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Language of Early- and Later-identified Children With Hearing Loss

Christine Yoshinaga-Itano, PhD*; Allison L. Sedey, PhD*; Diane K. Coulter, BA*; and Albert L. Mehl, MD‡

ABSTRACT. ***Objective.*** **To compare the language abilities of earlier- and later-identified deaf and hard-of-hearing children.**

Method. **We compared the receptive and expressive language abilities of 72 deaf or hard-of-hearing children whose hearing losses were identified by 6 months of age with 78 children whose hearing losses were identified after the age of 6 months. All of the children received early intervention services within an average of 2 months after identification. The participants' receptive and expressive language abilities were measured using the *Minnesota Child Development Inventory*.**

Results. **Children whose hearing losses were identified by 6 months of age demonstrated significantly better language scores than children identified after 6 months of age. For children with normal cognitive abilities, this language advantage was found across all test ages, communication modes, degrees of hearing loss, and socioeconomic strata. It also was independent of gender, minority status, and the presence or absence of additional disabilities.**

Conclusions. **Significantly better language development was associated with early identification of hearing loss and early intervention. There was no significant difference between the earlier- and later-identified groups on several variables frequently associated with language ability in deaf and hard-of-hearing children. Thus, the variable on which the two groups differed (age of identification and intervention) must be considered a potential explanation for the language advantage documented in the earlier-identified group.** ***Pediatrics*** **1998; 102:1161–1171;** ***hearing loss, early identification, early intervention, language, newborn hearing screening.***

ABBREVIATIONS. SD, standard deviation; *df*, degrees of freedom; dB, decibels; dB HL, decibels hearing level; CQ, cognitive quotient; MCDI, *Minnesota Child Development Inventory*; MLU, mean length of utterance; LQ, language quotient; ANCOVA, analysis of covariance.

Hearing loss that is bilateral and permanent is estimated to be present in 1.2 to 5.7 per 1000 live births.[1–4] The typical consequences of this condition include significant delays in language development and academic achievement. These delays are apparent for both children with mild and moderate hearing loss[5–7] as well as for those whose losses fall in the severe and profound ranges.[8–11] Despite advances in hearing aid technology, improved educational techniques, and intensive intervention services, there has been virtually no change in the academic statistics of this population since the systematic collection of national data >30 years ago.[12,13] These data indicate that the average deaf student graduates from high school with language and academic achievement levels below that of the average fourth-grade hearing student.[14,15] Similarly, for hard-of-hearing children, achievement is also below that of their hearing peers with average reading scores for high school graduates at the fifth-grade level.[15] These limitations in reading have a pervasive negative impact on overall academic achievement.[16]

Many professionals in both health care and special education have supported early identification of hearing loss and subsequent intervention as a means to improving the language and academic outcomes of deaf and hard-of-hearing individuals.[4,17–20] In 1994, the Joint Committee on Infant Hearing[21] released a position statement endorsing the goal of universal detection of infants with hearing loss as early as possible, preferably by 3 months of age. This position statement was endorsed by the American Academy of Pediatrics. This priority is in concert with the national initiative Healthy People 2000,[22] the National Institutes of Health Consensus Statement,[23] and the position statement of the American Academy of Audiology.[24] All of these position statements support the need to identify all infants with hearing loss. Both the Joint Committee on Infant Hearing and the American Academy of Audiology recommend accomplishing this goal by evaluating all infants before discharge from the newborn nursery.

Despite widespread support for universal newborn hearing screening, this mandate has been challenged by Bess and Paradise[25] partly on the grounds that "no empirical evidence . . . supports the proposition that outcomes in children with congenital hearing loss are more favorable if treatment is begun early in infancy rather than later in childhood (eg, 6 months vs 18 months)". At the time, this statement was reasonable in that before Bess and Paradise's commentary, studies examining the effects of early identification and subsequent intervention either defined early identification as before 18 months (rather than 6 months) of age[26] or did not specify the number of children identified by the age of 6 months.[27] Nevertheless, in one of these older studies, White and White[26] reported significantly better language scores for a group of severely and profoundly deaf children

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whose average age of identification was 11.9 months (with an average age at intervention of 14 months) as compared with children with the same degree of hearing loss whose average age of identification was 19.5 months (with an average age at intervention of 26 months).

Since the publication of Bess and Paradise's commentary, Robinshaw[28] described 5 young children with severe and profound hearing loss whose deafness was confirmed between 3 and 5 months of age. All of the children wore hearing aids by the age of 6 months. Robinshaw compared her deaf children with 5 normally-hearing control children and to data from a previous study involving 12 children with severe and profound hearing loss whose average age of identification was 2 years, 3 months. She found that the earlier-identified children acquired vocal communicative and linguistic skills at an age similar to the 5 normally-hearing control children and well before the deaf children who were identified later. Her investigation supports the value of early identification followed by immediate amplification; however, the group of children studied was small, only children with severe and profound hearing loss were included, and no data from standardized assessments were presented. In addition, the only treatment consistent across all 5 children was the early fitting of amplification. The frequency of additional early intervention varied among children.

Apuzzo and Yoshinaga-Itano[29] responded to Bess and Paradise's[25] concerns more directly. They compared language ability at 40 months of age across four age-of-identification groups: 1) 0 to 2 months, 2) 3 to 12 months, 3) 13 to 18 months, and 4) 19 to 25 months. The hearing loss of the children in each of the groups ranged from mild to profound and all of the children received ongoing intervention services from the same program shortly after their hearing loss was identified. Apuzzo and Yoshinaga-Itano reported that the first age-of-identification group (ie, those children identified before 3 months of age) had significantly higher language scores than those identified after the age of 2 months despite all children receiving similar intervention programming.

In the Apuzzo and Yoshinaga-Itano[29] study, all of the children in the earlier-identified group were diagnosed within the first 2 months of life because they presented with characteristics on the high risk registry for hearing loss. Within that study, there were only a few children without significant cognitive delay identified before 12 months of age despite including the entire sample of young children with hearing loss from a 10-year database of >350 children. Because of the small number of children in the earlier-identified group, the question of whether early identification and intervention was associated with better language scores for all deaf and hard-of-hearing children or only for children who exhibited specific demographic characteristics could not be addressed. Because of the institution of universal newborn hearing screening, within the last few years the number of children identified early with hearing loss who have normal cognitive ability has increased dramatically.

Moeller[30] reported a retrospective longitudinal study of 100 deaf and hard-of-hearing children, 25 of whom had been identified before 6 months of age. These children were tested every 6 months until the age of 5 years. Children identified with hearing loss before 6 months of age maintained age-appropriate language skills and had significantly better language skills than those children who were identified after 6 months of age. Similar to the study conducted by Apuzzo and Yoshinaga-Itano,[29] Moeller's early identification group consisted primarily of children identified through the high-risk register for hearing loss. Additionally, the earlier- and later-identified groups were not comparable on the full range of demographic variables frequently associated with language ability in deaf and hard-of-hearing children.

The purpose of the present investigation was to compare the language skills of a large group of children whose hearing losses were identified by 6 months of age with children who were identified after the age of 6 months. Because it was hypothesized that the advantage of early identification might vary, the effect was examined within a variety of subgroups formed on the basis of demographic variables frequently associated with language development. Specifically, comparisons of children who were earlier-identified versus later-identified were made within subgroups based on cognitive ability, age at testing, communication mode, minority status, gender, degree of hearing loss, socioeconomic status, and presence or absence of additional disabilities.

METHODS

Participants

The participants in this study were 150 deaf and hard-of-hearing children living in Colorado. At the time of data collection, the participants ranged in chronologic age from 1 year, 1 month to 3 years, 0 months (mean = 2 years, 2 months; standard deviation [SD] = 7.0 months). See Table 1 for a description of the demographic characteristics of this sample.

Age of Identification

The participants were divided into two groups based on the age of identification of their hearing loss. Group one (the earlier-identified group) consisted of 72 children (34 males; 38 females) whose hearing losses were identified between birth and 6 months of age. Group two (the later-identified group) included 78 children (41 males; 37 females) whose hearing losses were identified after the age of 6 months.

Intervention Program

Data regarding the age of amplification fitting were available for 80% of the sample. The median time that elapsed between identification and receiving amplification was 2 months for the earlier-identified group and 1 month for the children who were identified later. All of the participants in each group received ongoing early intervention services that focused on improving the child's communication and language skills. The onset date of these services was available for 82% of the sample. The median time between identification and ongoing intervention was 3 months for the earlier-identified group and 1 month for the group that was identified later. Three children in the earlier-identified group and 3 children in the later-identified group received their intervention services from a private center-based program that specialized in working with deaf and hard-of-hearing children. All of the remaining children in each group (96% of the total sample) were enrolled in the Colorado Home Intervention Program.

The Colorado Home Intervention Program provides early intervention services specifically to families who have deaf or hard-

TABLE 1. Demographic Characteristics of Study Sample by Age of Identification of Hearing Loss

Demographic Variable/ Category of Variable	Age of Identification of Hearing Loss			
	By 6 Months		After 6 Months	
	n	%	*n*	%
Gender				
Female	38	53	37	47
Male	34	47	41	53
Ethnicity				
Not a minority	53	74	56	75
Minority	19	26	19	25
Mother's education				
12 years or less	27	43	26	52
>12 years	36	57	24	48
Medicaid status				
Not on Medicaid	24	48	26	58
On Medicaid	26	52	19	42
Degree of hearing loss				
Mild	8	13	7	11
Moderate	17	27	10	16
Moderate-severe	16	25	13	21
Severe	10	16	14	23
Profound	11	18	14	23
Mode of communication				
Oral only	39	54	36	46
Oral and sign language	33	46	42	54
Multiple handicaps				
No other handicaps	37	53	42	59
Additional handicaps	33	47	29	41
Cognitive ability				
Cognitive quotient <80	21	29	44	56
Cognitive quotient ≥80	51	71	34	44
Age at data collection				
13 to 18 months	18	25	10	19
19 to 24 months	22	31	15	25
25 to 30 months	19	26	28	31
31 to 36 months	13	18	25	25

of-hearing children. The program is family focused with a cooperative partnership between the provider and the parents. A developmental assessment protocol consisting of parent questionnaires and an analysis of a videotaped parent-child interaction are used to develop each child's program. Goals and activities are individually and differentially determined according to the child's developmental data rather than being curriculum driven. Services are delivered in the home by a provider who visits the family ~1 hour per week. The vast majority of the service providers have graduate degrees in audiology, speech-language pathology, or deaf education. More than half of the providers have been with the program for 10 years or more. An important component of the program is ongoing, extensive in-service education for the providers in counseling strategies including theories of families systems. This program has been described in further detail by Stredler-Brown and Yoshinaga-Itano.[31]

Children in both age-of-identification groups received ongoing intervention for ~1 hour per week. As stated previously, the vast majority of the children in each group received services from the same intervention program. Thus, once intervention was initiated, there were no differences in either the intensity or type of services provided.

Ethnicity and Socioeconomic Status

Ethnicity data were available for all but 3 of the participants. In the earlier-identified group, 26% of the children were from an underrepresented minority group (primarily Hispanic) and the remaining 74% were Anglo-American. In the later-identified group, 25% of the children were from an ethnic minority group (again, primarily Hispanic).

Socioeconomic status was estimated by examining the level of education of the child's primary caregiver (typically the mother) and the Medicaid status of the family. The primary caregiver's educational level was available for 75% of the participants. The mean educational level of the caregivers of the children in the earlier-identified group was 13.6 years (SD = 2.4 years); for the later-identified group the mean was 13.3 years (SD = 2.3 years). A between-group *t* test indicated no significant difference in the means of the two groups (*t*, 0.62; degrees of freedom [*df*], 111; $P = .54$).

Data could be obtained for 63% of the participants regarding Medicaid status. Of these participants, 52% in the earlier-identified group and 42% in the later-identified group qualified for Medicaid. The proportion of families in each group receiving Medicaid did not differ significantly (*t*, 0.95; *df*, 93; $P = .35$).

Hearing Loss

All of the participants had congenital, bilateral hearing loss. Specific hearing threshold data were available for 120 of the 150 children. In the earlier-identified group, the participants' better ear pure tone average (ie, the average of the hearing thresholds at 500, 1000, and 2000 Hz) ranged from 27 decibels (dB) to 110+ dB (median = 58 dB). For the later-identified group, better ear pure tone averages ranged from 30 dB to 107+ dB (median = 67 dB), with the exception of 1 child who had a pure tone average of 22 dB and mildly decreased hearing in high frequency range.

The participants' severity of hearing loss (based on the pure tone average in the better ear) was categorized as mild (26–40 decibels hearing level [dB HL]), moderate (41–55 dB HL), moderate-severe (56–70 dB HL), severe (71–90 dB HL), or profound (>90 dB HL). The proportion of children in each of these categories for each age-of-identification group is presented in Table 1. The frequency distribution by hearing loss category was not significantly different when comparing the two age-of-identification groups ($\chi^2 = 3.09$; $df = 4$; $P = .54$).

Mode of Communication

Information regarding the mode of communication used by the family was available for all of the participants. In the earlier-identified group, 46% of the children were from families that communicated using a combination of sign language and spoken language; 54% were in families that used spoken language only. In the later-identified group, a combination of sign and spoken language was used by 54% of the families with only spoken language used by 46%. The distribution by mode of communication was not significantly different when comparing the two age-of-identification groups ($\chi^2 = 0.96$; $df = 1$; $P = .33$).

Cognitive Status and Additional Disabilities

The participants' cognitive status was estimated using the Play Assessment Questionnaire.[32] Age scores from this measure were transformed to cognitive quotients (CQs) by dividing the age score by the child's chronologic age and multiplying by 100. The CQs for this group of children ranged from 22 to 141. The mean CQ for the earlier-identified group was 88 with a SD of 23; for the later-identified group, the mean was 76 (SD = 19). A between-group *t* test revealed that the two groups differed significantly in cognitive skills (*t*, 3.52; *df*, 148; $P < .01$). This statistical difference was addressed in two ways. First, CQs were used as a covariate in all analyses. Additionally, comparisons between the earlier- and later-identified groups were conducted separately for the 65 participants with cognitive delay and the 85 participants without cognitive delay.

The presence of disabilities in addition to hearing loss was reported by the parent and the service provider. Forty-seven percent of the children in the earlier-identified group and 41% of the children in the later-identified group were reported to have one or more additional disabilities. The difference between the two groups in the proportion of children with additional disabilities was not significant (*t*, 0.75; *df*, 139; $P = .45$).

Procedures

All of the participants were assessed between the ages of 13 and 36 months. The children were divided into four groups based on their chronologic age at the time of testing. Table 1 presents the number and percentage of children within each age-of-identification group who fell into each of these four age ranges.

As part of a comprehensive developmental evaluation, the primary caregiver of each participant completed the *Minnesota*

Child Development Inventory (MCDI).[33] The 1974 version of this assessment was used for this study because data collection was begun before 1992 when the revised version became available.

The MCDI is a standardized instrument that assesses the development of children from 6 months to 6 1/2 years of age. It is composed of 320 items divided into eight scales that evaluate different areas of development. In the present study, two of these scales, expressive language and comprehension-conceptual, were examined. The expressive language scale consists of 54 items that measure expressive communication from simple gestural, vocal, and verbal behaviors to complex language expression. The comprehension-conceptual scale consists of 67 items that measure language comprehension from simple understanding to concept formulation. Parents complete this assessment by indicating which of the listed behaviors they have observed in their child.

This parent-report measure offers several advantages over administered assessments. First, this methodology takes advantage of parents' extensive knowledge about their child's language ability. Also, the measure is not subject to the influence of factors, such as fatigue or lack of familiarity with the examiner, that frequently limit a young child's performance during an administered assessment.

The reliability or internal consistency of each MCDI scale has been measured by the test's authors for specific age groups using the split-half method.[33] For the expressive language scale, reliability coefficients ranged from 0.54 to 0.92 (median = 0.88). The reliability of this scale for the present sample was computed using Cronbach's α and a coefficient of 0.94 was obtained. For the comprehension-conceptual scale, the test's authors obtained reliability coefficients ranging from 0.43 to 0.93 (median = 0.89) for the normative sample. For the sample of children in this study, a reliability coefficient of 0.95 was obtained.

There are extensive data supporting the concurrent and predictive validity of the MCDI language scales with both typically developing children and with children who have a variety of special needs.[34–37] Significant correlation coefficients of 0.51 to 0.79 have been obtained between the MCDI Expressive Language and Comprehension-Conceptual Scales and the verbal scale of the McCarthy Scales of Children's Abilities.[34–36] Significant correlations also have been found between the MCDI Expressive Language Scale and the Reynell Developmental Expressive Language Scale (r = 0.50) and the MCDI Comprehension-Conceptual Scale and the Reynell Developmental Receptive Language Scale (r = 0.52).[35] Tomblin, et al[37] compared a group of typically developing children's scores on the MCDI language scales with performance on the Sequenced Inventory of Communication Development and to the child's mean length of utterance (MLU) during a spontaneous language sample. All comparisons yielded significant correlations that ranged from 0.34 to 0.68.

Concurrent validity of the MCDI for a subsample of children (n = 109) in the present study was examined by correlating MCDI age scores with the child's MLU during a 25-minute interaction with his or her primary caregiver. Significant correlations ($P < .01$) of 0.76 and 0.78 were obtained between MLU and the expressive language and comprehension-conceptual scales, respectively. Validity was also measured by comparing the total words in the child's expressive lexicon from the MacArthur Communicative Development Inventory[38] with the MCDI language scores. Both the expressive language and comprehension-conceptual scales were significantly related to the MacArthur inventory (n = 136; r = 0.74 and r = 0.76, respectively; $P < .001$).

Statistical Analysis

To examine the participants' language abilities, language quotients (LQs) were derived for each child. These were calculated by dividing the child's age score on each MCDI subtest by his or her chronologic age and then multiplying by 100. Children whose language age matched their chronologic age received an LQ of 100. LQs for children whose language level was below their chronologic age were <100; LQs >100 indicated that the child's language age was greater than his/her chronologic age. Three LQs were obtained for each participant: a) an expressive LQ based on scores from the MCDI Expressive Language Scale; b) a receptive LQ based on scores from the MCDI Comprehension-Conceptual Scale; and c) a total LQ, calculated specifically for this study, which was obtained by averaging each participant's receptive and expressive LQ scores.

Cognitive ability, based on the Play Assessment Questionnaire,[32] was found to have high positive correlations with the participants' MCDI expressive and receptive language scores (r = 0.75, $P < .01$; and r = 0.74, $P < .01$, respectively). Because of this strong relationship between cognitive ability and the outcome measure of this study (ie, language scores) and because the two age-of-identification groups demonstrated significantly different cognitive ability, CQs were used as a covariate in all comparisons between the two groups.

The primary purpose of the statistical analyses in the present study was to compare the language abilities of the earlier- and later-identified groups. The question of whether or not the differences, if they were found, were consistent across a variety of demographic subgroups was also addressed. To obtain this information, eight separate analyses of covariance (ANCOVAs), covarying for cognitive ability, were performed. In each analysis, the total LQs of the two age-of-identification groups was compared. Additionally, each ANCOVA included a main effects comparison between different levels of a specific demographic variable (eg, males versus females). The interaction between the main effect and the effect of the demographic variable was examined to determine if the differences in age of identification were constant across the different levels of the demographic variable (eg, to determine if the age of identification effect existed for both males and females).

To determine if age of identification had a differential effect on children with normal versus low cognitive ability, the effect of age of identification was examined within two cognitive-ability subgroups as well as in the group as a whole. One cognitive-ability subgroup included children with normal cognitive skills and the other included participants with low cognitive skills. A CQ of 80 was selected as the cutoff to categorize participants into a normal- or low-cognition group. Using this criterion, 29% of the children in the earlier-identified group and 56% in the later-identified group were placed in the low-cognitive ability category.

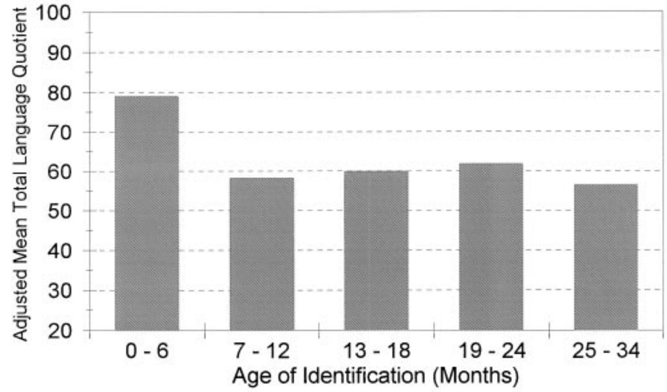
Within each cognitive-ability group, strong positive correlations were obtained between cognitive and language ability (r ranged from 0.73 to 0.75, $P < .01$) across the two cognitive groups and the three language measures. For this reason, cognitive ability continued to be used as a covariate, even when comparisons were made within the normal- or low-cognition groups. Additionally, for each ANCOVA, the cell means were calculated adjusting for cognitive ability to protect against possible imbalances in the specific cognitive scores of the children in the earlier- and later-identified groups.

This investigation was approved by the Human Subjects Review Board at the University of Colorado–Boulder.

TABLE 2. Results for Analyses of Covariance for Total Group: Language Quotient Scores by Age of Identification of Hearing Loss

Language Scale	Age of Identification	Adjusted Mean	Standard Deviation	Effect for Age of Identification	
				F[1,147]	P
Receptive	By 6 months	79.6	25.8	25.4	<.001
	After 6 months	64.6	20.9		
Expressive	By 6 months	78.3	26.8	25.8	<.001
	After 6 months	63.1	19.8		
Total language	By 6 months	79.0	25.6	29.5	<.001
	After 6 months	63.8	19.3		

Fig 1. Adjusted mean total language quotients for groups based on age of identification of hearing loss.



Pure Tone Average:	63	62	80	72	64
Cognitive Quotient:	88	74	82	76	71

RESULTS

Total Group

Children with hearing losses identified by 6 months of age had significantly higher LQs than those children whose hearing losses were identified after 6 months of age. This effect was found for their receptive LQs ($F[1,147] = 25.4$; $P < .001$), expressive LQs ($F[1,147] = 25.8$; $P < .001$), and total LQs ($F[1,147] = 29.5$; $P < .001$). Children who were identified earlier had adjusted mean LQs of 79.6 (SD = 25.8) for receptive language, 78.3 (SD = 26.8) for expressive language, and 79.0 (SD = 25.6) for total language. Children who were identified after 6 months of age had adjusted mean LQs of 64.6 (SD = 20.9) for receptive language, 63.1 (SD = 19.8) for expressive language, and 63.8 (SD = 19.3) for total language (see Table 2).

The average age of identification for children in the later-identified group ranged from 7 to 34 months (median = 16 months). To examine the effect of age of identification on these children, the participants were divided into four age-of-identification groups: a) 7 to 12 months ($n = 25$), b) 13 to 18 months ($n = 23$), c) 19 to 24 months ($n = 16$), and d) 25 months or later ($n = 14$). Adjusted mean expressive LQs by group were: a) 58.5 (SD = 21.2) b) 58.2 (SD = 18.4), c) 60.5 (SD = 20.3), and d) 55.8 (SD = 20.2). Adjusted mean receptive LQs by group were: a) 57.8

TABLE 3. Results of Analyses of Covariance for Children With Normal Cognition: Language Quotient Scores by Age of Identification of Hearing Loss

Language Scale	Age of Identification	Adjusted Mean	Standard Deviation	Effect for Age of Identification	
				F[1, 82]	*P*
Receptive	By 6 months	92.2	19.9	24.5	<.001
	After 6 months	71.7	19.7		
Expressive	By 6 months	90.5	21.9	25.8	<.001
	After 6 months	68.7	20.3		
Total language	By 6 months	91.3	19.8	29.6	<.001
	After 6 months	70.2	18.5		

TABLE 4. Results for Analyses of Covariance on Total Language Quotient by Demographic Variable and Age of Identification of Hearing Loss for Children With Normal Cognition

	n	Age of Identification			Demographic Measure			Interaction of Age of Identification and Demographic Measure		
		F	*df*	*P*	*F*	*df*	*P*	*F*	*df*	*P*
Gender	85	30.6	1, 80	<.01†	4.2	1, 80	.04*	1.0	1, 80	.33
Ethnicity	85	23.5	1, 80	<.01†	3.9	1, 80	.06	0.1	1, 80	.75
Mother's education	67	17.7	1, 62	<.01†	0.1	1, 62	.79	0.2	1, 62	.67
Medicaid recipient	54	4.8	1, 49	.03*	0.01	1, 49	.93	0.4	1, 49	.50
Degree of hearing loss	74	15.0	1, 63	<.01†	0.4	4, 63	.79	0.4	4, 63	.84
Mode of communication	85	28.5	1, 80	<.01†	3.7	1, 80	.06	0.01	1, 80	.92
Multiple handicaps	81	21.9	1, 76	<.01†	0.2	1, 76	.65	0.6	1, 76	.45
Age at data collection	85	30.3	1, 76	<.01†	2.2	3, 76	.09	0.2	3, 76	.89

* $P < .05$.
† $P < .01$.

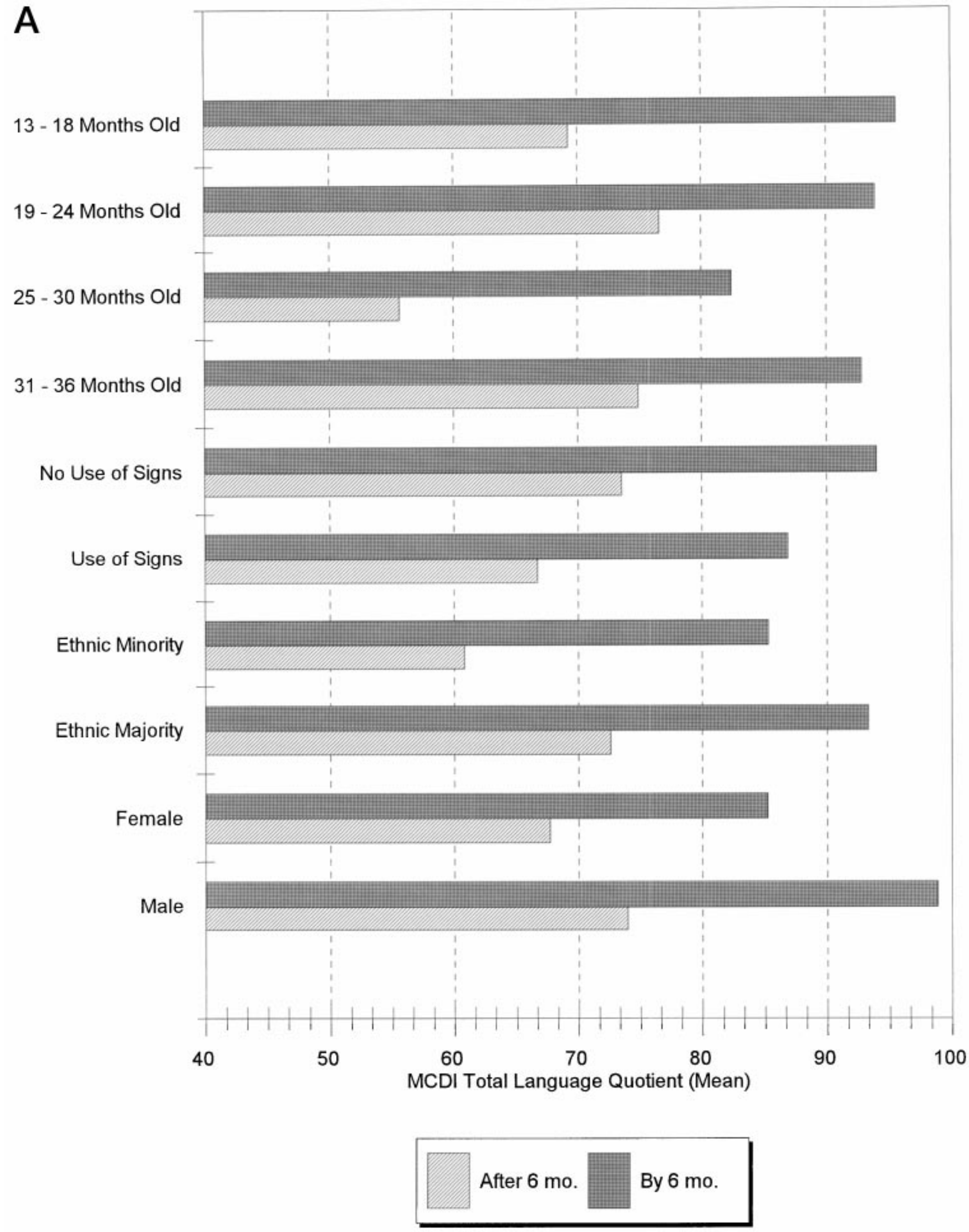


Fig 2. A, Adjusted mean total language quotients for the earlier- and late identified groups by demographic category for children with normal cognition. B, Adjusted total mean language quotients for the earlier- and later-identified groups by demographic category for children with normal cognition.

(SD = 24.0), b) 61.6 (SD = 21.2), c) 62.9 (SD = 15.7), and d) 57.1 (SD = 19.6). Adjusted mean total LQs were a) 58.2 (SD = 21.3), b) 59.9 (SD = 18.6), c) 61.8 (SD = 17.3), and d) 56.5 (SD = 19.1). Total LQs for each group are presented in Fig 1. The mean LQs for the four later age-of-identification groups were compared using a separate univariate ANCOVA, with CQs as the covariate, for each of the three language measures (receptive, expressive, and total). In all three analyses, no significant differences in language ability were found among the four later age-of-identification groups (expressive language: $F[3,73] = 0.18$, $P = .91$; receptive language: $F[3,73] = 0.42$, $P = .74$; total language: $F[3,73] = 0.29$, $P = .84$). To examine the relationship between LQs and age of identification in the later-identified group further, Pearson product moment correlations were calculated. No significant correlations were found for these later-identified children between age of identification and any of the three LQs (expressive language: $r = -0.06$, $P = .64$; receptive language: $r = -0.06$, $P = .60$; total language: $r = -0.06$, $P = .60$).

Children With Normal Cognitive Ability

Children with normal cognitive ability whose hearing losses were identified by 6 months of age had significantly higher LQs than children with normal cognitive ability whose hearing losses were identified after 6 months of age. This effect was found for their receptive LQs ($F[1.82] = 24.5$, $P < .001$), expressive LQs ($F,[1,82] = 25.8$, $P < .001$), and total LQs ($F[1.82] = 29.6$, $P < .001$). Children who were identified earlier had adjusted mean LQs of 92.2 (SD = 19.9) for receptive language, 90.5 (SD = 21.9) for expressive language, and 91.3 (SD = 19.8)

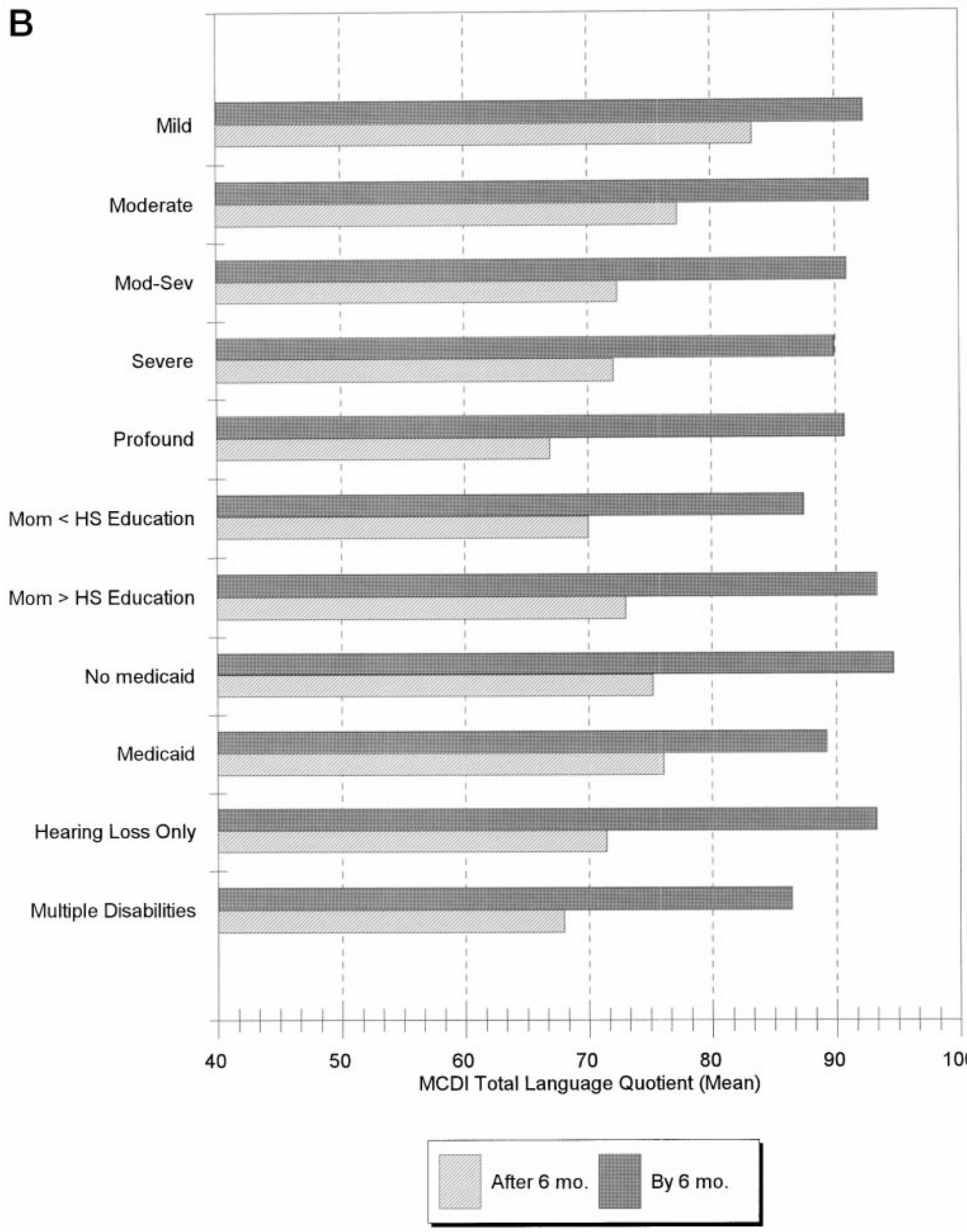


Fig 2. Continued.

for total language. In contrast, the later-identified group had adjusted mean LQs of 71.7 (SD = 19.7) for receptive language, 68.7 (SD = 20.3) for expressive language, and 70.2 (SD = 18.5) for total language (see Table 3).

To determine if earlier identification was associated with higher total LQs only for children with specific demographic characteristics, the effect was examined in a variety of subgroups of the current sample. This analysis was accomplished by conducting a series of eight two-way ANCOVAs with CQs used as the covariate. In each ANCOVA, the main effect of age of identification was tested. The second main effect tested was a demographic variable frequently associated with language ability. Specifically, the effect of one of the following demographic variables was assessed in each of the eight ANCOVAs: gender, minority status, maternal level of education, Medicaid status, degree of hearing loss, communication mode, presence of additional disabilities, and participants' age at the time of testing. A significant main effect for age of identification was found for all eight ANCOVAs (see Table 4 for specific *F*, *p*, and *n* values). Of the eight demographic variables tested, only gender yielded a significant main effect with males obtaining significantly higher total LQs than females ($F[1,80] = 4.2$, $P < .05$). Further analysis revealed that the MCDI adjusted age scores by gender because in the normative sample for this test, males demonstrated slower language development within this age range. Thus, the same raw score yielded a higher language age for a male than for a female. No significant differences were found between the raw scores of the female participants in

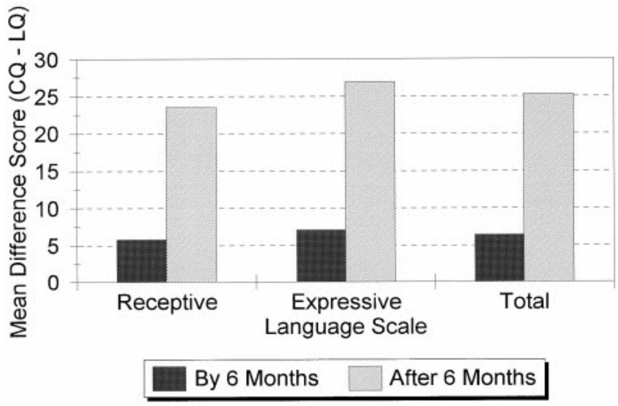


Fig 3. Discrepancy between cognitive quotient and language quotient by age of identification of hearing loss for children with normal cognition.

this study and the male participants (receptive language: *t*, 0.37; *df*, 148; $P = .72$; expressive language: *t*, 0.18; *df*, 148; $P = .86$; total language: *t*, 0.27; *df*, 148; $P = .79$). In all eight ANCOVAs, there was no significant interaction between age of identification and the demographic variable. Thus, the age of identification effect was consistent across all of the demographic subgroups tested. These results are illustrated graphically in Figs 2A and 2B where it also can be seen that for each demographic subset of the earlier-identified group the mean LQs were within the normal range (mean LQs = 82.4 to 98.8).

Hearing children typically demonstrate language skills that are commensurate with their cognitive abilities. This relationship has not been found among children with hearing loss. Significant differences between performance intelligence and language ability consistently have been found for school-aged children with significant hearing loss.[9,39,40] To examine this relationship in the two age-of-identification groups, the participants' LQs were subtracted from their CQ. Depending on the LQ used (ie, receptive, expressive, or total), these mean difference scores ranged from 5 to 7 quotient points for the earlier-identified group and from 24 to 26 points for the children who were identified later (see Fig 3). The cognitive-linguistic difference scores were used in a 2×3 mixed-design multivariate analysis of variance. For this analysis, age of identification was the between-subjects factor and type of language measure used in the difference calculation (receptive, expressive, or total) was the within-subjects factor. This analysis resulted in a large effect by age of identification ($F[1,83] = 23.5$, $P < .001$) and no significant effect for type of language measure ($F[2,166] = 2.15$, $P = .12$). The interaction of age of identification by type of measure was not significant ($F[2,166] = 0.5$, $P = .6$) indicating that the age of identification effect was consistent across the three (receptive, expressive, and total) cognition-language difference scores. The large difference between the later-identified children's CQ and LQ (CQ − LQ) indicates that the language skills of these children's are much poorer than would be expected given their cognitive ability.

TABLE 5. Results for Analyses of Covariance for Children With Low Cognition: Language Quotient Scores By Age of Identification of Hearing Loss

Language Scale/ Age of Identification	Adjusted Mean	Standard Deviation	Effect for Age of Identification	
			$F[1, 62]$	P
Receptive				
By 6 months	60.4	21.4	3.7	.06
After 6 months	51.8	18.9		
Expressive				
By 6 months	58.8	20.9	3.0	.09
After 6 months	51.7	17.5		
Total language				
By 6 months	59.6	20.6	3.8	.05
After 6 months	51.7	17.3		

Children With Low Cognitive Ability

Children with CQs below 80 whose hearing losses were identified by 6 months of age had an adjusted mean receptive LQ of 60.4 (SD = 21.4), an expressive LQ of 58.8 (SD = 20.9), and a total LQ of 59.6 (SD = 20.6). These means contrast with the means for the later-identified group that were 51.8 (SD = 18.9) for receptive language, 51.7 (SD = 17.5) for expressive language, and 51.7 (SD = 17.3) for total language (see Table 5). Differences between the two age-of-identification groups were not statistically significant when receptive or expressive LQs were used as the dependent measure (receptive language $F[1,62] = 3.7$, $P = .06$; expressive language: $F[1,62] = 3.0$, $P = .09$). When total language score was the dependent variable, the age-of-identification effect was significant ($F[1,62] = 3.8$, $P = .05$).

Similar to the results for children with normal cognitive ability, the discrepancy between the participants' CQ and LQ was significantly higher for the later-identified group ($F[1,63] = 4.31$, $P < .05$). As shown in Fig 4, the earlier-identified group had LQs that were remarkably similar to their CQs; the mean difference in the two quotients was <3 points. In the later-identified group, the mean gap between the children's CQ and LQ was 10 points. Thus, the earlier-identified group performed linguistically as well as would be expected given their cognitive ability, whereas the later-identified children demonstrated

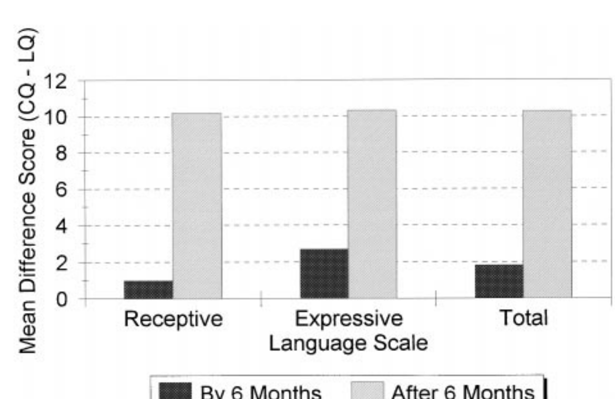


Fig 4. Discrepancy between cognitive quotient and language quotient by age of identification of hearing loss for children with low cognition.

language skills that were below cognitive-level expectations.

Interestingly, for those participants who were tested at 31 to 36 months age, the mean total LQ of the earlier-identified low-cognition group (n = 6) was almost identical with the mean of the children with normal cognition who were identified later (n = 8). As shown in Fig 5, the mean total LQ for both of these groups was between 71 and 72.

DISCUSSION

In this study, a group of children whose hearing losses were identified by 6 months of age demonstrated significantly better receptive and expressive language skills than did children whose hearing losses were identified after the age of 6 months. This language advantage was evident across age, gender, socioeconomic status, ethnicity, cognitive status, degree of hearing loss, mode of communication, and presence/absence of other disabilities. The language difference between the two age-of-identification groups was so large that the mean performance of the earlier-identified children was almost a full SD higher than the mean performance of later-identified children.

In this study, there was no significant difference between the earlier- and later-identified children on a wide variety of demographic variables frequently associated with language ability. In addition, on the average, both groups of children received intervention services within several months of the identification of their hearing loss. These services were provided by the same agency for the vast majority of children in both groups, and, once intervention was initiated, both groups received the same type and intensity of service. Despite the many similarities between the two groups, there were two identified variables on which the groups differed, ie, age of identification (and subsequent intervention) and cognitive ability. Differences in the participants' cognitive abilities were controlled statistically in all analyses. Thus, the remaining variable (age of identification and subsequent intervention) must be considered as a possible explanation for the language differences noted at 1 to 3 years of age.

To provide the most solid evidence that early identification and subsequent intervention impacts later language ability, a controlled, prospective investigation with random assignment to early- versus late-identified groups and treatment versus no-treatment groups might be proposed. Presently, such a study is not feasible for several reasons. First, random assignment to groups based on time of identification is not possible in an increasing number of states because of recent legislative mandates to screen the hearing of all newborns. Even in those states without universal hearing screening programs, parental cooperation for such a study is likely to be quite low. Under the Individuals with Disabilities Education Act, families are entitled to a timely evaluation if they suspect their child has a disability. Once parents become suspicious that their child has a hearing loss, it is unlikely they would be willing to delay an evaluation even if they previously had consented to being placed in a late-identification group.

Soliciting participation in a study that might result in assignment to a no-treatment (or delayed-treatment) group also is likely to meet with substantial parental resistance. This is because, in addition to timely assessment, the Individuals with Disabilities Education Act stipulates the provision of prompt intervention services after a disability is identified. It is likely that most parents would not be willing to delay these federally-guaranteed services for their child in the interest of research.

Because of the obstacles to randomly assigning children to early- and late-identification/intervention groups, the topic of early identification and intervention must be explored through descriptive studies using naturally occurring groups of children. The results of such descriptive studies become more powerful when they are replicated by a variety of different researchers with independent samples of children. Such is the case with the present question. The language advantage reported in this study for children who were identified earlier is consistent with several previous studies on the early identification of hearing loss. White and White,[26] Robinshaw,[28] Moeller,[30] and Apuzzo and Yoshinaga-Itano[29] all

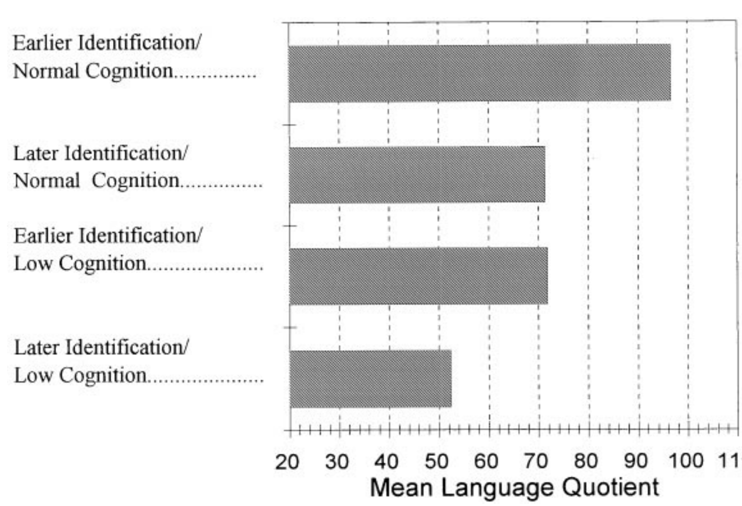


Fig 5. Mean total language quotient scores at 31 to 36 months by age of identification of hearing loss and cognition.

have reported significantly better language scores for children whose hearing losses were identified earlier.

In the present investigation, and in all four studies documenting a language advantage for the earlier-identified group, children received early intervention services shortly after their hearing losses were identified. It is unlikely that language differences of the magnitude documented in these studies would occur simply by identifying hearing loss early; early identification alone is unlikely to result in improved outcomes if it is not followed by early intervention.

Research on school-aged children with severe-to-profound hearing losses indicates a 40-point discrepancy between performance intelligence scores (mean of 100) and verbal intelligence scores (mean of 60)[9,39,40]; even academically successful deaf students demonstrate a 20-point discrepancy. It is interesting that a cognitive-language quotient discrepancy was already present by 3 years of age in the later-identified children in this study, raising the possibility that the cognitive-linguistic gap previously reported in school-aged children may have its roots in the first year of life.

In the four previous investigations that have noted better language skills in early-identified children, the average age of identification for the early group was below 12 months of age (with three of the four studies defining early identification as before 3 to 6 months of age). In the present study, there was no significant difference in language scores between four subgroups of later-identified children who were divided sequentially according to age of identification (from 7 months to greater than 25 months of age). This may explain the results of a previous study that examined the contribution age of intervention makes to later language ability and failed to find any significant contribution.[27] In that study, 91% of the children began intervention some time before 3 years of age. Specific information regarding the distribution by age of intervention was not provided; however, unless a large proportion of the children began intervention in the first 6 months of life, this study is consistent with the results of the present investigation. That is, the present findings, and the pattern that has emerged from previous studies, suggest that for an earlier-identified group to demonstrate significantly better language skills than a later-identified group, identification must truly occur early (ie, within the first 6 months of life).

Before the advent of universal newborn hearing screening programs, identifying hearing loss by 6 months of age was rarely accomplished. Parents generally do not suspect a hearing loss until their child fails to meet important speech and language milestones at 1 to 2 years of age. Also, screening programs that only test infants who present with one or more risk factors for hearing loss are typically testing only ~50% of children who actually have a hearing loss.[1,3,41,42] These factors have resulted in an average age of identification of 11 to 19 months for children with known risk factors for hearing loss[2,17,42–44] and 15 to 19 months for children without apparent risk.[17,43,44]

Taken as a group, previous and present research findings suggest that the first year of life, especially the first 6 months, is critical for children with hearing loss. When hearing loss was identified and treated by this time, several independent researchers have reported that, as a group, children demonstrated average language scores that fell within the normal range when they were 1 to 5 years old.[28,30] This finding is encouraging and suggests that early identification and subsequent intervention is associated with improved language development in deaf and hard-of-hearing children. If this is the case, it is critical that all infants with hearing loss be identified by 6 months of age and receive early intervention; universal newborn hearing screening would be an excellent vehicle for achieving this goal.

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Language of Early- and Later-identified Children With Hearing Loss
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