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RESEARCH ARTICLE

Preliminary standardization of consonant-vowel in noise test in normal Persian speaking children

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Abstract

Background and Aim: Children have more difficulty in understanding speech in noisy environment than adults. Different tests are available for evaluation of speech perception ability in noise in children, each examines different levels of auditory system. The present study aimed to obtain normative data for consonant-vowel in noise test for 8–12 years old Persian-speaking children.

Methods: A hundred and sixty children were selected in five age range groups of 8 to 12 years old (32 children in each age range) with normal hearing from school students in Tehran. The audiometry test was performed in octave interval between 500–4000 Hz. Then the consonant-vowel test was first performed in silence and then in signal-to-noise ratios (SNRs) of +12, +6, 0, −6, −12, at the listening comfort level and randomly in children ears.

Results: There were significant differences between age range of 8 and 9 years with other age groups in the SNR of −12. There was a significant difference in all children between the scores of left and right ears in −12, −6, 0 SNRs ($p < 0.05$). However, there was no specific pattern in each age group. The results showed that with increasing SNR, the scores of recognition of the syllables increased. Sex had no effect on consonant-vowel recognition in the presence of noise.

Conclusion: Recognition of the consonant-vowel in high SNR in both ears is stable before age 8, and this stability in the low signal-to-noise ratio is higher at around the age of 10.

Keywords: Speech perception; consonant-vowel in noise test; standardization; children

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Introduction

Speech perception in noise depends on both higher level (language and cognitive process) and lower level (perception of acoustic characteristics) functions [1]. Although peripheral auditory mechanism appears at early life, central auditory processing and higher level processing have more extended development trend [2]. Children's auditory function in silence is similar to adults. Because auditory structure in the brain is immature up to 10–12 years old and lack of automatic use of cognitive resources in

childhood, speech perception in noisy and reverberant environments is accompanied with more difficulty in children than adults [3].
There are various tests with different contents for evaluation of children's speech perception in noise function. Each test assesses a special location in the sensory or cognitive system based on the test materials [4]. Consonant-Vowel (CV) in noise test evaluates listening ability in noise. This test uses non-sense syllables. Test materials are monosyllabic and meaningless to maximize contribution of acoustic factors in the perception process and prevent effects of language clues. This test enables us to assess bottom-up pathways and subcortical in speech processing more precisely [5].
There are a few studies on consonants recognition in children [6-9]. Based on Neuman and Hochberg report, speech perception in 5–13 years old children is weaker than adults and at the age of 13, the results become similar. They also suggest that children and adults show comparable functions in silence [6]. Johnson compared the effects of noise and reverberation on recognition of consonants and vowels on non-sense syllables at different intensity levels in adults and children. They showed that children up to age 10 have less consonant recognition ability in noisy and reverberant conditions [7]. Nishi et al. studied American English consonants recognition and reported that increasing signal-to-noise ratio (SNR) from 0 to +10 improves recognition of non-sense syllables in the age-dependent manner [8]. Leibond and Buss studied recognition of 12 American English consonants in children and adults in the presence of speech-shaped noise and two-talker masker and reported that children's performance in speech-shaped noise and two-talker masker was lower than adults up to 10 and 13 years old, respectively. After these ages, their performance is comparable to adults [9].
In general, previous studies showed that children's recognition of consonants in noise differs from adults but improves with age. Therefore it seems essential to provide norms for CV in noise test score for different age groups in Persian speaking children. In this way, clinical and rehabilitation experts can have access to this information. Present study has conducted based on this necessity for establishing norm for children aged 8–12 years.

Methods

This is a cross-sectional comparative study. The study included 160 children (87 girls and 73 boys) in five age groups (32 students in each age group). The samples were selected based on available sampling from schools of District 6 in Tehran after official allowance from District 6 office of Ministry of Education. Inclusion criteria were as follows: both parents and children 8–12 years consent, normal (less than 15 dB HL for octave frequencies from 500 to 4000 Hz) and symmetric hearing (interaural threshold difference less than 10 dB) [10], normal otoscopy, right dominance based on Edinburg handedness scale [11], monoligualism (Persian native speakers), without psychological disorder, no professional musical activity, no history of head trauma, seizures, epilepsy, not under any neural system medications, no attention deficit problem, or developmental, behavioral and linguistic disorders.
Reliability and validity of Persian CV in noise test in adults has been confirmed. It consisted of 4 recorded lists presented in SNR −12, −6, 0, +6 and +12 dB. Each list has 25 non-sense CVs from combinations of /p/, /b/, /t/, /d/, /k/, /g/, /q/ consonants and long vowels. Syllables are /kā/, /gā/, /gī/, /gū/, /dā/, /dī/, /dū/, /tī/, /pī/, /pū/, /qī/, /qū/. In these 4 lists, lists number 2, 3 and 4 as well as lists 1 and 4 had high correlations [12].
The recorded materials are presented to each ear individually via circumaural headphones (Philips model; China) by using an Asus laptop (model K556U; Taiwan) and wave pad sound editor software at most comfortable level (MCL) 30 dBSL. Laptop and headphone were calibrated by an analog one-third octave sound level meter (model Bruel & Kjaer L2250; Denmark).
For calibration, headphone output level was set to the default and the output level of test stimuli from laptop was adjusted to 40 dB HL. To familiarize children with the test, at first lists

were presented in quiet. Then SNRs of −12, −6, 0, +6 and +12 dB were tested in a quiet room at school. Starting test ear (right or left) was random in children. Child was asked to repeat whatever was heard. In the study, two lists with high correlation in the previous studies were selected [12]. To eliminate learning effects, each list was presented to one ear. The time needed to complete the test in each child was about 9 minutes for each list and 20 minutes in total. The score was reported as correct response score in each SNR.

To describe data, mean and standard deviation were used. For checking normal distribution of data, Kolmogorov–Smirnov test was used. Effect of sex on results was tested by independent t-test and effect of test ear (right vs. left) was tested by paired-samples t-test. To test variance homogeneity, Levene's test was applied and variance homogeneity assumption was verified with significance level of 0.05. ANOVA test or Tukey test were used for comparing scores in different age groups. Repeated measurement was used for comparing different SNRs effects. Since the assumption of sphericity was not met, the Greenhouse-Geisser correction was applied and Bonferroni test was used for paired comparisons. SPSS 22 was used for data analysis at significance level of 0.05.

In the present study, all ethical considerations recommended by University of Social Welfare and Rehabilitation Sciences (USWR) were taken into account and the study was approved by USWR with ethical code of IR.USWR.REC. 1396,392. Participation in the study was based on obtaining an informed consent from all parents.

Results

In the present study, CV in noise test was performed on 160 children (87 girls and 73 boys) in 5 different age groups from 8 to 12 years old (32 in each group). They all had normal hearing without any neural or cognitive involvement. Test was conducted at quiet and then at SNR −12, −6, 0, +6 and +12 dB. Starting test ear in children (right vs. left) was random. Mean score for each ear in different age ranges were compared. Children's responses were scored based on the correct repeated CVs in each SNR for each ear separately. Fig. 1 shows the total mean score for all participants ($n = 160$) at different SNRs. As it is depicted, CV recognition was function of SNR and increased with SNR. The score variability was higher at lower SNRs. In the following section, scores for different age groups in each ear can be found for both sexes (independent t test). In general, children showed no significant score difference based on sex in none of the SNRs ($p > 0.05$) but the score in quiet was significantly different ($p = 0.017$).

In comparing sex effects, 8–11 years old age group showed no significant difference in none of the five SNRs (dB) but in 12 years old age group there was a significant difference in SNR +6 dB ($p = 0.033$), −6 dB ($p = 0.002$) and −12 dB ($p = 0.029$). The values for t with df = 158 and test power of less than 80% were $t(158) = -2.33$, $t(158) = 0.052$, $t(158) = 0.754$, $t(158) = -0.230$, $t(158) = 0.714$ and $t(158) = 0.456$ in quiet, SNRs of +12, +6, 0, −6 and −12 dB, respectively.

CV in noise test score was calculated based on mean score for each SNR in each individual ear. Fig. 2 shows mean scores for both ears in all SNRs in all test subjects. In general, children demonstrated a significant difference between two ears at SNR 0 ($p = 0.007$), −6 ($p = 0.001$) and −12 ($p = 0.002$) but there was not any statistical difference at SNRs of +6, +12 and quiet ($p > 0.05$).

Comparing mean scores of right vs. left ear showed no comparable pattern among age groups. The significant difference in different age groups were as follows: in 8 years old age group at SNR +6 ($p = 0.27$) and −6 ($p = 0.032$); in 9 years old age group at SNR 0 ($p = 0.021$), −6 ($p = 0.003$) and −12 ($p = 0.013$); in 11 years old age group at SNR 0 ($p = 0.02$) and −6 ($p = 0.012$); in 10 and 12 years old age groups no significant difference in none of the SNRs ($p > 0.05$). The value of t in quiet and at SNRs of +12, +6, 0, −6, −12 dB with df = 159 were $t(159) = -0.700$ with 10% power, $t(159) = -0.821$ with 12% power, $t(159) = 1.612$ with 36% power, $t(159) = 2.711$ with 78% power,

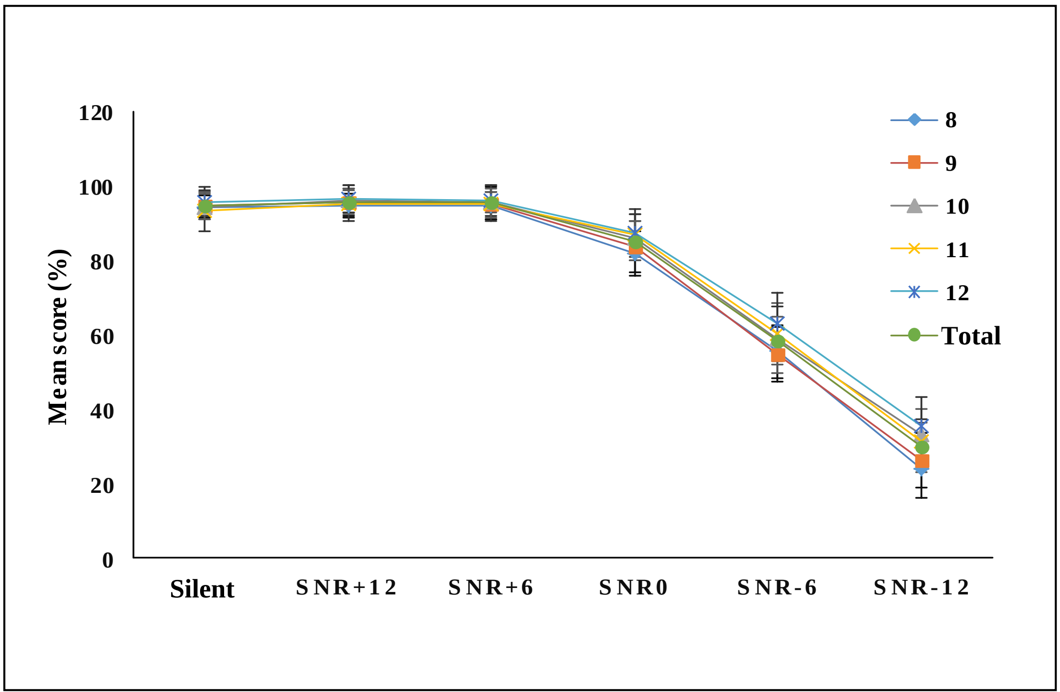

Fig. 1. Mean scores of consonant-vowel in noise test as a function of signal-to-noise ratio in each age group (n = 32 in each group, and n = 160 in total). SNR; signal-to-noise ratio.

t(159) = 3.283 with 90% power and t(159) = 3.099 with 86% power, respectively.

The mean score of CV in noise test was calculated for different age groups in each SNR for each ear separately (Table 1). ANOVA and multivariable ANOVA test was used for comparing total scores among five age groups. The results showed a significant difference at SNRs of 0, −6 and −12 dB between age groups ($p < 0.001$) but there was not any statistical significant difference in quiet and at SNR +6 and +12 dB ($p > 0.05$). The F value for quiet, SNRs of +12, +6, 0, −6 and −12 dB were F(4,155) = 1.394, F(4,155) = 0.855, F(4,155) = 0.510, F(4,155) = 5.192, F(4,155) = 6.546, F(4,155) = 13.611, respectively.

Mean and standard deviations of scores at different SNRs in all age groups are demonstrated in Fig. 1. It can be seen that that there are significant differences at 0, −6, and −12 dB. Tukey paired analysis in different age groups showed a significant difference between the following age groups: at SNR −12, between 8 years old age group with 10, 11 and 12 years old age groups $p < 0.001$); at SNR −12, between 9 years old age group with 10 ($p = 0.001$), 11 ($p = 0.025$) and 12 ($p < 0.001$) years old age groups; at SNR −6, between 8 years old age group with 12 years old age group (p =.001); at SNR −6, between 9 years old age group with 11 ($p = 0.047$) and 12 ($p < 0.001$) years old age group; at SNR 0, between 8 years old age group with 10 ($p = 0.030$) , 11 (P=0.005) and 12 ($p = 0.002$) years old age groups. There was no significant difference between 8 and 9 years old age group ($p > 0.05$). Also there was no significant difference between 10, 11 and 12 years old age group at any SNR ($p > 0.05$). Comparing results in different SNRs showed significant difference in all SNRs ($p < 0.001$) except between quiet and +6 dB ($p = 0.113$) and between +6 and +12 dB ($p = 1.00$).

Discussion

Based on previous studies, speech perception of children in noisy conditions is different from adults. There are different reasons for this finding, including myelin and secondary cortex

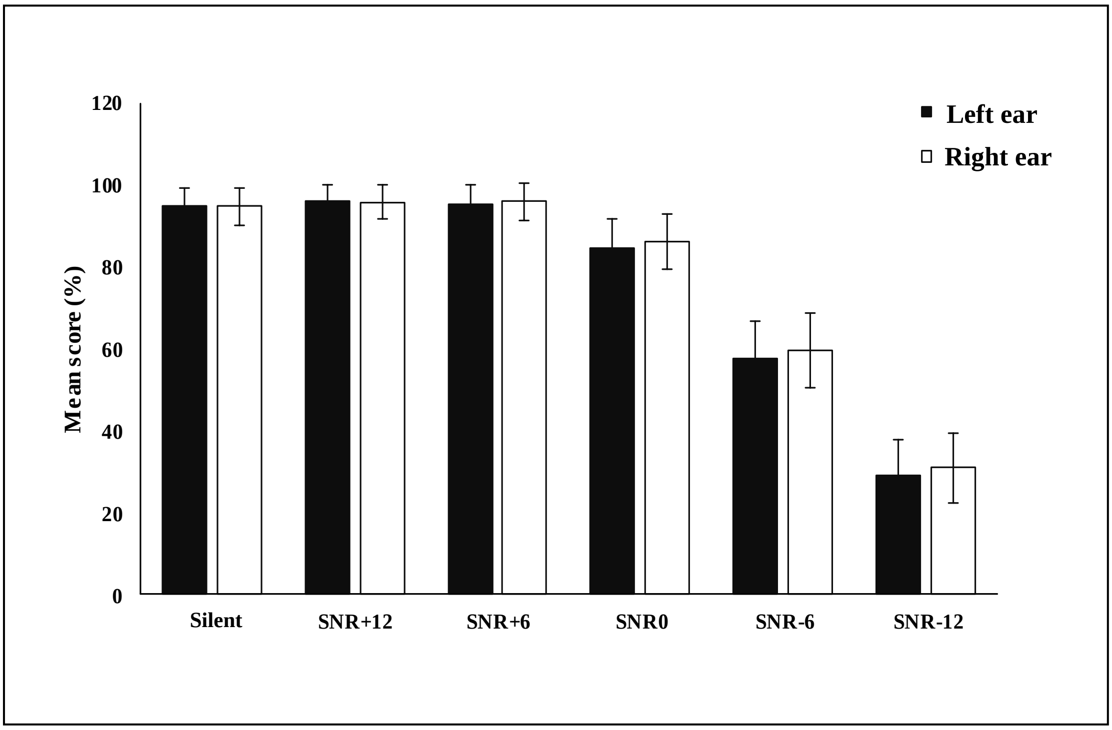

Fig. 2. Mean scores of consonant-vowel in noise test as a function of signal-to-noise ratio in the left and right ears in the total number of children. SNR; signal-to-noise ratio.

synapses difference up to adolescence, improvement of top-down skills due to brain growth and cognition in 7 to 11 years old [13] and neural coordination and phase locking. All these factors are important for resistance against adverse effects of noise on speech perception which improves with age [2].

In this study, mean CV in noise test score was evaluated at different SNRs. The results of the study indicate that syllable recognition score increases with SNR. This increase was lower at positive SNRs than negative ones. This finding was in agreement with Leibold and Buss findings. They suggested that consonant recognition performance in noise decreases with SNR reduction in children [9]. Nishi et al. showed that consonant recognition in noise depends on SNR [8] which is in agreement with the present study.

The comparison of CV in noise mean score among five age groups indicate that the score difference increases with SNR reduction which is in agreement with Leibold and Buss results [9]. Nishi et al. also reported that the score difference among age groups increased with SNR reduction [8].

The present study indicate no significant difference between any age groups at positive SNRs. This finding agrees with Danhauer et al. findings that reported children reach stable consonant recognition ability for positive SNRs at age 7 [14]. In the present study, there was a significant difference between 8−9 years old age groups with 10−12 years old age groups at SNRs 0, −6 and −12 dB. On the other hand, 10 years old age group showed no significant difference with 11 and 12 years old age groups. This demonstrates that mean score changes mostly accomplished by 10 years old and after that scores remain almost stable. This result is different from Leibold and Buss findings. They showed that consonant recognition had no significant difference between 8−10 years old and 11−13 years old age groups at SNR 0 and −5 dB. The disagreement between our study (one-year intervals) and Leibold and Buss

Table 1. Descriptive statistics of consonant-vowel in noise test scores in different signal-to-noise ratios in five age groups

Age groups (year)	Ear	Silent	+12 dB	+6 dB	0 dB	−6 dB	−12 dB
8 (n = 32)							
Mean (SD)							
	Right	94.75 (4.59)	95.25 (4.36)	96 (4.06)	83.12 (6.06)	57.12 (8.31)	24.87 (8.36)
	Left	94.37 (4.41)	94.87 (3.40)	93.75 (5.46)	80.62 (6.97)	53.87 (7.03)	23.12 (7.01)
Median							
	Right	94	96	96	84	56	24
	Left	92	96	96	80	54	24
Min-Max							
	Right	84−100	84−100	84−100	64−92	44−76	8−40
	Left	84−100	88−100	80−100	68−96	40−76	8−36
95 % Confidence interval (lower-upper)	**Right**	93.09−96.4	93.67−96.82	94.53−97.46	80.93−85.31	54.12−60.12	21.86−27.88
	Left	92.78−95.96	93.64−96.1	91.77−95.72	78.11−83.13	51.33−56.41	20.59−25.65
9 (n = 32)							
Mean (SD)							
	Right	94.12 (4.06)	95.75 (4.18)	96 (4.87)	85.25 (7.28)	56.62 (7.94)	27.62 (7.62)
	Left	95.62 (3.98)	95.75 (4.53)	95 (4.97)	82.4 (8.34)	53.25 (7.89)	24.75 (8.15)
Median							
	Right	92	96	96	86	56	28
	Left	96	96	96	80	52	24
Min-Max							
	Right	84−100	84−100	80−100	64−100	44−80	16−48
	Left	84−100	84−100	80−100	68−100	40−72	12−40
95 % Confidence interval (lower-upper)	**Right**	92.66−95.58	94.24−97.25	94.24−97.75	82.62−87.87	53.76−59.48	24.87−30.37
	Left	94.18−97.06	94.11−97.38	93.2−96.79	79.39−85.41	50.4−56.09	21.8−27.69
10 (n = 32)							
Mean (SD)							
	Right	94.50 (3.62)	95.75 (3.65)	95.62 (3.85)	85.50 (7.02)	59 (10.70)	34.25 (7.17)
	Left	94.62 (4.14)	96.62 (3.18)	96 (3.51)	87.12 (7.09)	59.25 (9.55)	32 (7.73)
Median							
	Right	92	96	96	88	58	32
	Left	92	98	96	88	56	32
Min-Max							
	Right	88−100	88−100	88−100	68−100	40−88	20−52
	Left	84−100	88−100	88−100	72−100	40−88	20−52
95 % Confidence interval (lower-upper)	**Right**	93.19−95.8	94.43−97.06	94.23−97.01	82.96−88.03	55.14−62.85	31.66−36.83
	Left	93.13−96.11	95.24−98	94.73−97.26	84.56−89.68	55.8−62.69	29.21−34.78

Table 1. Descriptive statistics of consonant-vowel in noise test scores in different signal-to-noise ratios in five age groups - continue

Age groups (year)	Ear	Silent	+12 dB	+6 dB	0 dB	−6 dB	−12 dB
11 (n = 32)							
Mean (SD)							
	Right	93.25 (5.69)	95.25 (5.32)	95.50 (5.63)	88.37 (5.95)	61.87 (9.14)	32.12 (6.46)
	Left	94 (6.18)	95.75 (4.86)	95.37 (5.48)	86 (5.83)	58.62 (7.22)	30.62 (7.90)
Median							
	Right	92	96	96	90	64	32
	Left	94	96	96	84	56	32
Min-Max							
	Right	80−100	80−100	80−100	76−96	40−84	12−52
	Left	80−100	84−100	80−100	72−96	40−72	20−48
95 % Confidence interval (lower-upper)	**Right**	91.19−95.3	93.33−97.16	93.46−97.53	86.22−90.52	58.57−65.17	29.79−34.45
	Left	91.77−96.22	93.99−97.5	93.39−97.35	83.89−88.10	56.01−61.23	27.77−33.47
12 (n = 32)							
Mean (SD)							
	Right	96.37 (3.42)	96.50 (3.76)	96.25 (3.92)	88 (7.18)	63.37 (8.07)	34.62 (9.23)
	Left	95.50 (3.62)	96.75 (3.43)	96.25 (4.05)	87.12 (5.98)	63.12 (8.54)	34.12 (8.05)
Median							
	Right	96	96	96	88	62	32
	Left	96	96	96	88	64	32
Min-Max							
	Right	92−100	88−100	88−100	72−100	52−80	20−52
	Left	92−100	92−100	88−100	76−100	44−80	16−52
95 % Confidence interval (lower-upper)	**Right**	95.14−97.6	95.14−97.85	94.83−97.66	85.4−90.59	60.46−66.28	31.29−37.95
	Left	94.14−96.8	95.51−97.98	94.78−97.71	84.96−89.28	60.04−66.2	31.21−37.03

(three-year intervals) findings might be due to different grouping method [9]. In addition, the results of the study is different from Johnson study on consonant and vowel recognition in noise. Johnson reported that CV in noise recognition maturation at SNR +10 occur at the age range of 10 up to adulthood [7]. The noticeable difference is a result of different scoring methods in these studies. In Johnson's study, consonants and vowels were scored separately but at the present study consonants and vowels were scored together as CVs.

As mentioned, there was a significant difference between right ear and left ear total score at SNRs of 0, −6 and −12 dB. There was not any study on ear effects in CV in noise test in children. Studies on other speech in noise tests with other materials such as sentence and word at different SNRs reported no significant difference between two ears [15-17]. The reason might be because of the different test materials. In the present study, non-sense CV in noise was used but other studies used meaningful speech materials in noise.

The present study showed no sex effect on test scores. This is in agreement with Yathiraj and Vanaja as well as Stollmn et al. that showed no significant score difference between girls and boys [15,18].

Conclusion

The present findings indicate that recognition score at negative SNRs (that need more neural synchrony and phase locking) differs at various age groups. Consonants recognition depends on age so that at positive SNRs, consonant recognition matures faster (before age eight) than negative SNRs (about age of ten).

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Conflict of interest
The authors declare that they have no conflict of interest.

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