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Relationship between auditory processing skills and academic achievement of elementary school children

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Aim. This study aimed to determine the prevalence of auditory processing difficulties in children and to examine possible relationships between auditory processing skills and school success. *Method*. In this study, a screening test Auditory processing disorder - (*Croatian*: PSP – 1) was used to determine the prevalence of auditory processing difficulties in elementary school children in Croatia. Furthermore, correlations between screening test, grade point average, and subjective assessment scores for reading, writing, and math were analyzed. A total of 412 participants from mainstream schools were grouped based on their chronological age and grade. *Results*. The findings revealed that 12 (approximately 2.9%) participants exhibited difficulties in the assessed auditory processing tasks, which is consistent with data from other studies indicating that between 2% and 5% of children have an auditory processing disorder. Specifically, the two auditory tasks involving dichotic listening proved to be the most challenging for all participants. The results indicated that students' academic performance, as measured by grade point average and teachers' ratings of students' academic and language skills, was poorer in students having pronounced auditory processing difficulties when compared to their same-grade peers. Teacher ratings were significantly correlated with screening test scores, whereas students grade average was not. *Conclusions*. The analysis also revealed that screening total scores were significantly positively correlated with teachers' ratings of students' reading, writing, and mathematical skills. These skills also correlated highly with students' average grades. These findings corroborate the notion that auditory processing deficits are inversely correlated with academic achievement, warranting further research into the diagnosis and management of Auditory processing difficulties.

Keywords: auditory processing difficulties, children, PSP-1, teacher assessment

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Introduction

Auditory processing disorder (APD), also recognized as central auditory processing disorder (CAPD), can be defined as a deficit in the ability to process and channel information through the auditory system and is reflected in difficulty in some or all of the following auditory abilities: sound localization and lateralization; auditory discrimination; auditory pattern recognition; temporal aspects of audition and auditory performance in competing and degraded acoustic signals (American Speech-Language-Hearing Association [ASHA], n.d.). Therefore, auditory processing serves a major role in the learning process and language abilities (Bellis & Bellis, 2015). The act of processing speech is very complex, encompassing the engagement of auditory, cognitive, and language mechanisms, often simultaneously (Medwetsky, 2011). The reported prevalence of APD varies greatly in the literature. Hind et al. (2011) provided an estimate of 0.5 – 1% of APD in children and adults. Other researchers suggested that approximately 2% – 5% of school-age children have APD (Bellis, 2007; Palfery & Duff, 2007), whereas a study conducted by Musiek et al. (1990) provided data indicating a prevalence of 7% of APD in childhood. More recently, Brewer et al. (2016) suggested that the prevalence of pediatric APD might be around 10% when occurring with common comorbid developmental disorders. It is noteworthy to mention that varying diagnostic criteria for APD were employed across these prevalence studies. Several studies have explored the prevalence of suspected APD, such as a recent study that reported a 9-11% prevalence using the Dichotic Digits Test (DDT) as a screening tool for APD with a large cohort of 7-12-year-old children (Skarzynski et al., 2015). Similarly, Moloudi et al. (2018) reported a 9.8% prevalence of suspected APD in 8-to 12-year-old Iranian children based on data from an APD questionnaire and two auditory processing tests. The results of these studies indicate that a significant number of elementary school children have difficulty processing auditory information, which in turn may negatively impact their academic performance.

Commonly reported behavioral characteristics associated with APD include difficulty comprehending speech in competing or reverberant environments, issues with sound source localization, frequent requests for repetition of auditory information, misunderstanding spoken messages, sensitivity to loud sounds, difficulty following rapid speech and complex auditory directions, delays in responding to spoken instructions or exhibiting inconsistent or inappropriate responses to spoken messages, distractibility by background sounds, inconsistent or inappropriate responses to spoken instructions, inattentiveness and distractibility, and literacy difficulties (DeBonis & Moncrieff, 2008; Geffner, 2019; Hamaguchi & Tazeau, 2007). Due to the fact that there is a substantial overlap in the above-mentioned characteristics with those associated with other cognitive and linguistic disorders (American Academy of Audiology [AAA], 2010), some researchers have questioned the validity of defining APD as a unique disorder. However, the majority of evidence supports the claim that 'APD is a deficit in neural processing that may coexist with, but is not the result of, dysfunction in other modalities' (ASHA n.d., 2005). School-age children with APDs may also present with various characteristics of language, reading, and spelling disorders as well as attention problems (Chermak et al., 1999). Well-established associations between APD and literacy and academic problems, as well as between APD and speech and language disorders, have been described in previous research (Bamiou et al., 2001; Banai & Kraus, 2006; de Wit et al., 2018; Dawes & Bishop, 2009; Dawes et al., 2009, Sharma et al., 2009). Similarly, high levels of comorbidity between APD and dyslexia (Iliadou et al., 2009; Sharma et al., 2009), specific language impairment (Ferguson et al., 2011; Miller & Wagstaff, 2011; Sharma et al., 2009), and attention disorders (Dawes et al., 2008) have been established. Given such difficulties, children with APD are at greater risk for academic difficulties and school failure (Chermak & Musiek, 2014). This is partially due to the fact that these children receive (auditory) information differently and have difficulties in memorization and recall of information, which in turn negatively affects academic and social outcomes (Yalçınkaya et al., 2009).

Due to the existence of differing guidelines and criteria and the lack of 'a gold standard' for diagnosing APD, valid diagnosis of APD in children continues to pose a challenge. Therefore, many studies have used the term 'suspected APD' or 'auditory processing difficulties' to describe individuals who have listening difficulties and score poorly on some of the assessed auditory processing tasks (de Wit et al., 2016). Despite the lack of a universally accepted definition, diagnostic criteria, and management protocol, the general public is becoming increasingly aware of the concept of APD, which has contributed to more referrals for auditory processing assessment (Bellis, 2011). Heine et al. (2016) concluded that the majority of referrals for audiological and auditory processing testing of students with APD came from school employees, including administrative staff, teachers, and special education personnel. Suspected speech and language disorders and problems in literacy and academic achievement were the most frequent reasons for making a referral for APD testing.

These reasons for referral are understandable, considering that they are observable even in mild cases of APD, especially with increasing chronological age. For example, adolescents with even mild APD have demonstrated decreased grade point average and academic performance compared to their peers (Heine & Slone, 2008). Similarly, both students diagnosed with APD and those referred for APD testing, but not diagnosed, score lower on standardized tests of reading, language, and mathematical knowledge compared with peers (Ferguson et al., 2011; Moore et al., 2010).

Findings from previous studies seem to indicate that there is a number of students enrolled in mainstream schools who do not have adequate auditory processing skills needed for optimal achievement in literacy and language. This, in turn, limits their achievement in related academic areas. Considering that the consequences of poorer auditory processing skills can be alleviated to some extent by including modifications in the teaching process, it is crucial to estimate the proportion of students with suspected APD. Precise estimation allows for adequate support planning in the school system.

For example, in Croatia, the primary educational system consists of eight grades of compulsory elementary school. In the first four grades, the curricula of the Croatian language, mathematics, and sciences are always taught by a single teacher. The homeroom teacher creates teaching plans, delivers content and assesses students, monitors students' academic progress, and refers students exhibiting learning-disruptive difficulties to other professionals. Due to their important role in tailoring the teaching process to the individual needs of students, it is crucial to educate teachers regarding auditory processing difficulties students might have.

Research Aim

The aim of this paper was to evaluate the auditory processing skills of elementary school children (as determined by their performance on different auditory processing tasks) as a function of age and gender. Also, the aim was to determine the prevalence of auditory processing difficulties in elementary school students. Finally, this study was aimed at examining possible relationships between auditory processing skills and school success.

Methods

Variables

The following variables related to participants were used in order to assess the study aims:

Age group (determined by their chronological age);

Gender;

Teacher's rating of academic skills (reading, writing, and math) and speech and language skills;

Grade point average;

Overall performance on PSP-1 test and performance on four PSP-1 subtests: Filtered Words, Speech in Noise, Dichotic Words, Dichotic Sentences.

Participants

A total of 412 children (218 boys and 194 girls) attending grades 1 to 4 in mainstream schools in Croatia participated in the study. Children with a previously established diagnosis of hearing loss, intellectual deficits, and learning disorders were excluded from the study. Furthermore, twenty-eight participants could not complete the auditory processing assessment in a single session due to attention problems, which subsequently led to their exclusion. The children were recruited from primary schools across Croatia. The participants were divided into four subgroups according to their grade: 125 in the first grade (M = 7.6 years, SD = 0.6 years), 100 students in the second grade (M = 8.5 years, SD = 0.5 years), 92 third grade students (M = 9.5 years, SD = 0.5 years) and 95 fourth grade students (M = 10.5 years, SD = 0.4 years).

All participants were informed of the research study in writing, and consent forms were signed by their parents. The study was approved by the institutional ethics committee.

Tests and procedures

Participants' teachers evaluated their students' reading, writing, and mathematical skills and assessed their speech and language abilities by rating each of these skills on a three-point scale (below average, average, or above average, in comparison to other classmates).

The PSP-1, a behavioral test battery used for auditory processing disorder screening, was administered to all children. This test battery contains four subtests – filtered words, speech in noise, competing (dichotic) words, and competing (dichotic) sentences – and is the only standardized behavioral assessment of auditory processing skills for children aged 5.5 – 11.5 years in Croatia. All test signals and stimuli were acoustically edited using the Adobe Audition ver. 2.0 software and stored on CD along with the calibrating sound for determining sufficient loudness. Analysis of the psychometric properties of the PSP-1 battery indicated that the four subtests demonstrate good reliability, as indexed by Cronbach's alpha values ranging from 0.650 to 0.895, and good concurrent validity, as determined using exploratory factor analysis (Hedjever et al., 2013). All subtests on the PSP-1 are verbal and use speech stimuli that are recorded on a CD and presented by a female native Croatian speaker.

The first subtest, filtered words (FW), contains two-word lists, each containing 17 words that are phonetically balanced between the ears. Before administering test items, participants heard two test items in each ear. The stimuli are presented monaurally as a series of low-pass filtered stimuli with a cutoff frequency of 1 kHz and a roll-off of 32 dB per octave. The percentage of correctly repeated words in both ears determined the score.

The second subtest, labeled speech in noise (SiN) or auditory figure-ground, is also a monaural, low redundancy task in which target words are presented over background babble noise at a greater intensity of 8dB SPL. The background noise is unintelligible babble noise of constant intensity. This subtest contains two training words per ear followed by two test series of 17 words per ear. The word stimuli for each ear are different, but phonetically balanced in each word list. The score is determined by the percentage of correctly repeated words in both ears.

Dichotic speech tasks encompassed dichotic words and dichotic sentences tasks, assessing binaural integration and separation abilities. These tests assess the central auditory nervous system and are often used in auditory processing testing (Weihing & Atcherson, 2014). In a dichotic words (DW) task, one word is presented in one ear while simultaneously presenting another word in another ear, requiring participants to divide their attention between the two ears and then report the stimuli heard in both ears. The word pairs are balanced regarding the frequency/intensity spectrum of the words as well as regarding the place and manner of consonant articulation in the word pairs. Furthermore, binaural pairs were balanced based on their duration at an accuracy level of 1 ms. The task is comprised of 60 different words, with 15 target words per ear. Prior to the test set, there are two dichotic training sets per ear. The percentage of correctly repeated words determines the score for each ear, in addition to the total subtest score for both ears.

The dichotic sentences (DS) task assesses binaural separation abilities. The participant is required to repeat the sentence heard in the designated ear after two sentences are simultaneously heard in both ears. Binaural sentence pairs are equalized based on their duration and onset at an accuracy level of 1 ms. Prior to administering the test sets, which consist of a total of 40 different sentences or 10 sentence pairs per ear, two training sets were presented for each ear. Each training set is comprised of one dichotic pair of sentences. The total subtest score is calculated as the sum of percentages of correctly repeated sentences in each ear.

Test administration

Teacher's three-point scale rating of reading, writing, mathematical skills, and speech and language abilities was obtained for each student. Also, background data for each student, including grade point average, was provided by school administrators.

Testing was conducted individually in a quiet room by a trained examiner. The PSP-1 test battery was administered in a single test session that lasted between 35 and 45 minutes, using a computer with headphones (Numark HF-125). All subtests were presented at a comfortable level of 65 dB SPL. For all participants, the four PSP-1 subtests were presented in the same order: (1) the FW test, (2) the SiN test, (3) the DD test, and (4) the DS test. In all tasks, the right ear was always assessed prior to the left ear. All participants were provided the same detailed test instructions and offered practice items to familiarize themselves with each listening task. Performance on training items was not scored nor included in the total result for each subtest. The participants were required to provide their answers orally.

Statistical analyses

Statistical analyses were performed using SPSS, version 21. Data were checked for normality using a Shapiro – Wilk test of normality and via visual inspection of normal QQ plots. The results indicated that several variables and age categories followed a skewed, non-normal distribution. Descriptive statistics were performed.

Also, the Mann–Whitney U test (MWU), Kruskal-Wallis H test, and Wilcoxon signed rank (WSR) tests were used to test for gender, ear, and age and age-specific ear differences, respectively.

Results

Descriptive statistics for each age group are presented in Table 1. Using boxplots, Figures 1a, 1b, 1c, and 1d present the results of the PSP-1 subtests divided by age group and ear, expressed as percent correct responses. On average, filtered words was the most challenging subtest, where the percentage of correct responses ranged from 54.3% to 69.4% across age groups. In contrast, the dichotic sentences subtest appears to have been the least challenging for all age groups, with scores ranging from 77.7% to 93% correct responses.

Table 1

Descriptive statistics for participant grades and performance on individual subtests and overall score on PSP-1 test

GRADE		N (M/F)	M	(%)	SD	Min.	Max.
1	FW	125	18.46	54.3	3.91	8	28
	SiN	125	18.50	66.1	2.62	13	26
	DW	125	44.02	73.4	8.22	18	57
	DS	125	15.55	77.7	3.64	4	20
	Overall	125 (65/60)	94.84		12.94	59	119
2	FW	100	20.54	60.4	4.07	10	29
	SiN	100	20.08	71.7	2.85	13	26
	DW	100	47.03	78.4	6.40	26	57
	DS	100	16.9	84.5	3.08	6	20
	Overall	100 (55/45)	101.37		13.00	67	127
3	FW	92	23.01	67.7	3.33	14	28
	SiN	92	21.87	78.1	2.67	16	27
	DW	92	49.55	82.6	5.22	27	57
	DS	92	18.45	92.2	2.04	10	20
	Overall	92 (53/39)	110.61		9.93	86	130
4	FW	95	23.61	69.4	3.04	17	33
	SiN	95	21.59	77.7	2.29	14	26
	DW	95	51.97	86.6	4.34	39	59
	DS	95	18.60	93.0	1.89	10	20
	Overall	95 (45/50)	115.13		8.42	84	130

Note: Participants were divided into four grades.

Legend: FW – Filtered Words subtest, SiN – Sound in Noise subtest; DW – Dichotic Words subtest; DS – Dichotic Sentences subtest; M – males; F – females

Descriptive analysis revealed differences between age groups for both total PSP-1 scores and subtest scores, where performance increased with age. Overall, a statistically significant difference between groups was found for the total PSP-1 score ($\chi^2(3) = 140.924$, $p < 0.001$). Post hoc tests were conducted to test pairwise comparisons on total PSP-1 score, revealing that group 2 had significantly higher scores than group 1 (χ^2 (1) = 54.49.84, p =0.017), group 3 had significantly higher scores than group 2 (χ^2 (1) = 82.51.24, $p < 0.001$), and finally, group 4 performed significantly better than group 3 (χ^2 (1) = 52.29, p = 0.008). Similar trends were observed when examining the PSP-1 subtest results, presented in Figures 1a, 1b, 1c, and 1d.

No significant gender differences were found in overall PSP-1 performance (U (1) = 23 617, p = 0.154).

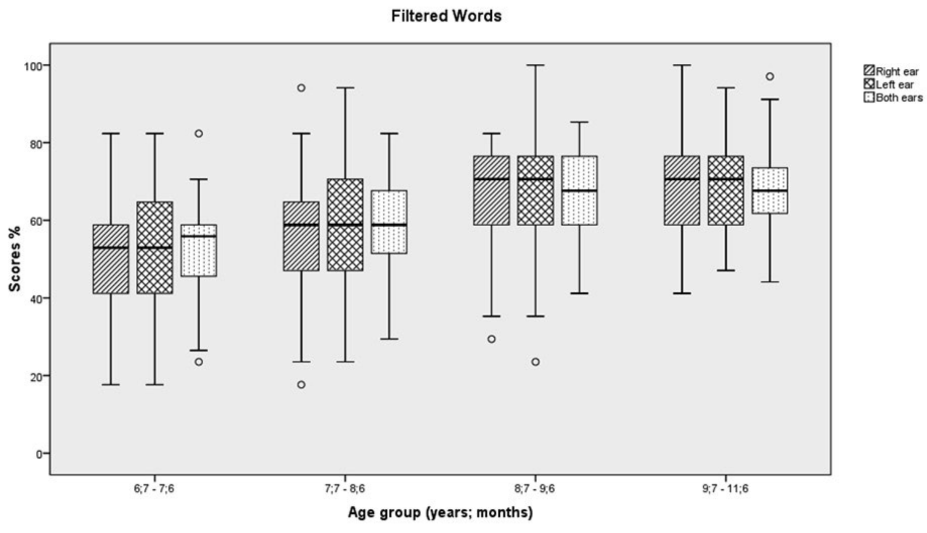
Filtered Words

In the Filtered Words subtest, post hoc pairwise comparisons revealed significant differences between all adjacent groups, exhibiting better performance with increasing age, except between the performance of the two older groups (3 and 4), where the same trend was observed but without reaching statistical significance.

No difference between genders was found on the Filtered Words subtest (U = 37935.5, p = 0.389). Finally, no significant ear differences were found on the Filtered Words subtest (Z = -1.742, p = 0.082).

Figure 1a

Performance on Filtered Words subtest by age group and ear



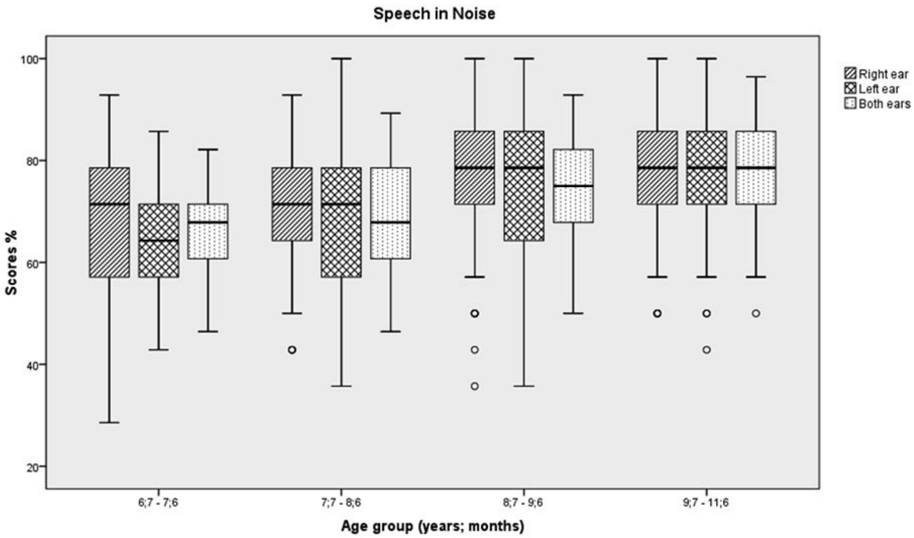
Speech in Noise

For the Speech in Noise subtest, the only significant difference was observed between groups 2 and 3 (χ^2 (1) = -59.60, p = 0.001).

Both boys and girls performed similarly in the Speech in Noise subtest (SiN, U = 36128.5, p = 0.890). Also, no differences between participants' right and left ear on this subtest were found to be statistically significant (Z = -0.851, p = 0.395).

Figure 1b

Performance on Speech in Noise subtest by age group and ear



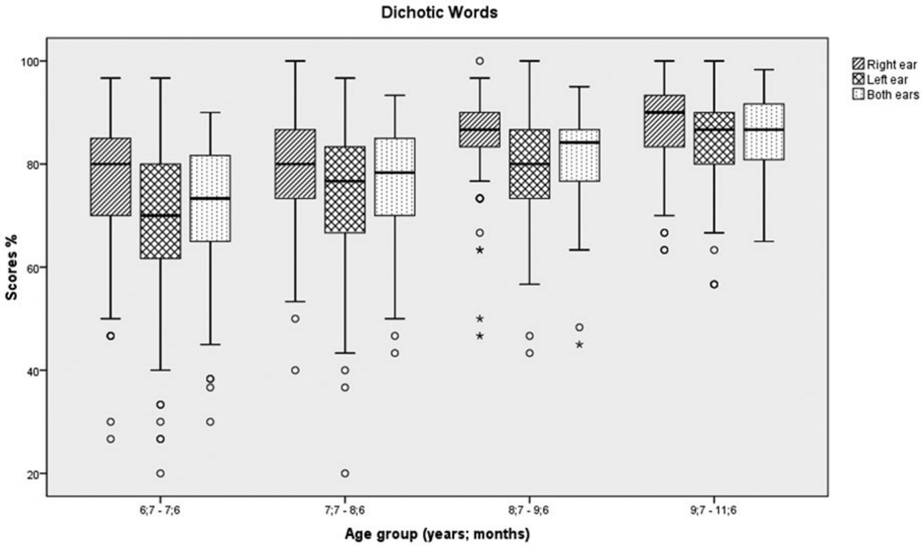
Dichotic Words

Performance on the Dichotic Words subtest was significantly different between adjacent age groups, except for the two youngest groups.

No significant gender differences were observed in the Dichotic Words subtest (U = 39286.5, p = 0.11).

Figure 1c

Performance on Dichotic Words subtest by age group and ear



Dichotic Sentences

Although performance on the Dichotic Sentences subtest was better with increasing age, the only significant difference was found between the two oldest groups.

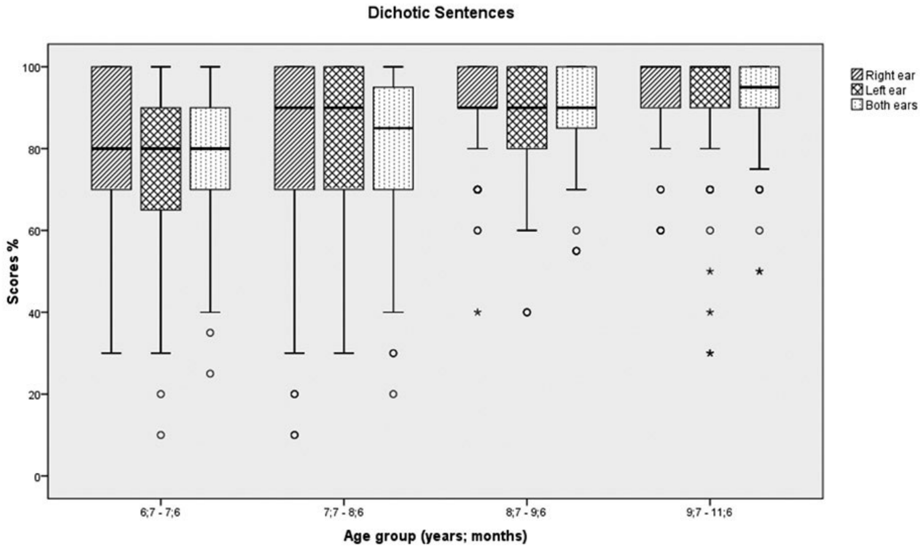
No significant difference between the performance of boys and girls on the Dichotic Sentences subtest was found (U = 39147, p = 0.12).

As expected, an ear effect in the dichotic speech tests was observed, where significantly better results in the right ear, or a right-ear-advantage (REA), was noted for Dichotic Words (Z = -8.60, p = 0.001) and Dichotic Sentences (Z = -7.22, p = 0.001) subtests. Furthermore, age-related ear differences were noted on the Dichotic Sentences task, where the right ear advantage decreased with increasing age. Although a similar trend for the Dichotic Words task could be observed, no statistically significant differences were noted for this task.

Scores on all PSP-1 subtests and the total PSP-1 score demonstrate strong positive and significant correlations (Table 2), with dichotic listening tasks exhibiting the highest correlation coefficient.

Figure 1d

Performance on Dichotic Sentences subtest by age group and ear



Relationship between the PSP-1 test results and academic achievements

As evident in Table 2, students' chronological age was strongly correlated with PSP-1 subtest scores and a total score, indicating a developmental relationship between age and auditory processing skills. Gender was not significantly correlated with total PSP–1 score, nor with PSP-1 subtest scores.

Teacher ratings of reading, writing, mathematics, and language were all significantly moderately interrelated. Also, teacher evaluations of students' reading, writing, mathematical, and language skills had significant moderate correlations with grade point averages, indicating a partial congruency between subjective and objective assessments of students' academic skills (0.334 – 0.506, $p \leq 0.01$). Furthermore, all teachers' ratings were significantly associated with PSP-1 total results. The strongest correlation was evident in teachers' ratings of students' language skills (0.305, $p \leq 0.01$) and reading ability (0.239, $p \leq 0.01$) that were significantly correlated with the PSP-1 total score. These two teachers' assessments were also significantly correlated with all four PSP-1 subtest results (please see Table 2). However, student grade point averages were not correlated with PSP-1 scores.

Table 2

Correlation between age, gender, students' grades, teacher ratings and performance on the four PSP-1 subtests and the overall PSP-1 score

	AGE	GENDER	GPA	READ	WRITE	MATH	SPEECHLANG	FW	SiN	DW	DS	PSP-1 total
AGE	-	- .012	-.197**	.086	.048	-.029	. 112*	.482**	.433**	.450**	.389**	.568**
GENDER		-	.119*	.070	.205**	-.119*	.071	.050	.011	.069	.069	.069
GPA			-	.482**	.452**	.506**	.334**	.021	-.008	.130*	.088	.094
READ				1	.539**	.472**	.442**	.112*	.128*	.247**	.195**	.239**
WRITE					1	.427**	.312**	.046	.051	.187**	.137**	.156**
MATH						1	.322**	.049	.129*	.124*	.170**	.149**
SPEECH LANG							1	.202**	.247**	.240**	.266**	.305**
FW								1	.492**	.460**	.477**	.747**
SiN									1	.343**	.364**	.636**
DW										1	.629**	.879**
DS											1	.752**
PSP-1 total												1

Legend: GPA – students grade average; Read – teacher rating of student's reading ability; Write – teacher rating of student's writing ability; Math – teacher rating of student's mathematical knowledge; Language – teacher rating of student's language skills; FW – student's score on PSP-1 Filtered Words subtest, SiN – student's score on PSP-1 Speech in Noise subtest; DW – student's score on PSP-1 Dichotic Words subtest, DS – student's score on PSP-1 Dichotic Sentences subtest, PSP-1 total – student's overall score on PSP-1

Note: * = $p \leq 0.05$; ** = $p \leq 0.01$

Case analysis of students who failed the PSP-1 test

Results on the PSP-1 subtests indicate that, overall, up to 6% of participants across the entire age range achieved scores significantly below the average (i.e., 2 standard deviations below the mean) on at least one of the subtests, suggesting that these children have auditory processing difficulties. The pattern of performance on PSP-1 subtests among these children differs from the result patterns of participants scoring within or above the average. Findings indicate that the most challenging tasks for this group appear to be dichotic listening subtests. Interestingly, there is no difference in the number of participants who 'failed' any of the subtests between age subgroups, indicating a consistent proportion of children with significant difficulty in auditory processing tasks, regardless of chronological age (Table 3).

Table 3

Number and percentage of students with results ≤ 2 SD on each PSP-1 subtest and the total score

Grade	N	Subtest 1: Filtered words *N (%)*	Subtest 2: Speech in noise *N (%)*	Subtest 3: Competing words *N (%)*	Subtest 4: Competing sentences *N (%)*	Total *N (%)*
1	125	5 (4.0 %)	3 (2.4 %)	6 (4.8 %)	9 (7.2 %)	7 (5.6 %)
2	100	4 (4.0 %)	5 (5.0 %)	6 (6.0 %)	5 (5.0 %)	4 (4.0 %)
3	92	4 (4.3 %)	1 (1.1 %)	6 (6.5 %)	5 (5.4 %)	3 (3.3 %)
4	95	1 (1.1 %)	1 (1.1 %)	2 (2.1 %)	4 (4.2 %)	3 (3.2 %)

Although these results do indicate a certain degree of auditory processing issues for a number of children, we cannot presume that these children can actually be diagnosed with auditory processing disorder. However, after applying diagnostic criteria for APD (results ≤ 2 standard deviations on at least *two* PSP-1 subtests), 12 (2.9%) participants exhibited difficulties that can be categorized as auditory processing disorder. Details regarding these participants can be found in Table 4.

Among children in the first grade, all but one of the children diagnosed with APD had a lower grade average compared to the mean grade average of other first graders (M = 4.67, SD = 0.63). Similarly, one of two second-graders diagnosed with APD had a lower grade average when compared to the mean average for all second-graders (M = 4.42, SD = 0.71). A similar trend can be observed in the results of the third and fourth-grade participants with APD, where one of the two third-graders with APD exhibited a lower grade average compared to the mean grade average (M = 4.40, SD = 0.68) and both fourth-grade participants with APD had lower grade averages compared to their peers (M = 4.12, SD = 0.84).

Table 4

Academic-related information of participants identified as having auditory processing disorder

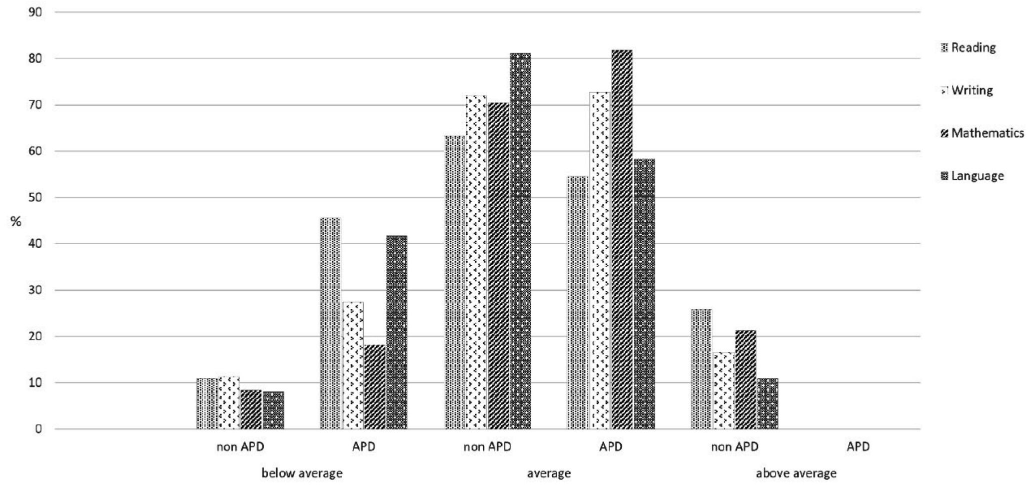
Participant #	Chronological Age	Grade	GPA	READ	WRITE	MATH	LANG
1	6.4	1	4.20	2	2	2	2
2	6.7	1	4.10	2	2	2	2
3	6.8	1	4.10	2	2	2	2
4	7.7	1	3.00	1	2	2	1
5	7.8	1	5.00	2	2	2	2
6	8.1	2	4.50	2	1	2	2
7	8.7	2	3.50	1	2	1	1
8	9.0	2	-	-	-	-	1
9	9.3	3	4.50	1	2	2	2
10	9.8	3	3.00	1	2	1	1
11	10.2	4	3.00	1	1	2	1
12	10.8	4	3.50	2	1	2	2

Legend: GPA – students grade average; Grade – current student's grade ranging from kindergarten to grade 4, READ – teacher assessment of student's overall reading skills, WRITE – teacher assessment of student's overall writing skills, MATH – teacher assessment of student's overall mathematical skills, LANG – teacher assessment of student's overall communication skills

This trend is also reflected in teacher evaluations of students' reading, writing, and mathematical abilities, as well as language skills, where the majority of participants with APD were assessed by their teachers as below average in at least one of the above-mentioned skills. Also, a much higher proportion of students rated poorly by teachers was found in the group of participants with APD than in the non-APD group, a finding that was evident in all areas evaluated by teachers (Figure 2). The greatest difference between the two groups of students (APD and non-APD) was found in teacher ratings of reading and language skills. Approximately 40% – 50% of students with APD were rated as below average in these skills, compared to only 8% – 11% of non-APD students. Interestingly, none of the 12 participants diagnosed with APD were assessed as above average in any of the assessed areas.

Figure 2

Proportions of students rated by teachers as below average, average and above average in academic-related skills



Discussion

The present study provided data on the prevalence of auditory processing difficulties in elementary school children and examined possible relationships between their auditory processing skills and academic achievement. Because children were assessed using an APD test battery without having undergone current psychological and audiological evaluation, the term 'suspected' is used cautiously here. However, because strict cutoffs were applied in the PSP-1 test battery, there is a high level of certainty that the reported percentage reflects the true APD prevalence in this population.

The findings indicated differing relative patterns of performance on the four auditory processing tasks used in this study. Children identified as having auditory processing difficulties achieved poor scores in dichotic listening tasks, including both binaural separation and integration, as compared to their performance on the other two tasks. Auditory processing difficulties become more pronounced in challenging listening situations, such as noisy backgrounds or poor acoustic environments (Sloan, 1998), which are often found in classrooms. In contrast, performance on dichotic tasks was superior in comparison to the filtered words task and speech in noise tasks for participants without auditory processing problems. In addition, the findings of this study demonstrated no gender effect, a finding that is corroborated by previous results (Fuente & McPherson, 2006; Keith, 2000; Mattsson et al., 2018; McDermott et al., 2016; Pedersen et al., 2017). Furthermore, the findings demonstrated patterns of improved test performance and decreased score variability with age.

The results of this study indicate a right-ear advantage (REA) in both dichotic listening tasks, which is similarly consistent with other findings (Iliadou et al., 2010; Mattsson et al., 2018, Moncrieff & Wilson, 2009, Pedersen et al., 2017; Shinn et al., 2005; Vanniasegaram et al., 2004). An age-dependent reduction in the right ear advantage was also noted, also corroborating findings from other studies (Moncrieff, 2011). Both the tendency for greater REA at a younger age and a maturation-influenced decrease in REA are thought to reflect the maturation of the corpus callosum fibers (Musiek & Weihing, 2011) and a left hemisphere dominance for linguistic processing (Mattsson et al., 2018; Moncrieff, 2011). However, on a non-dichotic task in the Filtered Words subtest, better performance of the left ear was found. This might be explained by a learning effect, as the order of stimuli presentation was always right ear first, followed by left ear.

The results showed that academic performance, as measured by grade point average, was poorer in students considered as having auditory processing disorder when compared to their same-grade peers. Although there was not a significant correlation between grade point average and auditory processing skills, the majority of students with APD (8 out of 12) did have lower grade average in comparison to the mean grade average. Teachers' assessment of students' academic and language skills was moderately correlated with students' grade point averages. However, whereas teacher evaluations were significantly correlated with total PSP-1 scores, there was no correlation between grade point averages and total PSP-1 scores. Furthermore, the strongest correlation between teachers' ratings and auditory processing skills was evident in reading and language skills. This was an expected finding, since progress in these academically relevant skills is greatly affected by the often-cited symptoms of APD, such as misunderstanding spoken messages, difficulty following complex auditory directions, delays in responding to spoken instructions or distractibility by background sounds, inconsistent or inappropriate responses to spoken instructions, inattentiveness and distractibility, and literacy difficulties (Geffner, 2019). It is also interesting to note the higher proportion of students with APD who received a 'below-average' rating from their teacher in reading, writing, mathematical abilities, as well as language skills compared to ratings of their non-APD peers. The greatest difference between the two groups of students (APD and non-APD) was found in teacher ratings of reading and language skills.

These findings highlight the importance of teacher assessments in identifying school-age children who might have auditory processing problems. This study provides insight into the prevalence of APD in Croatian school-age children and emphasizes the role of teachers in identifying children suspected of APD. Classroom teachers in the lower grades (1st-4th) of primary school deliver the curriculum and evaluate and monitor children's academic performance. Their broad knowledge and training in a variety of educational and associated issues enable them to successfully identify children suspected of various speech, language, and hearing problems. This study demonstrated that literacy and language skills and poor academic performance were connected to concerns regarding APD, a finding that is supported by previous findings (Heine et al., 2016). In children with APD, there is no problem with the recognition of letters (written or graphic forms). Their problems are combining the letter sounds and syllables and encoding. Moreover, there is also a problem in the process of decoding the graphic images or letters into sounds (Yalçınkaya et al., 2009). However, to ensure that children with auditory processing disorder receive comprehensive diagnostic assessment and effective treatment, a multidisciplinary team consisting of teachers, speech-language pathologists, psychologists, and parents needs to be involved (AAA, 2010; ASHA n.d., 2005); Bamiou et al., 2006; Emanuel et al., 2011). Furthermore, studies have indicated that teachers need additional training in APD symptomatology (Ryan & Logue-Kennedy, 2013) in order to be more efficient members of a multidisciplinary team involved in APD diagnostics.

Limitations and future research

Although the inclusion criteria for participation in this study included the absence of diagnosed hearing loss, intellectual deficits, and learning disorders, the authors did not carry out any formal diagnostic assessments, which might have been used to control for comorbidity of APD with language and learning disorders. Furthermore, the criteria for diagnosing APD recommended by (ASHA n.d., 2005) were followed (i.e., results of ≤ 2 standard deviations below the mean on at least two validated auditory processing tests). However, because the PSP-1, the only standardized APD test battery currently available in Croatia does not contain any subtests using non-speech sounds as stimuli, the (ASHA n.d., 2005) recommendation to use a non-verbal test was not followed. These limitations should be addressed in subsequent studies.

Conclusion

The main findings of this study confirmed the results of previous research stating the prevalence of APD in elementary school children is almost 3%. Students who did have pronounced auditory processing difficulties differed from their peers in the types of auditory tasks that were difficult. The current study also showed that these students struggled not only in processing auditory information but also tend to have poorer school success and were rated more poorly by their teachers in reading, writing, mathematics, and language skills. Therefore, findings point to the need for additional training in

APD symptomatology for elementary school (grade 1-4) teachers to become valued members of a multidisciplinary team supporting students with auditory processing disorder.

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Odnos između sposobnosti slušnog procesiranja i akademskog postignuća dece osnovnoškolskog uzrasta

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Cilj: Cilj ovog istraživanja je da utvrdi prevalenciju poremećaja slušnog procesiranja kod dece i ispita postojanje veze između veština slušnog procesiranja i uspeha u školi. *Metod*: Za utvrđivanje prevalencije poremećaja slušnog procesiranja kod školske dece u Hrvatskoj korišćen je skrining test Poremećaj slušnog procesiranja – 1 (PSP – 1). Pored toga, analizirane su korelacije između rezultata na skrinig testu, ukupne srednje ocene i rezultata subjektivnih procena čitanja, pisanja i matematičkih sposobnosti. Ukupno 412 učesnika iz redovnih škola je grupisano na osnovu hronološkog uzrasta i razreda. *Rezultati*: Rezultati ukazuju da je 12 učesnika (približno 2.9%) imalo poteškoće na zadacima slušnog procesiranja, što je u skladu sa rezultatima drugih studija prema kojima se poremećaj slušnog procesiranja javlja kod 2-5% dece. Dva zadatka vezana za dihotičko slušanje su se pokazala kao najizazovnija za sve učesnike. Rezultati pokazuju da su postignuća učenika u školi, merena ukupnom srednjom ocenom i procenama njihovih akademskih i jezičkih veština od strane nastavnika, bila lošija kod učenika sa izraženim poremećajem slušnog procesiranja u poređenju sa vršnjacima iz istog razreda. Rezultati na skrinig testu Poremećaj slušnog procesiranja značajno koreliraju sa procenama nastavnika, ali ne i sa ukupnom srednjom ocenom. *Zaključak*: Značajna pozitivna korelacija je utvrđena i između ukupnih rezultata na skrinig testu i procenama čitanja, pisanja i matematičkih sposobnosti učenika od strane nastavnika. Ove sposobnosti učenika takođe značajno koreliraju sa njihovim srednjim ocenama. Ovi nalazi potvrđuju ideju da je poremećaj slušnog procesiranja u obrnutoj korelaciji sa postignućem u školi, što opravdava dalja istraživanja vezana za dijagnozu i tretman poremećaja slušnog procesiranja.

Ključne reči: poremećaj slušnog procesiranja, deca, PSP-1, procena nastavnika

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