Journal of Speech and Hearing Research, Volume 29, 332–347, September 1986

ANALYTIC STUDY OF THE TADOMA METHOD: LANGUAGE ABILITIES OF THREE DEAF-BLIND SUBJECTS

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This study reports on the linguistic abilities of 3 adult deaf-blind subjects. The subjects perceive spoken language through touch, placing a hand on the face of the speaker and monitoring the speaker's articulatory motions, a method of speechreading known as Tadoma. Two of the subjects, deaf-blind since infancy, acquired language and learned to speak through this tactile system; the third subject has used Tadoma since becoming deaf-blind at age 7. Linguistic knowledge and productive language are analyzed, using standardized tests and several tests constructed for this study. The subjects' language abilities prove to be extensive, comparing favorably in many areas with hearing individuals. The results illustrate a relatively minor effect of limited language exposure on eventual language achievement. The results also demonstrate the adequacy of the tactile sense, in these highly trained Tadoma users, for transmitting information about spoken language sufficient to support the development of language and learning to produce speech.

A number of papers have recently appeared on the Tadoma method of speechreading, a vibrotactile method of speech perception used by deaf-blind subjects (Norton et al., 1977; Reed, Doherty, Braida, & Durlach, 1982; Reed, Durlach, & Braida, 1982; Reed, Durlach, Braida, & Schultz, 1982; Reed et al., 1985; Reed, Rubin, Braida, & Durlach, 1978; Snyder, Clements, Reed, Durlach, & Braida, 1982). This method of speechreading has been used in training deaf and deaf-blind individuals for both receiving and producing speech, and for developing a knowledge of language (Alcorn, 1932; Gruver, 1955; Van Adestine, 1932; Vivian, 1966).

In the Tadoma method, the person receiving speech places a hand on the face and neck of the speaker and monitors the articulatory motions associated with normal speech production. In the typical hand placement, the thumb rests lightly on the talker's lips and the fingers spread out over the face and neck (Vivian, 1966). For the deaf-blind Tadoma speechreader, there is no auditory or visual input. Speech perception is achieved through the tactile sense alone. One advantage of using Tadoma for speechreading is that Tadoma users can receive speech from virtually any speaker, and thus are not limited to communication with specially trained individuals with whom they share a manual system of communication (Reed et al., 1985; Schultz, Norton, Conway-Fithian, & Reed, 1984).

Training in the skilled use of Tadoma for receiving and producing speech may extend over years of intensive, individual instruction. Students first receive training in speech reception, followed by training in speech production through imitating a teacher's articulatory motions (Schultz et al., 1984). In learning to produce speech, the student monitors the teacher's articulation by placing a hand on the teacher's face and neck, and then attempts to match the articulation while placing a hand on his or her own face.

The extent of the use of Tadoma in schools for the hearing-impaired and deaf-blind in the United States and Canada is described in a recent survey article (Schultz et al., 1984). Schultz et al. report on the use of Tadoma with students of varying disabilities, both as a primary means of speech training and in conjunction with other methods of speech and language training. The method was most widely used from 1920 to 1960, and its use has apparently declined since then. The survey reports that there are some 15 to 20 deaf-blind persons in the United States today who rely on Tadoma as their primary means of speech communication.

There was little discussion of the method in the research literature until the late 1970s, when reports on the speechreading abilities of experienced Tadoma users began to appear (see above). This recent research is motivated by an interest in developing tactile aids for speech communication by the hearing-impaired and the deaf-blind. The study of Tadoma is relevant to this goal in the information it provides about the capabilities of the tactile sense and the parameters involved in the use of Tadoma. The adequacy of the tactile sense for processing temporal information such as speech is clearly a question of basic importance with regard to the feasibility and design of such tactile aids. The degree of success that can be attained by Tadoma users in processing speech and developing language thus has serious implications for the potential of tactile aids to transmit spoken language information to deaf individuals.

A preliminary probe of the language knowledge of one deaf-blind Tadoma subject appeared in Norton et al. (1977). The purpose of this report is to extend the study to additional language measures on the original subject, and to present results of language testing with 2 additional highly experienced deaf-blind Tadoma users.

The 3 subjects are totally deaf and blind, 2 of them since they were 1½ years old. To examine the language[1]

[1]Throughout the body of this paper, the term *language* is used to refer to English. This is a study of the English of our subjects, and even though American Sign Language is mentioned, we did

0022-4685/86/2903-0332$01.00/0

of these Tadoma users, we administered several standardized verbal intelligence measures, a syntax test in use with deaf populations, and a number of special-purpose linguistic tests constructed for this study. In addition we analyzed samples of their oral and written language. The study is an exploratory one, and our purpose was to sample a wide range of diverse abilities, rather than attempt an exhaustive and systematic account in any one area. We thus have included in the testing an examination of vocabulary, and a range of syntactic, semantic, and prosodic features of language.

METHOD

SUBJECTS

Subject LD

LD, age 55, has been totally deaf and blind since age 19 months, following a case of spinal meningitis. His development was normal until that time, but he emerged from a 9-week coma having lost both sight and hearing. His use of language ceased, and he received no language training for almost 4 years. At age 5:4 (years:months) he entered the Perkins School for the Blind in Watertown, MA, and his language training through Tadoma was begun. Records of his early school years, reported by Stenquist (1974), provide details of his progress. Within 8 months he had 40 expressive words, and by age 7 he had 410 words and was combining 3 words into sentences. His schooling continued at the Perkins School until age 20, at which time his Stanford Achievement Test scores show an average Grade Equivalent of 6.6, with Grade Equivalents of 7.6 in Language Usage, 9.0 in Spelling, and 7.0 in Word Meaning. LD lives today in his own home, is married, and holds a factory job. Tadoma is his primary means of communication, aided occasionally by tactile finger-spelling and sign which he learned as an adult. His oral language and Tadoma speechreading abilities are sufficient for him to engage in fluent conversation with untrained hearing individuals. His literacy skills enable him to read Braille and type his own letters.

The results of audiometric testing indicate no pure-tone response in the right ear, while minimal low frequency response (probably vibrotactile) was observed in the left ear. LD demonstrates no ability to discriminate or identify speech sounds auditorily. He has attempted to use a variety of hearing aids with no success. Results of visual testing indicate no measurable visual acuity.

Subject RB

RB, age 49, has been deaf and blind since 20 months of age, as a result of spinal meningitis. His development was normal until that time. When he was 2½ he entered St. Mary's School for the Deaf in Buffalo, NY, where he remained until age 17. He was trained in Tadoma for speaking and receiving speech, and in the use of sign language, signed into his hand. After graduation from St. Mary's, he went on to study electronics at the Burgard Vocational High School. Today he works as an electronic technician, is a licensed ham radio operator, and has learned computer programming.[2] RB is able to read Braille and type his own letters. He is fluent in American Sign Language, and he often uses tactile sign or fingerspelling in communicating with people who command these manual systems. He reports that his communication with others is achieved about half the time using sign language, and half the time using Tadoma. His Tadoma proficiency and oral language are adequate for him to engage in conversation with untrained hearing speakers.

Results of pure-tone testing indicate minimal low frequency response (probably vibrotactile) in the right ear, with no response in the left ear. RB demonstrates no ability to discriminate or identify speech sounds auditorily and has never used a hearing aid. Visual tests reveal no measurable visual acuity.

Subject JC

JC, age 54, developed normaly until age 7, when she lost both sight and hearing as a result of spinal meningitis. She was subsequently trained in Tadoma at the Arizona State School and the California School for the Blind. She attended the University of the Pacific where she obtained a B.A. in Sociology. Today JC works for a State Department of Rehabilitation as the state-wide consultant for deaf-blind persons. JC reads Braille and is able to type her own correspondence and original short stories. Tadoma is JC's primary means of communication, and she is proficient enough to engage in fluent conversation with untrained hearing individuals. Her spoken language is sufficient to enable her to lecture at conferences which she attends in connection with her employment. She has not received training in sign language, but is skilled in tactile reception of fingerspelling.

JC has no measurable hearing or sight. She has no response to pure tones in either ear across the audiometric frequencies. She demonstrates no awareness of speech sounds and has never used a hearing aid. Similarly, tests of vision reveal no measurable visual acuity.

DESCRIPTION OF TESTS

Verbal Subtests from WAIS, WISC-R and Stanford-Binet

Verbal subtests from three intelligence scales in use with the hearing population were selected to provide

not analyze the subjects' competence in this area.

[2]RB uses Morse code to talk on his ham radio, and reads the computer screen by tactile Morse code output.

some standardized measures of the subjects' verbal abilities. Performance was measured on tests of vocabulary, differences between abstract words, proverbs, and the like. These tests were all administered orally, with a copy in Braille available for reference in case of doubtful perception. The subjects often referred to the Braille copy to be certain they were perceiving the words and questions accurately.

Two subtests were administered from the Wechsler Adult Intelligence Scale (WAIS, 1955). The WAIS Vocabulary subtest, which requires the subject to provide word definitions, has a maximum raw score of 80 and an average scaled score in the range of 8 to 12 (with a maximum of 19). The WAIS Similarities subtest, which requires a description of how two items are alike, has a maximum raw score of 26 and an average scaled score identical to that for the Vocabulary subtest. The Vocabulary subtest from the Wechsler Intelligence Scale for Children (WISC-R, 1974) was administered as well to provide a fuller picture of vocabulary knowledge, even though the scaled score is applicable only to chronological age 16. The maximum raw score on this test is 64. Finally, four subtests of the Stanford-Binet Intelligence Scale (1960) were administered. These included (a) Differences between abstract words (which requires a subject to define differences between three pairs of words, e.g., *laziness* and *idleness*); (b) Essential differences (which requires the subject to describe the principal difference between three pairs of words, e.g., *work* and *play*); (c) Abstract words III (which requires definition of five words, e.g., *generosity*); and (d) Proverbs (which requires the subject to relate the meaning of several proverbs, e.g., "All that glitters is not gold").

Test of Syntactic Abilities

The Test of Syntactic Abilities (Quigley, Steinkamp, Power, & Jones, 1978) was administered to provide a measure of the subjects' abilities with reference to norms for deaf individuals. This test was developed for evaluating the English skills of deaf pupils. It contains a 120-item screening test to evaluate performance on a set of nine grammatical structures (e.g., negation, conjunction, verb processes). The test items, which are presented in multiple-choice format with four alternatives, were administered in Braille. Normative data on a population of 505 students ages 8 to 18 with a hearing loss greater than 20 and less than 120 dB are available. Average performance in the norming group is 68% correct.

Special-Purpose Linguistic Tests

Special-Purpose linguistic tests were designed for this study to examine the subjects' knowledge of a range of syntactic structures and the principles of semantic interpretation of syntactic structures. Particular prosodic features of language were also studied. The tests cover a variety of grammatical properties within the domain of transformational-generative grammar (Chomsky, 1965, 1975), examining the subjects' interpretations of sentences that involve fairly complex and subtle grammatical features of English. These are aspects of grammar that, for the most part, would not have been taught to the subjects but that they would have had to acquire independently through experience and exposure to language use. The features selected are ones that are commonly known to native speakers of English. The test questions have all been answered successfully by hearing native English-speakers, both high school students and a variety of adult volunteers whom we have questioned informally. We were interested in the degree to which the subjects have been able to acquire these basic but complex language forms, and the nature of the deficits, if any.

A Braille copy of the structural tests was prepared, and the subjects read the questions and reviewed them orally before responding. Considerable care was taken to ensure that the subjects perceived the questions accurately. For the tests of stress and intonation, the test materials were spoken to the subjects. They gave all of their answers orally.

The items included in each of the Special-Purpose tests are listed in the Appendix, and a brief description is included here. The individual tests contain different numbers of items and scores are reported as percentage of items correct.

Structure. The structural tests examine the subjects' knowledge of syntactic and semantic features of English. Subjects are asked, for example, to report on the meaning or acceptability of sentences that contain semantic complexities, ambiguities, or grammatical anomalies. On tests entitled Deletions, Article Switch, Ambiguity, and Illicit Comparison and Conjunction, subjects answer questions about meaning of the sentences, the correctness of the sentences, or how two sentences differ in meaning. On Tag Questions, Contractions, and Phrase Analysis, subjects are asked to produce target linguistic forms.

For example, on the Article Switch test, the task is to describe the difference in meaning between two sentences which differ in placement of *a* and *the*:

1. Maggie looked at *the* puppy at Peter's Pet Shop, but later she decided not to buy *a* puppy.
2. Maggie looked at *a* puppy at Peter's Pet Shop, but later she decided not to buy *the* puppy.

In sentence 1 Maggie saw a particular puppy at the shop and later decided not to buy any puppy at all. In sentence 2 Maggie saw a puppy at the shop and later decided not to buy that particular puppy.

On the Ambiguity test, the task is to give more than one meaning for sentences such as "The long drill was boring" and "The chicken is ready to eat."

Prosodics. These tests examine subjects' knowledge of and ability to utilize intonation and stress cues to derive meaning in phrases and sentences. The items consisted of Compound Noun Stress, Contrastive Stress, and Yes/no Question Intonation. In Compound Noun Stress, for example, subjects are asked to distinguish the meanings of *GREENhouse* (special place for growing plants) and *green HOUSE* (a house which is green).

In contrast to the other language tests, which were all presented in Braille or had Braille copies available for reference, the prosodic tests were delivered orally to the subjects. These tests examined the subjects' ability to perceive the prosodic features through Tadoma, as well as their recognition of the linguistic function of the prosodic information, if perceived. Sentences were repeated as often as necessary to ensure optimal tactile access to the prosodic features pronounced by the speaker.

Developmental Sentence Scoring

The Developmental Sentence Scoring (DSS) procedure of Lee's Developmental Sentence Analysis (Lee, 1974) was applied to a sample of each subject's spontaneous speech, produced during normal conversation in the laboratory with members of the research group. The DSS procedure analyzes 50 complete consecutive sentences spoken by a subject, scoring occurrences of pronoun usage, verb types, conjunctions, negatives, and the like. Although the DSS measure is intended to assess developmental language disorders of young children and is normed only to age 6:11, a DSS score on adult speech can be informative in comparison to these early levels. An adult score well above the scores of the 6-year-old norming group, for example, may be interpreted as evidence of language development beyond the middle childhood stage. The mean DSS score for the norming group at age 6:6 is 10.94, with a range from 8.11 to 13.78.

For each of the 3 subjects, the number of sentences analyzed was less than the recommended 50. For this reason, the scores reported should be considered a "rather tentative DSS" (Lee, 1974, p. 163). In each case, scores were calculated by dividing the total sentence scores by the number of sentences contained in the sample.

RESULTS

This section presents the results for each of the 3 subjects, along with samples of their spoken and written language. The test results across subjects are summarized in Tables 1 through 3.

SUBJECT LD

Verbal Subtests from WAIS, WISC-R, Stanford-Binet (Table 1)

LD performed well on six of the seven standardized tests, comparing favorably with the hearing population. His WAIS Vocabulary scaled score is 12, at the high end of average for hearing individuals. On the WISC-R Vocabulary, he scored 50 out of a possible 64. His definitions were generally thorough and well-stated, for example, *sentence:* "complete group of words written in one sentence; a judge gives a sentence."; *calamity:* "a great disaster."

TABLE 1. Scores for the 3 subjects on the Standardized Measures for the Hearing Population.

Tests	*Subjects* LD	RB	JC
WAIS Vocabulary: Scaled (raw)	12 (54)	7 (22)	17 (76)
WAIS Similarities: Scaled (raw)	8 (6)	13 (19)	16 (22)
WISC-R Vocabulary: Raw (of 64)[a]	50	32	61
Stanford-Binet:			
Differences between abstract words	83%	0	100%
Essential differences	100%	33%	100%
Abstract words III	80%	30%	100%
Proverbs	0	0	100%
Developmental Sentence Scoring (DSS)[b]	26.6	24.97	20.67

[a]WISC-R Vocabulary scores are reported as raw scores only. A scaled score cannot be assigned because the test is applicable only up to age 16. [b]Tentative DSS, based on fewer than 50 sentences.

His WAIS Similarities score was within the average range for hearing individuals, but at the low end of the scale. He consistently described similarities between the items by naming common attributes: "In what way are a *coat* and a *dress* alike?" "Both made of cloth." "A *dog* and a *lion*?" "Both have teeth, tails, four paws, both covered with hair." Even with continued prompting, LD did not provide category-type answers such as "They are both clothing" or "both animals."

On the Stanford-Binet Essential Differences subtest, he scored 100%, and on the Abstract Words subtests he missed one item each. His responses were accurate and to the point. For example, "What is the principal difference between an optimist and a pessimist?": "An optimist is a person who looks at the bright side of something, and who knows the best time's to come. A pessimist is a person who is on the dark side of things and who thinks nothing can be done."

TABLE 2. Percent correct response for the 3 subjects on the Test of Syntactic Abilities.

Structures	*Subjects* LD	RB	JC	*(Deaf norms)*[a]
Negation	100	89	100	(83)
Conjunction	100	91	100	(64)
Determiners	100	86	100	(78)
Question formation	100	100	100	(73)
Verb processes	90	100	90	(63)
Pronominalization	100	90	100	(67)
Relativization	89	89	100	(59)
Complementation	94	89	100	(65)
Nominalization	89	83	100	(65)
Total	95	90	99	(68)

[a]Based on the data of Quigley, Steinkamp, Power, and Jones (1978).

TABLE 3. Percent correct response for the 3 subjects on the Special-Purpose linguistic tests.

Tests	Subjects LD	RB	JC
Structure			
Deletions	50	63	100
Article switch	0	75	100
Ambiguity: Sentences	50	43	100
Subject phrases	40	20	100
Illicit comparison	100	80	100
Illicit conjunction	83	0	100
Tag questions	17[a]	0	100
Contractions	50[a]	27	100
Phrase analysis	100	100	100
Prosodics			
Compound noun stress	67[a]	75	100
Contrastive stress: Pronoun reference	0	0	100
Focus of negative	0	0	100
Yes/no question intonation	0	0	0

[a]In these cases, less than the full test was administered. The percentage listed is based on a count of correct responses with respect to the number of items actually given. See text for details.

LD performed poorly on the Proverbs test. On this measure, he was able to give only literal restatements of the proverbs. In no case was he able to refer to the generality or larger truth embodied in a proverb, and we conclude that he does not understand the special character of proverbs.

Test of Syntactic Abilities (Table 2)

LD's overall score of 95% correct on this test places him well above the norm of 68% for deaf subjects. His answers were 100% correct on five of the structures: Negation, Conjunction, Determiners, Question Formation, and Pronominalization. He missed one item on Verb Processes and Complementation and two items each on Relativization and Nominalization.

Special-Purpose Linguistic Tests (Table 3)

Structure. LD's judgments on the structural tests were mixed. On the Deletions test, which required him to identify missing information, he answered correctly for the sentences that follow the general rules of English, and incorrectly on the exceptions. For example, in answer to "Who is supposed to wash the dishes?" in the two sentences

1. John told Susan to wash the dishes.
2. John promised Susan to wash the dishes.

he answered "Susan" to both, instead of "John" in sentence 2. The general rule requires *Susan* in such constructions, and sentence 2 with the verb *promise* is an exception.

He performed poorly on all four pairs of sentences on the Article Switch test. He either did not recognize a meaning difference in the pair, or if he thought the two sentences were different, described the meanings inaccurately.

On the Ambiguity (Sentences) test, he easily detected lexical ambiguity, describing meaning differences accurately. He was successful in detecting about half of the structural ambiguities, detecting deep and surface structure ambiguity about equally. He paraphrased the structural ambiguities that he detected quite well. For example, for *They are moving sidewalks* he said, "Means two things. People are moving sidewalks, or it could mean they are conveyor sidewalks. The sidewalks are moving."

On the Ambiguity (Subject phrases) test, LD initially filled in only *is* or *are*. When asked if the other verb was possible, he answered yes and reported the two meanings for two of the five sentences.

He achieved a perfect score on the Illicit Comparison sentences, easily and accurately describing what was the matter with each one. For example, he rejected "This math problem is not as hard as that rock" because "A rock is hard to knock, to touch (he rapped on the table). Math is hard in the head."

On the Illicit Conjunction test he also achieved a high score. He distinguished the acceptable sentences from the unacceptable ones, accepting the good ones immediately, and pausing at some length over the unacceptable ones. These latter were clearly questionable to him, and he ended up accepting some and rejecting others.

Performance was poor on Tag Questions. LD was able to give the correct tag for only the first sentence: *John is an engineer*: "isn't he?" On subsequent sentences, he resorted to a generalized tag such as "Is that so?" and was unable to produce the syntactically accurate form. The test was discontinued after six sentences.

Only half of the items were answered correctly on the Contractions test. It is of interest that these were the items that have only one possible expansion: *won't, should've, they're.* The ones that he missed, *you'd* and two instances of *what's*, are ambiguous and depend on sentence context. *You'd,* for example, may derive from either *you would* or *you had* and *what's* may derive from *what is, what does* or *what has.* There was no ambiguity, of course, in the context of the test sentences.

On the Phrase Analysis measure, LD correctly filled in *is* or *are* in all the sentences, showing an accurate perception of the internal structure of the subject phrase.

Prosodics. LD did well on only one prosodic test, Compound Noun Stress. On the Compound Noun Stress test, LD gave correct meanings for *hot DOG* and *HOT dog, green HOUSE* and *GREENhouse. Black BOARD* and *BLACKboard* were indeterminate. LD was tested on only these three word-pairs. His success on the first two examples shows an ability to perceive and interpret stress appropriately at the level of this test, where stress functions to distinguish word and phrase meaning.

LD did poorly on both Contrastive Stress tests, where stress is used for emphasis or contrastive purposes. On the Contrastive Stress: Pronoun Reference measure, he did not perceive the stress differences that we pronounced in the sentences and reported that they sounded the same to him. On the Contrastive Stress: Focus of

Negation measure, he did perceive the stress differences as pronounced, but reported no resulting difference in meaning.

On the Yes/no Question Intonation test, LD did not perceive the intonation differences between the questions and the statements. He was able to correctly identify the intonation as rising or falling about half the time, no better than chance. When it was explained to LD that rising intonation signals a question, he answered "That's news to me." It is of interest, however, that in conversation LD responds entirely appropriately to such "questions." Note the following exchanges in a conversation with LD:

You live in Kansas?	LD: Yes.
You cross the border?	LD: Yes.
Someone gives you a ride?	LD: Yes, a friend from work.
In a taxi? By car?	LD: By car.

LD always recognizes that such constructions require answers when they occur in context in conversation. Intonation, which he does not perceive, is apparently a superfluous cue under such circumstances.

Developmental Sentence Scoring (Table 1)

The DSS procedure was applied to a corpus of 30 sentences spoken by LD in conversation with members of the research group. LD's DSS score, on the basis of the 30 sentences, is 26.6, well above the 10.94 mean for age 6:6.

Here is a portion of LD's oral language sample:

> Oh, one time one of my friends took me to a huge trucking garage where he works. This trucking garage repairs transportation trailer trucks and trailer cabs. You know how high they are. Well, I stayed at the garage for more than an hour and a half or two hours and I saw all the giant mechanical equipment there is. And I saw the small equipment for testing and cleaning out carburetors. And I was taken to a place where trucks were smashed up in an accident. And I saw one cab flattened down to about a foot high. The cab—you know how big the cab is—but it was squashed down about one foot. And I was amazed to see the trucks that got smashed up in an accident. And my mechanics friend told me that the driver who got out of that cab that was squashed down by accident, got out by [?] escape. He came out alive. He was not killed but he was very badly injured.

As can be seen in this sample, LD's spoken language is of high quality, comparable to that of individuals with normal hearing. His vocabulary is mature, for example, *mechanical equipment, carburetor, repairs, injured.* He uses complex sentence structure, for example, two levels of subordination: *I was amazed* (main verb), *to see the trucks* (embedding 1), *that got smashed up* (embedding 2), and several passives: *was taken, was squashed down, was not killed.* This sample is typical of his speech, which is noteworthy for its fluency, naturalness and low incidence of error.

Note also LD's appropriate use of the verb *see: I saw all the giant mechanical equipment, I saw one cab . . ., I was amazed to see the trucks. . . .* This use of sight verbs is typical of LD's productions. Throughout his conversations, there is frequent and appropriate use of visual terminology. For example, elsewhere he has commented: *It's a beautiful place, I like to see the snow come and go.* Further, his definitions of sight verbs like *gaze, fade,* and *dazzle* are exact. It is of interest that the accurate knowledge and use of sight terms has been noted for hearing blind subjects, whose access to language is not limited as in the case of a person who is also deaf (Landau & Gleitman, 1985, pp. 94–97). The linguistic and cognitive mastery of such sight vocabulary is all the more dramatic when it develops in the absence of both sight and hearing, as in LD's case.

Written Language

A sample of LD's writing is included as another example of his language production, and to illustrate his level of literacy. This is an excerpt from a letter typed by LD to a member of the MIT research group.

> Since my next trip will be in the summer, I hope we can find some free time to go surfboarding to see if I can handle the surfboard easier than waterskis, then maybe try the skis later. Also I want to spend more time examining the train engine, with some old workclothes on, and I hope you can find a man who knows about all the many valves, and devices on the engine, so he can really explain them to me.

The writing is comparable to the writing of hearing individuals. Sentence structure is complex, including four levels of subordination: *I hope* (main verb), *we can find . . . time* (embedding 1), *to go surfboarding* (embedding 2), *to see* (embedding 3), *if I can handle . . .* (embedding 4). Sentence length averages 40.5 words, indicating a good command of the written language. There are no errors in grammar, spelling, or punctuation. This sample is typical of LD's productions.

In summary, LD has an excellent command of English. His spoken and written language are fluent, mature, and largely error-free, comparable to the speech and writing of literate, hearing individuals. His vocabulary compares favorably with norms for the hearing, and his syntax is above norms for the deaf. The tests show above average or average performance on all but one of the standardized tests for the hearing population, with a lack of understanding of the special character of Proverbs. He scores well above norms for the deaf on a syntax test for deaf subjects. On the Special-Purpose linguistic tests he performs well on about half of the structural tests. Specifically, he succeeds with Illicit Comparison and Conjunction, deletions which follow the general rules of English, and some contractions. He recognizes lexical ambiguity more readily than structural ambiguity. He is unable to provide tags for tag questions, to interpret the semantic effect of Article Switch, and to fill in deletions that are exceptions to general rules. The prosodic features of language present difficulty for him. He is unable to perceive the intonation pattern that signals yes/no questions. His perception of stress differences is variable. He

both perceives and interprets stress differences in compound nouns, but with contrastive stress shows variable perception and no knowledge of effect on sentence interpretation.

SUBJECT RB

Verbal Subtests from WAIS, WISC-R, Stanford-Binet (Table 1)

RB's best performance on these tests was on the WAIS Similarities, where his score is above average for hearing individuals. His answers were direct and accurate: In what way are a *dog* and a *lion* alike? "Both animals." A *table* and a *chair*? "Both pieces of furniture." He readily answered by naming the category to which both items belong for eight of the pairs.

On the WAIS Vocabulary subtest his scaled score of 7 is just below the average range for hearing individuals. His WISC raw score is 32 out of a possible 64. His responses to the words that he knew were well-stated, for example, *fabric:* "piece of material like cloth, made of cotton, silk"; *repair:* "to fix, to get things into shape."

On the Stanford-Binet Differences between Abstract Words and Essential Differences, the only difference he stated was between *work* and *play:* "Work is doing the duty to do the job. In play, you don't do the duty, you're just having fun." In all other cases, he did not know the meaning of one or both words, and merely defined the individual words he knew. Of the Abstract Words III, he gave a full definition only for *independent:* "do anything you please without anybody stopping you."

For Proverbs, RB was unable to give any generalizations, and merely gave literal restatements. We provided considerable prompting and explanations of the special character of proverbs, and modeled the answers we were seeking, but RB persisted with literal interpretations only.

Test of Syntactic Abilities (Table 2)

RB's overall score on this test was 90%, well above the norm for deaf individuals. He scored 100% on both Question Formation and Verb Processes. He missed one item each on Negation, Conjunction, and Pronominalization, two items each on Determiners, Relativization, and Complementation, and three items on Nominalization.

Special-Purpose Linguistic Tests (Table 3)

Structure. RB's judgments on the structural tests were mixed. On the Deletions measure, he filled in the missing information correctly for the regular constructions, and incorrectly for most of the exceptions. The one exception with which he was successful was *Mary is easy to see.* He answered correctly for a variety of adjectives in this sentence frame:

Mary is anxious to see. Who wants to see? "Mary"

Mary is hard to see. Who is having trouble seeing? "The person who is trying to see Mary."

He did well on the Article Switch test, stating the meaning difference accurately for three of the four sentence pairs. This test performance is of particular interest because RB often omits the article *a* when speaking. He uses it more regularly in his writing. He clearly understands its function in these test sentences.

On the Ambiguities (Sentences) test, RB easily detected the lexical ambiguities and explained all of them well. He had trouble with the structural ambiguities, detecting only two of the deep structure ambiguities, "Flying planes can be dangerous" and "The chicken is ready to eat", and none of the surface structure ones.

On the test of Ambiguity (Subject phrases), RB initially filled in only *is* or *are.* When asked if the other verb was possible, he answered yes and gave the two meanings in only one case.

He did well on the Illicit Comparison measure, explaining what was wrong with all but one of the sentences very accurately. For example, on hearing *The movie was longer than her hair,* he laughed and said, "No good. The movie gives you the length of time. Girl's hair is a measurement. Difference between time and measurement."

The results on the Illicit Conjunction test were indeterminate. RB interpreted the task as one of judging if the two events could occur together, rather than attending to the conjoined sentence and making a judgment about its form. His judgments about the two events were sensible and carefully made, but not related to the point at issue here.

He performed poorly on Tag Questions, failing to supply any tags correctly. The task was discontinued after four sentences, because it appeared pointless and RB lost interest very quickly.

On the Contractions test, RB expanded approximately one quarter of them correctly, including some whose form varies with sentence context such as *he'd.* He expanded it correctly to *he had* in the sentence "I knew he'd finished his work by 5 o'clock".

On the Phrase Analysis measure, RB correctly filled in *is* or *are* for all the sentences, assigning the correct internal structure to all the subject phrases.

Prosodics. RB did well on only one prosodic test, Compound Noun Stress. On the Compound Noun Stress test, RB responded correctly to three of the four pairs. He perceived the stress differences and correctly differentiated the meanings of *hot DOG* and *HOT dog, green HOUSE* and *GREENhouse,* and *white HOUSE* and *WHITE house.* At this level of word and phrase meanings, he is successful in using stress cues to signal linguistic distinctions.

He failed to make any of the relevant distinctions on the Contrastive Stress: Pronoun Reference measure, and it was difficult to determine whether he actually perceived the stress difference in all cases.

On the Contrastive Stress: Focus of Negation test, he did perceive the stress placement on different words in the sentence. However, he recognized no associated difference in meaning or implication. After the function of stress in such cases was explained to him with examples, RB did understand and subsequently gave three correct answers on additional sentences.

He did not perceive the intonation differences on the Yes/no Question Intonation test. To test his pitch perception we tried singing high and low notes, and he was able to detect large differences in pitch. The intonation changes in the sentences, however, were apparently not large enough for him to perceive.

Developmental Sentence Scoring (Table 1)

The DSS procedure was applied to a corpus of 29 sentences, spoken by RB in conversation with the research group. RB's DSS score on the basis of the reduced corpus is 24.97, well above the 10.94 mean for age 6:6.

Here is a portion of RB's oral language sample:

> When I am ready to go back to work, I am thinking to take retirement because my job is 15 miles away from home, and I do not have good transportation. My father has to take me to work and he is going to be 76 years old. And if I should be working another 18 years till retirement, will he be in perfect health for another 18 years?

This sample is typical of RB's productions. His sentence structure shows frequent use of subordination, for example, *I am thinking* (main verb), *to take* (embedding 1), *because my job is . . .* (embedding 2). His vocabulary is mature, for example, *transportation, retirement.* His speech nevertheless contains deviations from idiomatic usage, for example, *I am thinking to take retirement,* in place of 'I am thinking of retiring," and *if I should be working another 18 years* in place of the colloquial "if I work another 18 years" or perhaps the somewhat more formal "if I should work another 18 years." This last example reflects the common difficulty with verb tense that many deaf speakers experience, a frequent problem for RB. He also is sporadic in his use of the third-person singular marker -s on verbs. Other speech samples contain examples of both the presence of -s and its absence, for example, *when I type it come out in Morse Code, my brother goes to Montreal, maybe he knows something.* Another occasional error in RB's speech is omission of the article *a.* Some examples are: *so I get bit rusty, I have IBM-PC computer, Montreal is nice place, I was going to bring camera. . . .* Again, he reflects errors common to many deaf speakers.

Written Language

A sample of RB's writing is included to demonstrate another aspect of his language production. This is an excerpt from a letter typed by RB to a member of the MIT research group.

> Friday morning, we had some programs at the auditorium at Perkins School. I had a surprise when they called my name to give a talk about M.I.T. on the stage. I told about the different tests like Tadoma methods and some words and etc. After the programs, we had picnic and games in the play ground. I met many more people, and talked with them. At 4:30, C. took J. and me to the air port. We had supper there. E. met me in Buffalo, and I am glad to see family and friends again.
>
> Today I was reading Popular Mechanics and Consumer Report and slept for a while. Tonight, I experimented with the buzzer. This buzzer will be experiment for the electric braille writer. I hope the braille typewriter will be here tomorrow.

In his writing, RB uses the article *a* with more consistency than in his spoken language: *I had a surprise, to give a talk, for a while,* although occasional omissions occur: *we had picnic, will be experiment.* His writing is for the most part grammatical. Sentences tend to be brief, with longer sentences showing the use of subordination: *I had a surprise* (main verb), *when they called* (embedding 1), *to give a talk* (embedding 2). Spelling is good, with errors in this sample limited to word-juncture conventions in compound nouns: *air port, play ground.* Punctuation is appropriate. This sample is typical of RB's written language.

In summary, RB has a good command of English. His spoken language is mature and fluent, and his written language is competent. Both his speech and writing exhibit some features common to deaf speakers, such as lack of verb tense agreement and omission of the article *a.* His vocabulary is just below the average range for hearing speakers, and his syntax is well above norms for the deaf. He scores above average for hearing subjects on one standardized test (WAIS Similarities), and below average for hearing subjects on the other standardized tests. On the Special-Purpose linguistic tests, he performs well on half of the structural tests. Specifically, he succeeds with Article Switch and Illicit Comparison, deletions which follow the general rules of English, and some contractions. He recognizes lexical ambiguity more readily than structural ambiguity. He is unable to provide tags for tag questions, to detect Illicit Conjunction, and to fill in deletions that are exceptions to general rules. The prosodic features of language present difficulties for him. He is unable to perceive the intonation pattern that signals yes/no questions. His perception of stress differences is variable. He both perceives and interprets stress differences appropriately in compound nouns, but with contrastive stress shows variable perception and no prior knowledge of effect on sentence interpretation. Considering that RB communicates with others only half the time using speech through Tadoma (by his own report he uses sign language about half the time), his grasp of English is impressively solid.

SUBJECT JC

JC's language performance and all responses to the tests are extremely high level. She is unusually sophisticated linguistically and scores well above average for the

hearing population. Of course JC's language was well established before she became deaf and blind at age 7, but the excellence she displays today clearly results from continued adequate and even rich exposure to language. She has advanced not only beyond a 7-year-old's linguistic ability, but outdistances the average hearing adult.

Verbal Subtests from WAIS, WISC-R, Stanford-Binet (Table 1)

JC's WAIS Vocabulary and Similarities scaled scores are well above average, 17 and 16, respectively. She missed only two words on the WAIS Vocabulary subtest, giving excellent definitions throughout. For example, *breakfast:* "the morning meal when one has broken the fast of the night"; *matchless:* "peerless; nothing is as good as what that is; incomparable"; *travesty:* "a mockery, usually something ugly; something that was beautiful made to look ugly and obscene." Her raw score on the WISC was 61 out of 64. Her explanations in the WAIS Similarities were quite sophisticated, for example, *dog/lion:* "They are both animals. I could have said both are quadrupedal animals."; *eye/ear:* "They are both used for receiving sensory impulses. They are both senses."

All of JC's answers on the Stanford-Binet tests were correct. Some examples are: difference between *poverty/misery:* "Poverty refers to not having earthly goods; misery refers to pain and agony."; definition of *generosity:* "Noun that refers to being generous, open-handed, very giving, unselfish, very liberal."

She interpreted the Proverbs appropriately. For "We only know the worth of the water when the well is dry", she responded: "We don't appreciate what we have until we no longer have it. Or, we don't think about our blessings until we lose them." She was even able to construct a generalization for a proverb with which she was not familiar. For "Large oaks from little acorns grow", she said: "Well, I'm not sure, but it could mean that you might have to start from the bottom but you could build up into great strength. Like Tadoma—I started with single sounds first and built up finally into sentences."

Test of Syntactic Abilities (Table 2)

JC scored 99% on this test, missing only one item in Verb Processes. When asked this particular question a second time, she answered correctly. Her near-perfect performance indicates full command of the syntactic structures on this test.

Special-Purpose Linguistic Tests (Table 3)

JC's record on the Special-Purpose linguistic tests is elegant and simple. She achieved a perfect score on every one of these tests, with the exception only of Yes/no Question Intonation under Prosodics. She completed all the structural tests and all the other prosodic tests with 100% accuracy, enjoying the type of thought they engendered and stopping to discuss meanings and words throughout the test. There is no need to discuss her scores individually as they were all 100%, but examples of her responses are provided.

Structure. JC's judgments on the structural tests showed considerable depth of understanding.

On the Deletions test, she handled the consistent examples and the exceptions with equal facility. Her explanations were excellent. For example, to "I told him what to eat. Who is to eat?" She responded: "Whoever the 'him' is. The boy is to eat." For "I asked him what to eat. Who is to eat?" she said: "The person speaking. The 'I.' "

On the Article Switch test, her responses captured the meaning differences precisely. For sentence pair 3, the one about the puppy in the pet shop, she said "(a) The implication is that Maggie looked at a particular puppy, but decided not to buy any puppy at all. (b) A puppy, one puppy. She decided against buying this particular puppy, but she might buy another one."

On the Ambiguities (Sentences) test, she gave excellent paraphrases of the two meanings of the sentences, handling lexical, deep structure and surface structure ambiguity all with equal ease. For example, for "Flying planes can be dangerous," she said "A plane flying in the air can be a dangerous object. Flying planes yourself can be dangerous." For "I know a taller man than Bill": "Well, it might mean—I know a man who is taller than Bill. Or, I know a man taller than the one Bill knows who is tall." For "Dick finally decided on the boat": "He decided to take the boat, or he made his decision while on the boat."

On the Ambiguity (Subject phrases) test, JC recognized the ambiguity for all the sentences. She supplied both *is* and *are* for each one, unprompted, and explained the meaning differences accurately.

She analyzed the nature of the problem with the Illicit Comparison sentences in a very sophisticated fashion. In each case she stated the two senses of the adjective, describing the difference with precision. For example, "The movie was longer than her hair": "Not a good comparison. Hair is long in terms of inches. A movie is long in terms of time or hours." "This math problem is not as hard as that rock": "Wrong comparison as before. A math problem is difficult to work out. A rock is hard in terms of solidity, not in terms of working out."

On the Illicit Conjunction test, she gave good explanations of why the sentences were unacceptable. For example, "Bill called John a fool and Susan up": "No, it doesn't fit. These two don't go together. It sounds like he called Susan the word 'up'. It should mean he called her up on the telephone."

On the Tag Questions test, JC finished the list easily, answering quickly and with certainty. Her response to the final sentence was exceptional: "The one who robbed the bank was John, _____?" She supplied, "wasn't it? You had me trapped there. I wasn't sure. I almost said 'is that not so?'—'n'est-ce pas?', or in German 'nicht wahr?' "

She expanded all Contractions readily, 100% correctly. On the Phrase Analysis measure, she supplied *is* or *are*

correctly for all the sentences, interpreting the internal structure of the subject phrase appropriately.

Prosodics. JC succeeded on all prosodic tests except for Yes/no Question Intonation. On the Compound Noun Stress test, JC finished the test pairs successfully, and we gave her additional items on which she also was successful, for example, *BLACKbird:* "species of bird" vs. *black BIRD:* "any bird black in color," and *FRENCH teacher:* "teacher who teaches the language French" vs. *French TEACHER:* "teacher herself is French." Clearly she both perceived the stress differences and interpreted them correctly.

She completed both the Contrastive Stress: Pronoun Reference and Focus of Negation tests easily and correctly. She exhibited no difficulty in perceiving the stress, and in recognizing its use for this type of linguistic contrast and emphasis.

Her replies in the Focus of Negation test were as follows:

JOHN didn't sell Bill the car.	"A car was sold to Bill but it wasn't John who sold it."
John didn't SELL Bill the car.	"John may have loaned Bill the car."
John didn't sell BILL the car.	"John sold a car all right, but not to Bill."
John didn't sell Bill the CAR.	"John sold Bill something, but not a car."

The Yes/no Question Intonation test was the one test on which JC performed poorly. She did not perceive the rising/falling intonation differences, and classified most of the sentences as statements. It is of interest that the speaker took care to vary only the intonation while he spoke the sentences, holding his body still. In discussion afterward, JC explained, "I don't believe I can do it on the basis of inflection. I go by the movements of the head. In real life if someone was asking me something like that they would say, 'You missed the first part of the movie?' " (accompanied by drawing her body up and back, and spoken with neutral intonation).

Developmental Sentence Scoring (Table 1)

The DSS procedure was applied to a sample of 36 sentences that JC spoke during a conversation with the MIT research group. JC's DSS score on the basis of this corpus is 20.67, well above the 10.94 mean for age 6:6.

A portion of JC's oral language sample is provided below:

E: What is the story about how you and Judy got together?

> JC: Well, Judy was teaching a class at American River College. A night class. It's on interpreting. She wanted me to give a talk to the class, about interpreting for the deaf-blind. Well, she drove me home with her since it was at night, a night class. We had dinner, then started out. She has a big camper-car, and what did it do but just politely stop in the middle of the street at a stop sign and refused to go. So we sat there. She tried to signal somebody, to ask them to call her garage. Her gestures were unnoticed. But finally some young man passing stopped. He was on his way to college, so he phoned the garage for her, then he came back and waited. Nothing happened. Finally he went on to college to let everybody know, when we weren't there, what had happened. And then he came back again. Later a group of the students and some of the parents came out to rescue us. We never got to the class that night.

As can be determined by this sample, JC's spoken language is of high quality, comparable to the speech of hearing individuals. It is fluent, idiomatic and conversational. Note the use of the interesting phrase *and what did it do but just politely stop. . . .* This sample is typical of JC's oral language in its naturalness and freedom from error.

Written Language

A sample of JC's writing is included to demonstrate her writing ability. This is an excerpt from a letter typed by JC to a member of the MIT research group.

> Thank you enormously for all you did for me at MIT, and for being such an overwhelmingly nice person. And great thanks to N. also. You two together treated R. and me just about like royalty. We certainty did appreciate everything you did for us.
>
> Now about that Abraham Lincoln robot in Disneyland. I didn't think of it until we were on the plane headed for home, and, when I did, I wondered if you or N. knew about it. Someone told me that when the robot recites the Gettysburg address the lips move so distinctively deaf persons can read them. I asked my boss J. about this; she said it didn't seem to her the lip-movement was all that distinctive. So I think you are right: it has more to do with lighting and sound than with any motion of the lips.

The writing is sophisticated and fluent. Sentence structure is complex, including several instances of two-level deep subordination: *Someone told me* (main verb), *the lips move* (embedding 1), *deaf persons can read them* (embedding 2); *she said* (main verb), *it didn't seem* (embedding 1), *the lip-movement was . . .* (embedding 2). Vocabulary is advanced, for example, *overwhelmingly, distinctively.* Grammar, spelling and punctuation are error-free. This sample is typical of the writing in JC's letters. She also writes short stories, for both children and adults.

In summary, JC's knowledge of English is extraordinarily advanced. Indeed, her abilities exceed those of the average hearing adult. Her spoken and written language are mature, fluent, and error-free. She scored well above average for the hearing adult on all the standardized tests, and performed almost perfectly on the syntax test for the deaf. She achieved a perfect score on all the Special-Purpose tests, with the exception only of the Yes/no Question Test in which she did not perceive intonation differences. JC has the linguistic command of a highly literate and sophisticated adult, and we may assume she has reached her full potential in language.

DISCUSSION

This section summarizes the results for the language areas studied: vocabulary, syntax, prosodics, and spoken and written language.

Vocabulary

The vocabulary skills of the 3 subjects were good, and compare favorably with hearing individuals. On standardized tests for the hearing (WAIS Vocabulary), JC scored well above average and LD scored at the high end of the average range; RB scored just below the average range. Their definitions were of high quality and contained many details. For example, LD defined *diamond* as "a stone that comes out of the ground; very hard stone, for rings and machine tools." and JC gave this definition for *espionage:* "undercover work which includes spying and destruction in enemy countries." The high level was maintained throughout. On the WAIS Similarities test, the performance of all 3 equaled or exceeded the hearing standard.

Examples of complex vocabulary occurred in the spontaneous conversation of the subjects as well, in many cases where a simple word would have done. For example, note the use of *varieties, intricate,* and *opportunity* in LD's conversation: "They transferred me to another department so I can do many *varieties* of work." "I do many different kinds of jobs such as making *intricate* wires for the tail lights . . ." "So I never got the *opportunity* to practice with the hearing aid."

On the other standardized tests drawn from Stanford-Binet, performance for 2 of the subjects was excellent. JC succeeded even with Proverbs, which were out of range for the other subjects. Knowledge of the special character of proverbs appears to require exposure or perhaps instruction beyond what has been available to LD and RB. We do not have information about the source of JC's knowledge, but it was clear she understood the principle of proverb interpretation, as she was able to offer a correct generalization even for a proverb with which she was unfamiliar.

Syntax

The syntactic abilities of all 3 subjects were excellent in comparison with a deaf population. Their scores on a syntax test normed on a deaf population (Quigley et al., 1978) were well above the norms for deaf speakers. In addition, the Special-Purpose linguistic tests indicated many areas of syntactic competence. In JC's case, there was complete command of all structures tested, and a high degree of metalinguistic skill as well. The other 2 subjects showed a good command of general syntax, with areas of deficit limited to particular details of English.

The deficits are evident in the following areas on the Special-Purpose linguistic tests. LD and RB, for example, interpreted syntactic constructions according to the general rules of English and often failed to take account of particular exceptions. An example is LD's processing of the verb *promise* as a regular verb, rather than as an exception, on the Deletions test. This processing according to general rules and lack of familiarity with exceptions is consistent with reduced language exposure imposed by deafness and with early stages in child language development as well. A strength of the language learner is the ability to construct implicit rules on the basis of a few examples, and then to use these rules widely, extending them to related constructions and new vocabulary. Specific exceptions must be learned one by one. Until each one is learned, the language user assumes the general rules apply. This was the case with LD and RB on the Deletions test for words whose exceptional status was unfamiliar to them. Their answers revealed knowledge of the basic rules, and a lack with regard to specific details. They simply used the regular rules too widely, LD for all the exceptions and RB for all but one set: the adjectives *easy* and *hard* in *Mary is easy/hard to see.* In this one case, RB was able to interpret the structure with *easy/hard* as an exception, recognizing that *Mary* is the object, rather than the subject, of the verb *see.*

Another syntactic difficulty that LD and RB exhibited was with Tag Questions. Neither one was able to supply correct tags on this test. The form of a tag in English is complex and constrained by the form of the sentence to which it is added. Because of their complexity, tags are typically learned fairly late by children and pose problems for foreigners learning English. They are an unusual construction, peripheral to the basic structure of the language. Other languages, for example, have only one form for tags (cf. German *nicht wahr* and French *n'est-ce pas*) rather than variable tags of complex form, and English itself offers the option of using the single word *right?* as in *You ordered the roast beef, right?* Nonmastery of tags affects a limited aspect of the language, not a basic structure.

The function of articles in the language is far more basic to the language itself. English has both a definite and an indefinite article that occur with high frequency, and that interact in interesting and subtle ways as brought out in the Article Switch test. Incomplete command of the article system is a deeper problem than failure to accommodate particular exceptions or tag questions. What is interesting here is that LD performed poorly on the Article Switch test, although his use of articles in speech and writing was, so far as we could observe, flawless. This test uncovered a gap in his knowledge that was not apparent from observations of his productive language. By contrast, RB's speech and writing contain omissions of the article *a,* but his knowledge of the article system is complete enough to include the subtleties measured in the test. These are interesting examples of the distinction between linguistic competence and linguistic performance. Language production does not always reflect what speakers know about their language, and spoken language may be an inaccurate indicator of underlying knowledge. It is often possible, as in this case, to learn more about specific areas of competence by probing comprehension than by analyzing spoken language samples.

Ambiguity detection is another domain in which both LD and RB exhibited reduced performance. Ambiguity detection differs from the other tests of syntax in that it relies more heavily on linguistic awareness than the other

tests. Subjects may not succeed in detecting an ambiguity, that is, notice a second meaning for a sentence on their own, although they can recognize and confirm (or reject) a second meaning when it is suggested. Our testing examined detection ability, a metalinguistic skill. Both LD and RB easily detected lexical ambiguity, and had less success with structural ambiguity. This accords with the developmental picture in children, in whom the ability to detect structural ambiguity develops considerably later than detection of lexical ambiguity. Recognizing structural ambiguity appears to require greater metalinguistic skill, which the 2 subjects have not achieved.

In sum, the syntactic deficits of the 2 subjects tend to be limited to marginal aspects of English, with the basic syntax of the language largely in place. Syntactic knowledge exceeds that of most deaf persons for all 3 subjects, and in JC's case, equals that of highly sophisticated hearing speakers. JC's superior language skills, of course, may well reflect the fact that her exposure to language, before loss of sight and hearing, was considerably longer than that of the other subjects.

Prosodics

These tests required the subjects to use suprasegmental aspects of the speech signal (stress and intonation) to make lexical and syntactic interpretations. Two separate questions were under investigation here. One, could the subjects perceive, with Tadoma, the physical differences in stress and intonation that the examiner pronounced? And, two, if the differences were perceived, could the subjects use this information to make correct syntactic interpretations?

Recall that in all the other tests, perception was not under examination. In the other tests attempts were made to overcome any limitations of Tadoma perception by providing Braille copies of the tests, and discussing the wording of the tests with the subjects to make sure they understood the questions. In these prosodic tests perception itself was examined, along with knowledge of the linguistic role of the suprasegmental features.

All 3 subjects experienced difficulty with the prosodic tests. The one test they all did well on was the Compound Noun test. All 3 were able to distinguish compound nouns like *GREENhouse* from the phrase *green HOUSE,* reporting the meanings correctly. Clearly they perceived the stress difference, and understood the linguistic function it serves in distinguishing compound nouns from adjective-noun sequences.

JC was the only subject to succeed with the Contrastive Stress tests. In both Focus of Negation and Pronoun Reference she made the correct interpretations, clearly perceiving the variations in stress and understanding their function. LD and RB performed poorly on both Contrastive Stress tests. Although they reported perceiving the stress variations in the Focus of Negation sentences, they did not recognize any meaning differences associated with the stress differences. On the Pronoun Reference test LD did not perceive the stress differences, and results for RB were indeterminate.

It is of interest to consider the linguistic distinction in stress processes that LD and RB have and have not mastered. As noted, they succeeded with Compound Noun Stress and did not succeed on Contrastive Stress. The compound noun/adjective-noun phrase distinction with which they had no trouble is a stress-related syntactic and lexical process that is basic to the language. The contrastive case that they failed to interpret, although they perceived the stress, uses stress for emphasis and contrastive purposes. It appears that the basic processes are known, and it is the more peripheral processes (such as emphasis and contrast) which are missing. Once again, as was the case in syntax, LD and RB succeeded with structures that are general and regular in the language, and had trouble with the exceptional constructions.

Intonation posed a problem for all 3 subjects. None of them perceived the differences in rising/falling intonation on the Yes/no Question test. This failure to perceive intonation differences is consistent with the relatively poor ability of humans to discriminate frequency changes in tactile stimulation as documented by Rothenberg, Verrillo, Zahorian, Brachman, and Bolanowski (1977). Given that intonation was not available to be interpreted as a cue in such constructions, it is hardly surprising that the subjects were unable to succeed on this test.

Oral and Written Language

The oral language of the 3 subjects was fluent and mature. In the case of JC and LD it is comparable to the language of hearing individuals. RB's spoken language contained some features common to deaf speakers, such as lack of verb tense agreement and article omission, for example.

The tentative DSS scores for all 3 subjects placed them well above the 6-year-old level. All 3 scored above 20, in contrast to the mean for the 6-year-old norming group of 10.94.

The written language of all 3 subjects was fluent and grammatical. They did their own typing, and showed mastery of the mechanisms of spelling and punctuation. They all used subordination in their writing.

General Summary

The 3 Tadoma users have a command of English that exceeds that of many deaf persons, and in many areas compares favorably with hearing speakers. Their backgrounds differ, and they provide evidence in different ways that spoken language can be learned effectively through an unorthodox sensory route. Touch might seem unlikely as a candidate for transmission of spoken language, but we see that it may function successfully for learning language both from the early stages, as with LD and RB who were deafened in infancy, and at the advanced level, as with JC who was deafened after language

was well established. Even when a deaf-blind individual divides his/her already limited linguistic exposure between English and ASL, as in RB's case, spoken language can still develop to a high degree.

In JC's case, we are interested in aspects of language that she has learned since age 7. Her situation might be viewed as less dramatic than LD's and RB's, as in her case considerable vocabulary and a major portion of English grammar were already known. JC might have managed linguistically had she not continued to develop her language past age 7, but merely maintained what she knew at that time. Preservation of the status quo would have permitted communication with others, and, from the point of view of this study, provided satisfactory evidence that speech can indeed be perceived and language preserved through touch alone. JC, however, did not remain at the linguistic level of a 7-year-old. She has made normal progress into mature language. Her language today is in fact not only normal but extraordinarily advanced. As noted earlier, she has the linguistic command of a highly literate and sophisticated adult. With the exception of intonation which is not available through Tadoma, all the linguistic details are in place.

JC is impressive not only in her high test scores, but also in the detailed accuracy and linguistic finesse with which she handled the questions. She has an extremely well-developed sense of language, a high degree of metalinguistic awareness, and an analytic ability with language that amazed us. Her responses were the sort that might have come from a graduate student in linguistics.

All of these results attest to JC's ability to progress with language fully and normally, indeed to a level well above average, with recourse only to touch as a source of input. It would seem that the tactile sense has enabled her to reach full potential in language, with mastery of all detail that we were able to test. Whereas with our other 2 subjects we observe Tadoma fostering language development from an initial (or very early) stage to a fairly advanced level but one that lacks various linguistic details, in JC's case Tadoma has supported extensive elaboration. The information is clearly available, at the early and at the most advanced levels, even through the ill-suited tactile sense.

CONCLUSION

This study demonstrates that the skin is able to transmit information about speech that is rich enough to permit the development of language. With our subjects the eye and the ear have been bypassed successfully and the necessary information delivered to the brain through touch alone. The 3 subjects also demonstrate that speech can be successfully processed on-line without sight or hearing, and that the tactile sense can suffice not only for perception of spoken language but also for learning to produce speech.

Further, our observations reveal a relatively minor effect on language achievement of severe restriction on amount and range of language input. Exposure to language is drastically reduced for the deaf-blind, whose world is 18 inches away, arm's length. Language input is available only when a conversational partner is literally within reach, and from reading Braille. Nevertheless, on the basis of even such limited linguistic evidence, for these 3 subjects virtually normal language is established, and the areas of deficit are few.

We note certain conditions that are present for our subjects, and we are left to wonder which of them are critical to the success of their endeavor. With regard to background, our subjects are not multiply handicapped, but only sensorially deprived. Brain function is normal so far as we know. In all 3 cases, mental development was normal up to the time of illness, and language was developing normally.

With regard to training, various factors may contribute to the success of Tadoma. First, the subjects received many years of one-on-one training in this method from devoted teachers. Second, the nature of the Tadoma display (a talking face) is such that multidimensional access to information about the speech signal (including vibration, air flow, and lip and jaw movements) is provided. Third, Tadoma combines learning to produce speech with learning to perceive it. Finally, the use of the hand in Tadoma may provide a significant reception advantage over systems that employ other body sites.

Individual qualities may also play a role, and it should be recognized that our 3 subjects may not be typical of the deaf-blind population as a whole. They certainly do not represent individuals who were congenitally impaired. Personal aptitude and characteristics such as inquisitiveness and drive may be important factors in a person's ability to learn and use spoken language with a system such as Tadoma. This unorthodox sensory route to language, though available to some individuals, may not be equally accessible to all.

We simply do not know which of these factors, or what others that we have not considered, are critical to the success of our subjects. As observers of one of nature's experiments, we can only examine the outcome and speculate about conditions. What is clear, however, is that language is established under conditions of extreme stimulus poverty. The human language faculty is clearly adequate to the task of constructing a rich linguistic system even under the unusual conditions of an impoverished stimulus delivered through an unlikely channel.

ACKNOWLEDGMENTS

The work reported here was carried out in the Sensory Communication Group of the Research Laboratory of Electronics at the Massachusetts Institute of Technology. We are indebted to the members of the research group for their close collaboration throughout all phases of the research. In particular we are grateful to Charlotte Reed for many discussions of the work and for her extensive help in the preparation of this report.

This work was supported by the National Institutes of Health (Grant No. 1 R01 NS14092).

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Received August 12, 1985
Accepted January 27, 1986

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APPENDIX

SPECIAL-PURPOSE LINGUISTIC TESTS

The Special-Purpose tests administered to the subjects are presented in full here. Items in these tests were drawn from a variety of sources in the linguistic literature. Among the sources are Fromkin and Rodman (1983) and Akmajian and Heny (1975).

An asterisk (*) preceding a sentence indicates an ungrammatical sentence.

STRUCTURE

Report on Sentence Meaning

(a) *Deletions.* Identify missing information.

1. Mary encouraged John to apply for the job. Who is to apply?
2. Mary was encouraged by John to apply for the job. Who is to apply?
3. John is eager to see. Who is doing the seeing?
4. John is easy to see. Who is doing the seeing?
5. John told Susan to wash the dishes. Who is to wash the dishes?
6. John promised Susan to wash the dishes. Who is to wash the dishes?
7. I told him what to eat. Who is going to eat?
8. I asked him what to eat. Who is going to eat?

(b) *Article switch.* Describe the difference in meaning between two sentences which differ in placement of *a* and *the.*

1a. I bumped into *a* man on Maple Street, and when I turned around to apologize, *the* man ran away.
b. I bumped into *the* man on Maple Street, and when I turned around to apologize, *a* man ran away.
2a. I didn't mind killing *the* chicken, but I didn't enjoy eating *a* chicken afterwards.
b. I didn't mind killing *a* chicken, but I didn't enjoy eating *the* chicken afterwards.
3a. Maggie looked at *the* puppy at Peter's Pet Shop, but later she decided not to buy *a* puppy.
b. Maggie looked at *a* puppy at Peter's Pet Shop, but later she decided not to buy *the* puppy.
4a. The police saw *the* robber on Main St., and shot *a* man on Walnut St.
b. The police saw *a* robber on Main St., and shot *the* man on Walnut St.

(c) *Ambiguity*

Sentences. Give two meanings for these sentences.

1. Is he really that kind?
2. The long drill was boring.
3. They fed her dog biscuits.
4. Leonard finally decided on the boat.
5. She hit the man with the glasses.
6. He bought the picture in her living room.
7. Congress passed a dangerous drug bill.
8. He kept the car in the garage.
9. They are moving sidewalks.
10. They are biting dogs.
11. Flying planes can be dangerous.
12. The chicken is ready to eat.
13. The shooting of the hunters was terrible.
14. I know a taller man than Bill.

Subject phrases. Fill in *is* or *are*, and give two meanings according to ambiguous subject phrase.

1. Flying planes_____dangerous.
2. Moving sidewalks_____dangerous.
3. Exploding firecrackers_____illegal.
4. Biting dogs_____a nuisance.
5. Speeding cars_____deadly.

Account for Ungrammaticality

(a) *Illicit comparison.* Tell what is wrong in sentences in which two items (though both *long*, for example) may not be compared.

1. *The movie was *longer* than her hair.
2. *This math problem is not as *hard* as that rock.
3. *John is as *sad* as the movie I saw last week.
4. *Hydrogen is *lighter* than the blue she painted her room.
5. *Red velvet is *softer* than her voice.

(b) *Illicit conjunction.* (6 sentence pairs: 3 acceptable, 3 unacceptable) Decide if two sentences may be legitimately conjoined. If not, explain.

1. John was looking for a hat.
   John was looking for a pair of gloves.
   John was looking for a hat and a pair of gloves.
2. Mary read an interesting book.
   Mary read a fascinating magazine.
   Mary read an interesting book and a fascinating magazine.
3. John walked along the crowded street.
   John walked down the steep steps.
   John walked along the crowded street and down the steep steps.
4. The station wagon looked like a good buy.
   The station wagon looked like a truck.
   *The station wagon looked like a good buy and a truck.
5. Peter took his sweater off.
   Peter took his time.
   *Peter took his sweater off and his time.
6. Bill called John a fool.
   Bill called Susan up.
   *Bill called John a fool and Susan up.

Produce Structure Dependent Forms

(a) *Tag questions.* Place appropriate tag at end of statement to turn it into a question.

1. John is an engineer, _____?
2. You and Bill have been here since 6 o'clock, _____?
3. You aren't certain of what you think, _____?
4. Bill and I don't always agree, _____?
5. These points, the chairman will take up later, _____?
6. Mary shouldn't see him alone, _____?
7. They could have been going, _____?
8. There were three men in the park, _____?
9. In the park were three men, _____?
10. Three men were in the park, _____?
11. For you to do that would be crazy, _____?
12. What I just said bothered you, _____?
13. I bet Mary won't leave today, _____?
14. I expect John won't sing the songs, _____?
15. I don't expect John will sing the songs, _____?
16. John is the one who robbed the bank, _____?
17. It was John who robbed the bank, _____?
18. The one who robbed the bank was John, _____?

(b) *Contractions.* Give full form of the contracted item.

1. *What's* he been doing all day?
2. He *could've* tried harder.
3. *What's* in that box on the table?
4. He *won't* do that again.
5. *You'll* never agree with me.
6. *What's* he want that book for?
7. *He'd* never been here before today.
8. I knew *you'd* be good at this.
9. I *should've* said no.
10. I knew *he'd* finished his work by 5 o'clock.
11. I know *he's* been here before.

(c) *Phrase analysis.* Fill in *is* or *are* according to the internal structure of the subject phrase containing *Verb -ing.*

is:
1. Washing dishes _____ dull.
2. Raising flowers _____ fun.
3. Knitting sweaters _____ satisfying.
4. Painting pictures _____ hard.
5. Writing letters _____ interesting.

are:
1. Sleeping children _____ beautiful.
2. Dancing bears _____ amusing.
3. Growling lions _____ frightening.
4. Swimming ducks _____ pleasant.

PROSODICS

These tests examine the subject's knowledge of and ability to utilize intonation and stress cues to meaning in phrases and sentences.

(a) *Compound noun stress.* Distinguish the meaning of compound nouns and adjective-noun sequences.

1. Look at that *HOT dog/hot DOG* on the front steps.

2. He stopped to look at the *GREENhouse/green HOUSE* on the corner.
3. Who lives in the *WHITE House/white HOUSE?*
4. There are three *BLACKboard erasers/black BOARD* erasers in that box.

(b) *Contrastive stress: Pronoun reference.* Identify pronoun reference with normal and contrastive stress.

1. Peter kicked Bill, and then *I* kicked 'im. Who did I kick?
2. Peter kicked Bill, and then *I* kicked *him.* Who did I kick?
3. Peter kicked Bill, and then 'e kicked *Mary.* Who kicked Mary?
4. Peter kicked Bill, and then *he* kicked *Mary.* Who kicked Mary?
5. Peter kicked Bill, and then 'e hit 'im. Who hit who?
6. Peter kicked Bill, and then *he* hit *him.* Who hit who?

Contrastive stress: Focus of negation. Identify difference in implication as different words are stressed.

1. *John* didn't sell Bill the car.
2. John didn't *sell* Bill the car.
3. John didn't sell *Bill* the car.
4. John didn't sell Bill the *car.*

(c) *Yes/no question intonation.* Differentiate statements from questions on the basis of intonation.

Statements (falling intonation)

1. They don't know the girl's last name.
2. It snowed again on Thursday.
3. The children are asleep already.

Questions (rising intonation)

1. She tore her sweater in the fight?
2. He hurt himself this morning?
3. He'll be here at nine tomorrow?