Evaluating central auditory processing in children

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IN ORDER TO evaluate central auditory processing in children, it is important first to agree upon a definition of that term. As Keith (1981, this issue) has pointed out, a variety of terms such as *central auditory perception* and *auditory perceptual skills* have been used interchangeably with *central auditory processing,* none having been precisely defined. These terms may be understood as referring to the analyses of signals that have been transduced by the peripheral auditory system and/or to the neurological processes involved in obtaining information from signals presented in the auditory modality. Relatively little is known, however, about the analysis or coding of auditory signals in the auditory system beyond the peripheral level, or about the neurological processes involved. Thus central auditory processing refers most frequently to psychologically and behaviorally defined phenomena measured in relation to an auditory signal. Examples are discrimination, identification, speed of processing, sequencing, and short-term memory. Behavioral testing designed to evaluate these phenomena has been performed within paradigms provided by experimental psychology and speech science. Clinicians' current understanding of children's processing of auditory stimuli is based almost exclusively on data from studies of behavioral responses to auditory stimuli.

Interest in central auditory processing among speech-language pathologists has been motivated by the hypothesis that there are cause-and-effect relationships between deficits in auditory processing on the one hand and language and language-based learning disorders in children on the other. Some investigators, reasoning that language depends on the ability to process the speech waveform, suggest that auditory processing deficits and, in particular, deficits in the processing of rapidly changing stimuli are more basic or primary in nature than language disorders (Tallal & Piercy, 1974, 1975).

In fact, there is at present little support for this hypothesis (American Speech–Language–Hearing Association [ASHA], 1980). Upon review, the practice of examining nonspeech auditory abilities such as sound localization, auditory flutter fusion, or the discrimination of tone sequences in language- or learning-disordered children appears to have little diagnostic value. Such procedures do not provide information about the manner in which children process linguistic information, nor do they help one to determine how auditory speech processing may differ in normal and language-disabled children.

Speech-language pathologists are more concerned with the manner in which children process speech as opposed to nonspeech sounds. In this article, therefore, behaviorally defined operations, in normal and language-disordered children, relating primarily to speech processing and to the comprehension of speech, are emphasized. Information about nonspeech processing is referred to only when it is relevant to the problem of speech perception.

Most of the available information about speech perception is focused on the process of decoding the speech signal into phonemes (i.e., consonants and vowels), the smallest units of sound used in language to signal differences in meaning. Studies of adult speech perception have concentrated on phoneme perception and studies of children have largely followed that tradition.

EXISTING CLINICAL TESTS OF SPEECH PERCEPTION

Clinical tests of speech perception have, as their goal, assessment of speech sound discrimination and auditory memory for speech materials. They derive from efforts to diagnose language disorders in normal hearing children and to evaluate the performance of hearing aids in hearing impaired children. Some crossover may take place, however, in that speech-language pathologists may become interested in tests devised for use in audiologic practice and audiologists may become interested in tests devised for diagnostic purposes in speech-language pathology. Examples of tests used by speech-language pathologists are: the Wepman Auditory Discrimination Test (Wepman, 1973); the Goldman-Fristoe-Woodcock Diagnostic Auditory Discrimination Test Parts I, II, and III (Goldman, Fristoe, & Woodcock, 1974b); the Goldman-Fristoe-Woodcock Auditory Memory Tests (Goldman, Fristoe, & Woodcock, 1974a); the Auditory Sequential Memory subtest of the Illinois Test of Psycholinguistic Abilities (ITPA) (Kirk, McCarthy, & Kirk, 1982). The Goldman-Fristoe-Woodcock tests employ tape recorded materials. Examples of tests typically associated with hearing aid evaluation are: the Word Intelligibility of Picture Identification (WIPI) Test (Ross & Lerman, 1970, 1971); and the Phonetically-Balanced Test of Speech Discrimination for Children (PBK-50) (Haskins, 1949).

Performance on these tests is likely to be influenced by such variables as attention, level of unrelated activity, and vigilance. In addition, the tests employing pictures may tap visual and cognitive processes (e.g., those involved in recognizing a picture, as well as in speech sound discrimination). Finally, the tests are likely to reflect linguistic abilities such as naming, word recognition, and the ability to follow verbal directions. Thus the tests are not language-free and are not tests of speech perception only.

More recently developed speech perception tests have endeavored to deal with this problem by controlling for the level of linguistic difficulty of test materials. Some have incorporated nonsense syllables as a means of removing the effects of children's semantic or syntactic knowledge. These tests include

- the Speech Perception in Noise Test (SPIN) (Elliott, 1979), in which the effects of predictability of sentences and of signal-to-noise ratio are estimated;
- the Northwestern University Children's Perception of Speech Test (NU-CHIPS) (Elliott et al., 1979; Elliott & Katz, 1980), a test of word understanding in which items from the vocabulary of 3-year-old children are used. Normative data indicate performance that improves with age in quiet but not in noisy conditions, in 5- to 10-year-old children;
- the Nonsense Syllable Test (Resnick, Dubno, Hoffnung, & Levitt, 1975), a test of speech discrimination, also administered in quiet and noise, that yields reliable results with children 8 years and older (Bess & Gilber, 1981) as well as adults;
- a distinctive feature analysis of speech sound discrimination (Koenigsknecht & Lee, 1968), based on a target identification test in which both real words and nonsense consonant-vowel-consonant (CVC) syllables are employed (results from this test indicated that items differing in only one phonetic feature are more difficult for children to discriminate than items differing in two or more features).

EXPERIMENTAL PROCEDURES FOR ASSESSING SPEECH PERCEPTION

Tests that employ word or sentence materials are subject to the objection that they tap linguistic abilities, not speech perception abilities. (See also Keith, this issue.) The use of nonsense syllable pairs from a small set, on the other hand, may make it possible to investigate the effects of the physical acoustic properties of the speech signal on speech perception. In such tests, children are asked to listen to syllables that could occur in a meaningful word, yet are not meaningful in themselves. Computer-generated syllables or altered real speech syllables may be used; and, in generating these stimuli, specific acoustic properties such as formant frequencies (concentrations of energy in given frequency regions), formant transitions (changes in frequency in these energy concentrations over time), and voice onset time (time of initiation of voicing in relation to the release of a stop consonant) may be varied in systematic ways.

The speech waveform is a complex signal. It is still not known exactly how the signal is decoded in normal adults. Early studies revealed that, contrary to the expectations of phoneticians, the sounds of spoken language do not occur as discrete signals or "beads on a string," but rather occur in parallel over the course of units of syllable size or greater. If the transformation from sound to phoneme were a discrete process, it would be far easier to understand and describe it. Instead, for example, the patterns of energy characterizing the stop consonants change as a function of the following vowel in CVC syllables (Liberman, Cooper, Shankweiler, & Studdert-Kennedy, 1967).

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Experimental studies of normal children's speech perception are relatively recent. The past 15 years have witnessed the majority of such studies. It seems that developmental research has received only minor attention from speech scientists, perhaps because of the erroneous assumption that children do not differ significantly from adults. This assumption received support from initial studies of infant speech perception. These studies, involving operant conditioning or physiological monitoring techniques, demonstrated that normal infants can discriminate between certain phonemes much as adults do (e.g., Eimas, Siqueland, Jusczyk, & Vigorito, 1971; for a review see Kuhl, 1979). More recent studies of infants have shown that some speech discriminations are not present until late infancy (Eilers, Wilson, & Moore, 1977), and cross-linguistic studies suggest that for some sounds, infants' discrimination is related to their language environment (Eilers, Gavin, & Wilson, 1979). Furthermore, initial assumptions that early discriminative abilities are sufficient to account for the acquisition of a specific native phonology have correctly been questioned.

Categorical perception

Although most attention has been paid to infant speech perception, a group of studies have been conducted with children between the ages of approximately 3 and 14 years of age. Most of these studies have followed the procedures used to test categorical perception in adults (Liberman et al., 1967). Categorical perception refers to a mode of perception in which the ability to discriminate between sounds appears limited to the ability to label them differently. Studies of this phenomenon use synthesized stimuli, which are made to differ in equal physical steps from one phoneme to another. Thus, for example, a stimulus continuum may be created so that the acoustic patterns appropriate for the syllable */ba/* change gradually into the pattern appropriate for the syllable */da/*. However, when subjects are asked to label these stimuli, they respond as though they only hear the endpoint phonemes, */ba/* and */da/*, and frequently do not hear any ambiguous sounds in the transition from one to the other. When the same subjects are asked to discriminate between pairs of stimuli from adjacent points on the continuum, they show that they cannot as easily discriminate pairs when they come from the same phoneme class (e.g., different examples of */ba/*) as when they come from different phoneme classes (e.g., */ba/* versus */da/*).

Current understanding of categorical perception has been considerably refined since it was first discovered. Many modifications have been made in the original interpretations of this perceptual effect. Although categorical perception can no longer be offered as the sole explanation for speech perception, it provides a useful set of data for comparisons across age. A number of researchers have questioned whether the labeling and discrimination functions found in adult subjects would also be observed in children of all ages.

In fact, developmental changes are observed across age for normal children. Most change is seen between the ages of 3 and 10 years of age, but even in adolescence, children differ from adults on certain measures. For example, as children progress from early childhood to middle childhood, their ability to categorize stimuli consistently from physical continuua improves (Bernstein, 1982; Greenlee, 1978; Krause, 1978; Simon & Fourcin, 1978; Zlatin & Koenigsknecht, 1975). Discrimination also improves with age. Improvement is shown in tests for phoneme contrasts, and for pairs of stimuli that differ acoustically but are within the same phoneme class (Eguchi, 1976; Elliott, Longinotti, Meyer, Raz, & Zucker, 1981).

Descriptions of developmental changes in the speech perception of normal children are important for understanding children with developmental disabilities. Whereas differences between normal and impaired children of a particular age were once thought to represent neurological (hard-wired) differences, it is now becoming apparent that impaired children may be exhibiting developmental lags in speech perception. Their responses are similar to those of younger normal children and are not necessarily deviant.

Categorical perception has not been investigated in language-impaired children. Preliminary data from a group of specifically language-impaired children studied by Tallal and Stark (unpublished data) suggest that their performance is poorer than that of age-matched normal control children, and may resemble that of much younger children.

The findings from normal children are somewhat perplexing in relation to some of the results of infancy studies. The performance of these children at ages 2 through 5 years appears to be less accurate than that of normal prelinguistic infants for some phonemes. The task presented to the older child, however, involves cognitive/linguistic processes and decision making at a much different level than that demanded of the infant. The interaction between auditory and cognitive/linguistic processes may be most severely affected in language-disabled children.

Sequencing, rate processing, and serial memory

In a recent project (Stark & Tallal, 1981; Tallal & Stark, 1981), auditory processing capabilities, including identification, sequencing, rate processing, and serial memory for nonsense syllable stimuli (stop + vowel syllables) were studied in normal and specifically language-impaired (SLI) children. Two subject groups, one delayed in language development and the other developing language normally, were selected for the project. The children considered for the SLI group were sufficiently impaired in receptive and expressive language to have been placed in schools or classes for the communicatively impaired.

The children in both groups were required to have normal oral sensory and motor functioning, to have demonstrated normal hearing, to have no history of hearing impairment, and to be within normal limits in nonverbal intelligence (performance IQ between 85 and 125 on the WISC-R [Wechsler, 1974] or the Wechsler Preschool and Primary Scale of Intelligence [WPPSI] [Wechsler, 1963]). In addition, the subjects were required to present neither signs of neurological impairment nor a history of neurologic deficit or lesion.

Thirty-five SLI children and 36 normal children, aged 5 to $8^1/_2$ years, who met the above criteria were identified. The children selected for the two subject groups were given an extensive battery of experimental tests. This battery included perceptual tests that were administered in the auditory and visual modalities as well as cross-modally (auditory plus visual).

Each test included a stimulus pair which might be auditory, visual, tactile, or cross-modal in nature. These pairs were presented in binary sequences or series within a procedure named the Repetition Method (Tallal & Piercy, 1974, 1975). The child was required to give a nonverbal response by pressing one of two panels in response to each of the members of these stimulus pairs. Each test included a number of subtests that were always given in the same order. These subtests of the Repetition Method were: (a) *Detection,* in which the child learned to push one button in response to one member of a stimulus pair, such as one of two nonsense syllables or one of two tones; (b) *Association,* in which the elements were presented in a random series one at a time and the children pushed the button associated with the syllable, tone, or other element presented; (c) *Sequencing,* in which the elements were presented in random order two at a time and the children pushed the two buttons associated with the signals presented, in the sequence in which the signals were presented; and (d) *Serial Memory,* in which the elements were presented in random order 3 to 7 at a time, and the children again followed these longer sequences in their button-pushing responses. *Special Sequencing Subtests* (Rate-Processing Subtests), in which consonant-vowel formant transition rates or intervals between stimuli were varied, were presented, as well as a standard Sequencing Subtest. If the children failed the standard Sequencing Subtest for some test items, they were given a Same/ Different Discrimination Subtest as a means of exploring the reasons for failure at the Sequencing Subtest level.

The children were also given an oral sensorimotor test battery, a neurodevelopmental battery, and a series of visual scanning or cancellation tests in which they were required to select and mark letters, digits, words, nonsense shapes, and forms presented among similar items. These tests resulted in approximately 425 independent variables that were available for comparison, including 28 demographic

Table 1. Final composite multiple regression equation

Variable name	Regression equation	Computed *t* test/ *p* value	Partial correlation coefficient	Final *F* text/ *p* value	Standard error	Step *F* overall	Multiple *R*
			SLI children				
	72.70						
Rate processing for synthetic CV syllables /*ba*/ and /*da*/, 10 ms ISI, (no. of errors)	−2.52	−4.13/.00	−6.22	17.08/.00	8.80	17.08	.60
Identification of synthetic CV syllables /*ba*/ and /*da*/, 80 ms vowel formant transitions (no. of trials taken to reach criterion)	1.08	4.97 /.00	.69	6.19/.02	8.13	13.11	.69
Identification of synthetic CV syllables /*ba*/ and /*da*/, 40 ms vowel formant transition (no. of errors)	−.83	−3.79/.00	−.59	10.02/.00	7.10	14.80	.78
Identification of 250 ms tones (high and low) (no. of errors)	−.82	−3.31/.00	−.54	10.93/.00	6.10	17.77	.85
			Normal children				
	64.41						
Visual scan for *en* in real words	1.30	3.53/.00	.53	114.07/.00	6.75	114.07	.87
Visual scan for *narp* among other nonsense words	.80	3.98/.00	.57	13.45/.00	5.80	84.04	.91
Right-left discrimination, reaction time	−1.28	−3.72/.00	.55	10.09/.00	5.15	74.36	.93
Visual scan for pictured objects with names having initial *b*	.69	2.33/.03	.38	5.44/.03	4.84	64.62	.94

and/or social, family, and medical history variables.

The SLI children were found to differ significantly from the normal children on all of the subtests of speech perception that were administered with synthesized speech stimuli (stop consonant-vowel stimuli), and on all of the subtests except the easier Identification Subtest when comparable recorded real speech stimuli (stop consonant vowel syllables) were employed. Thus the findings indicated that SLI children were significantly inferior to normal children in speech processing capabilities.

It was then asked whether the speech processing and language abilities of the normal or the SLI children were correlated with one another. The results are summarized in Table 1. Table 1 indicates that, from the entire set of over 400 variables, 4 auditory perception variables contributed most to "prediction" of level of receptive language in the SLI children; that is, these variables were most highly correlated with receptive language.

A Rate Processing variable, namely, sequencing of the synthetic syllables */ba/* and */da/* presented with a very short interstimulus interval (10 ms), was first in order of importance of these variables. The multiple r for this variable in relation to level of receptive language, however, was only .60. Many SLI children did not reach criterion levels of performance on a test of lower-level Association subtest in which the same syllables were presented one at a time; thus they were not able to proceed to the Rate Processing task involving these same syllables. The value of the multiple r was increased to .78 by the addition of two speech perception tests. The first test was an association test for the syllables */ba/* and */da/* with a 40 ms vowel formant transition and an 80 ms vowel formant transition. In addition, a nonspeech auditory perception variable, namely, Association for 250 ms tones, one low (fundamental frequency of 100 Hz) and one high (fundamental frequency of 350 Hz), also made a significant contribution to prediction of receptive language scores in these children. All of the SLI children except one were able to respond with a certain minimal level of accuracy on these easier Association tasks.

Table 1 indicates a quite different result for the normal children. From the set of over 400 variables, 3 visual cancellation variables and a right-left discrimination test from the neurodevelopmental battery contributed most to prediction of receptive language scores in normal children. Auditory speech perception variables, it should be noted, were also quite highly correlated with receptive language in these normal children, but not as highly correlated as the more advanced, reading-related visual cancellation variables. These latter variables included selection and marking scores that reflected a knowledge of phoneme-grapheme correspondence, as well as the ability to analyze words according to their component phonemes and syllables. Optimum performance on these visual cancellation tests may well build on the normal children's well-developed speech perception abilities. The SLI children, whose speech perception scores were poorer than those of the normal children, were not able to perform well on the reading-related visual cancellation tasks. It has been shown in other studies that speech perception abili-

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These results must be regarded as preliminary, because multivariate statistical analyses of this kind optimally require many more subjects (i.e., a much more favorable ratio of number of subjects to number of variables) than were available in this project. However, the results do suggest that correlations involving speech processing and language comprehension, even if reliable, would be open to interpretation as evidence of either maturational lag *or* deviant development of speech processing in the SLI children.

Additional evidence from a follow up study of the SLI children is relevant to this latter issue (Bernstein & Stark, in prep.). The Sequencing, Rate Processing, and Serial Memory Subtests using synthetic speech stimuli (*/ba/* and */da/*) were repeated with children from both groups in the previous project after an interval of 3½ to 4 years. At the time of follow up (Time 2), the SLI children showed some progress in language development as compared with the time of initial contact (Time 1). However, the majority of these children were still significantly language impaired. At Time 2, performance was at or near ceiling level for sequencing and rate processing on the part of subjects in both groups, indicating that perceptual development occurred in both the normal and the SLI children. Neither the SLI nor the normal children, however, performed at ceiling level on the Serial Memory Subtest. All children improved with respect to the Serial Memory Subtest from Time 1 to Time 2. However, significant age and language ability effects in relation to the Serial Memory Subtest were not present in the data from Time 2. These results suggest that speech processing in the SLI children may be related to a maturational lag rather than a central nervous system lesion. The lag may be in perceptual learning rather than in some more peripheral process, as suggested by Tomblin and Quinn (1983).

IMPLICATIONS

The data from the Tallal-Stark studies suggest that perception of synthesized nonsense syllables may be correlated with language comprehension in both normal and SLI children from 5 to 8 years old. The exact nature of this relationship, should it be substantiated in further work, remains to be determined. It is possible that reception of language and the ability to identify, to sequence, and to remember series of speech events presented in the auditory modality, develop together in both normal and SLI children. Certainly the longitudinal results found by Bernstein and Stark (in prep.) indicate that early perceptual deficits do not prevent language development. Both language understanding and speech processing may reflect higher-level perceptual learning. Both may require higher-level cognitive decisions on the part of the child at certain levels of development. A study by Bain, Till, Olswang, and Raffin (1982) suggests, for example, that normal and language-impaired children may not differ in speech discrimination abilities when the experimental paradigm minimizes linguistic and cognitive processing and when natural speech stimuli are presented.

The studies reported thus far do not rule out a causal relationship between speech perception and development of language comprehension. It is also entirely possible, however, that both speech perception abilities and language comprehension relate to other variables not well understood. These might include the quality of language experienced by the child, and aspects of neuroanatomical and neurophysiological development, especially in the left hemisphere.

Further investigation of the development of speech processing in language-impaired children is impeded by the lack of a cohesive theoretical framework for such studies. Do children first perceive single acoustic features and gradually integrate them into feature complexes that may be identified as phonemes in syllables; or do they perceive syllables holistically and only gradually acquire the ability to "unpack" these larger units perceptually and according to the sets of individual features of which they are composed? At what ages do children begin to perceive different allophones of a given phoneme as belonging to the same class in their language? At what ages are they capable of recognizing as equivalent phonemes and syllables produced by different speakers or in different contexts? In other words, when and how do they form equivalence classes?

It seems likely that research in this area will not progress further until a model dealing with these aspects of the development of speech perception evolves. In the meantime, the importance of the experimental work that has been carried out thus far for clinical assessment and intervention must be considered.

The techniques that have been used in assessing speech processing, although providing information of interest, are not yet appropriate for use in a clinical diagnostic situation. However, in the course of the Tallal-Stark and Stark-Bernstein studies, a great deal was learned about the language-disabled children who typically manifest speech processing deficits when compared with normally developing children on experimental testing.

These children had more severe expressive than receptive language impairment. Their receptive difficulties should not, however, be underestimated. While their word recognition abilities tended to be high, and superior to other linguistic abilities, their performance on the Token Test (DeRenzi & Vignolo, 1962; DiSimoni, 1978), a receptive test that provides little contextual support and in which the language presented is highly nonredundant, was quite severely impaired. In particular, their scores on Part IV of the Token Test, that part that places greater stress on auditory memory, were low (see also Tallal, 1975).

It was observed that, when these language-disabled children were expected to respond to requests and instructions in the classroom, their performance was much poorer than would be predicted on the basis of their conversational ability. In situations where they knew the topic of conversation, and where they could use their word recognition ability to advantage and make guesses as to what was likely to be said, they appeared to understand spoken language well. Their understanding of academic information presented formally in the classroom was likely to be poor (i.e., at the level of their performance on the Token Test, *not* that exhibited in casual conversation).

As a group, these language-disabled children showed impulsivity on experimental testing by means of the Matching Familiar Figures Test (Catts, Condino, & Stark, 1982; Kagan & Kogan, 1970). This finding has been confirmed by Condino (1983). It is not clear how this impulsivity may relate to the children's language impairment, in other words, whether they show impulsivity because of their inability to rely on verbal mediation in generalizing and evaluating responses, or whether the impulsivity is a more basic characteristic. It is believed that this characteristic affects their academic progress, however.

As a group, these children manifested significant phonologic disorders. There appeared to be a relationship between the speech perception and speech production difficulties manifested by these children. Specifically, when asked to imitate nonsense syllables and nonsense words, they showed much greater difficulty in imitation of stops than was predicted on the basis of their spontaneous speech production (Shriberg, Smith, Stark, & Locke, 1981; see also Stark & Tallal, 1979; Tallal, Stark, & Curtiss, 1976 for a further description of these difficulties; and Golick, 1977, for a description of phonological processes that may be observed in the spontaneous speech of language-disabled children).

When the clinician suspects that a language-disabled child has an auditory speech processing problem, it might be helpful to find out if the foregoing pattern of language and auditory memory test scores is present. In particular, it is important in such cases to determine whether the child's: nonverbal cognitive abilities are superior to his or her verbal cognitive abilities; performance on the Token Test matches that described above; and auditory memory span for digits and sentences is impaired. It is also important to determine whether an articulation disorder, if present, reflects immature use of phonological rules.

Although there has been considerable debate about the role of auditory processing deficits in relation to developmental language disabilities, and although this debate is likely to continue, the clinician need not wait for the debate to be resolved before making decisions about approaches to intervention. For example, in children who are thought to have speech processing deficits, auditory training may well be contraindicated. Such training could emphasize unduly the skills that may be least well developed. Auditory training involving nonspeech materials (e.g., tones) could be especially counterproductive (see also Thal & Barone, 1983). Instead, every effort should be made to make certain that the child understands what is said to him or her, especially in the classroom. A slower than normal rate of production of speech may be adopted by the clinician or the teacher. Other strategies, such as careful introduction of new topics, use of simple explanations and short sentences, repetition, and use of alternate forms of expressing the same ideas, should be considered as well. The child should be encouraged to express in his or her own words the ideas that have been presented with the aid of these strategies.

Second, if such children show impulsivity, they should be trained to reflect on their own responses and to generate alternative responses. This training should begin with academic tasks that are clearly within the child's competence and should gradually be extended to new tasks as they are in the process of being acquired.

If children who are thought to have speech processing deficits show impulsivity, they should be trained to reflect on their own responses and to generate alternative responses.

Third, if speech articulation delay or impairment is found, the presence of a phonologic disorder should be investigated further. An attempt should be made to discover the phonological rules the child may be using and to modify that rule system. Production should be practiced in the context of phrases and sentences that are within the child's comprehension and that the child is capable of generating productively.

Clearly, these strategies might not be appropriate in the case of the child whose language disorder was primarily a pragmatic disorder, for example, the autistic child with delayed echolalia recently described by Prizant (1983) (see also Wetherby, this issue), nor for certain retarded children with delayed language abilities (see Das, this issue). Similarly, a quite different approach might need to be adopted in the case of a child with a severe receptive language disorder and superior expressive abilities, such as the "hyperlinguistic" adolescent described by Yamada (1981).

In summary, more sophisticated procedures for assessing speech perception in children are required. By documenting auditory speech processing impairments in language-impaired children, clinicians may add to their description of such children's disorders. Thus the ability to plan appropriate remediation is enhanced. The increasing sophistication of such procedures and the growth of understanding of the development of speech perception in normal children are necessary in order that the clinician's diagnostic approach may become more refined. It is not necessary for clinicians, however, to invoke speech processing deficits as an explanation of language disorders in children in order to justify the development of appropriate intervention procedures. Instead, they may choose (for the present) to consider speech processing deficits as a concomitant of certain specific language disorders and also of mixed language disorders with a phonologic-syntactic component.

It may be important for clinicians to document in individual children patterns of language disability, including auditory memory span deficits, that have been shown experimentally to be related to deficits in speech processing. It may be concluded that training in auditory perception is not likely to benefit children who show such patterns of language disability. Instead, a variety of compensatory strategies may be considered and remediation may address phonological and syntactic processes more directly.

REFERENCES

ASHA. 1980. Position Statement of the American Speech, Language, and Hearing Association on Language and Learning Disabilities.

Bain, B. A., Till, J. A., Olswang, L. A., & Raffin, M. J. M. (1982). *Auditory discrimination in language-disordered and normal children.* Paper presented at the meeting of the American Speech-Language-Hearing Association, Toronto.

Bernstein, L. E. (1982). Ontogenetic changes in children's speech sound perception. In N. Lass (Ed.), *Speech and language: Advances in basic research and practice: Vol 8* (pp. 191–220). New York: Academic Press.

Bernstein, L. E., & Stark, R. E. (in preparation). Speech perception development in language impaired children: A four-year follow-up study.

Bess, F. H., & Gilber, A. M. (1981). Syllable recognition skills of unilaterally hearing-imparied children. *ASHA, 23,* 724.

Carrow, E. (1973). *Test for Auditory Comprehension of Language.* Austin, TX: Learning Concepts.

Catts, H. W., Condino, R., & Stark, R. E. (1982). Impulsivity in language-impaired children. *ASHA, 23,* 773.

Condino, R. (1983). *Characteristics of the problem solving process in children developing language normally and spectfically language impaired children for nonverbal, visual tasks.* Unpublished doctoral dissertation. St. Louis University.

DeRenzi, E., & Vignolo, L. A. (1962). The Token Test: A sensitive test to detect receptive disturbances in aphasics. *Brain, 85;* 556–678.

Di Simoni, F. (1978). *The Token Test for children.* Higham, MA: Teaching Resources.

Eguchi, S. (1976). Difference limens for the formant frequencies: Normal adult values and their development in children. *Journal of the American Audiological Society, 1,* 145–149.

Eilers, R. E., Gavin, W., & Wilson, W. R. (1979). Linguistic experience and phonemic perception in infancy: A crosslinguistic study. *Child Development, 50,* 14–18.

Eilers, R. E., Wilson, W. R., & Moore, J. M. (1977). Developmental changes in speech discrimination in infants. *Journal of Speech and Hearing Research, 20,* 766–780.

Eimas, P. D., Siqueland, E. R., Jusczyk, P., & Vigorito, J. (1971). Speech perception in infants. *Science, 171,* 303–306.

Elliott, L. L. (1979). Performance of children aged 9 to 17 years on a test of speech intelligibility in noise using sentence material with controlled word predictability. *Journal of the Acoustical Society of America, 66,* 651–653.

Elliott, L. L., Connors, S., Kille, E., Levin, S., Ball, K., & Katz, D. R. (1979). Children's understanding of monosyllabic nouns in quiet and in noise. *Journal of the Acoustical Society of America 66,* 12–21.

Elliott, L. L., & Katz, D. R. (1980). *Northwestern University Children's Perception of Speech (NU-CHIPS).* St. Louis: Auditec.

Elliott, L. L., Longinotti, C., Meyer, D., Raz, I., & Zucker, K. (1981). Developmental differences in identifying CV syllables. *Journal of the Acoustical Society of America, 70,* 669–677.

Goldman, R., Fristoe, M., & Woodcock, R. W. (1974a). *The Goldman-Fristoe-Woodcock Tests of Auditory Memory.* Circle Pines, MI: American Guidance Service.

Goldman, R., Fristoe, M., & Woodcock, R. W. (1974b). *The Goldman-Fristoe-Woodcock Auditory Discrimination Tests (Parts I, II and III).* Circle Pines, MI: American Guidance Service.

Golick, M. (1977). *Language disorders in children: A linguistic investigation.* Unpublished doctoral dissertation, McGill University, Montreal.

Greenlee, M. (1978). Learning the phonetic cues to the voiced-voiceless distinction: A comparison of child and adult speech perception. *Papers and Reports in Child Language Development, 15,*160–169.

Haskins, H. L. (1949). *A phonetically-balanced test of speech discrimination for children.* Unpublished master's thesis, Northwestern University, Evanston, IL.

Kagan, J., & Kagan, N. (1970). Individual variation in the cognitive process. In P. H. Mussen (Ed.), *Manual of child psychology, Vol. 1* (pp. 1273–1365). New York: Wiley.

Keith, R. W. (1981). Audiological and auditory-language tests of central auditory function. In R. W. Keith (Ed.), *Central auditory and language disorders in children* (pp. 61–76). San Diego, CA: College-Hill Press.

Kirk, S. J., McCarthy, J. J., & Kirk, W. D. (1982). *Illinois Test of Psycholinguistic Abilities*. Urbana, IL: University of Illinois Press.

Koenigsknecht, R. A., & Lee, L. L. (1968). *Distinctive feature analysis of speech sound discrimination*. Paper presented at the meeting of American Speech, Language, and Hearing Association Convention, Denver, CO.

Krause, S. E. (1978). *Developmental use of vowel duration as a cue to postvocalic consonant voicing: A perception and production study*. Unpublished doctoral dissertation, Northwestern University, Evanston, IL.

Kuhl, P. K. (1976). Speech perception in early infancy: The acquisition of speech sound categories. In S. K. Hirsh, D. H. Eldredge, I. J. Hirsch, & K. Silverman (Eds.), *Hearing and Davis: Essays honoring Hallowell Davis* (pp. 265–280). St. Louis: Washington University Press.

Liberman, A. M., Cooper, F. S., Shankweiler, D. P., & Studdert-Kennedy, M. (1967). Perception of the speech code. *Psychological Review, 74*, 431–461.

Prizant, B. M. (1983). Language acquisition and communicative behavior in autism: Toward an understanding of the "Whole" of it. *Journal of Speech and Hearing Disorders, 48*, 296–307.

Resnick, S. B., Dubno, J. R., Hoffnung, S., & Levitt, H. (1975). Phoneme errors on a nonsense syllable test. *Journal of the Acoustical Society of America, 58*, S114.

Ross, M., & Lerman, J. W. (1970). A picture identification test for hearing-impaired children. *Journal of Speech and Hearing Research, 13*, 44–53.

Ross, M., & Lerman, J. (1971). *Word intelligibility by picture identification*. Pittsburgh: Stanwix House.

Shankweiler, D., & Liberman, I. Y. (1976). Exploring the relations between reading and speech. In R. M. Knights & D. K. Bakker (Eds.), *Neuropsychology of learning disorders* (pp. 297–314). Baltimore: University Park Press.

Shriberg, L., Smith, B. L., Stark, R. E., & Locke, J. (1981). *Classes of articulation disorder in young children*. Miniseminar presented at the American Speech-Language-Hearing Association.

Simon, C., & Fourcin, A. J. (1978). Cross-language study of speech pattern learning. *Journal of the Acoustical Society of America, 63*, 925–935.

Stark, R. E., & Tallal, P. (1979). Analysis of stop consonant production errors in developmentally dysphasic children. *Journal of the Acoustical Society of America, 66*, 1703–1712.

Stark, R. E., & Tallal, P. (1981). Perceptual and motor deficits in language impaired children. In R. W. Keith (Ed.), *Central auditory and language disorders in children* (pp. 121–144). Houston, TX: College-Hill Press.

Tallal, P. (1975). Perceptual and linguistic factors in the language impairment of developmental dysphasics: An experimental investigation with the Token Test. *Cortex, 11*, 196–205.

Tallal, P., Stark, R. E., & Curtiss, B. (1976). Relation between speech perception and speech production impairment in children with developmental dysphasia. *Brain and Language*, 3, 305–317.

Tallal, P., & Piercy, M. (1974). Developmental aphasia: Rate of auditory processing and selective impairment of consonant perception. *Neuropsychologia 12*, 83–94.

Tallal, P., & Piercy, M. (1975). Developmental aphasia. The perception of brief vowels and extended stop consonants. *Neuropsychologia 13*, 69–74.

Tallal, P., & Stark, R. E. (1981). Speech acoustic-cue discrimination abilities of normally developing and language impaired children. *Journal of the Acoustical Society of America 69*, 568–574.

Thal, D. J., & Barone, P. (1983). Auditory processing and language impairment in children: Stimulus considerations for intervention. *Journal of Speech and Hearing Disorders, 48*, 18–24.

Tomblin, J. B., & Quinn, M. A. (1983). The contribution of perceptual learning to performance on the repetition task. *Journal of Speech and Hearing Research, 26*, 369–372.

Wechsler, D. (1963). *Wechsler Preschool and Primary Scale of Intelligence (WPPSI)*. New York: Psychological Corp.

Wechsler, D. (1974). *Wechsler Intelligence Scale for Children-Revised (WISC-R)*. New York: Psychological Corp.

Wepman, J. M. (1973). *Auditory Discrimination Test*. Chicago: Language Research Associates.

Yamada, J. (1981). *Evidence for the independence of language and cognition: Case study of a "hyperlinguistic" retarded adolescent. Vol.* 3. UCLA Working Papers in Cognitive Linguistics, Los Angeles.

Zlatin, M. A., & Koenigsknecht, R. A. (1975). Development of the voicing contrast: Perception of stop consonants. *Journal of Speech and Hearing Research, 18*, 541–553.