonal pattern and the rhyming sounds subtest.

Study limitations

The lowest age of participants in the original DTAP is 6 years; and in our study, it was 8 years. The reason for determining the base age as 8 is that children over 8 years of age are active members of their school. In addition, children who are under 8 years of age cannot complete the subtests because of their short attention spans. Another limitation of our study was that it did not measure auditory memory and attention. The third limitation was a small sample size comprising 8 age groups, which included 10 participants each. Further studies should be conducted with larger groups of children. Another restriction was related to the phoneme and word lists. It is thought that these lists might be revised, and sound records might be more professional in terms of audibility and the results might have been affected by this.

Conclusion

Auditory perception test batteries in Turkey were administered to both children and their families. However, the results of all subtests of TR-DTAP can be obtained directly from the children. TR-DTAP could be an important tool in improving the productivity of Turkey's Audiology clinics by providing the opportunity to evaluate auditory perception skills on an individual basis. Normative data could be used in the assessment of children who may be at risk of poor auditory perception or processing skills. Therefore, DTAP is an adaptable and useful tool for Turkey, and further studies are needed with greater populations of Turkish participants. Future aims are to revise the test battery according to the preliminary results and provide validity and reliability for TR-DTAP.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of İstanbul University-Cerrahpaşa Faculty of Medicine (Date: 07/12/2016 No:442697).

Informed Consent: Written consent was obtained from the participants' families.

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References

1. Kolarik AJ, Moore BC, Zahorik P, Cirstea S, Pardhan S. Auditory distance perception in humans: a review of cues, development, neuronal bases, and effects of sensory loss. *Atten Percept Psychophys*. 2016;78(2):373-395. [Crossref]
2. Saffran JR, Werker JF, Werner LA. The infant's auditory world: Hearing, speech and the beginnings of language, Kuhn D, Siegler RS, William D, Lerner RM, editors. Handbook of Child Psychology. 6th ed. Hoboken, NJ: John Wiley and Sons; 2006.p.58-108. [Crossref]
3. Sharma A, Dorman MF, Kral A. The influence of a sensitive period on central auditory development in children with bilateral and unilateral cochlear implants. *Hearing Res*. 2005;203(1-2):134-143. [Crossref]
4. Rubel EW, Popper AN, Fay RR. Development of the auditory system. Springer Handbook of Auditory Research. 1st ed., New York: Springer-Verlag; 2002.p.112-115.
5. Shamma SA, Micheyl C. Behind the scenes of auditory perception. *Curr Opin Neurobiol*. 2010;20(3):361-366. [Crossref]
6. Yoon HS, Templeton TN. The practice of listening to children: The challenges of hearing children out in an adult-regulated world. *Harv Educ Rev*. 2019;89:55-84. [Crossref]
7. Cole EB, Flexer C. Children with hearing loss: Developing listening and talking, birth to six.1st ed. San Diego, Oxford, Brisbane: Plural Publishing; 2007.p.108-112.
8. Nicholas JG, Geers AE. Effects of early auditory experience on the spoken language of deaf children at 3 years of age. *Ear Hear*. 2006;27(3):286-298. [Crossref]
9. de Wit E, van Dijk P, Hanekamp S, Visser-Bochane MI, Steenbergen B, van der Schans CP, et al. Same or different: The overlap between children with auditory processing disorders and children with other developmental disorders: A systematic review. *Ear Hear*. 2018;39(1):1-19. [Crossref]
10. Lezak MD, Howieson DB, Bigler ED, Tranel D. Neuropsychological Assesment. 5th ed. New York:Oxford University Press, 2012.p.56-59.
11. Encyclopedia of Children's Health. (cited 2017 Jun 3): Available from: URL: http://www.healthofchildren.com/A/Auditory-Discrimination-Test.html
12. Wang HLS, Chen IC, Chiang CH, Lai YH, Tsao Y. Auditory perception, suprasegmental speech processing, and vocabulary development in Chinese preschoolers. *Percept Mot Ski*. 2016;123(2):365-382. [Crossref]
13. Yücel E, Sennaroğlu G. Test manual of auditory perception for children. Advance-Bionics, 2011.
14. Brungart DS, Simpson BD. Cocktail party listening in a dynamic multitalker environment. *Attent Percept Psycho*. 2007;69(1):79-91. [Crossref]
15. Miolo G, Chapman RS, Sindberg HA. Sentence comprehension in adolescents with down syndrome and typically developing children role of sentence voice, visual context and auditory-verbal short-term memory. *J Speech Lang Hear R*. 2005;48(1):172-188. [Crossref]
16. Chung WL, Jarmulowicz L, Bidelman GM. Auditory processing, linguistic prosody awareness, and word reading in Mandarin-speaking children learning English. *Read Writ*. 2017;30:1407-1429. [Crossref]
17. Sharma A, Dhamani I, Leung J, Carlile S. Attention, memory, and auditory processing in 10- to 15-year-old children with listening difficulties. *J Speech Lang Hear R*. 2014;57(6):2308-2321. [Crossref]
18. Johnson ML, Bellis TJ, Billiet C. Audiological assesment of (C) APD. Geffner D, Ross-Swain D, editors. Auditory Processing Disorders-Assesment, Management and Treatment. UK: Plural Publishing; 2007.p.75-94.
19. Liu SY, Liu TC, Teng YL, Lee LA, Lai TJ, Wu CM. Environmental sounds recognition in children with cochlear implants. *PloS One*. 2013;8(6):e66100. [Crossref]
20. Eisenberg LS, Shannon RV, Martinez AS, Wygonski J, Boothroyd A. Speech recognition with reduced spectral cues as a function of age. *J Acoust Soc AM*. 2000;107(5 Pt 1):2704-2710. [Crossref]
21. Bellis TJ, Bellis JD. Central auditory processing disorders in children and adults. Celesia G, Hickok G, editors. Handbook of Clinical Neurology. Amsterdam: Elsevier; 2015.p.537-556. [Crossref]
22. Vilela N, Sanches SGG, Carvallo RMM. Development of auditory perception in preschool children. *Int J Pediatr Otorhinolaryngol*. 2020;129:109777. [Crossref]
23. Yaralı M, Yagcioglu S, Guven AG, Aksoy S. Comparison of regularity detection between individuals with and without speech-in-noise problems using electrophysiological methods. *J Int Adv Otol*. 2016;12(3):271-276. [Crossref]
24. Hirsch IJ, Watson CS. Auditory psychophysics and perception. *Annu Rev Psychol*. 1996;47:461-484. [Crossref]
25. Eggermont JJ. The role of sound in adult and developmental auditory cortical plasticity. *Ear Hear*. 2008;29(6):819-29. [Crossref]
26. Reynolds CR, Voress JK, Pearson NA. Developmental test of auditory perception examiner's manual; 2008.
27. Rawool WV. Temporal processing in the auditory system. Ross-Swain D, Geffner D, editors. Auditory Processing Disorders-Assesment, Management and Treatment. UK: Plural Publishing; 2007.p.117-137.
28. Shan CH. A study of tonal patterns applied to teaching singing for seventh graders, Doctora thesis, (cited 2011 May 5): Available from: URL: http://ndltd.ncl.edu.tw/handle/84843546888798479823.
29. Meng X, Sai X, Wang XC, Wang J, Sha S, Zhou X. Auditory and speech processing and reading development in Chinese school children: Behavioural and ERP evidence. *Dyslexia*. 2005;11(4):292-310. [Crossref]

Appendix A. Turkish developmental test of auditory perception (TR-DTAP)

Item number	Enviromental sounds	Word discrimination	Phonemes in isolation	Tonal pattern	Rhyming sounds
1	oyuncak korna/düdük sesi	tren-tren	p-t (pay-tay)	/._./-/._./	haz-naz
2	bowling topu sesi	sert-ser	ü-ü (kül-kül)	/.._../-/._.._/	fes-feyz
3	korna/vapur sesi (kalın/ince)	semt-semt	ii-i (fiil-fil)	/_ _ _/-/.._/	tek-terk
4	kapı kapanma sesi	kan-can	t-v (ter-ver)	/._._ _/-/_..../	bot-kot
5	bir şeyin kırılma sesi	aksi-eksi	u-i (but-bit)	/.../-/...._/	kip-tip
6	posta kutusunun kapanma sesi	mor-mor	i-i (giy-giy)	/.._../-/.._../	alt-al
7	aslan/kaplan sesi	buz-tuz	f-t (fren-tren)	/..../-/_.../	kist-jest
8	inek sesi	sap-şap	m-m (muz-muz)	/._../-/.._./	radar-kadar
9	gerçek ördek/oyuncak ördek sesi	pim-prim	ç-ş (çık-şık)	/...._/-/.../	mor-bor
10	oyuncak ördek sesi	fiil-fil	a-e (sen-san)	/._ _/-/._ _/	pis-pas
11	fermuar sesi	kamp-kamp	f-f (fon-fon)	/._ _ _/-/_ .._/	faks-raks
12	kedi sesi	diyagram-diyafram	i-e (biz-bez)	/...../-/._ _ _/	dört-ört
13	kapı sesi	tat-tayt	b-p (bul-pul)	/_ _ _./-/_ _ _/	mit-ümit
14	kavga/yumruk sesi	omur-emir	o-i (sol-sil)	/_._./-/._./	but-bot
15	motosiklet sesi	çapa-çaba	k-g (kel-gel)	/_ _../-/_ _../	pan-van
16	makineyi çevirme (tilt)/kapı sesi	fark-fark	a-a (fal-fal)	/._../-/..../	kov-şov
17	uyarı/siren sesi	san-sen	f-v (fer-ver)	/.../-/..../	tost-test
18	vahşi hayvan sesi	ben-bin	a-o (kat-kot)	/..../-/..../	post-tost
19	oyuncak düdük sesi	tos-tost	z-z (bez-bez)	/.._ _/-/.._/	kapı-katı
20	araba kontağı sesi	lens-lens	o-e (ton-ten)	/._./-/._./	ast-kast
21	basketbol topu sesi	file-fire	oy-oy (boy-boy)	/_ _ _ _ _/-/_ _ _ _ _/	kes-ses
22	polis sireni	tur-vur	s-z (siz-zil)	/._._./-/._._/	kit-kist
23	ambulans sesi/polis sireni	loto-loto	s-t (siz-tiz)	/._ _./-/._ _/	mor-sor
24	çiftlik hayvanları sesi	sinek-bilek	a-u (kaş-kuş)	/_./-/._./	serin-derin
25	uçak kalkış/iniş sesi	her-ver	h-h (hat-hat)	/.._/-/_../	heyt-beyt
26	at kişneme sesi	acı-açı	u-e (kul-kel)	/._._./-/._._./	hun-sun
27	demir kapı sesi	yalan-yalan	st-st (stok-stok)	/._._/-/._._/	üst-ast
28	cam kırılma sesi	tok-tok	e-e (set-set)	/_.._/-/_.._/	kin-çin
29	at sesi	sarar-zarar	p-t (post-tost)	/_._ _/-/_ _ . _/	senet-sinek
30	çocuk ağlama sesi	kar-gar	o-u (kol-kul)	/._ _/-/_ _./	kol-kel
31	-	-	l-r (klon-kriz)	-	-