Original Article

Variation in Speech Perception in Noise as a Function of Age in Typically Developing Children

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Abstract

Introduction: Speech recognition performance has been observed to vary with the age of the listener. Children having difficulty in understanding speech in noisy situations is found to have an adverse effect on learning. The primary aim of the study was to determine the difference in word and phoneme scores in the presence of noise in three age groups of children studying in primary school. The secondary aim was to check whether there was a gender difference within an age group. **Materials and Methods:** Three groups of typically developing children (≥7 to <8; ≥8 to <9; and ≥9 to <10 years), who were exposed to Kannada from early childhood, were evaluated to determine their speech perception abilities in the presence of noise. **Results:** Within each age group, no significant difference was observed between gender for word and phoneme scores in all four lists. The word and phoneme scores were similar across the lists within an age group but differed across age groups for all lists. The older children outperformed the younger children. **Conclusion:** The study indicated that with increase in age, word and phoneme recognition scores improve. However, within an age group, children obtained similar word and phoneme scores across the four lists, indicating the equivalence of the lists in the presence of noise. Furthermore, there was no significant difference in word and phoneme scores between the males and females for all lists within each age group.

Keywords: Phoneme scores, speech-in-noise, word scores

Date of Submission : 09-04-2018 **Date of Revision :** 28-07-2018 **Date of Acceptance :** 04-12-2018 **Date of Web Publication :** 28-06-2019

Introduction

Speech recognition performance has been observed to vary with the age of the listener, although it was found to be challenging in the presence of noise for all ages.[1] Normal hearing children were found to have more difficulty in understanding speech in the presence of noise compared to normal hearing adults.[2] It has been observed that children required higher signal-to-noise ratios (SNRs) compared to adults to recognize speech in the presence of background competing sounds such as multitalkers.[3-5]

Improvement in speech recognition performance in the presence of noise across age groups in childhood has been reported in the literature.[3,6,7] It was found that the overall recognition of nonsense syllables in the presence of speech-shaped noise was significantly poorer for the 4–5-year-old children compared to children aged 6–7 and 8–9 years and adults.[7] Among the age groups that they studied, the adult-like performance was observed only in the oldest group of children aged 8–9 years. However, adult-like responses were observed by Nittrouer and Boothroyd[5] in children as young as 4–6 years in the presence of speech-shaped noise when tested at ± 3 dB SNR and at 0 dB SNR among the adults. The children were found to have poorer syllable and sentence recognition compared to adults in the presence of spectrally matched noise. This type of noise was reported to produce greater auditory masking of speech sounds in the former group. They also observed that children aged 5–7 years required a 5 dB higher SNR to reach 71% accuracy in identifying monosyllables when compared to children aged 10 years and older. Further, it was reported that the identification of monosyllable nouns in the presence of noise by children reached normal adult values by 10 years of age.

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Access this article online

Quick Response Code:

Website: www.jisha.org

DOI: 10.4103/jisha.JISHA_17_18

How to cite this article: Mamatha NM, Yathiraj A. Variation in speech perception in noise as a function of age in typically developing children. J Indian Speech Language Hearing Assoc 2019;33:32-7.

It has been observed that children having difficulty in understanding speech in noisy situations were found to have an adverse effect on learning.[2,8] In addition, evaluating the ability of children to understand speech in the presence of background noise might help audiologists in quantifying and diagnosing various auditory perceptual difficulties as well as selecting appropriate hearing aids. Thus, it is essential to establish whether children have difficulty in perceiving speech in the presence of noise in their native language. As studies have indicated that the performance of children differs from that of adults, it is mandatory that data available for adults are not used for children.

Vaidyanath and Yathiraj[9] developed a speech-in-noise test in Kannada and utilized the same on adults. While the test stimuli were appropriate for children, the performance of children in the presence of noise was not established. Hence, the present study aimed at assessing the effect of age on speech recognition performance in the presence of noise in children. The secondary aim was to check for gender differences within each age group.

Materials and Methods

Using a purposive sampling technique, children aged ≥7–<10 years, studying in Kannada medium primary schools, were evaluated. Their speech perception in the presence of noise was evaluated using speech-in-noise test in Kannada (SPIN-K) developed by Vaidyanath and Yathiraj.[9]

Participants

Children who were exposed to Kannada from early childhood and were fluent speakers of the language were selected from Kannada medium schools in and around Mysuru. Only those with at least 2 years of formal education were selected. A total of 123 children were selected for the study who were divided into three age groups (≥7–<8; ≥8–<9; and ≥ 9–<10). Each age group had 41 children (20 males and 21 females).

All the children had absence of an obvious external and middle ear problems on an otoscopic examination; normal hearing sensitivity indicated by pure-tone thresholds of <15 dB HL for air conduction (500 Hz, 1 kHz, 2 kHz, 4 kHz, and 8 kHz) and bone conduction (500 Hz, 1 kHz, 2 kHz, and 4 kHz). They had A-type tympanogram with reflexes present below 100 dB HL at 500 Hz, 1 kHz, 2 kHz, and 4 kHz. In addition, only those with normal intelligence on the Raven's coloured progressive matrices[10] were selected. All the children had speech identification scores of 90% or higher on the "Phonemically balanced word test in Kannada"[11] in a quiet condition. Further, they had no complaint or history of any middle ear pathology, speech and language problem, psychological, and/or neurological problems, as noted in the medical records of the children maintained in the school. All the children passed a screening checklist for auditory processing disorders.[12] Before testing, written consent was obtained from the caregiver of the children, in compliance with the Ethical Guidelines for Bio-Behavioural Research Involving Human Subjects[13] of the All India Institute of Speech and Hearing, Mysuru.

Instrumentation

A calibrated, dual channel, diagnostic audiometer (Grason-Stadler Inc. 61) with supra-aural earphones (TDH-50) and a BC vibrator (B-71) was used to establish pure-tone thresholds. An immittance meter (GSI Tympstar version 2, Grason-Stadler Inc., USA) was used to establish normal middle ear functioning.

Stimuli

Perception of speech in the presence of noise was evaluated utilizing the four lists of the test "Speech identification in noise in Kannada (SPIN-K)" developed by Vaidyanath and Yathiraj.[9] The test contained bisyllabic words taken from "phonetically balanced word identification test in Kannada"[14] that has vocabulary appropriate for children aged 5 years and above. An 8-speaker speech babble developed by Vaidyanath and Yathiraj[9] served as the noise.

Procedure

The compact disc version of SPIN-K was played using a computer, the output of which was routed through the same audiometer that was used for pure-tone audiometry. The participants heard the stimuli through headphones. The SPIN-K test was administered at 0 dB SNR monaurally at 40 dB SL (Ref SRT). Twenty children were tested in their right ear first and 21 in their left ear first to avoid any ear order effect. All the children heard all four lists and the order of the lists was randomized to avoid any order effect. To avoid fatigue influencing the test results, breaks were provided to those children who showed signs of restlessness. The children were instructed to repeat the words while ignoring the noise. The number of correct responses was noted for each ear separately and scored.

Word and phoneme scores were calculated separately for each individual. Every word correctly identified was given a score of "1" and every incorrectly identified word was given a score of "0." The maximum possible word score for each list was 25. Likewise, each correctly identified phoneme was given a score of "1" and an incorrectly identified phoneme a score of "0." As the maximum possible phoneme score varied across the lists (List 1 = 100, List 2 = 103, List 3 = 101, and List 4 = 105), these scores were converted to percentage to enable comparison across the lists.

The test–retest reliability of SPIN-K test was done within an interval of 1 month after the initial testing. This was done on 6 children from each age group.

Analyses

Statistical analyses were carried out using SPSS software (Version 20, IBM Corp., Armonk, NY, USA). A Shapiro–Wilk test of normality indicated that word scores obtained in all the age groups, for all the lists, were not normally distributed ($P < 0.05$). However, the phoneme scores obtained in all the age groups for all the lists were normally distributed ($P > 0.05$). Hence, nonparametric tests were carried out for analyzing word scores, while parametric statistics were carried out for analyzing the phoneme scores. Both descriptive and inferential statistics were done. The gender effect was checked

using Mann–Whitney U-test. To check the overall difference in word scores between the lists, Friedman test was carried out. Likewise, to determine if an overall difference existed between the three age groups for word scores, Kruskal–Wallis test was performed. Further, Mann–Whitney U-test was done to determine which of the age groups differed from each other. The overall effect of the phoneme scores was checked using a one-way repeated measure ANOVA, with the scores across the four lists being the within-subject variable and the three age groups being the between-subject variable. Tukey's *post hoc* test was administered to determine the difference in phoneme scores between pairs of age groups.

Results

The findings of the statistical analyses are provided to reflect the between-group comparisons (gender and age) and the within-group comparison (word lists). This information is provided below separately for the word scores and for the phoneme scores.

Comparison of scores of SPIN-K across gender

The scores obtained by the male and female participants were found to differ only marginally. To confirm if there existed a significant difference between the gender, Mann–Whitney U-test was administered separately for each of the four lists for each of the three age groups. No significant difference in word and phoneme scores was found between the males and females. This was observed for all lists within each age group. To correct for the Type I error arising because of administration of multiple Mann–Whitney U-tests (one for each list), alpha correction was applied which yielded a $P = 0.025$. Between-gender comparison on each of the four lists was therefore statistically not significant ($P > 0.025$), and hence, further analyses were done by combining the scores of the males and females. "The combined mean, median, and standard deviation of both the word and phoneme scores, obtained for the 3 age groups and 4 list are provided in Tables 1 and 2, respectively."

It can be seen in Tables 1 and 2 that both the mean and median scores for words and phonemes across the list were similar within each age group. However, the word and phoneme scores varied across the three age groups, with the scores increasing with increase in age. This was observed for all four lists.

Comparison of word scores across lists within each age group

To establish if there existed any significant difference between the four lists on the word scores, Friedman's test was administered separately for each age group. No significant main effect in word scores was found across the lists for the 7-year-old children ($\chi^2[3] = 0.60$, $P = 0.894$); 8-year-old children ($\chi^2[3] = 3.46$, $P = 0.326$); and 9-year-old children ($\chi^2[3] = 7.03$, $P = 0.071$).

Comparison of word scores across age groups for each list

To establish if there was any significant main effect of age on the word scores, Kruskal–Wallis test was performed separately for each list. It was found that there was a significant main effect of age on the word scores for list 1

Table 1: Mean, standard deviation, median, and range of the word scores obtained for each list in each age group (≥7-<8; ≥8-<9; and ≥9-<10)

Lists	Age groups		
	7 years (n=41)	8 years (n=41)	9 years (n=41)
List 1			
Word scores			
Mean	14.0	14.78	16.97
Median	14.0	15.0	17.0
SD	1.20	1.29	1.25
Range	12-17	13-18	15-20
List 2			
Word scores			
Mean	14.02	15.04	17.21
Median	14	15	17
SD	1.58	1.16	1.23
Range	11-18	13-17	15-20
List 3			
Word scores			
Mean	14.02	14.85	16.92
Median	14	15	17
SD	1.17	0.96	1.19
Range	12-17	13-17	14-19
List 4			
Word scores			
Mean	14.07	15.0	17.09
Median	14	15	17
SD	1.21	1.24	1.13
Range	12-17	13-18	15-19

Maximum word score=25. SD: Standard deviation

Table 2: Mean, standard deviation, median, and range of the phoneme scores obtained for each list in each age group (≥7-<8; ≥8-<9; and ≥9-<10)

Lists	Age groups	7 years (n=41)	8 years (n=41)	9 years (n=41)
List 1	Mean	82.30	84.64	88.31
Phoneme scores	Median	82.18	84.16	88.12
	SD	2.48	2.32	1.98
	Range	77-88	77-90	85-93
List 2	Mean	82.40	84.85	88.52
Phoneme scores	Median	82.18	85.15	89.11
	SD	2.43	2.27	2.14
	Range	77-88	79-89	84-93
List 3	Mean	82.52	84.71	88.40
Phoneme scores	Median	83.17	84.16	88.11
	SD	2.56	2.20	2.47
	Range	77-87	79.21-89.11	84.16-94.06
List 4	Mean	82.37	84.81	88.38
Phoneme scores	Median	83.17	85.15	88.12
	SD	2.41	2.24	2.13
	Range	77.23-87.13	79.21-89.11	84-92

Maximum phoneme scores for list 1=100; list 2=103; list 3=101; and list 4=105. SD: Standard deviation

(H [2] = 62.72, $P < 0.001$), list 2 (H [2] = 63.19, $P < 0.001$), list 3 (H [2] = 67.06, $P < 0.001$), and list 4 (H [2] = 64.65, $P < 0.001$). As there was a significant main effect of age on word scores, Mann–Whitney U-test was administered to see which pairs of age groups differed from each other. The results of the Mann–Whitney U-test are given in Table 3. The results indicated that the word scores were significantly different between all age groups, that is, the 7-year-old group obtained significantly poorer scores than the 8-year-old group and the 9-year-old groups. Likewise, the 8-year-old group obtained significantly poorer scores than the 9-year-old group. This trend was observed for all four lists. To correct for the Type I error arising because of administration of multiple Mann–Whitney U-tests (one for each age group), alpha correction was applied which yielded a $P < 0.018$ ($P < 0.025$). Between-age comparison of word scores on each of the four lists was therefore found to be statistically significant ($P < 0.025$).

Comparison of phoneme scores across lists and across age groups

To see if there existed any significant main effect of the four lists on the phoneme scores across each age group, one-way repeated-measures ANOVA with age group as between subject factor was carried out. The results indicated that there was no significant main effect of the list (F [3, 360] = 1.33, $P = 0.26$) on phoneme identification scores. Furthermore, there was no interaction between phoneme scores and age groups (F [6, 360] = 0.36, $P = 0.90$).

A significant main effect of age (F [2, 120] = 75.88, $P < 0.001$) was obtained for the phoneme identification scores. As there was a significant main effect of age on phoneme scores, Tukey's *post hoc* test was done to see which pairs of age groups had significantly different phoneme scores, with the scores of the four lists combined. The 7-year-old group obtained significantly poorer scores than the 8-year-old age group ($P < 0.001$) as well as the 9-year-old group ($P < 0.001$). Likewise, the 8-year-old group obtained significantly poorer scores than the 9-year-old group ($P < 0.001$).

Test–retest reliability of SPIN-K test

An intraclass correlation coefficient was calculated to check the test–retest reliability of the word scores. This was done using one-way random effects, absolute agreement, and test–retest measure. The results indicated that the word scores were highly reliable in all the three age groups for all the lists, as can be seen in Table 4.

From the above results, it can be observed that both word and phoneme scores obtained are similar across males and females and also across the four lists. However, word and phoneme scores differed significantly across age. Test–retest reliability indicated that the data obtained are highly reliable.

Discussion

The results of the study are discussed with reference to gender difference, variation in performance across lists in each age group, and variations across age groups. This is provided for both word as well as phoneme scores.

The results of the study indicate that the male and female participants performed equally well in all the age groups. This gender equality was observed for both word and phoneme scores. Thus, it can be inferred that in children aged 6–9 years, performance in the presence of noise is not affected by the gender of the participant. Similar findings were also reported by Yathiraj and Vanaja.[15] They too observed similar finding on the Indian English version of SPIN in children aged 6–10 years. Thus, the gender equality in the perception in the presence of noise is not restricted by the language of the test.

It was also observed that SPIN-K word and phoneme scores across the four lists within each age group were not statistically significant. This suggests that the word scores and phoneme scores were equivalent across the four lists in all the age groups. Hence, it can be construed that the presence of noise does not affect the equivalence of phonemically balanced word lists, in typically developing children. Thus, as can be done in the absence of noise, any one of the lists can be used to evaluate speech recognition scores in noise. Hence, it can be concluded that irrespective of the age of the participants, perception of words across the lists of SPIN-K remained similar.

In the present study, across age groups, there was a significant change in scores. With increase in age from 7 to 9 years, the scores improved. This occurred for both word and phoneme scores for all four lists. This indicates that perception of speech in the presence of noise improves with increase in age. Further, from Table 3, it can be observed that the effect size was larger when the scores of the youngest (7 years) were compared with the oldest group (9 years) and when the two older groups were compared (8 and 9 years). However, it was low when the scores

Table 3: Significance of difference between age groups obtained from results of Mann-Whitney U-test for word scores for each list

Lists	7 and 8 years old				7 and 9 years old				8 and 9 years old			
	Z	*U*	*P*	Effect size (*r*)	*Z*	*U*	*P*	Effect size (*r*)	*Z*	*U*	*P*	Effect size (*r*)
List 1	−2.59	570	0.010	0.29	7.17	77	0.00	0.8	6.01	202	0.000	0.66
List 2	3.20	503	0.001	0.35	6.89	105	0.00	0.76	6.25	178	0.000	0.7
List 3	3.55	472	0.000	0.4	7.05	90	0.00	0.78	6.36	167	0.000	0.7
List 4	3.07	520	0.002	0.34	7.22	72	0.00	0.8	6.02	203	0.000	0.66

Table 4: Intraclass correlation, 95% CI (lower bound and upper bound) obtained for word scores in each list in each age group (≥7-<8; ≥8-<9; and ≥9-<10)

Lists	Age groups	Intra-class correlation	95% CI	
			Lower bound	Upper bound
List 1	7	0.87	0.502	0.969
Word scores	8	0.67	0.309	0.919
	9	0.82	0.303	0.957
List 2	7	0.83	0.299	0.957
Word scores	8	0.78	0.102	0.945
	9	0.84	0.362	0.961
List 3	7	0.81	0.229	0.952
Word scores	8	0.91	0.647	0.978
	9	0.92	0.682	0.980
List 4	7	0.74	0.048	0.935
Word scores	8	0.89	0.589	0.975
	9	0.740	0.048	0.938

CI: Confidence interval

of the two younger groups were compared (7 and 8 years). This indicates that between the two younger age groups, other covariables probably affected the difference in performance rather than just the perception of speech in the presence of noise. It is speculated that although the words were familiar to children in this age group, variables such as the frequency of usage of the words or sustained vigilance could have affected the results. Support for this speculation is taken from the studies by Gale and Lynn[16] and Paus.[17] It was observed by Gale and Lynn[16] that children aged 7 years had lesser sustained attention compared to older children. Likewise, younger children have also been found to have poorer vigilance compared to older children as reported by Paus.[17]

Studies reported in literature have noted that unlike adults, children require more favorable SNRs to obtain scores similar to adults.[3-5,7,18-20] The reasons for this child–adult differences have been noted to be due to the prolonged development of the auditory neural processing although the peripheral auditory system matures early in life.[21] The development of speech recognition in noise is considered as a late maturing skill in the long auditory perceptual development and it has been observed that children cannot reach adult-like performance until 13–15 years of age.[22] It has been reported that the difference between the performance of children and adults could be due to the greater auditory masking of speech sounds in the former group compared to the latter group.[5,23]

The current study indicates that SPIN-K can be used effectively while testing typically developing children in the presence of noise. Thus, the test can be used to evaluate children with suspected auditory closure/separation problems.

Conclusion

The findings of the study regarding the performance of typically developing children on a speech perception test in noise as a function of age indicated that with increase in age, the performance improved. However, the oldest age group (9 years) failed to obtain adult-like responses, indicating that perception in the presence of noise continues to develop beyond this age. Further, it was noted that both males and females performed equally well in all the three age groups that were studied (≥7 to < 8; ≥8 to < 9; and ≥ 9 to < 10 years). The four word lists of SPIN-K that were equivalent in quiet were found to be also equivalent in the presence of speech babble at 0 dB SNR. Thus, it is recommended that the four lists of SPIN-K can be used interchangeably while establishing speech perception abilities of children in the presence of noise. The test can be used to differentiate children having auditory closure/separation problems from those who do not have such problems.

Acknowledgment

We would like to thank AIISH for permitting to carry out the study and all the participants of the study.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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