4-1990

Perception of Gated, Highly Familiar Spoken Monosyllabic Nouns by Children With and Without Learning Disabilities

Lois L. Elliott
Northwestern University

Margo E. Scholl
Northwestern University

James O. Grant
Grand Valley State University, grantj@gvsu.edu

Michael A. Hammer
Northwestern University

Perception of Gated, Highly Familiar Spoken Monosyllabic Nouns by Children With and Without Learning Disabilities

Lois L. Elliott, Margo E. Scholl, James O. Grant, and Michael A. Hammer

A forward-gating procedure employing highly familiar monosyllabic words was used in auditory testing of age- and gender-matched children with learning disabilities and normally achieving children aged 8 to 11 years. The portion of the word presented, or "gate," was longer on each successive trial. Nondisabled children identified an average of one more word than the children with learning disabilities, but the mean duration required for word identification did not differ between groups. Better receptive vocabulary scores were associated with identification of words at shorter durations only among the children with learning disabilities. The two groups of children had similar numbers of different meaningful-word and different nonword incorrect responses. The children with learning disabilities exhibited poorer fine-grained auditory discrimination than a control group of nondisabled children. The study concluded that auditory closure skills for the gating task were as good among children with learning disabilities as among nondisabled children, but that sensory discrimination problems may contribute significantly to the learning difficulties of the former group.

Numerous situations require understanding of speech under less-than-ideal listening conditions. One such circumstance occurs when the latter part of a word is masked by a loud cough, a shout, traffic noise, and so forth. If the initial part of the word occurs under favorable listening conditions and if the listener has good ability to apply cognitive processes to the information received, he or she may be able to identify the word anyway. This type of situation has been formalized in both experimental tasks and a diagnostic test.

The Auditory Closure subtest of the Illinois Test of Psycholinguistic Abilities–Revised (ITPA) (Kirk, McCarthy, & Kirk, 1968) requires the examiner to pronounce words while omitting specific, indicated sounds. Even though this subtest has been used in testing children with learning disabilities, the procedure incorporates considerable interexaminer variability in production of the stimulus items.

Wood (1974) developed tape-recorded experimental stimuli intended to measure auditory closure. For example, one set contained monosyllabic words that had been filtered in frequency. A pair of words—filtered and unfiltered—was presented and the listener's task was to judge them as "same" or "different." This procedure resulted in better stimulus control than typifies live-voice administration of the Auditory Closure subtest of the ITPA. Wood concluded that "signal restoration did not emerge as a separate component" and suggested that auditory discrimination and auditory closure "might represent inseparable tasks for young children" (p. 80).

Auditory closure has been formalized in an experimental task called the "gating paradigm" (Grosjean, 1980). In this procedure, portions of words are presented, usually beginning at the word onset. For example, if 60 msec gates were used and forward gating employed, one stimulus would contain the initial 60 msec of a word, the second would contain the initial 120 msec, and the third would contain the initial 180 msec of the word. Computer-controlled techniques are used to produce stimulus items for the gating task; therefore, stimulus time durations are exact. In the gating paradigm, the listener's task is to identify the word; this may require considerable guessing when the stimulus duration is brief. Grosjean (1980) used the gating paradigm to replicate influences of word frequency (Rubenstein & Pollack, 1963), word length (Mehler, Segui, & Carey, 1978), and sentence context (Kalikow, Stevens, & Elliott, 1977; Miller, Heise, & Lichten, 1951) on speech perception.

As mentioned earlier, the gating procedure may be considered partly analogous to the task of understanding speech that has an unfavorable signal-to-noise ratio where portions of words are obliterated by noise throughout the message. This letter paradigm constitutes the basis for a test that measures perception of speech in noise (Kalikow, Stevens, & Elliott, 1977). Nondisabled adults as well as nondisabled children achieve better auditory closure (i.e., have higher percentage correct scores) when the task is to understand the final word of a sentence that contains contextual information than when no context is present (Elliott, 1979; Kalikow et al., 1977). Elliott and Busse (1987) demonstrated that young adults with learning disabilities also performed well when responding to sentences with contextual clues that were presented against a noise background. However, when those same listeners with learning disabilities responded to sentences having no contextual information, their performance was much poorer than that of nondisabled controls. These outcomes were interpreted as suggesting that the young adults with learning disabilities had good cognitive skills and that their problems were more closely related to sensory discrimination.

The sentence task used by Elliott and Busse (1987) and the gating task share several important features. Both require speech understanding on the basis of incomplete acoustic information. Both present stimuli at comfortable listening levels, well above threshold. Both require closure, a form of cognitive processing, to achieve a correct response. Also, both may include contextual information (the stimuli of the gating task may be preceded by a carrier sentence). A difference between these procedures is that the sentence task used by Elliott and Busse (1987) presents sentences against speech babble and uses several different signal-to-noise ratios. In contrast, the gating task is typically administered in quiet.

The major purpose of the present study, then, was to use the auditory gating paradigm in testing age-matched children with learning disabilities (LD) and nondisabled or normally achieving (NA) children to determine whether the former group would demonstrate good closure for word retrieval, as did the young adult subjects with LD of the Elliott and Busse (1987) study. Contextual information was not used in order to focus the task on word retrieval, an area where subjects with LD have been reported to have difficulty (Blalock, 1987). Instead, the stimuli were highly familiar words that had been established to be within the receptive vocabularies of 3-year-old inner-city children (Elliott et al., 1979).

A minor purpose of the present study was to document performance of the children with learning disabilities on the fine-grained auditory discrimination task (Elliott, 1986; Elliott, Busse, Partridge, Rupert, & DeGraaff, 1986; Elliott, Hammer, & Scholl, in press; Elliott, Longinotti, Meyer, Raz, & Zucker, 1981). This procedure determines the smallest acoustic differences that can be discriminated along continua of computer-synthesized consonant-vowel syllables. It differs from other approaches that have been used to study auditory discrimination in children with LD (e.g., Godfrey, Syrdal-Lasky, Millay, & Knox, 1981; Goldman, Fristoe, & Woodcock, 1976; Tallal, Stark, Kallman, & Mellits, 1981) in several ways. The procedure measures just-noticeable-differences (JNDs), not phoneme boundaries or ordering of stimuli; the test continua of synthesized stimuli contain much smaller between-item acoustic differences than may be produced in natural speech; and, the task measures perception of acoustic, not phonetic or phonemic, differences. Two JND measures pertain to the place-of-articulation speech feature, which is associated with frequency discrimination, and another two pertain to the voice-onset-time feature, which is associated with temporal discrimination. The listener pushes response buttons to perform a same-different task. Trial-by-trial feedback is provided automatically by the computer program that runs the task. Finally, catch trials provide information about the listener's attention to the task. Previous work has shown that young children with LD have poorer fine-grained auditory discrimination than their normally achieving agemates (Elliott et al., 1989). Because the fine-grained auditory discrimination task was not administered to those in the NA group, comparison data from a different group of normally achieving youngsters were used.

METHOD

Subjects

Eighteen children with LD were recruited from a summer camp for children with learning disabilities. Their ages ranged from 8 years 2 months to 12 years 0 months (mean = 120.3 months); there were 3 girls and 15 boys. Essentially all children within this age range whose parents signed the informed consent form participated. One child was of African-American heritage; all others were Caucasian. All subjects had been identified by their schools as having learning disabilities. Three were in self-contained classrooms, 13 received less than 50% of their instruction in a resource room, and 2 were in regular classrooms but received additional tutoring for their learning disabilities. Their mean Performance Scale score for the Wechsler Intelligence Scale for Children–Revised (WISC-R) (Wechsler, 1974) was 100.0 (*SD* = 9.5); mean Verbal Scale score was 92.8 (*SD* = 10.2). These children's mean standard score for reading on the Wide Range Achievement Test–Revised (WRAT-R) (Jastak & Wilkinson, 1984) was 74.2 (*SD* = 16.3). Therefore, although the measured intellectual abilities of the children with learning disabilities fell within the normal range, they exhibited underachievement in their reading-decoding skills.

Eighteen NA children who were matched in age, gender, and general socioeconomic status (upper middle class) to the children with LD were recruited from the northern suburbs of Chicago by means of posters at swimming pools and day camps. Their ages ranged from 8 years 3 months to 11 years 9 months (mean = 121.5 months, not significantly different from the mean for the children with LD).

Several procedures were administered to potential subjects in order to control for possible auditory (or, for the NA children, receptive vocabulary) problems. Conventional pure tone air conduction thresholds were obtained bilaterally at the octave frequencies from 500 through 4000 Hz; subjects were required to have auditory sensitivity equal to or better than 20 dB HL at all frequencies (see Note 1). All children were required to have normal middle ear pressure (i.e., normal tympanograms) in the test ear. The Peabody Picture Vocabulary Test–Revised (PPVT-R) (Dunn & Dunn, 1981) was administered; NA children were required to score at age level or above.

Children with LD were tested on both the gating and the fine-grained auditory discrimination tasks; NA children were tested only on the gating procedure. Therefore, a gender- and age-matched control sample of different normally achieving (DNA) children who had previously completed the fine-grained auditory discrimination procedure was drawn from the files of the continuing Elliott et al. (1989) project. DNA children lived in a medium-sized midwestern city; they had family backgrounds that were less affluent and less well educated than the LD and NA children. Mean age of the DNA children was 117.2 months—3 months younger than the mean age of the children with LD. The mean PPVT-R standard score of the DNA children was 97.8, only several points higher than the mean PPVT-R standard score for the children with LD, but the DNA children were making normal progress in school.

Gated Stimuli

Twenty monosyllabic nouns representing concrete objects and selected from the Northwestern University–Children's Perception of Speech Test (NU-CHIPS) (Elliott & Katz, 1980a, 1980b) were used as stimuli (see Table 1); two additional monosyllabic nouns from the same instrument were used as practice items. The male-talker NU-CHIPS recording was used to derive the gated stimuli.

Because some children might be expected to have short attention spans, it was important to keep test time as short as possible. Two procedures were adopted for this purpose; the minimum duration

TABLE 1
Words Used in the Gating Task

Practice items:
1. *coat*
2. *comb*

Test items:

1. *ball*	11. *foot*
2. *bear*	12. *hand*
3. *bike*	13. *man*
4. *boat*	14. *milk*
5. *bus*	15. *school*
6. *cake*	16. *sink*
7. *door*	17. *snake*
8. *dress*	18. *train*
9. *duck*	19. *tree*
10. *food*	20. *witch*

for each monosyllabic stimulus was 120 msec, and each additional gate was 60 msec. Previous research (Elliott, Hammer, & Evan, 1987) revealed that few listeners of any age would correctly identify any of the words when presented with only the first 120-msec portion. The shortest word was 390 msec in duration; therefore, the shortest gate was less than one-third the total duration of the shortest stimulus. Gate increments of 60 msec were brief enough to reveal between-group performance differences, but long enough so that test time was not unduly prolonged.

Computer-based procedures for creating the gated stimuli were identical to those used by Elliott et al. (1987). Each word was represented by a set of gated intervals, the size of the set depending on the duration of the word. These were combined into a group of presentations that all shared the same initial 120-msec interval and that then had increasing durations. A 5-sec silent period separated each presentation of the same word to allow time for the subject to respond and for the experimenter to record the response. In addition, a 5-msec 1-kHz tone preceded the first (i.e., briefest) presentation of each word, alerting the subject as well as the experimenter to a new stimulus item. The 20 test words were presented in random order, but in the same order to all listeners, with all presentations of the same word completed before the next word began. Subjects responded to auditory stimuli only; no pictures or other representations of the stimulus items were present.

Experimental Gating Task

The experimenter began by saying:

> I am going to play some words for you. Your job will be to tell me what you think each word is. You will hear each word several times. In the beginning, it may be hard to decide what the word is, but you *must* give an answer.
>
> We will start with a set of practice trials so you can see how this works. [The first practice trial was begun and stopped as needed to reinstruct and answer questions.] Do you have any questions? [If not, the second practice trial was begun.] This is another practice run. [Subjects generally had no difficulty with the task and the experimenter proceeded immediately to the test trials.]
>
> OK, we are ready to begin. Remember to try to guess the word as soon as you can.

The experimenter recorded the response—a word or partial word—to each item. If the subject paused too long before responding, the tape recorder was turned off and the response was requested. When the response was not a complete word, it was recorded phonetically. When the experimenter was uncertain whether the response was a word or a nonword, "What does ______ mean?" was asked. Subjects' responses were not tape-recorded because children sometimes direct more attention to the recorded sound of their voices than to the task. General encouragement, but no direct feedback, was given.

Gated stimuli were presented monaurally via headphones at 30 dB Sensation Level (see Note 2) re each listener's threshold for spondaic words (i.e., *ice cream, football,* etc.). Testing was conducted in a relatively quiet schoolroom for children with LD, and Audiocups were used for additional attenuation of ambient sound. Testing of NA children was conducted in a sound-treated chamber and was completed in a single session that lasted about an hour. Testing for children with LD usually continued over two or more sessions of 45 minutes to an hour each, because additional procedures were administered to them *after* the gating task had been completed.

Experimenters

All collection of experimental data and all hearing testing was conducted by regular staff members of the project directed by the first author (Elliott et al., 1989). These investigators had completed hundreds of hours of testing children with learning disabilities and nondisabled children on these and similar tasks. These examiners also administered the PPVT-R measures to the nondisabled children. Collection of PPVT-R and other information for the children with learning disabilities was directed by the third author.

Data Analyses for Experimental Gating Task

The "isolation point" (IP) was defined as the word duration at which the subject first correctly reported the stimulus word without subsequently changing his or her response. Occasionally a subject did not succeed in identifying a word, even at the longest gate (this event has been observed in other research—Elliott et al., 1987; Grosjean, 1980). In this instance, 60 msec was added to the duration of the longest stimulus of the set for that word, and the resulting value was used in statistical analyses. This approach was conservative in that it assumed the subject would identify the stimulus if only one more gate were presented—an outcome that might not have occurred. Because not every word was identified by every subject, the percentage of words correctly identified at the longest duration was also analyzed.

RESULTS

Outcomes for the gating task were considered in terms of percentages of words identified, mean isolation points, response strategies as reflected by different meaningful-word and nonword incorrect responses, and the relation of receptive vocabulary to performance on the gating task.

The average percentages of words that were correctly identified, at least at the longest durations, are shown in Table 2. NA children, on average, identified approximately one more word (5.3%) than the children with LD. This difference was statistically significant; for arcsine-transformed values, $t(34) = 2.18$, $p < .05$.

Mean Isolation Points are also shown in Table 2. The total average duration of the stimuli items was 513 msec. Thus, both groups of children correctly identified the stimulus items after hearing an average of just over 60% of the word durations. Children with LD required an average of 6.8 msec longer durations than NA children for word identification, a difference that was not significant, $t(34) = 0.52$, $p > .05$.

Even though mean IPs did not differ between groups, there was a possibility that the two groups of children responded differently to the task. *Different* meaningful-word and *Different* nonword incorrect responses (i.e., responses before the IP) were assumed to represent at least one aspect of the child's response strategies. These two values were tabulated for each child and averaged (see Table 2). No between-group differences occurred.

The NA children had higher mean PPVT-R standard scores than the children with LD; $t(34) = 7.34$, $p < .001$ (see Table 2). When the two groups of children were combined, those with higher PPVT-R standard scores identified significantly more words ($r = .44$) (see Table 3). This correlation, however, did not achieve significance in the subgroups. Only among the children with LD were higher PPVT-R standard scores significantly associated with lower (i.e., better) mean IPs ($r = -.49$). No other correlations with PPVT-R standard scores achieved significance. (PPVT-R age scores had no significant correlations for the combined groups, or for the NA children. For the children with LD, however, the PPVT-R age score had an even higher correlation than the standard score with the mean IP: $-.62$.)

Mean fine-grained auditory discrimination performance for the LD and DNA groups is shown in Table 4, which indicates that, for all four measures, performance of the children with LD was numerically poorer than for the DNA children. Differences did not achieve statistical significance for the two place-of-articulation measures, but were significant for the two voice-onset-time measures; JBP, $t(34) = 2.1$, $p < .05$; JPB, $t(34) = 2.6$, $p < .02$.

DISCUSSION

These results demonstrate similar behavior between children with LD and NA children on a task on which the youngsters with LD might have been expected to perform more poorly. The NA children, as a group, identified only one more word than the children with LD. Only among the children with LD did those with higher PPVT-R standard scores identify words at shorter durations (see Table 3). This indicates that those children with LD whose difficulties were particularly related to receptive vocabulary, as measured by the PPVT-R, demonstrated especially poor ability to achieve closure for these highly familiar

TABLE 2
Mean Performance on the Peabody Picture Vocabulary Test-Revised (PPVT-R) and the Gating Task Among Children with Learning Disabilities (LD) and Normally Achieving (NA) Children

	Group			
	LD		NA	
	M	*SD*	*M*	*SD*
PPVT-R standard score	95.3	8.1	123.4	14.1
Percentage of words identified	90.8	8.3	96.1	4.7
Isolation point (msec)	326.8	40.0	320.0	38.9
Number of different meaningful incorrect responses	1.8	0.3	1.9	0.4
Number of different nonmeaningful responses	0.2	0.2	0.2	0.3

TABLE 3
Correlations of Peabody Picture Vocabulary Test-Revised (PPVT-R) Standard Scores with Percentage of Words Identified, Mean Isolation Points, and Numbers of Different Meaningful and Nonmeaningful Incorrect Guesses for Children with Learning Disabilities (LD) and Normally Achieving (NA) Children

	Group		
	Total $n = 36$	LD $n = 18$	NA $n = 18$
Percentage of words identified (arcsine transformed)	.44*	.36	.24
Isolation point (msec)	−.18	−.49*	−.02
Number of different meaningful incorrect responses	.04	−.34	−.02
Number of different nonmeaningful responses	−.07	−.09	−.06

*$p < .025$, one-tailed test. **$p < .005$, one-tailed test.

TABLE 4
Mean Fine-Grained Auditory Discrimination for Synthesized Consonant-Vowel Syllables Among Children with Learning Disabilities (LD) and Different Normally Achieving (DNA) Children

	Group			
	LD		DNA	
	M	*SD*	*M*	*SD*
Place-of-articulation				
JDB	2.4	1.4	1.8	0.9
JDG	3.6	1.2	3.1	0.9
Voice-onset-time				
JBP	3.9	1.5	3.0	1.0
JPB	4.0	1.4	3.1	0.7

Note. A smaller score is a better score.
JDB = just noticeable difference (JND) measured from best exemplar of *da* in the direction of *ba*.
JDG = JND measured from best exemplar of *da* in the direction of *ga*.
JBP = JND measured from best exemplar of *ba* in the direction of *pa*.
JPB = JND measured from best exemplar of *pa* in the direction of *ba*.

words, whereas the children with LD with better receptive vocabularies, whose problems may have concerned math skills, for example, demonstrated better auditory closure.

Children with LD and NA children had averages of 1.8 and 1.9 *different* meaningful incorrect responses to stimuli with durations shorter than their IPs; both groups of children gave averages of 0.2 different nonword responses before their IPs. These numbers may be compared with values reported by Elliott et al. (1987), who found that 5- to 7-year-old children made an average of 2.6 different meaningful incorrect guesses and 0.3 different nonword incorrect responses whereas 15- to 17-year-olds made an average of 1.9 different meaningful incorrect responses and 0.03 different nonword guesses. Not only did the children with LD and the NA children of this study use similar response strategies, as measured by meaningful and nonword incorrect responses, in addressing the gating task, but also, this aspect of their performance compared favorably with that of normally achieving teenagers tested on the same procedure (see Note 3).

The percentage of words identified by the NA children also compared favorably with the performance of teenagers (Elliott et al., 1987); the latter group identified an average of 96.8 words correctly, less than one more word than the NA children of this study. In contrast, the children with LD, whose average age was 10 years, 3 months, identified about as many words by presentation of the longest gate as previously tested, younger normally achieving children (Elliott et al., 1987) whose average age was 6 years, 3 months.

The good performance of the youngsters with LD on the gating task contrasted with their relatively poor fine-grained auditory discrimination. These results—good performance on a task involving auditory closure and poor performance on an auditory task based more directly on sensory discrimination—extend to a much younger age range and to a different task the findings of Elliott and Busse (1987). The findings are not in accord with Wood's (1974) conclusions and suggest that auditory closure and fine-grained auditory discrimination are independent skills. These children with LD appear to have auditory closure skills that function well for word retrieval. One may speculate whether the poorer fine-grained auditory discrimination of the children with LD resulted in their having poorer receptive vocabularies (as measured by the PPVT-R). Phrased in everyday language, does difficulty hearing small acoustic differences between speech sounds lead to difficulty in learning new words?

SUMMARY

Children with learning disabilities and normally achieving children showed similar performances on the forward-gating, word-identification procedure when highly familiar monosyllabic words served as stimuli. NA children identified only one more word than did the youngsters with LD; there were no differences between the two groups in mean word durations required for correct identification. These similar performances occurred even though the children with LD had poorer receptive vocabularies, as measured by the PPVT-R, and poorer fine-grained auditory discrimination than age- and Gender-matched controls, particularly for consonant sounds differing in voice-onset-time. Response strategies for the gating task, as reflected by incorrect meaningful and nonword responses of the two groups of children, did not differ. Results suggest that the cognitively based, auditory closure skills of these children with LD match those of their normally achieving agemates and that sensory processing problems of the sort assessed by the fine-grained auditory discrimination task may contribute significantly to their learning difficulties.

ABOUT THE AUTHORS

Lois L. Elliott, *PhD, is professor of audiology in the Department of Communication Sciences and Disorders and professor of otolaryngology and head and neck surgery at the Medical School, Northwestern University.* **Margo E. Scholl**, *BS, is a technical researcher in the audiology program, Communication Sciences and Disorders Department, Northwestern University.* **James O. Grant**, *PhD, is associate professor of special education, Grand Valley State College.* **Michael A. Hammer**, *MA, is a project coordinator, Program in Audiology and Hearing Impairment, Communication Sciences and Disorders Department, Northwestern University. Address: Lois L. Elliott, Program in Audiology and Hearing Impairment, Northwestern University, 2299 Sheridan Rd., Evanston, IL 60208-3550.*

AUTHORS' NOTES

1. This work was supported, in part, by a grant from NINCDS (NIH).
2. We thank Bonnie B. Siu for data collection assistance.

NOTES

1. HL, or Hearing Level, compares an individual's auditory sensitivity with a standard. 0 dB HL represents average hearing levels of young adults who have no history of noise exposure or ear disease. Hearing levels of 25 dB HL or numerically smaller values are considered to be within the range of normal hearing.
2. Sensation Level refers to number of decibels (dB) above a listener's threshold. Spondaic words have two syllables of equal stress. For example, if a listener's threshold (level or loudness required for 50% correct response) for spondaic words were 15 dB HL, then stimuli at 30 dB Sensation Level would be presented at 45 dB HL.
3. It might be noted that stimuli of the Elliott et al. (1987) study had the same initial gate duration (120 msec) as stimuli of this study; however, stimuli durations of the Elliott et al. (1987) work increased in 30-msec increments instead of the 60-msec increments used here. (Stimuli in both studies increased to the same maximum durations.) It is not clear whether the difference in increment size could have affected numbers of different meaningful and nonword incorrect responses. Even if this difference had an impact, it is not clear what it might have been.

REFERENCES

Blalock, J.W. (1987). Auditory language disorders. In D.J. Johnson & J.W. Blalock (Eds.), Adults with learning disabilities: Clinical studies (pp. 81–105). New York: Grune & Stratton.
Dunn, L.M., & Dunn, L.M. (1981). Peabody picture vocabulary test–Revised. Circle Pines, MN: American Guidance Service.
Elliott, L.L. (1979). Performance of children aged nine to seventeen years on a test of speech intelligibility in noise using sentence with controlled word predictability. Journal of the Acoustical Society of America, 66, 651–653.
Elliott, L.L. (1986). Discrimination and response bias for CV syllables differing in voice onset time among children and adults. Journal of the Acoustical Society of America, 80, 1250–1255.
Elliott, L.L., & Busse, L. (1987). Auditory processing by learning disabled young adults. In D.J. Johnson & J.W. Blalock (Eds.), Adults with learning disabilities: Clinical studies (pp. 107–129). New York: Grune & Stratton.
Elliott, L.L., Busse, L.A., Partridge, R., Rupert, J., & DeGraaff, R. (1986). Adult and child dis-
(continued on p. 259)