Evaluation of Auditory Discrimination in Children With ADD and Without ADD

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ABSTRACT: Auditory discrimination abilities of children with and without attention deficits were investigated to measure the variability due to different response modes (verbal [NU-6] and picture pointing [GFW]) and competing messages (GFW). Results showed no differences between response modes in quiet, but significant differences in noise between groups with children having ADD showing poorer speech discrimination. Additionally, differential effects between types of competing messages for the same task were not found in the ADD group. These results are discussed in relation to the clinical use of these tests, the relationships seen between results, and implications for educational management.

KEY WORDS: Auditory Discrimination; Speech-in-Noise; Response Mode; Competing Message; Attention Deficit Disorder; ADD; ADHD; Audiological Evaluation; FM Auditory Trainers.

Many children presenting with distractibility to background noises have been identified as having attention deficit disorders (ADD).[1-9] These children are often described as having: short attention spans, inattentiveness, distractibility, hyperactivity, and impulsivity.

Distractibility to background noise is often a reason that children with ADD are referred to audiologists for hearing testing. When a child is referred for an audiological evaluation because of problems

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attending in the presence of background noise, the evaluator may test the ability of the child to repeat words or point to pictures representing these words in quiet and in the presence of different types of noises (Speech-in-Noise testing). As such, different response modes (verbal vs. pointing) and competing messages (noise, non-meaningful speech, meaningful speech) are being used to evaluate speech discrimination in noise with children having ADD.[1-5] The present study investigated the differences between children with ADD and children without ADD in their abilities to discriminate words when verbal repetition and picture pointing tasks are employed. Additionally, this study determined whether words presented in quiet or in the presence of a variety of background distractors, such as noise (non-meaningful non-speech), cafeteria noise (non-meaningful speech), and running speech (meaningful speech) produces differences in auditory discrimination for these children.

Methodology

Subjects

Twenty-seven children classified using the DSM-III-R criteria[10] as having attention deficit disorders with (ADHD, ICD-9-CM code 314.00) or without (ADD, ICD-9-CM code 314.01) hyperactivity were chosen for subjects in the present study. All children were diagnosed with ADHD or ADD by one of the authors (WK), a child psychiatrist based on the DSM-III-R guidelines,[10] parent reports, and a psychoeducational examination. There were 22 boys and 5 girls ranging in age from 6 to 12 years, with a mean age of 8 years-9 months in this experimental (ADD) group. The children, all from middle to upper middle class families, were indentified as having at least a normal I.Q., and were all at grade level in their educational settings. All children were referred to our center for routine audiological evaluations to rule out hearing loss related to their attention deficits. As part of the audiological assessment, speech discrimination in quiet and in noise (S/N + 10) using the recorded NU-6 short interval word list was assessed using a verbal repetition response mode. Additionally, speech discrimination was assessed utilizing the Goldman-Fristoe-Woodcock Auditory Selective Attention Test[11] employing a picture pointing response mode for words presented in quiet and in a variety of background noises.

A comparison (Non-ADD) group of 15 children was selected from the friends and relatives of staff members from our Speech and Hearing Center. These children were identified as having at least normal I.Q.s, and were functioning on grade level in their educational settings. Furthermore, this comparison group of children were not classified as ADD or ADHD, but were given the same audiological test battery as the experimental group. The children were screened to rule out behaviors consistent with DMS-III-R criteria[10] for ADD,

as cited on a checklist used by the evaluator (see Appendix). None of these children obtained any significant positive responses on the checklist to warrant concern. All children had expressive and receptive language within one year of chronological age. These children were selected from middle to upper middle socioeconomic status households as determined by parental educational and occupational levels. The children in this control group ranged in age from 6 years to 12 years, with a mean age of 9 years-6 months. There were 10 boys and 5 girls in this group.

For both groups, all subjects were found to have normal hearing (thresholds equal to or less that 15 dBHL) for the octave frequencies 250 to 8000 Hz, as well as for speech recognition thresholds (SRT). Therefore, only the results of the speech discrimination tasks will be presented in this paper.

Procedures

All subjects were evaluated audiometrically in a two room, double walled IAC test suite. All test materials (tones and speech) were presented through TDH-49 earphones in MX41AR cushions attached to a GSI 10 diagnostic audiometer. Speech discrimination was administered using recorded NU-6 short interval word lists, Forms A and B, with half lists presented to each ear per condition. The subjects heard words in quiet followed by words mixed with speech noise presented ipsilaterally at a signal-to-noise ratio of +10dB (S/N+10). The level of presentation for the words was 50 dBHL. This procedure permitted a comparison for each ear between speech discrimination in quiet and speech discrimination with a non-meaningful competing speech noise. Additionally, these comparisons were made for speech discrimination utilizing verbal responses.

For evaluation of speech discrimination utilizing a picture pointing response mode, the Goldman-Fristoe-Woodcock Auditory Selective Attention (GFW) Test was employed.[11] This test is commercially available, and utilizes a tape recording of words presented in quiet (11 words), and in three different background noises (33 words each subtest): fan noise (non-meaningful non-speech), cafeteria noise (non-meaningful speech), and voice (meaningful speech). For the background noise subtests, the S/N ratio varies from favorable (words louder than competition) to unfavorable (competition louder than words). The tape recording accompanying the test has the standard S/N ratio variances established for each of the three subtests (S/N +6, 0, and −6). The GFW Test was presented in the standard manner to the children with the tape recorder's volume set at a comfortable listening level, and all material presented to both ears in the sound field.

Although the NU-6 and GFW tests vary in words utilized, methods of presentation, signal-to-noise ratios employed and number of test items, these two tests were chosen because they are commercially available and provide a means to assess children's abilities to listen in a variety of adverse conditions. It was felt that the results obtained from the present study would provide information regarding differences in audiological behavior between these two groups of children.

Table 1
Speech Discrimination in Quiet for Children With ADD and Without ADD on the NU-6 and the GFW Quiet Subtest

		NU-6		*GFW-Q*
		Right Ear	*Left Ear*	*Raw Score*
Non-ADD	Means	99%	98%	11
(n = 15)	S.D.	2.03	2.57	9.47
ADD	Means	97%	96%	10.85
(n = 27)	S.D.	4.25	6.69	0.45
t		2.32*	1.82**	1.69**

*$p < 0.05$
**$p > 0.05$

Results

Table 1 presents the results for speech discrimination in quiet for the two tests, NU-6 and GFW. Review of this table indicates that both groups of subjects had no problems discriminating words in quiet on both tests. Comparison between groups revealed no significant differences for the left ear on the NU-6 Test (non-ADD mean = 98%; ADD mean = 96%; $t = 1.82$, $p > 0.05$) or for the GFW Test (non-ADD mean = 11; ADD mean = 10.85; $t = 1.69$, $p > 0.05$). However, the results for the right ear on the NU-6 test were significant (non-ADD mean = 99%; ADD mean = 97%; $t = 2.25$, $p < 0.05$), with a mean difference of only 2%. It is felt that this result for the right ear reflects the greater variability in test scores for the ADD group rather than an actual difference between the two groups for the right ear. Essentially, the results indicate excellent discrimination abilities for both groups of children when testing speech discrimination in quiet.

Table 2 presents the results for the NU-6 Test with speech-in-noise. A significant difference in discrimination abilities between these two groups exists for both ears (RE: non-ADD mean = 88%; ADD mean = 54%; $t = 9.60$, $p < 0.005$; LE: non-ADD mean = 88%; ADD mean = 58%; $t = 11.21$, $p < 0.005$). Results indicate that discrimination of the NU-6 words is significantly poorer for children with ADD when non-meaningful speech noise competes with the words. For the children without ADD, although discrimination did decrease, the propor-

Table 2
Speech Discrimination in Noise on the NU-6 Test for Children With ADD and Without ADD

		Right Ear	*Left Ear*
Non-ADD (n = 15)	Means	88%	88%
	S.D.	5.95	7.08
ADD (n = 27)	Means	54%	58%
	S.D.	17.47	11.21
t		9.60*	11.21*

*$p < 0.005$

tion was less than an average of 12% compared to about a 40% drop off in the ADD group between quiet and noise conditions.

Table 3 presents the results for the GFW test for both groups of children. In contrast to the NU-6 test in which results are reported in percent correct scores, the GFW has 3 subtests each with 33 items. The standard method for scoring the GFW Test is to report the child's results in percentiles per age group. However, a review of the standardized percentile scores reveals that a child can show a great difference with merely a small increase in the number of items correctly identified. For example, a child in the 11-11 to 12-11 age range obtaining a total GFW score of 102 would be ranked in the 24th percentile. Merely adding 3 points to this total score (from 102 to 105) would show that this same child is now in the 68th percentile rank for his age group. As such, it was decided to report the GFW Test results in

Table 3
Speech Discrimination in Noise on the GFW Subtest for Children With ADD and Without ADD

		Fan	*Cafeteria*	*Voice*
Non-ADD (n = 15)	Means	30	30	31
	S.D.	1.61	1.25	1.29
ADD (n = 27)	Means	28	27	28
	S.D.	2.57	3.49	4.45
t		3.68*	4.09*	3.60*

*$p < 0.005$

the absolute number of items correctly identified for each subtest. Therefore, the results reported in Table 3 reflect the number of correct items out of 33 total items for each subtest. This table indicates a significant difference between the two groups for all three types of competing messages (Fan Noise: non-ADD mean = 30, ADD mean = 28, t = 3.68; Cafeteria Noise: non-ADD mean = 30, ADD mean = 27, t = 4.09; Voice: non-ADD mean = 31, ADD mean = 28, t = 3.60). All comparisons yielded $p < 0.005$. Therefore, it appears that for both verbal response and picture pointing response modes, children without ADD are better able than children with ADD to identify the words they hear, regardless of the type of background noise presented.

Since different background noises are used with the GFW Test, comparisons among these different noise backgrounds for each group of children were made. Table 4 presents the differential effects of noise on children with and without ADD. For the children without ADD, there was no differential effect between the distracting properties of Fan Noise vs. Cafeteria Noise ($t = 0.90$; $p > 0.05$), but for both the Fan and Cafeteria Noises, discrimination scores were more decreased than the Voice background (Fan vs. Voice: $t = -3.41$, $p < 0.005$; Cafeteria vs. Voice: $t = -2.30$, $p < 0.05$). In contrast, the children with ADD showed no differential effects between the different background noise conditions (Fan vs. Cafeteria: $t = 1.76$; Fan vs. Voice: $t = -1.65$; Cafeteria vs. Voice: $t = 3.71$). All comparisons yielded $p > 0.05$.

Table 4
Differential Effects of Noise on the GFW Subtest for Children With ADD and Without ADD

		Fan vs. Cafe.	*Fan vs. Voice*	*Cafe. vs. Voice*
Non-ADD	Means	0.4	−1.27	0.87
(n = 15)	S.D.	1.67	1.39	1.41
t		0.09*	3.41**	−2.30***
ADD	Means	1.0	−0.93	0.07
(n = 27)	S.D.	2.90	2.88	3.71
t		1.76*	−1.65*	0.09*

*$p > 0.05$
**$p < 0.005$
***$p < 0.05$

Discussion

Results of the present study yielded several interesting findings. For example, speech discrimination as measured by the NU-6 (verbal response to words) and GFW (picture pointing response to words) tests yielded essentially excellent speech discrimination scores in quiet for the two groups, regardless of the type of response mode employed (verbal or pointing). Furthermore, both tests can be used with children having ADD to evaluate their speech discrimination abilities. These two tasks indicate that speech discrimination in quiet did not essentially differ between the children with and without ADD in this study. However, the ADD group yielded more variability than the non-ADD group, as supported by the larger standard deviations for the ADD group on the NU-6 Test for each ear.

In contrast to the results in quiet, when measuring speech discrimination abilities in the presence of competing messages, results indicated that the NU-6 Test presented with an ipsilateral speech noise is by far a much more difficult task than any of the three noise subtests of the GFW battery. Additionally, the difference in discrimination between these two groups is greatest for the NU-6 Test. There are several factors that could account for the differences noted. One factor involves the words used on the NU-6 Test which may be less familiar to children. For example, the NU-6 Test employs such words as "laud" which would certainly appear to be an uncommon word. It is felt that in order to process these less familiar words, a significant amount of what can be called "processing energy" is needed. When the competing noise is mixed with these words, "processing energy" is diverted towards filtering out the unwanted noise. As such, less energy is available for discriminating the test words. What is hypothesized is that more energy is needed to filter the unwanted noise by the children with ADD compared with the children without ADD. As such, a significant decrease in "processing energy" is available for understanding the words. This factor may account for the differences noted in speech discrimination abilities in noise for the two groups of children on the NU-6 Test. Another factor could be that, when speech and noise compete, the child with ADD is unable to sort out the figure-ground perception, and cannot focus on the figure while attenuating the background. Figure-ground discrimination skills have been noted to be troublesome in this population.

A second factor involves the use of different response "sets" be-

tween the NU-6 and GFW Tests. That is, the NU-6 Test uses an open response set in which the children repeat a word they think they heard, with no limits to their choices. In contrast, the GFW Test uses a closed response set. In this case, the choices are limited to one of four pictures presented per item. In this latter case, the child is assisted in processing what is heard on two accounts. First, he/she sees the pictures before and during the presentation of the word. This may assist in focusing attention on the features of the words needed for processing accurately. Second, the child can only respond within the limit of one of four pictures presented, regardless of what he/she heard. Therefore, the use of a closed response sets could make the GFW test items easier to process compared with the open response set of the NU-6 Test. This factor needs further investigation. Nevertheless, the child is presented with at least two phonetically similar words (e.g., lake/rake, wig/wing), and can easily make discrimination errors on initial and final consonants when competing noise interferes.

The final analysis of the test results looked at the differential effects of the competing messages on the auditory discrimination abilities of children with and without ADD. The GFW Test results were compared since the NU-6 test only employed one competing noise, whereas the GFW Test employed three different competing messages: Fan Noise, Cafeteria Noise and Voice. It is interesting that both Fan and Cafeteria Noises had no differential effects for the children without ADD. Only the Voice competing message affected their test scores significantly by making the competing message task easier, thus, yielding a higher number of correctly identified words. It is felt that the Voice message (i.e., a person reading a story) may have contained many linguistic and acoustic cues that assisted these youngsters in filtering out this competing message. The fact that the story had meaning may have facilitated the ability of children without ADD to filter out the presentation of the story while the Fan and Cafeteria Noises contained no meaningful information making it more difficult to block out. Perhaps one must utilize some extra processing energy in order to monitor what is being filtered during the presentation of these non-meaningful competing messages in order to filter out the noise and not the test words.

In contrast to this explanation for the children without ADD, it is hypothesized that the children in the ADD group did not have the same processing capabilities as that of the comparison group. As such, these children with ADD did not have the abilities to utilize the

linguistic and acoustic advantages of the Voice competition as previously discussed. They often listened to the story while failing to hear the stimulus word. Further investigation is needed to support this claim.

The results of this study provide a better understanding of the auditory discrimination abilities of children with ADD, as well as the processing differences these children apply to competing message listening tasks. Additionally, the results demonstrate that both the NU-6 Test and GFW Auditory Selective Attention Test can be utilized to evaluate auditory discrimination abilities in children with ADD. In view of the differences found with the NU-6 and GFW Tests, the results indicate that the NU-6 test may be more sensitive in identifying children with and without attention deficits who are affected by background noise.

An important implication of the present study relates to the educational management of children with ADD. Results of this study demonstrate that background noise is a significant distractor for these children regardless of the meaningfulness or the type of the competing message. Perhaps, any type of distractor may interfere with the processing of information for children with ADHD/ADD. If this finding were adapted to the classroom, it suggests that background noise needs to be controlled to maximize learning with children having attentional problems. The current authors have found this to be valid when we compare the improvements in learning found for children identified as having ADHD/ADD after FM auditory trainers have been utilized with these children in their classrooms. We have often recommended the use of FM units with children having ADHD/ADD who have problems with speech understanding in background noise. Reports received by us from these children's schools and parents have stated that the children are performing better in school, are less distractable, and are better able to participate in class. This has been especially helpful for children integrated into the mainstream school setting. Furthermore, a long range study of a child fit with an FM auditory trainer confirms the improvements noted pertaining to classroom performance and improved listening in noise.[12] Additionally, observations of this child in his school setting made by one of the authors (JRL) after the child used the FM unit for three years have demonstrated that the youngster is now able to attend and focus appropriately upon the relevant aspects of classroom activities without the use of the FM system.

In view of the finding from the present study, further investigation

is needed to identify what factors could account for the differences in auditory processing between children with and without attention deficit disorders. As we gain a better understanding of the auditory processing abilities of children with ADHD and ADD, we can develop better educational management strategies for them.

Summary

The present investigation looked at the differences in auditory discrimination abilities for a group of children with attention deficit disorders and a comparison group without attentional problems. Utilizing both verbal response and picture pointing response modes, speech discrimination in quiet and noise was investigated. Additionally, a comparison between three different noise distractors was made.

Results of the present study found that speech discrimination in quiet did not differ between the two groups, and was excellent for both groups. In contrast, speech discrimination in noise differed significantly with the children having attentional problems performing poorer especially on the verbal response mode task. Furthermore, whereas there was a differential effect for the type of noise distractor for the children without ADD suggesting that competing meaningful speech was easier to tune out than non- meaningful distractors, no differential effect was found for the children with ADD.

The conclusions drawn from this study suggest that children with ADD may not have the same filtering or figure-ground capabilities as children without ADD. This conclusion suggests that children with ADD may perform better in classroom settings where background noises can be carefully controlled. One suggestion discussed for controlling background noise is the use of FM auditory training units.

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Appendix

Diagnostic Criteria for ADD Checklist (from DSM-III-R, 1987)

Does your child show the following behaviors over (at least) the last 6 months? and, Were these behaviors noticed before the age of 7 years?

Does your child have any physical or neurological disorder?

(Behavior checklist)
Does your child. . . . . .

_____ 1. often fidget with his/her hands or feet or squirm in his/her seat?
_____ 2. have difficulties remaining seated when required to do so?
_____ 3. become easily distracted by extraneous stimuli?
_____ 4. have difficulties waiting his/her turn in games or group situations?
_____ 5. often blurt out answers to questions before the questions have been completely stated?
_____ 6. have difficulties following through on instructions from others (not because he/she is purposely oppositional or does not understand the instructions)?
_____ 7. have difficulties sustaining attention in tasks or play activities?
_____ 8. often shift from one uncompleted task to another?
_____ 9. have difficulty playing quietly?
_____10. often talk excessively?
_____11. often interrupt or intrude on others such as butts into other people's business?
_____12. often not seem to listen to what is being said to him or her?
_____13. often lose things necessary for tasks or activities at school or home such as toys, pencils, books, assignments, notices?
_____14. often engage in physical activities without considering possible consequences but not for thrill seeking (such as runs out into the street without looking)?

(A YES to at least 8 of the above 14 would disqualify the child for the non-ADD control group, as long as the behaviors were noticed as having occurred since before age 7. A YES to the question regarding a physical or neurological disorder also disqualified the child from the control group.)