Predicting Language Production in Children and Adolescents With Down Syndrome: The Role of Comprehension

Robin S. Chapman
Hye-Kyeung Seung[1]
Scott E. Schwartz[2]
Elizabeth Kay-Raining Bird[3]
University of Wisconsin–Madison

Predictors of language production skills in 12-minute narratives are investigated cross-sectionally in 48 children and adolescents with Down syndrome (trisomy 21), aged 5 to 20 years, in comparison to 48 control children aged 2 to 6 years matched statistically for nonverbal mental age and mother's years of education. Two models were evaluated by hierarchical regression analyses using predictors drawn from the domains of group membership, chronological age, cognition, socioeconomic status, and hearing screening status (Model I) and, additionally, comprehension performance (Model II). Results showed that Model II was more successful. In the DS group, it explained 68% of the variability in number of different words, 80% in MLU, and 32% in intelligibility. Corresponding percentages for the control group were 72%, 71%, and 26%. A mechanism linking comprehension of input to early stages of production practice through activation of the early speech motor area is proposed.

KEY WORDS: Down syndrome, mental retardation, language

Children with Down syndrome show selective deficits in expressive lexicon, syntax, and intelligibility compared to mental age-matched controls or their own comprehension performance, a pattern which has been proposed as phenotypic, or characteristic, of the group (e.g., Chapman, Seung, Schwartz, & Kay-Raining Bird, 1998). They also show considerable variation in production skills (see Chapman, 1995, 1997a, 1997b; Fowler, 1990; Miller, 1988 for reviews). Among the variables associated with this variation are chronological age (Chapman et al., 1998; Rondal, Ghiotto, Bredart, & Bachelet, 1988) and nonverbal mental age (Cardoso-Martins, Mervis, & Mervis, 1985; Miller, Miolo, Sedey, & Murray-Branch, 1993), which are also predictors, along with hearing status, of comprehension skill (Chapman, Schwartz, & Kay-Raining Bird, 1991). In studies of typically developing children, mother's education has also been a strong predictor of children's rates of expressive language development (Hoff-Ginsberg, 1991). In this study, the contributions of hearing status, chronological age, nonverbal mental age, and mother's education to prediction of language production skills are

[1]Currently affiliated with the University of Texas–El Paso
[2]Currently affiliated with the Boulder Valley, CO, School District
[3]Currently affiliated with Dalhousie University

examined in both children with Down syndrome and children who are typically developing and matched for nonverbal mental age. The effect of adding comprehension as a predictor is evaluated in a second model to see if it contributes additional explained variance.

Mental Age and Language Production

The chronological ages at which children with Down syndrome have been reported to meet early language production milestones vary widely. Emergence of first words varies from 8 to 45 months (Berry, Gunn, Andrews, & Price, 1981; Strominger, Winkler, & Cohen, 1984). Emergence of first two-word combinations ranges from 1 to 6 years. However, taking nonverbal mental age into account reduces the apparent variation. First spoken words emerge at approximately the same mental ages as typically developing children (Cardoso-Martins et al., 1985), but for a majority of children with Down syndrome, early cumulative spoken vocabularies show a slower rate of progress than controls (Beeghly & Cicchetti, 1986; Miller, Sedey, Miolo, Murray-Branch, & Rosin, 1992). Early communicative gestures are less likely to be accompanied by vocalizations for children with Down syndrome (Greenwald & Leonard, 1979).

Increasing Gaps Between Mental Age and Expressive Language

Emergence of multiword utterances also occurs at mental ages similar to controls (Cardoso-Martins et al., 1985; Miller et al., 1993), but mean length of utterance in morphemes (MLU) in free-speech samples increases more slowly thereafter, despite its correlation with increasing chronological age in the 1.0–3.5 range (Rondal et al., 1988). Miller (1988) reported 50% of his preschool sample (11 to 58 months initially) to show production-only deficits; 2 years later, 72% of the same sample was so categorized. A similar finding emerges (Wiegel-Crump, 1981) when speech samples are scored according to the Developmental Sentence Scoring (DSS) protocol (Lee & Canter, 1971); DSS scores were equivalent to mental age (MA) performance below 2 years MA, but fell below the 15th percentile thereafter, despite their increase with MA.

For older children with Down syndrome, deficits on grammatical closure tasks (McCarthy, 1965) and deficits in expressive syntax in free speech samples have been reported (Miller et al., 1993; Rogers, 1975; Ryan, 1975; Rosin, Swift, Bless, & Vetter, 1988). Fowler (1990; Fowler, Gelman, & Gleitman, 1994) has proposed that language skills plateau in adolescence; if so, chronological age is a critical predictor. In the cohorts studied by Chapman et al. (1998), we found significant increases in language production of adolescents with Down syndrome comparing early to late adolescents on both conversational and narrative measures, providing evidence against plateauing based on a critical age or simple syntax limitation.

In this study, the contributions of both mental age and chronological age to explained variance in language production skills are evaluated.

Comprehension Skills

Vocabulary comprehension skills, in contrast, keep pace with cognitive development (Rosin et al., 1988) or appear more advanced than cognitive level in adolescence (Chapman et al., 1991), depending on the measures of cognition used. Use of the Columbia Test of Mental Maturity (Rosin et al., 1988) or the Pattern Analysis subtest of the Stanford-Binet result in higher mental ages for adolescents with Down syndrome than when the Bead Memory subtest assessing sequential visual memory is averaged in, as in the Chapman et al. (1998) study. Syntactic comprehension performance is either similar to nonverbal cognitive skills (Chapman et al., 1991) or delayed (Rosin et al., 1988), again depending on the cognition measures used. Chapman et al. (1991) reported that vocabulary comprehension (Peabody Picture Vocabulary Score) and syntax comprehension (Test of Auditory Comprehension of Language–R total score) did not differ for the Down syndrome group (aged 5 to 20 years) and mental age matched controls. However, the adolescents in the Down syndrome group showed advanced vocabulary comprehension compared to the controls, as indexed by the difference scores between PPVT score and TACL–R total score. In the Chapman et al. (1991) study, mental age and chronological age accounted for most of the variance in PPVT vocabulary score (78% of the total 82%) and TACL–R (80% of the total 84%) scores in the Down syndrome group, with 4% explained by hearing screening. Whether variation in comprehension skill contributes to explained variation in production skill, despite the significant gap in absolute performance level, has not been examined. This question is addressed in the second model evaluated in the present study.

Other Issues

Variation in expressive language skill might also be predicted from socioeconomic status variables, notably mother's years of education, which predict variability in the expressive language skills of typically developing children (Hoff-Ginsberg, 1991). Also, individuals with Down syndrome have been known to have frequent ear infections as well as a higher prevalence of hearing problems (Brooks, Wooley, & Kanjilal, 1972; Balkany, Downs, Jafek, & Krajiceck, 1979; Dahle & McCollister, 1986; Fulton & Lloyd, 1968; Keiser, Montague, Wold, Maune, & Pattison, 1981; van Gorp & Baker, 1989). Participants were included in this study if they had at most a mild hearing loss. Thus, both mother's years of education and hearing screening status are included as predictors of language production skill in this study.

Models of Production

Predictors of comprehension skill, investigated previously for these same participants (Chapman et al., 1991), included chronological age, sex, mental age, hearing status and history, and socioeconomic status. Here we employ two hierarchical regression models to evaluate the contribution of the predictors of comprehension previously identified—chronological age, mental age, hearing status, and socioeconomic status—to the production performance of the group. In Model I, these are the only predictors used. In Model II, language comprehension is added to the set to see if it contributes additional explained variance. Language comprehension is measured by the TACL–R total score instead of the subtest scores or the vocabulary (PPVT–R) score for the following reasons: (a) The contribution of overall language comprehension to spontaneous narrative production is a focus of the present study. (b) TACL–R subtest scores reported in the previous study (Chapman et al., 1991, p. 1109) suggest that total score well represents the comprehension performance of the individuals with Down syndrome of the current study, including both vocabulary and syntactic aspects. By using the total score, the number of variables entered in the model can be reduced. Language comprehension was entered before nonverbal mental age in Model II because nonverbal mental age had already been statistically matched in the two groups and because the contribution uniquely contributed by comprehension could be evaluated by comparing Model I and Model II.

Model I (Without Comprehension)

We add group membership as a predictor whose significance will indicate effects unique to the group (DS or controls) and sequence the predictors as group, hearing status, chronological age, cognition, and mother's education, including the three factors associated with typical development last. This ordering allows us to test whether nonverbal cognition explains added variance after chronological age is taken into account, and whether mother's education explains added variance after cognition is taken into account. It also allows us to evaluate the amount of variance in production skill explained by the full set of known predictors of comprehension performance.

Model II (With Comprehension)

Model II is identical to Model I except that comprehension has been entered as a predictor of production after hearing status, allowing us to evaluate the additional variance contributed by comprehension status in comparison to Model I. This order in Model II allows us to see how much variation in language production is potentially explained by comprehension after hearing status is taken into account. The unique contribution of comprehension, after variance shared with cognition, mental age, and mother's years of education is taken into account, can be inferred by comparing the total variance explained in Model I with Model II.

These models are examined for several aspects of language production skill: lexical, indexed by different number of words produced; morpho-syntactic, indexed by mean length of utterances in morpheme; volubility, indexed by total number of utterances in 12 minutes; and speech intelligibility, indexed by the proportion of total utterances that are complete and intelligible.

Method

Participants

Forty-eight children and adolescents with Down syndrome (ages 5.6 to 20.3 years) and 48 typically developing children (ages 2.2 to 6.1 years) were recruited from Wisconsin and northern Illinois. These are the same children studied in Chapman et al., 1990, 1991, and 1998. Children with Down syndrome were excluded if sign language was their primary means of communication (based on parental report) or if they had a moderate hearing loss (pure tone average for the frequencies 500, 1000, and 2000 Hertz greater than 45 dB in the better ear, on the day of test). The control group was matched statistically to the mean mental age in the Down syndrome group [$t(94) = -.21$, $p > .01$], as determined from the average of age-equivalent scores on Bead Memory and Pattern Analysis subtests of the Stanford Binet: Fourth Edition (Thorndike, Hagen, & Sattler, 1986) and on mother's years of education in the Down syndrome group [$t(94) = -1.28$, $p > .01$].

Procedures

All children participated in a 3-hour protocol including a hearing screening; conversation and narration with the examiner; the Expressive Vocabulary, Bead Memory, and Pattern Analysis subtests of the Stanford-Binet: Fourth Edition (Thorndike et al., 1986), the Test for Auditory Comprehension of Language, revised (TACL–R; Carrow-Woolfolk, 1985), and several other tasks. Breaks were incorporated frequently as necessary. Background data were collected through questionnaire, parent interview, and follow-up telephone conversations. Parent interviews elicited background data on parent education and occupation. All tasks were audio- and videotaped. A Sony TCM-5000 EV audiocassette tape recorder with an external Sound Grabber microphone and a Panasonic WV3260 color video camera with an external solar-powered microphone attached to a Panasonic VHS recorder (Model AG-1950) were used.

Hearing Screening

Hearing was screened on the day of test using a portable Beltone audiometer in the experimental room. Pass/fail data were collected for each ear at 25 and 45 dB HL (ANSI-1969) for the frequencies 500, 1000, and 2000 Hz.

Narrative Language Sample

Expressive language skills were assessed through a 12-minute narrative free speech sample with the examiner, which included a request to tell about favorite stories, movies, or TV shows; to describe recent events depicted in family photographs (brought from home); to describe the Cookie Theft picture (a complex event in which the mother is washing dishes while water pours onto the floor and the child behind her is stealing cookies); to complete three story stems that provide a protagonist and a setting (from Stein & Glenn, 1982); and (if necessary to complete the 12 minutes) descriptions of complex pictures and videotaped nonverbal events drawn from other parts of the protocol. Narrative sample was used instead of conversation sample because the narrative sample contained more word tokens and types, as well as longer MLU than conversation samples, better reflecting language skills at higher levels (Chapman et al., 1998).

Narrative Transcription

These taped narrative samples were transcribed with a Sony BM-75 Dictator/Transcriber Unit as computer files using SALT (Systematic Analysis of Language Transcript) conventions (Miller & Chapman, 1990). Utterance segmentation followed intonational contour, except where multiple clauses were conjoined by *and* or *and then*; in these cases, the utterance was segmented after the second clause (and subsequent pairs of clauses). Unintelligible portions of an utterance were transcribed as unintelligible syllables if three listenings did not produce an interpretation.

Reliability

All transcripts were checked for reliability by independent transcribers. When there were disagreements, they were corrected and analyzed with the SALT program. Reliability was established by tallying the number of disagreements in which morphemes were added, deleted, changed, or put into or out of mazes or in which utterance segmentation changed. These changes averaged 6.1 per mean 456 words of narrative transcript for the controls (99%) and 7.8 per mean 367 words (98%) for the group with Down syndrome.

Measures of Language Production

Number of different word roots and mean length of utterance (MLU) in morphemes were measured from complete and intelligible utterances in the 12-minute narrative samples using the SALT program, Vax version (Miller & Chapman, 1990). Intelligibility was indexed as the proportion of complete and intelligible utterances over total utterances. Total utterances reflected all utterance attempts. A summary of language production measures is provided in Table 1.

Predictors of Language Production Performance

Predictor variables for language production performance were constructed in six domains: group (individuals with Down syndrome or typically developing children), chronological age, nonverbal cognition, language comprehension performance, hearing status, and socioeconomic status. Selection of the predictors was based on research findings reviewed in the introduction. Means and standard deviations of the predictors (Table 2) and intercorrelations among the predictors

Table 1. Summary characteristics of the language production measures from the 12-minute narrative (N = 48).

	Down syndrome		Controls	
Variables	*M*	*SD*	*M*	*SD*
Different words	132.79	56.07	155.44	60.55
MLU in morphemes	2.98	1.44	4.70	1.72
Total utterance	160.77	42.41	120.00	33.94
Intelligibility (proportion)	0.83	0.11	0.90	0.07

Table 2. Summary characteristics of the predictors (N = 48).

	Down syndrome		Controls	
Predictors	*M*	*SD*	*M*	*SD*
Chronological age (years)	12.54	4.50	4.16	1.16
Cognition (years)[a]	4.57	1.48	4.63	1.40
Syntax comprehension (years)[b]	4.35	1.42	4.67	1.29
Mother's education (years)	13.33	1.87	13.88	2.27
Hearing screening status[c]	9.23	2.53	11.69	0.80

[a]Mean mental age = mean of Bead Memory and Pattern Analysis scores on Stanford-Binet, 4th ed. [b]Mean age score on Test of Auditory Comprehension of Language. [c]Number of total passes at 500, 2, and 1 kHz in both ears (Max = 12).

(Table 3) are presented for both groups. The following section briefly describes the predictor variables.

Group

Group membership (Down syndrome or typically developing) was used as a predictor. When group membership accounted for a significant portion of the variance, each group was further examined separately.

Nonverbal Cognition

Raw scores on the Stanford-Binet: Fourth Edition Pattern Analysis and Bead Memory subtests were converted into age-equivalent scores for each participant. A mean mental age score was computed by averaging the two age-equivalent scores.

Age

Chronological age in years was used a predictor.

Hearing Status

The total number of passes achieved for both ears was used as a hearing status variable. No participant failed any frequency at 45 dB in the better ear, so the index of failures in the better ear varied from 3 to 6. Total passes varied from a low of 3 to maximum of 12 (2 ears × 2 intensities × 3 frequencies).

Socioeconomic Status

The number of years of mother's education was used as a socioeconomic status variable (Stevens & Cho, 1985).

Comprehension

Language comprehension (measured by TACL–R total age equivalent scores) was selected as a predictor for language production performance because it incorporated comprehension of vocabulary, morphology, grammatical, and syntactic structure. The additional contribution of language comprehension to language production performance was tested by comparing two models in hierarchical multiple regression analyses: without comprehension (Model I) and with comprehension (Model II).

Table 3. Intercorrelations among the predictors.

Predictors	CA	Cognition	Mother's education	Hearing screening
Down syndrome				
CA				
Cognition	.56*			
Mother's education	–.06	–.02		
Hearing screening	.01	.05	.15	
Comprehension	.77*	.78*	.05	.26
Controls				
CA				
Cognition	.82*			
Mother's education	.34	.28		
Hearing screening	–.08	.12	–.09	
Comprehension	.84*	.89*	.36	.03

*$p < .001$

Results

Hierarchical multiple regression analyses were run for each language production variable. Two models, without language comprehension (Model I) and with language comprehension (Model II), were tested. Variables were entered in the order of group, hearing status, chronological age, cognition, and mother's education in Model I and in the order of group, hearing status, comprehension, chronological age, cognition, and mother's education in Model II.

Results are reported by the language production measures derived from the narrative sample: number of different words, mean length of utterance, total utterances, and intelligibility.

Lexicon (Number of Different Words Produced)

Chronological age (27%) ($F_{change} = 36.25$, $p < .0001$) and cognition (19%) ($F_{change} = 35.35$, $p < .0001$) added significant portions of the variance accounted for in Model I. Language comprehension accounted for a significant portion of variance (62%) ($F_{change} = 175.76$, $p < .0001$) in Model II. Total variance accounted for was 55% in Model I and 69% in Model II. By adding comprehension as a predictor in Model II, the total variance accounted for was increased about 14% compared to Model I. However, hearing status and mother's education did not account for significant variance either in Model I or in Model II. Group membership's contribution (4% in both Model I and II) bordered on significance ($p = .06$) and is in the direction of difference expected (fewer different words in the DS group). Thus we examined the regression analyses for groups separately.

Down Syndrome Group (Table 4)

Hearing status contributed 8% of the variance in the DS group (Models I and II), which indicated a trend of significance ($F = 3.87$, $p = .055$). Chronological age accounted for 35% of the variance ($F_{change} = 26.95$, $p < .0001$); cognition added an additional 13% of variance in Model I ($F_{change} = 12.89$, $p < .001$). Language comprehension alone accounted for 60% of the variance in Model II, (F_{change} =

Table 4. Multiple regression on different words produced (DS group).

Predictors	R2	R2 change	*F* (eqn)	Sig.	BetaIn
Model I (without comprehension)					
Hearing status	.08	.08	3.87	.055	.2785
Chronological age	.42	.34***	16.50	.000	.5878
Cognition	.55	.13***	18.20	.000	.4368
Mother's education	.56	.00	13.59	.000	.0680
Model II (with comprehension)					
Hearing status	.08	.08	3.87	.055	.2785
Comprehension	.68	.60***	47.20	.000	.8026
Chronological age	.68	.00	31.02	.000	–.0685
Cognition	.68	.00	22.75	.000	.0174
Mother's education	.68	.00	17.81	.000	.0202

***p < .0001

Table 5. Multiple regression on different words produced (controls).

Predictors	R2	R2 change	*F* (eqn)	Sig.	BetaIn
Model I (without comprehension)					
Hearing status	.02	.02	0.80	.376	–.1306
Chronological age	.58	.56***	30.60	.000	.7503
Cognition	.60	.02	21.88	.000	.2733
Mother's education	.63	.03	17.99	.000	.1760
Model II (with comprehension)					
Hearing status	.02	.02	0.80	.376	–.1306
Comprehension	.69	.67***	49.68	.000	.8196
Chronological age	.70	.01	34.12	.000	.1969
Cognition	.71	.01	26.15	.000	–.2290
Mother's education	.72	.01	21.69	.000	.1190

****p* < .0001

83.60, $p < .001$). Total variance accounted for was 56% in Model I and 68% in Model II, indicating that comprehension contributed an additional 10% of unique explained variance, in addition to the 50% shared with the predictors of Model I.

Control Group (Table 5)

The contribution of hearing status (2%) was negligible in the controls ($F = 0.8$, $p = .38$). Chronological age accounted for 56% of the variance in Model I ($F_{change} = 59.40$, $p < .0001$), and language comprehension accounted for 67% of the variance in Model II ($F_{change} = 96.90$, $p < .0001$). Total variance accounted for was 63% in Model I and 72% in Model II, indicating the comprehension added 5% of uniquely explained variance to the 62% shared with the predictors of Model I.

Syntax (Mean Length of Utterance in Morphemes)

Group membership accounted for significant variance (23%) in Mean Length of Utterance in both Model I and II ($F = 28.17$, $p < .0001$). Chronological age (21%) ($F_{change} = 34.80$, $p < .0001$) and cognition (23%) ($F_{change} = 65.27$, $p < .0001$) accounted for significant variance in Model I. Language comprehension added significant variance (52%) in Model II ($F_{change} = 211.30$, $p < .0001$). Total variance accounted for was 70% in Model I and 79% in Model II.

Based on the significance of group membership as a predictor, the DS and control group were further examined separately.

Down Syndrome Group (Table 6)

In Model I, hearing status accounted for 7% of the variance ($F_{change} = 3.49$, $p = .068$); chronological age contributed an additional 35% of the variance accounted for ($F_{change} = 34.75$, $p < .0001$); and cognition added 24% more ($F_{change} = 29.96$, $p < .0001$). In Model II, hearing status accounted for 7% ($F_{change} = 3.49$, $p = .068$) and language comprehension accounted for 71% of the variance ($F_{change} = 143.97$, $p < .0001$). Model I accounted for total variance of 66%, and Model II accounted for 80%, indicating that comprehension accounted for an additional 14% of uniquely explained variance in expressive syntax, in addition to the 57% shared with the predictors of Model I.

Control Group (Table 7)

In Model I, only chronological age accounted for a significant portion of variance (62%) ($F_{change} = 73.38$, $p < .0001$). In Model II, language comprehension accounted

Table 6. Multiple regression on MLU (Down syndrome group).

Predictors	R2	R2 change	*F* (eqn)	Sig.	BetaIn
Model I (without comprehension)					
Hearing status	.07	.07	3.49	.068	.2657
Chronological age	.42	.35***	16.26	.000	.5908
Cognition	.65	.23***	27.81	.000	.5858
Mother's education	.66	.01	21.14	.000	.0922
Model II (with comprehension)					
Hearing status	.07	.07	3.49	.068	.2657
Comprehension	.78	.71***	79.16	.000	.8722
Chronological age	.79	.01	56.56	.000	–.2032
Cognition	.80	.01	43.08	.000	.1337
Mother's education	.80	.00	34.01	.000	.0409

****p* < .0001

Table 7. Multiple regression on MLU (controls).

Predictors	R2	R2 change	*F* (eqn)	Sig.	BetaIn
Model I (without comprehension)					
Hearing status	.00	.00	0.07	.796	–.0384
Chronological age	.62	.62***	36.78	.000	.7893
Cognition	.66	.04	28.18	.000	.3524
Mother's education	.67	.01	21.75	.000	.1143
Model II (with comprehension)					
Hearing status	.00	.00	0.07	.796	–.0384
Comprehension	.67	.67***	45.11	.000	.8162
Chronological age	.70	.03	34.34	.000	.3424
Cognition	.70	.00	25.20	.000	.0372
Mother's education	.71	.01	20.20	.000	.0786

***$p < .0001$

for 67% (F_{change} = 90.02, $p < .001$). Model I accounted for a total variance of 67%, and Model II accounted for 71%, with language comprehension responsible for most of the variance. The contribution of hearing status and mother's education to MLU in the controls was negligible in both models. Comparison of Model I and Model II indicates that the explained variance in syntax uniquely associated with comprehension was 4%, with the remaining 67% shared with Model I predictors.

Volubility (Total Utterances)

A significant portion of variance in total utterances was accounted for by group membership both in Model I (23%) (F_{change} = 27.04, p < .001) and in Model II (24%) (F_{change} = 27.04, $p < .001$). Hearing status, age, cognition, or mother's education added negligible portions of explained variance when entered afterward in either model, and language comprehension did not contribute additional explained variance in Model II. Nor did these predictors explain variance when examined separately by group.

The Down syndrome group produced more utterances than the control group in the 12 minutes. Total explained variance was less for total utterances (23% in Model I; 24% in Model II) than for either different words or MLU and unrelated to the predictors of the latter two, aside from group membership.

Intelligibility

In Model I, group membership accounted for 13% of the variance (F_{change} = 14.54, $p < .001$) and chronological age accounted for an additional 18% (F_{change} = 25.55, $p < .0001$). In Model II, group membership accounted for 13% of the variance (F_{change} = 14.54, $p < .001$), and language comprehension accounted for 12% (F_{change} = 16.12, $p < .001$). Total variance accounted for was 37% in Model I and 38% in Model II.

Down Syndrome Group (Table 8)

In Model I, hearing status accounted for 8% (F_{change} = 3.84, p = .056); chronological age accounted for additional significant variance (24%) (F_{change} = 16.16, $p < .001$). In Model II, chronological age contributed 11% (F_{change} = 6.97, $p < .05$); language comprehension accounted for 14% of the variance (F_{change} = 7.88, $p < .01$). Total variance accounted for was 32% in both Model I and Model II, indicating that comprehension did not contribute additional unique variance to intelligibility, beyond the 14% shared with chronological age and hearing status.

Control Group (Table 9)

In Model I, the predictors accounted for a total variance of only 11%; chronological age accounted for 9% of the total variance (F_{change} = 4.59, $p < .05$). Contributions by hearing, cognition, and mother's education were negligible. In Model II, language comprehension alone accounted for 17% of variance (F_{change} = 9.27, $p < .01$). Total variance accounted for was 11% in Model I and 26% in Model II, indicating that comprehension added 15% of uniquely associated explained variance to the prediction of intelligibility.

Discussion

Phenotypic Patterns of Language Production in Down Syndrome

Group

The hierarchical models chosen incorporated group membership, hearing status, chronological age, nonverbal cognition, and mother's years of education, in that

Table 8. Multiple regression on intelligibility (DS group).

Predictors	R2	R2 change	*F* (eqn)	Sig.	BetaIn
Model I (without comprehension)					
Hearing status	.08	.08	3.84	.056	.2776
Chronological age	.32	.24**	10.63	.000	.4938
Cognition	.32	.00	6.95	.001	–.0289
Mother's education	.32	.00	5.11	.002	.0246
Model II (with comprehension)					
Hearing status	.08	.08	3.84	.056	.2776
Comprehension	.21	.14*	6.15	.004	.3844
Chronological age	.32	.11*	6.97	.001	.5368
Cognition	.32	.00	5.11	.002	–.0018
Mother's education	.32	.00	4.00	.005	.0282

*$p < .05$. **$p < .001$.

Table 9. Multiple regression on intelligibility (controls).

Predictors	R2	R2 change	*F* (eqn)	Sig.	Betaln
Model I (without comprehension)					
Hearing status	.02	.02	1.09	.302	.1520
Chronological age	.11	.09*	2.88	.066	.3017
Cognition	.11	.00	1.88	.147	–.0064
Mother's education	.11	.00	1.38	.255	–.0243
Model II (with comprehension)					
Hearing status	.02	.02	1.09	.302	.1520
Comprehension	.19	.17*	5.28	.009	.4086
Chronological age	.20	.01	3.59	.021	–.1531
Cognition	.26	.06	3.70	.011	–.5782
Mother's education	.26	.01	3.01	.021	–.0960

*$p < .05$

order, in Model I and added comprehension after hearing in Model II. Group membership in both models proved to be a significant (or borderline significant) predictor of variability in all the language measures: 4%, for number of different words; 23%, for MLU; 13%, for intelligibility, and 23%, for total utterances. These results are consistent with the view that children with Down syndrome, relative to controls matched for nonverbal cognition, have a *specific language impairment* (in the case of the poorer performance on different words and MLU) as well as problems of intelligibility that are *phenotypical characteristic.*

Lexical Development

Models I and II accounted for more variability in number of different words in the control group (63%; 72%) than in the DS group (56%; 68%). Comprehension and hearing status (borderline significant) were the only variables entering for the DS group in Model II; comprehension alone is the only significant variable for the control group. Thus, the contribution of chronological age and cognition appear to be mediated through comprehension (which adds significant explained variance in addition to these two measures) in both groups. However, the comprehension scores in the DS group are higher than the production scores, whereas at equivalent achievement levels in the MA group. Thus, *variation* in comprehension predicts a substantial portion of *variation* in production, but group membership predicts the absolute level of lexical achievement. The marginal contribution of hearing status (8%) to performance by children with Down syndrome reflects the existence of mild hearing losses in the group, but does not account for sufficient variance to explain the production-comprehension gap (indeed, entering comprehension first would remove the contribution of hearing status, which appears to act on lexical diversity through its contribution to comprehension).

Mean Length of Utterance

This is the variable most closely associated with group membership. When the groups are considered separately, Model I explains equal variance (67%–66%) in controls as in the DS group; chronological age is the one significant predictor in the model for controls. Chronological age, cognition, and a borderline contribution of hearing status contribute to explained variance in the DS group. The addition of comprehension as a predictor in Model II accounts for more variance in both the DS group (80%) and the controls (71%) and eliminates the variance explained by chronological age and cognition. Thus, *variation* in comprehension predicts *variation* in production even though the absolute level of mean length of utterance achieved differs significantly between the groups.

Intelligibility

Group membership predicted a significant portion (13%) of the intelligibility scores. When the groups were considered separately, Model I explained three times the variance (32%) for the DS group as the controls (11%), with chronological age accounting for most of that variance and hearing status contributing an additional, borderline significant 8% in the DS group. The addition of comprehension as a significant predictor did not alter the total amount of explained variance in the DS group but somewhat reduced the amount of variance attributed to chronological age entered afterward (14%). Taking this pattern of findings together with the previous study of comprehension in Down syndrome (Chapman et al., 1991), it appears that hearing status and chronological age affect intelligibility directly, with improvements in adolescence. In the controls, Model II increased explained variance to 26%, eliminating the variance explained by chronological age.

Total Utterances

Group membership accounted for 23% to 24% of the variance in Model I or II. Considered within groups, however, neither model accounted for more than 7% of variance in total utterances for either the DS or control group. The group with Down syndrome produced more, though shorter, utterances. Whether this is also a phenotypic characteristic is questionable, we believe, on the basis of the method of this particular study for collecting the 12-minute transcripts; we compensated for any reduced time of talk on a particularly narrative topic by going to additional narrative tasks (more stories, additional complex event pictures). Hypotheses about differences in amount of talk, however, might better be tested by comparing amount of talk on a single story retelling or narration, thus controlling for potential content.

Pragmatic Effects of Reduced Intelligibility

The fact that intelligibility of many speakers with Down syndrome is limited might also affect the ways in which they choose to talk to achieve communicative success. Reduced intelligibility may lead speakers indirectly to reduce sentence length and increase the number of utterances attempted in order to get their message across at the expense of syntactic complexity and cohesion. One would also expect more utterance attempts and shorter mean length of utterance, both of which were found. However, if this view is correct, one would expect correlations between intelligibility and total utterances or MLU. These results were not obtained, suggesting that a pragmatic interpretation of the reduced expressive language scores is not supported by these data.

Failure of Mother's Years of Education as a Predictor

Mother's years of education were modestly correlated with production in the control group (though not the Down syndrome group) and are thus consistent with other researchers' results (Hoff-Ginsberg, 1991). Entering this variable last in the models, however, failed to explain additional variance, suggesting that the way in which this variable influences language production is mediated by the prior variables of cognition, comprehension, or both, in typically developing children.

A Speculative Interpretation of the Importance of Comprehension

The most striking result in the present study is the importance of variation in comprehension skill in predicting variation in language production as indexed by lexical diversity and mean length of utterance. This basic result is true for both groups, despite the gap, for individuals with Down syndrome, between production and comprehension performance. If we interpret this relation causally, we are led to the view that comprehension, rather than cognition or chronological age, drives the variation in expressive language skill, with some additional factor (associated with Down syndrome) driving the reduced gain in expressive skill as a function of comprehension status. This view is elaborated here, despite its speculative nature, because it has strong implications for clinical practice.

First, to view the effect of comprehension on production as causal is to set aside the practice of cognitive referencing (Abbeduto & Short, 1994) in setting language goals for individuals with Down syndrome. Indeed, it is to suggest a revision of the general clinical practice of targeting only language production skills in cases where receptive skills are consistent with nonverbal cognitive levels. The clinical recommendation, if comprehension skill makes causal contributions to production, is to target both, even when comprehension skills are higher than expressive skills.

What might be the actual mechanism for a causal link between comprehension and production? One that presents itself in the context of the limited auditory short-term memory skills of individuals with Down syndrome (Seung & Chapman, 1999) is a flow of information from auditory activation to the phonological mappings in anterior Broca's area (BA45), acting as internal "production practice" of an early stage of speech organization, when rate of input and processing demands permit, and reflective of the degree of prior long-term language learning. Such activation is demonstrated in adult PET imaging studies of hearing and repeating word lists with no requirement for rehearsal (Price et al., 1996); it might be construed as the physical instantiation of a nonintentional, subvocal version of the articulatory loop that has been posited as part of phonological working memory (Baddeley, 1990). However, this version is dependent on the developmentally learned mapping of speech production onto speech perception (Kent, 1992) and hence on long-term phonological and language learning, as is consistent with recent revisions in theorists' views of phonological memory (Gathercole & Martin, 1996). The claim, then, is that comprehension leads to activation of anterior Broca's area and thus acts as a kind of practice of early stages of production, when it occurs, thus linking the amount of language input addressed to and comprehended by the child to features of production. In the case of individuals with Down syndrome, we might speculate that the specific expressive language deficit arises from a reduction in the neural connectivity, or the perception-production mapping, between these sites or a reduced level of activation feeding forward. Thus, individuals with Down syndrome would be less able than comprehension-matched controls to produce words they have just encountered in comprehension.

Clinical Implications

Taken together with our evaluation of the specific expressive language deficits in Down syndrome (Chapman et al., 1998), these findings suggest that expressive language should be a continuing target of language intervention in the adolescent years. Further, these analyses suggest that programs should target comprehension, as well as production, skills to achieve growth and that nonverbal mental age measures should not be taken as indicative of the upper limit of lexical comprehension that individuals with Down syndrome can achieve. Intelligibility should continue to be a target of speech intervention in adolescent years; the cross-sectional data suggests that improvement is possible. The regression analyses suggest that transient or continuing hearing problems are related to reduced intelligibility as well as MLU and comprehension skills and that hearing should be closely monitored.

Limitations of the Present Study

A number of predictors that could be examined were not included in the present study, including auditory short-term memory and sentence short-term memory measures; these factors were evaluated in the protocol at subsequent test times. Speech-motor functioning, which we successfully evaluated in this first test time only in the older subject groups is another factor of potential importance. The assessment of hearing was limited to screening, rather than threshold, measures by the time requirements of the protocol. The study is additionally limited by being cross-sectional rather than longitudinal; longitudinal follow-up will be carried out.

Acknowledgments

This research was supported by NIH Grant R01 HD23353 to the senior author. The help of the children and parents who participated is gratefully acknowledged, as is the assistance of Denise Maybach in supervising the transcription lab.

References

Abbeduto, L., & Short, K. (1994). Relation between language comprehension and cognitive functioning in persons with mental retardation. *Journal of Developmental and Physical Disabilities, 6*, 347–369.

American National Standards Institute. (1969). *Specifications for audiometers* (ANSI S3.6-1969). New York: Author.

Baddeley, A. (1990). *Human memory: Theory and practice.* Hillsdale, NJ: Lawrence Erlbaum.

Balkany, T., Downs, M. P., Jafek, B. W., & Krajicek, M. J. (1979). Hearing loss in Down's syndrome. *Clinical Pediatrics, 18*(2), 116–118.

Beeghly, M., & Cicchetti, D. (1986). *Early language development in children with Down syndrome: A longitudinal study.* Paper presented at the 11th Annual Boston University Conference on Language Development.

Berry, P., Gunn, P., Andrews, R., & Price, C. (1981). Characteristics of Down's syndrome infants and their families. *Australian Paediatrics Journal, 17*, 40–43.

Brooks, D. N., Wooley, H., & Kanjilal, G. C. (1972). Hearing loss and middle ear disorders in patients with Down syndrome (mongolism). *Journal of Mental Deficiency Research, 16*, 21–29.

Carrow-Woolfolk, E. (1985). *Test for Auditory Comprehension of Language–Revised*. Allen, TX: DLM Teaching Resources.

Cardoso-Martins, C., Mervis, C. B., & Mervis, C. A. (1985). Early vocabulary acquisition by children with Down syndrome. *American Journal of Mental Deficiency, 90*, 177–184.

Chapman, R. S. (1995). Language development in children and adolescents with Down syndrome. In P. Fletcher & B. MacWhinney (Eds.), *Handbook of child language* (pp. 641–663). Oxford: Blackwell Publishers.

Chapman, R. S. (1997a). Language development. In S. Pueschel & M. Sustrova (Eds.), *Adolescents with Down syndrome* (pp. 99–110). Baltimore: Brookes.

Chapman, R. S. (1997b). Language development in children and adolescents with Down syndrome. *Mental Retardation and Developmental Disabilities Research Review, 3*, 307–312.

Chapman, R. S., Kay-Raining Bird, E., & Schwartz, S. E. (1990). Fast mapping of words in event contexts by children with Down syndrome. *Journal of Speech and Hearing Disorders, 55*, 761–770.

Chapman, R. S., Schwartz, S. E., & Kay-Raining Bird, E. (1991). Language skills of children and adolescents with Down syndrome: I. Comprehension. *Journal of Speech and Hearing Research, 34*, 1106–1120.

Chapman, R. S., Seung, H.-K., Schwartz, S. E., & Kay-Raining Bird, E. (1998). Language skills of children and adolescents with Down syndrome: II. Production deficits. *Journal of Speech, Language, and Hearing Research, 41*, 861–873.

Dahle, A., & McCollister, F. (1986). Hearing and otologic disorders in children with Down syndrome. *American Journal of Mental Deficiency, 90*, 636–642.

Fowler, A. (1990). Language abilities in children with Down syndrome: Evidence for a specific syntactic delay. In D. Cicchetti & M. Beeghly (Eds.), *Children with Down syndrome: A developmental perspective* (pp. 302–328). Cambridge: Cambridge University Press.

Fowler, A., Gelman, R., & Gleitman, L. R. (1994). The course of language learning in children with Down syndrome. In H. Tager-Flusberg (Ed.), *Constraints on language acquisition* (pp. 91–140). Hillsdale, NJ: Lawrence Erlbaum Associates.

Fulton, R. T., & Lloyd, L. L. (1968). Hearing impairment in a population of children with Down's syndrome. *American Journal of Mental Deficiency, 73*, 298–302.

Gathercole, S., & Martin, A. (1996). Interactive processes in phonological memory. In S. Gathercole (Ed.), *Models of short-term memory* (pp. 73–100). East Sussex, UK: Psychology Press.

Greenwald, C. A., & Leonard, L. B. (1979). Communicative and sensorimotor development of Down's syndrome children. *American Journal of Mental Deficiency, 84*, 296–303.

Kent, R. (1992). Phonological development as biology and behavior. In R. Chapman (Ed.), *Processes in language acquisition and disorders* (pp. 67–85). St. Louis: Mosby-Year Book.

Hoff-Ginsberg, E. (1991). Mother-child conversation in different social class and communicative settings. *Child Development, 62*, 782–796.

Keiser, H., Montague, J., Wold, D., Maune, S., & Pattison, D. (1981). Hearing loss of Down syndrome adults. *American Journal of Mental Deficiency, 85*(5), 467–472.

Lee, L., & Canter, S. (1971). Developmental sentence scoring: A clinical procedure for estimating syntactic development in children's spontaneous speech. *Journal of Speech and Hearing Disorders, 36*, 315–341.

McCarthy, J. J. (1965). *Patterns of psycholinguistic development of mongoloid and non-mongoloid severely retarded children*. Unpublished doctoral dissertation, University of Illinois, Urbana, IL.

Miller, J. F. (1988). The developmental asynchrony of language development in children with Down syndrome. In L. Nadel (Ed.), *The psychobiology of Down syndrome* (pp. 167–198). Cambridge, MA: MIT Press.

Miller, J. F., & Chapman, R. S. (1990). *Systematic analysis of language transcripts*. Madison, WI: Language Analysis Laboratory, Waisman Center.

Miller, J., Miolo, G., Sedey, A., & Murray-Branch, J. (1993). *The emergence of multiword combinations in children with Down syndrome.* Poster presented at Symposium on Research in Child Language Disorders, Madison, WI.

Miller, J., Sedey, A., Miolo, G., Murray-Branch, J., & Rosin, M. (1992). *Longitudinal investigation of vocabulary acquisition in children with Down syndrome.* Poster presented at Symposium for Research on Child Language Disorders, Madison, WI.

Price, C. J., Wise, R. J. S., Warburton, E. A, Moore, C. J., Howard, D., Patterson, K., Frackowiak, R. S. J., & Friston, K. J. (1996). Hearing and saying: The functional neuro-anatomy of auditory word processing. *Brain, 119*, 919–931.

Rogers, M. G. H. (1975). A study of language skills in severely subnormal children. *Child: Care, Health, & Development, 1*, 113–126.

Rondal, J. A., Ghiotto, M., Bredart, S., & Bachelet, J.-F. (1988). Mean length of utterance in children with Down syndrome. *American Journal on Mental Retardation, 93*, 64–66.

Rosin, M., Swift, E., Bless, D., & Vetter, D. (1988). Communication profiles of adolescents with Down syndrome. *Journal of Childhood Communication Disorders, 12*, 49–64.

Ryan, J. (1975). Mental subnormality and language development. In E. Lenneberg & E. Lenneberg (Eds.), *Foundations of language development* (pp. 269–277). New York: Academic Press.

Seung, H.-K., & Chapman, R. S. (1999). *Digit span in individuals with Down syndrome and typically developing children: Temporal aspects*. Manuscript submitted for publication.

Stein, N., & Glenn, C. (1982). Children's concept of time: The development of a story schema. In W. J. Friedman (Ed.), *The developmental psychology of time* (pp. 255–282). New York: Academic Press.

Stevens, G., & Cho, J. H. (1985). Socioeconomic indexes and the new 1980 census occupational classification scheme. *Social Science Research, 14*, 142–168.

Strominger, A. Z., Winkler, M. R., & Cohen, L. T. (1984). Speech and language evaluation. In S. M. Pueschel (Ed.), *The young child with Down syndrome* (pp. 253–261). New York: Human Sciences Press.

Thorndike, R. L., Hagen, E. P., & Sattler, J. M. (1986). *Stanford-Binet Intelligence Scale* (4th ed.). Chicago, IL: Riverside.

van Gorp, E., & Baker, R. (1989). The incidence of hearing impairment in a sample of Down's syndrome school children. *International Journal of Rehabilitation Research, 7*, 198–200.

Wiegel-Crump, C. A. (1981). The development of grammar in Down's syndrome children between the mental ages of 2-0 and 6-11 years. *Education and Training of the Mentally Retarded*, February, 24–30.

Received July 14, 1999

Accepted September 13, 1999

Contact author: Robin S. Chapman, PhD, Waisman Center, 1500 Highland Ave., Madison, WI 53705. Email: chapman@waisman.wisc.edu