15356

Adaptive Behavior and Cognitive Function of Adults With Down Syndrome: Modeling Change With Age

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Abstract

Fifty-eight adults with Down syndrome (ages 31 to 56 years at time of first testing, mean age, 43.5) were assessed longitudinally over 10 years for the purpose of modeling aging-related change in cognitive function and adaptive behavior. Cognitive function was assessed seven times using the Woodcock–Johnson Tests of Cognitive Ability-Revised Early Development Battery. Adaptive behavior was evaluated five times using the Inventory for Client and Agency Planning. Multi-level (hierarchical linear) modeling procedures were used to model change with age. Findings provided further evidence of changes in performance with age and included selected effects for participants who completed the 10 years of study and those who were lost to follow-up as well as for age cohorts.

Although life expectancy during the past 50 years has dramatically improved for persons with Down syndrome, there are mixed findings regarding the aging process for this population. In 1988, Baird and Sadovnick estimated that fewer than 50% of adults with Down syndrome would survive to reach age 60. For persons in their 30s, 40s, and 50s, the identification of age-related changes in adaptive behavior and cognitive functioning have been presented in the literature (Devenny, Hill, Paxtot, Silverman, & Wisniewski, 1992; Devenny et al., 1996; Prasher, 1994, 1995a, 1995c, 1995d; Prasher & Chung, 1996; Prasher, Chung, & Haque, 1998). Much of this discussion, however, has been focused on the increased propensity for dementia of the Alzheimer's type (Dalton, Seltzer, Adlin, & Wisniewski, 1993; Lai, 1992; Lott & Lai, 1982; Tait, 1983) and the identification of premature age-related declines in selected areas of functioning (Buchanan, 1990; Zigman, Schupf, Lubin, & Silverman, 1987; Zigman, Seltzer, Adlin, & Silverman, 1992).

Changes in the adaptive behavior of adults with Down syndrome have been associated with dementia (Prasher & Chung, 1996; Zigman et al., 1987), depression (Prasher & Hall, 1996), decline in cognitive function (Fenner, Hewitt, & Torpy, 1987), etiology (Rasmussen & Sobsey, 1994), epilepsy (Prasher, 1995a), obesity (Prasher, 1995a), and sensory impairment (Prasher, 1994, 1995d; Prasher & Krishnan, 1993). Losses in adaptive skills as individuals with Down syndrome age have been reported in several studies (Fenner et al., 1987; Prasher & Chung, 1996; Silverstein et al., 1988; Zigman et al., 1987); however, findings have been mixed. For example, Miniszek (1983) found that older adults with Down syndrome who were still fairly independent performed lower than did younger adults. Burt et al. (1995) reported few significant age-related declines in functioning among 34 adults who were followed longitudinally. Fourteen females and 20 males, ranging in age from 22 to 56 years, were assessed on behavioral parameters for three to five observations, and no effects of age on performance were found over the years of study. Burt et al. noted that potential methodological weaknesses, such as sample selectivity (e.g., studying only healthy people plus an underrepresentation of older individuals), suggest caution in drawing conclusions from their findings.

In a 3-year prospective study, Prasher et al. (1998) found that dementia was associated with age-related change in the adaptive behavior of 128 adults with Down syndrome. Their findings were consistent with those reported by Burt et al. (1995).

Although age at entry into the study, residence, gender, and sensory loss were not found to be determining factors for adaptive behavior declines, Prasher et al. noted that a longer time might be needed in order to more fully determine the actual influence of these factors. Prasher and Chung (1996) noted the potential confounding of several factors (e.g., depression, impaired sensory function, and dementia) with declines in adaptive functioning.

Rasmussen and Sobsey (1994) found significant adaptive behavior losses with age in adults with Down syndrome over 40, particularly in the areas of communication and self-help. Collacott (1992) reported significant differences in adaptive functioning comparing 10-year cohorts of adults with Down syndrome; however, cross-sectional differences cannot be interpreted as aging effects within subjects. In a very large study of 2,144 participants, Zigman et al. (1987) identified a significantly greater rate of decline in adaptive skills associated with increasing age. Although the findings reported in the literature present an overall picture of expected declines with age in adaptive functioning of individuals with Down syndrome, further elucidation of differences in adaptive skills across cohorts and rates of change over time will be helpful, especially with regard to adults with Down syndrome who are in their 40s, 50s, and 60s. This information would be particularly useful in identifying aging-appropriate and needed services as well as helping in the development of interventions designed to slow losses or prevent premature declines.

Studies of cognitive change with age in persons who have Down syndrome also have provided mixed results. Earlier investigators found that persons with Down syndrome were more likely to exhibit declines in cognitive functioning at earlier ages than were people with mental retardation due to other etiologies (Dalton & Crapper-McLachlan, 1984; Wisniewski, Howe, Williams, & Wisniewski, 1978; Thase, 1982; Thase, Tigner, Smeltzer, & Liss, 1984, Zigman, Schupf, Zigman, & Silverman, 1993). Most of these researchers employed cross-sectional designs and contended with cohort confounds. More recently, investigators have used longitudinal designs, such as Devenny et al. (1996), who reported results after 6 years of comparing adults with Down syndrome (ages 31 to 63 years) and adults with mental retardation due to other etiologies (ages 31 to 76 years). They found only modest change in individuals in both groups after the

age of 50. Further, these changes were seen to parallel age-associated changes experienced by adults without mental retardation. In another longitudinal study, Burt et al. (1995) found that adults with Down syndrome who ranged in age from 22 to 56 years at entry into the study showed minimal change over a 3- to 4-year period. In these longitudinal studies, although admittedly covering relatively short time spans, researchers did not find evidence of major decline or high incidence of the development of Alzheimer's-type dementia.

A large body of research on persons without mental retardation has shown modest age-related declines in short-term memory and speeded motor performance (Botwinick, 1984), whereas there were no significant declines in most other areas of cognitive function. The most comprehensive theory of intellectual function as related to age differences is the Horn-Cattell theory of fluid and crystallized abilities, which posits two classes of abilities: one vulnerable to decline with age (fluid) and one that is not and may continue to develop until late in life (crystallized) (Cattell, 1963; Horn, 1972, 1988, 1998; Horn & Cattell, 1966). Horn and his colleagues (Horn, 1982; Horn & Donaldson, 1976) have proposed that crystallized intelligence is spared by age because it reflects the cumulative effects of experience, education, and acculturation, whereas fluid intelligence is impaired by age because of a gradual age-related deterioration of physiological and neurological mechanisms necessary for basic intellectual functioning. Evidence for support of the theory in the normal aging population is provided in the classic debate between Horn and Donaldson (1976, 1977) on the one hand and Baltes and Schaie (Baltes & Schaie, 1976; Schaie & Baltes, 1977) on the other. Whereas Baltes and Schaie concluded that much of the variation in cognitive function found in their studies was due to the effects of varying background experiences associated with different age cohorts, Horn and Donaldson argued that distinct abilities exhibited different patterns with age, some improving and some declining. In the present study we used the Horn-Cattell theory and a cognitive battery based explicitly on the theory (Woodcock–Johnson Tests of Cognitive Ability-Revised) to assess age-related change in cognitive functioning in adults with Down syndrome.

The mixture of cross-sectional and longitudinal designs in previous research, perhaps, has complicated the clarity of changes related to aging and

cohort differences in adaptive and cognitive function in adults with Down syndrome. Longitudinal studies are the superior approach for identifying age-related change and the potential for accelerated decline in this population (Burt et al., 1995; Devenny et al., 1992, 1996; Prasher et al., 1998). Prospective studies can indicate probable areas of age-related change that may have implications for preventive action in a given individual or group of individuals (Kane, 1990; Seltzer, 1990). In addition, longitudinal designs may avert the potential for erroneous conclusions about age-related change that may emerge from cross-sectional comparisons (Baltes, Reese, & Nesselroade, 1977; Salthouse, 1982).

In this paper we report changes with age in adaptive behavior and cognitive functioning for 58 adults with Down syndrome who participated in a 10-year prospective, longitudinal study. Our purpose in this study was to (a) model change as a function of aging and membership in a particular age cohort and (b) distinguish individuals who completed the study from those who were lost to follow-up.

Method

Study Panel

The study panel was developed using a network of 31 local agencies that agreed to serve as research test sites. Based on client confidentiality practices, the cooperating agencies contacted all eligible individuals to ascertain their interest in participating. Sixty-six potential individuals were identified. Enrollment into the study was based on the following criteria: the individual (a) was not a resident of a large, self-contained institution; (b) was known to the human service system and was receiving day program services; (c) was older than 30 at the time he or she entered the study; (d) had a level of functioning in the mild to moderate range of mental retardation; and (e) possessed receptive and expressive skills necessary for understanding and responding to simple questions and directions. We prescreened all eligible individuals to confirm their ability to understand simple directions and provide basic responses; 58 qualified individuals completed their initial assessments during 1988–1990.

At the time of first testing, the study sample consisted of 27 males and 31 females who ranged in age from 31 to 55.8 years (M = 43.5). At the completion of the study, 38 subjects (21 females, 17 males) were still active and able to continue with cognitive assessments. Their mean age was 40.33

years at the time of the first cognitive function assessment (range = 31 to 52.2), and their mean age at the last assessment was 48.21 years (range = 39 to 60). At last testing, 1 person was in her 30s, 24 in their 40s, 12 in their 50s, and 1 individual was in her 60s.

During the 10-year study, 20 subjects (10 male, 10 female) were lost to follow-up. Their mean age at time of first cognitive assessment was 46.59 years (range = 35.2 to 55.8) and at the last time of testing, was 50.44 years (range = 38.3 to 60.8). The distribution of ages at last test included 1 male in his 30s, 8 people in their 40s, 9 in their 50s, and 2 in their 60s. Of these 20 individuals, 3 participated in 2 assessments, 17 completed 3 assessments, and 9 completed 5 assessments; however, by the 6th assessment cycle, all had been lost to follow-up testing. Subject loss was based on morbidity and mortality causes in most cases, including 12 documented deaths (6 females, 6 males). The females who died ranged in age from 46 to 63 years (M = 55.4), and the range in age for males was 40 to 55 years (M = 48.1). Seven individuals (3 females, 4 males) died from dementia; 2 males, from cancer; 2 females, from congestive heart failure; and 1 female, from diabetes and seizures.

Six subjects were lost to follow-up due to reports of serious behavioral problems, diagnosed dementia, and/or persistent health problems, with a marked decline in health/functional status such that testing was no longer permissible. Two individuals had moved to another state, and their care givers requested no further testing because of these people's health status. Documentation by phone interview of health and functional status was developed for all participants who were lost to follow-up testing; actual diagnostic testing by the researchers was not carried out; thus, the information reported here is based on our best reconstruction of what transpired.

Procedure

A field-based testing schedule was established in a Midwestern state with the assistance of local service agencies that agreed to serve as research sites. Site representatives from these agencies supported project staff by arranging scheduled appointments, providing a pleasant and private room for all testing, and providing release time for the participants from their regular day activities (including work). An informed consent statement was read to all subjects, which they signed at the first visit of

each assessment cycle, witnessed by an advocate to assure that they were properly informed about the study. Over 10 years, 58 subjects were followed prospectively with cognitive assessments up to seven times and five evaluations of adaptive behavior.

Adaptive behavior. The Inventory for Client and Agency Planning—ICAP (Bruininks, Hill, Weatherman, & Woodcock, 1986) was used to assess adaptive behavior. The ICAP is a valid, reliable, and simple to administer instrument. Functional independence is evaluated in four domains of adaptive behavior (i.e., Motor, Social/Communication, Personal Living, and Community Living Skills). These domain scores are combined to provide an overall score of Broad Independence. Validity (i.e., criterion-related) and reliability (i.e., split half, test–retest, interrater) coefficients of the ICAP when used for studies with adult samples have been reported to be in the .80 to .98 range.

The ICAP was completed by a professional care giver who was frequently assisted by a parent. Our data-collection procedure for the ICAP ensured that the care giver was someone who was familiar with the participant on an ongoing and daily basis and had known this individual for longer than one year (Bruininks et al., 1986). Bruininks et al. reported that interrater reliabilities for the ICAP are in the "high .80s and low .90s—even after controlling for age—with a median coefficient of about .90. The age-corrected coefficient for the ICAP" (p. 64) has been reported to be as high as .92. Repeated studies of the interrater reliability of the ICAP provide support for the robustness of this assessment scale for different assessors provided that the assessor is adequately familiar with the individual being evaluated (Johnson, 1989; Wikoff, 1989).

Cognitive functioning. The Woodcock–Johnson Tests of Cognitive Ability-Revised (hereafter called the Woodcock–Johnson) was chosen for use in this study because of its theoretical basis, namely, the Horn-Cattell theory of fluid (Gf) and crystallized (Gc) intelligence, its wide age-range of standardization, and its demonstrated utility for assessing developmental changes (McGrew, Werder, & Woodcock, 1991). Previous research has shown marked differences in cognitive change with age in persons without mental retardation. Crystallized intelligence tends to increase with age, whereas fluid abilities tend to decline (Horn 1970). Carroll (1993), in a comprehensive review and re-analysis of factor analytic approaches to intelligence, concluded that the Horn-Cattell Gf–Gc model "appears to offer

the most well-founded and reasonable approach to an acceptable theory of the structure of cognitive abilities" (p. 62). A common misconception about Gf–Gc theory is that it is a two-factor theory consisting only of fluid and crystallized abilities. Actually, up to nine broad Gf–Gc abilities have been identified in the factor-analytic research literature (McGrew, 1994). In addition to its multiple-intelligences approach, the Woodcock–Johnson was standardized on a large sample of people ranging from age 2 to 90, making it useful for longitudinal study of age-related change.

For this study, the five subtests comprising the Woodcock–Johnson Early Developmental Battery were chosen because they are intended to be used with individuals who function at lower cognitive levels. The five subtests, each representing a different area of cognitive ability, were:

1. *Memory for Names* (long-term memory) measures the ability to learn associations between unfamiliar auditory and visual stimuli (an auditory–visual association task). The subject is shown a picture of a space creature and told the creature's name. Then he or she is shown a page of space creatures and asked to point to the creature just introduced and to other previously introduced space creatures as named by the examiner (Woodcock & Mather, 1989, p. 20).

2. *Memory for Sentences* (short-term memory) measures the ability to remember and immediately repeat single words, phrases, and sentences presented auditorily by use of a tape player or, in special cases, by an examiner. In this task, the participant makes use of sentence meaning to aid recall (Woodcock & Mather, 1989, p. 20). (In the present study, the examiner presented the material because a number of our subjects resisted use of the head set.)

3. *Incomplete Words* (auditory processing) measures auditory closure. After hearing a recorded word that has one or more phonemes missing, the subject identifies the complete word (Woodcock & Mather, 1989, p. 21).

4. *Visual Closure* (visual processing) is designed to measure the ability to identify a drawing or picture that is altered in one of several ways. The picture may be distorted, having missing lines or areas, or have a superimposed pattern (Woodcock & Mather, 1989, p. 12).

5. *Picture Vocabulary* (comprehension knowledge) measures the ability to recognize or name familiar and unfamiliar pictured objects. Six of the beginning items are in multiple-choice format that

only requires a pointing response (Woodcock & Mather, 1989, p. 21).

These five subtests were also combined for an overall measure called Broad Cognitive Ability. A median reliability of .96 for test–retest with adults of low ability has been reported (McGrew et al., 1991). The shortened Early Developmental Battery correlates .96 with the Woodcock–Johnson Standard Scale of seven subtests with subjects in the adult age range (Woodcock & Mather, 1989).

Cognitive testing was conducted by a qualified psychological examiner. The time between direct assessment of cognitive function varied for subjects but stayed within a set time frame, with the shortest interval occurring at 10.8 months (mean and mode for all subjects) and the longest interval spanning 24 to 28 months (mean and mode, respectively). The overall mean for time between assessments was 18 months and the mode was 21.6 months.

Results

Data Analysis Procedure

Modeling change presents problems in data collection and analysis that have been difficult for investigators of individual development to solve. Researchers who utilize standard statistical techniques (e.g., ordinary least squares [OLS] regression analysis or analysis of variance [ANOVA]) typically drop subjects from the analysis if they are not present at every point in the analysis, are measured at different time points, or drop out of the study for some reason. Dropping cases with incomplete data, at best, results in loss of information, and, at worst, produces a selection bias if the cases dropped are substantially different from those who remain. Second, errors in the measurement of key concepts make it difficult to estimate changes over time. Third, multiple observations over long periods are required to obtain precise estimates of structural changes (Bryk & Raudenbush, 1987).

The present study of age-related change in adults with Down syndrome was designed to address these problems. Over a 10-year period, as many as seven assessments of cognitive function and five evaluations of adaptive behavior were obtained for 58 subjects ranging in age from 31 to 56 years. Hence, the data are repeated measures over time on 58 individuals. We employed multi-level (or hierarchical linear) modeling techniques to analyze the data using the HLM 5 program (Bryk & Raudenbush 1992; Kreft & De Leeuw, 1998; Raudenbush,

Bryk, Cheong, & Congdon, 2000; Snijders & Bosker, 1999). Analyzing longitudinal data such as ours has become the "main type of application of the hierarchical linear model in the biological and medical sciences" (Snijders & Bosker, 1999, p. 166). In contrast to typical ANOVA, ANCOVA, and OLS regression techniques, multi-level models take advantage of all of the available data, even though some subjects are lost to follow-up before the completion of the study, are observed at different times and ages, or have missing data. Hence, we avoided selection bias and reduced statistical power due to a loss of information. Multi-level modeling also facilitates the estimation of random coefficients models that allow each respondent to have a unique growth trajectory. By contrast, standard fixed effects ANOVA, ANCOVA, and OLS regression analysis techniques force all subjects to have identical growth trajectories, a condition almost never observed in practice.

Because we expected performance to eventually decline with increasing age, we felt that a linear model of change, which assumes a constant increase or decrease in performance, was inappropriate. To reflect the expected nonlinear growth trajectory with increasing age, we modeled change as a quadratic function of age. Specifically, each person's pattern of age-related change was described by the following quadratic equation:

$$Y = B_0 + B_{age} (AGE) + B_{age2}(AGE)^2 + e$$

where Y is the measured value of the dependent variable, AGE is the subject's age measured in years after age 31, B_0 is the estimated intercept, B_{age} is the coefficient of AGE, and B_{age2} is the coefficient of the square of AGE. Typically, B_{age} is positive and B_{age2} is negative. If B_{age} is positive and B_{age2} is negative, the value of Y will initially increase as age increases, but the increase will be smaller in each succeeding year. At some point, Y will begin to decline as age continues to increase and the decline in Y will accelerate with age. (Note that the *rate of change* of Y is not constant but varies with age. The rate of change of Y is equal to $B_{age} + 2B_{age2}[AGE]$. For positive B_{age} and negative B_{age2}, Y increases initially, but eventually declines as the effect of AGE drives the equation negative. The inflection point at which Y begins to decline occurs when AGE = $-B_{age}/(2B_{age2})$, which is also the point at which the rate of change of Y is 0. As AGE continues to increase, Y declines from its maximum value. If B_{age} and B_{age2} are both negative, the value of Y declines

continuously with AGE, and the *rate* of the decline accelerates with age.)

For estimation purposes, we centered AGE on 31 years, which means that our AGE variable equals actual age minus 31. Hence, 0 on our age variable corresponds to 31 years of age for a respondent, 1 corresponds to 32, and so on. We chose to center AGE on 31 because the youngest subject at first measurement was 31. The advantage of using this scale for age is that it forces the intercept to fall within the range of our observed data and makes the value of the intercept interpretable as the mean value of Y for respondents who are 31 years old. (Note that the value of Y for any particular respondent may have been higher or lower at age 31 than the mean for all respondents. See Bryk and Raudenbush, 1992, pp. 27–29, and chapter 6 on the importance of centering variables in cases such as his one.)

Hence, we were able to test for differences in mean outcomes for the two groups in our study at the age of the youngest subjects when our data collection effort began. Allowing for differences in the values of Y among respondents at the beginning of the study is important because it adjusts our growth rate estimates for group differences in initial performance. The *e* of the Level-1 model is a random disturbance unique to each individual in the study.

Our model resembles a typical linear regression model with the exception that each person is allowed to have a unique growth trajectory. In a typical OLS regression, the coefficients in the model are assumed to apply to all subjects in the study; hence, the model is said to be a "fixed effects" model. The coefficients (B_0, B_{age}, and B_{age2}) in our models are not fixed, but vary from one individual to the next to reflect the real-life fact that different individuals' growth trajectories differ in their shapes. We will refer to the model above that expresses Y as a quadratic function of AGE as the "individual-level" model because it describes the general form of how Y varies with age for each individual. (In other words, the nonlinear model describing how Y varies with age requires including two functions of the variable named "AGE" in the equation: AGE and the square of AGE; AGE and the square of AGE do not have independent effects. Both are needed simultaneously to carry the concept of how Y varies nonlinearly with age.) The multi-level modeling procedures employed here that allow the individual-level models to differ from

person-to-person are called "random effects" models.

How the individual-level models differ across individuals can be expressed by a set of equations that describes how the coefficients in the individual-level model differ from person-to-person. We refer to these models as "difference" models because they describe how individual growth trajectories differ. (The multi-level modeling literature typically refers to our individual-level models as Level-1 models and our difference models as Level-2 models [e.g., Snijders & Bosker, 1999].) Two kinds of differences across individual-level models can be distinguished. First, there are unique, unmeasured differences among individuals that cause their growth trajectories to differ. Second, individuals vary systematically according to measured factors that cause growth trajectories to differ. The difference models are as follows:

$$B_0 = G_{0,0} + G_{0,1}(COHORT)$$
$$+ G_{0,2}(GROUP) + U_0$$
$$B_{age} = G_{age,0} + G_{age,1}(COHORT)$$
$$+ G_{age,2}(GROUP) + U_1$$
$$B_{age2} = G_{age2,0} + G_{age2,1}(COHORT)$$
$$+ G_{age2,2}(GROUP) + U_2$$

Note that for each coefficient in the individual-level model, there is a difference model that describes how that individual-level coefficient differs across individuals. For example, the individual-level intercept, B_0, varies across individuals depending upon which age COHORT they belong to, which GROUP they belong to, and the unique value of U_0 that applies to them. The variables COHORT and GROUP constitute the two measured factors that may explain differences in individual growth trajectories.

We measure COHORT as the age of the subject at the time that he or she first entered the study. As is the case with the Level-1 AGE variable, COHORT is scaled as actual age minus 31: Hence, COHORT = 0 for a person who was 31 years old at first measurement, 1 for a person who was 32 at first measurement, and so on. The COHORT variable permitted us to test for differences between younger and older age cohorts to determine whether cognitive or adaptive behavior performances differed as a function of their age upon entry into the study. For example, if older cohorts differed in some

systematic way from younger cohorts (perhaps due to differences in treatment regimes), failure to control for age cohort would introduce a bias into the estimates of the individual-level coefficients.

The second factor that we include in the difference models is a person's group status. The GROUP variable makes it possible to estimate differences in the age-specific changes in performance for those who completed the study (GROUP = 0) compared to those who were lost to follow-up (GROUP = 1). Hence, GROUP controls for any systematic differences in the two groups of subjects that might have biased the estimation of their individual-level parameters. We believe that this contrast distinguishes subjects who apparently remained in good health during the period of the study from those whose health was deteriorating. Rapid declines in health should be reflected in performance measures and should be controlled in the models.

The U terms in each difference model represent random differences among individuals that also produce differences in the individual-level model coefficients. (Because the U terms are unmeasured random differences among individuals, the individual-level coefficients are random coefficients, hence, the term *random-effects models*. Note that the difference models resemble OLS regression models but differ from them because the dependent variable in each model is not a measured outcome but, rather, a coefficient in the individual-level model. Typical OLS regression models and closely related estimation techniques do not take these unmeasured differences in individual-level coefficients into account.) The U term captures the effects of the unmeasured factors unique to each individual that cause performance on the outcome measures to differ from that of others in ways that are not reflected by the measurable systematic factors that we include in the models. The inclusion of the U terms is an important difference in our modeling strategy from those of typical fixed effects ANOVA, ANCOVA, and OLS regression models. Our multi-level, random effects models allow each person to have a different rate of change in individual performance on the outcome measures. We abandon the unrealistic assumption of typical quantitative analyses of change that all subjects experience change in the same way by recognizing that individuals differ in unique ways that are not generalizable.

We followed standard practice in our data analysis procedure. First, we estimated the individual-

level model specified above for all 11 outcome measures with the COHORT and GROUP variables omitted from the difference equations. This preliminary step allowed us to evaluate the adequacy of the individual-level model specification, including the specification of the random effects. For all 11 outcome measures, an extraordinarily large number of iterations were required for convergence of the estimation procedure, indicating that a simplification of the model was appropriate. (The number of iterations required for convergence of the maximum-likelihood estimation procedure varied between 1,617 for Social/Communication Skills and 8,270 for Memory for Names.) An excessively large number of iterations is a diagnostic that often indicates that too many random coefficients have been specified for the amount of available data (Bryk & Raudenbush, 1992, pp. 202–203; Snijders & Bosker, 1999, p. 82) and too many random coefficients appeared to be the source of the problem in our case. Consequently, the random U term in the difference model for the square of AGE was dropped, which still allowed the individual-level coefficient to vary systematically with COHORT and GROUP while omitting the unique effects for individuals. (In all but 1 of the 11 performance measures, the difficulty in obtaining an iterative solution was caused by a statistically negligible variance in the random U term for the square of the AGE coefficient. The one exception was the Social/Communication Skills measure, which appeared to have a statistically significant variance, $p < .003$, for the square of AGE coefficient. At any rate, the results reported in Tables 1 and 2 for this outcome are negligibly different from the results obtained when the U term for the square of AGE coefficient is included. Dropping the U term from the square of AGE difference model, therefore, appears to be a reasonable simplification of the models based on our data. The model for the coefficient of the square of AGE becomes $B_{age2} = G_{age2,0} + G_{age2,1}[COHORT] + G_{age2,2}[GROUP]$.) The number of iterations required for convergence dropped substantially (typically in the range of 20 to 50 rather than the thousands previously obtained), indicating that the specifications of the random effects were reasonable.

Next, we obtained estimates for the coefficients in the difference models for each of the 11 outcome variables. Specifically, the COHORT and GROUP variables were included as causes of differences in the individual-level model coefficients (B_0, B_{age}, and B_{age2}), the U terms were retained for the B_0 and B_{age}

Table 1 Longitudinal Changes With Age in Adaptive Behavior for Adults With Down Syndrome: Two-Level Random Effects Quadratic Growth Models

Measures of adaptive behavior[a]/ Level 2 variables	Level 2 models for the Level 1 intercept			Level 2 models for the Level 1 linear age slope			Level 2 models for the Level 1 quadratic age slope		
	Parameter estimate	SE	t	Parameter estimate	SE	t	Parameter estimate	SE	t
Social/Communication Skills									
Base	475.82	8.00	59.51*	.85	2.08	.41	−.04	.16	−.27
Group[b]	7.08	27.70	.26	1.25	5.77	.22	−.31	.29	−1.07
Cohort[c]	−1.22	2.73	−.45	.14	.17	.83	−.01	.01	−.97
CoXgrp[d]	−1.84	4.72	−.39	.19	.38	.50	.01	.01	.50
Community Living Skills									
Base	488.34	11.46	42.60*	−.34	1.53	−.22	−.03	.12	−.26
Group	15.77	40.83	.39	6.08	6.68	.91	−.62	.35	−1.79
Cohort	−2.20	2.77	−.79	.27	.18	1.47	−.01	.00	−1.76
CoXgrp	−7.90	6.01	−1.31	.54	.59	.91	−.01	.02	.31
Motor Skills									
Base	454.25	14.82	30.65*	−.15	2.48	−.06	.02	.15	.16
Group	31.73	54.40	.58	3.62	9.45	.38	−.41	.38	−1.07
Cohort	8.20	3.37	2.44*	−.61	.29	−2.11*	.01	.01	.95
CoXgrp	−14.97	9.22	−1.62	1.18	.89	1.33	−.01	.02	−.55
Personal Living Skills									
Base	494.45	6.62	74.66*	2.71	1.25	2.17*	−.17	.09	−1.90*
Group	19.91	29.64	.67	−.57	4.83	−.12	−.21	.21	−.97
Cohort	−0.56	1.88	−.30	.02	.15	.20	.00	.00	.91
CoXgrp	−5.94	5.26	−1.13	.73	.48	1.51	−.01	.01	−.92
Broad Independence									
Base	479.42	9.51	50.42*	.68	1.49	.46	−.05	.11	−.46
Group	15.40	37.26	.41	3.56	6.40	.56	−.43	.29	−1.47
Cohort	.89	2.33	.38	−.03	.16	−.18	.00	.00	−.17
CoXgrp	−7.75	5.77	−1.34	.63	.56	1.12	.00	.02	−.10

Note: All models estimated by restricted maximum likelihood. Level 1 age variable centered on age=31. [a]Sample size for adaptive behavior models is 58. [b]0 for subjects who completed the 10-year study, 1 for those who were lost to follow-up. [c]Age at time of entry into the study minus 31. [d]Cohort X Group interaction. *$p < .05$, two-tailed test.

models, whereas the U term for the B_{age2} models was omitted.

The results of these analyses are reported in Tables 1 and 3. We then evaluated the models using a multi-parameter Wald test of the hypothesis that the model fit would not be significantly degraded if one or more variables were dropped from the dif-

ference models at the same time (Bryk & Raudenbush, 1992, pp. 50–52). Larger chi-square values for the test produce smaller p values. The smaller the p value, the more likely that the fit of the model is seriously degraded by dropping at least one of the variables being tested. We dropped variables from the difference models on the basis of the multi-pa-

Table 2 Longitudinal Changes With Age in Adaptive Behavior for Adults With Down Syndrome: Trimmed Growth Models

Measures of adaptive behavior[a] / Level 2 Variables	Level 2 models for the Level 1 intercept			Level 2 models for the Level 1 linear age slope			Level 2 models for the Level 1 quadratic age slope			Wald test[b]	
	Parameter Estimate	SE	t	Parameter estimate	SE	t	Parameter estimate	SE	t	χ^2 (df)	p
Social/ Communication Skills											
Base	467.53	5.42	86.24*	2.16	.66	3.29*	-.11	.02	-4.69*	11.41 (9)	.25
Group[c]											
Cohort[d]											
CoXgrp[e]											
Community Living Skills											
Base	472.97	7.73	61.18*	1.21	.93	1.30	-.13	.04	-3.37*	11.62 (6)	.07
Group				.90	.85	1.05	-.11	.05	-2.07*		
Cohort				.11	.05	1.96*					
CoXgrp											
Motor Skills											
Base	478.32	10.72	44.62*	.66	1.36	.48	-.11	.04	-2.57*	9.1 (9)	.43
Group											
Cohort											
CoXgrp											
Personal Living Skills											
Base	491.76	5.14	95.70*	1.79	.65	2.76*	-.14	.03	-4.47*	11.33 (6)	.08
Group				1.15	.75	1.53	-.11	.04	-2.90*		
Cohort				.11	.04	2.71*					
CoXgrp											
Broad Independence											
Base	476.62	6.61	72.12*	2.15	.86	2.50*	-.13	.03	-4.22*	14.7 (9)	.10
Group											
Cohort											
CoXgrp											

Note. All models estimated by restricted maximum likelihood. Level 1 age variable centered on age=31. [a]Sample size for adaptive behavior models is 58. [b]See Byrk and Raudenbush (1992, pp. 50–52) for discussion of multiparameter test for trimmed models. [c]0 for subjects who completed the 10-year study, 1 for those who were lost to follow-up. [d]Age at time of entry into the study minus 31. [e]Cohort × Group interaction.

* p < .05, two-tailed test.

Table 3 Longitudinal Changes With Age in Cognitive Function for Adults With Down Syndrome: Two-Level Random Effects Linear Growth Models

Measures of cognitive function[a]/ Level 2 variables	Level 2 models for the Level 1 intercept			Level 2 models for the Level 1 linear age slope			Level 2 models for the Level 1 quadratic age slope		
	Parameter estimate	SE	t	Parameter estimate	SE	t	Parameter estimate	SE	t
Picture Vocabulary									
Base	52.91	7.58	6.98*	1.25	.92	1.37	−.08	.05	−1.63
Group[b]	−6.87	24.50	−.28	3.68	2.21	1.67	−.18	.09	−1.95*
Cohort[c]	−5.61	1.18	−4.73*	.41	.10	4.05*	−.01	.00	−2.46*
CoXgrp[d]	.17	4.54	.04	−.16	.41	−.39	.01	.01	.10
Memory for Sentences									
Base	47.77	6.82	7.00*	−.73	1.06	−.69	−.01	.06	−.18
Group	−10.16	24.81	−.41	−1.01	6.68	−.15	−.14	.29	−.05
Cohort	−.55	1.60	−.34	.09	.11	.82	.00	.00	−.67
CoXgrp	3.28	3.10	1.06	−.17	.22	−.74	.00	.01	.44
Memory for Names									
Base	61.54	9.28	6.63*	.35	1.19	.29	−.04	.07	−0.51
Group	.23	21.73	.01	4.25	3.30	1.29	−.18	.15	−1.22
Cohort	.80	1.70	−.47	.11	.14	.79	.00	.00	−.68
CoXgrp	.76	4.20	.18	−.40	.32	−1.26	.01	.01	2.19*
Visual Closure									
Base	91.70	9.40	9.75*	2.56	1.51	1.69	−.26	.08	−3.18*
Group	−50.01	28.09	−1.78	7.44	3.36	2.22*	−.24	.16	−1.48
Cohort	−11.26	1.85	−6.10*	.81	.14	5.65*	−.01	.00	−2.22*
CoXgrp	8.31	4.89	1.70	−.86	.46	−1.88	.02	.01	1.81
Incomplete Words									
Base	75.12	5.82	12.92*	1.17	.94	1.25	−.05	.05	−.92
Group	−53.68	36.03	−1.49	8.80	7.27	1.21	−.40	.29	−1.38
Cohort	−3.86	1.33	−2.91*	.25	.10	2.48*	.00	.00	−1.36
CoXgrp	5.14	2.83	1.82	−.59	.28	−2.10*	.02	.01	2.00*
Broad Cognitive Skills									
Base	52.93	7.45	7.11*	.78	.80	.98	−.09	.05	−1.72
Group	−24.45	28.61	−.85	4.24	4.85	.87	−.17	.21	−.79
Cohort	−6.56	1.34	−4.88*	.54	.09	5.66*	−.01	.00	−4.22*
CoXgrp	4.73	4.26	1.11	−.56	.38	−1.46	.02	.01	1.66

Note: All models estimated by restricted maximum likelihood. Level 1 age variable centered on age=31. [a]Sample size is 58 for cognitive skills models. [b]0 for subjects who completed the 10-year study, 1 for those who were lost to follow-up. [c]Age at time of entry into the study minus 31. [d]Cohort × Group interaction. *$p<.05$, two-tailed test.

rameter tests and report the results of the trimmed models in Tables 2 and 4. We also report the results of the multi-parameter test that compares the trimmed model to the full model for each of the 11 performance measures. The absence of a variable in the trimmed models of Tables 2 and 4 indicates that there were no statistically significant differences from the untrimmed models of Tables 1 and 3. In other words, the absence of a variable in a difference model indicates that the corresponding individual-level coefficient did not differ by cohort status or group membership, as appropriate.

As an illustration of our data analysis procedure, consider the Table 1 results for the ICAP Social/Communication Skills measure. None of the t tests for the individual coefficients were statistically significant at the .05 level. Because the t tests were not independent of each other, they cannot be used to trim the models. We estimated a number of multi-parameter Wald tests to reach a decision as to the best estimates to report in Table 2. The tests were conducted in sequence, such that higher order terms were dropped before lower order terms as is standard practice. For example, the interaction of COHORT and GROUP (i.e., the Cohort × Group term) of COHORT and GROUP was dropped before the main effect of either COHORT or GROUP could be dropped. The Table 2 results for Social/Communication Skills indicates that COHORT and GROUP and the interaction between the two were dropped from all three difference equations. The Wald test with 9 degrees of freedom equaled 11.41, which corresponds to an upper-tail probability of .25. Because .25 is greater than the critical value of .01, the Table 2 estimates were not significantly poorer than those of Table 1. (We relied upon a p value of .01 as the critical value for the Wald tests. Dropping variables corresponding to those missing from Tables 2 and 4 produced p values less than .01.) Hence, we found no systematic differences in the individual-level coefficients due to differences in age cohort status or group membership for the Social/Communications Skills measure. Of course, the estimated growth trajectories of the various individuals in the study were not identical because the U terms in the difference models differed for each individual. The difference model coefficients reported in Tables 2 and 4 represent a kind of average of the individual-level growth patterns for all of the subjects in the study. (We do not report the estimates of the individual-level growth trajectories, although it is possible to do so

for each of the 58 subjects on each of the 11 outcome measures. Because our goal was to identify the typical growth patterns of adults with Down syndrome rather than the unique trajectories of particular individuals, we focused on the average patterns implied by the difference model coefficients.)

What are the typical growth trajectories in adaptive behavior and cognitive function described by the coefficients in Tables 2 and 4? Because the growth pattern implied by the individual-level model is nonlinear, even a rather simple pattern with no COHORT or GROUP differences is difficult to visualize. More complicated results in which COHORT and GROUP differences produce different "typical" growth patterns for different sets of participants are even more difficult to visualize and interpret. The relative importance of the COHORT and GROUP effects and how they vary with age is difficult if not impossible to evaluate based on an examination of the coefficients in Tables 2 and 4 alone. To facilitate visualization and discussion of the analysis results, we plotted in Figures 1 and 2 the trajectories implied by the coefficients in Tables 2 and 4, as is becoming standard practice in the interpretation of nonlinear models (e.g., Long, 1997).

Adaptive Behavior

In the case of Social/Communication Skills, the top-left graph of Figure 1 indicates that performance remains relatively constant until about age 45, and then a gradual decline begins that accelerates with age. The decline overall between age 31 and 61 is a modest 8%. This pattern of change also applies to those in different age cohorts or groups. The patterns on the ICAP measures for Motor Skills and Broad Independence are similar to that of Social/Communication Skills (see Figure 1). The acceleration in the decline of Motor Skills after age 45 is faster than that of Social/Communication Skills. Consequently, the Motor Skills decline by 17% between age 31 and 61. The overall ICAP measure of Broad Independence bears a closer resemblance to the Social/Communication Skills pattern, with an overall decline of 11% in performance between AGES 31 and 61.

The patterns displayed in Figure 1 for Community Living Skills and Personal Living Skills are more complicated, but remarkably similar to each other in shape. The shape of the curves differs for those in different age cohorts and group membership, as indicated by the increasing fan of the four

Table 4 Longitudinal Changes With Age in Cognitive Skills for Adults With Down Syndrome: Trimmed Growth Models

Measures of cognitive function[a]/ Level 2 variables	Level 2 models for the Level 1 intercept			Level 2 models for the Level 1 linear age slope			Level 2 models for the Level 1 quadratic age slope			Wald test[b]	
	Parameter estimate	SE	t	Parameter estimate	SE	t	Parameter estimate	SE	t	χ (df)	p
Picture Vocabulary											
Base	31.14	6.39	4.87*	2.11	.57	3.69*	−.03	.02	−1.64	17.58 (8)	.02
Group[c]											
Cohort[d]	−.77	.33	−2.31*								
CoXgrp[e]											
Memory for Sentences											
Base	46.32	3.35	13.84*	−.28	.45	−.62	−.02	.02	−1.09	12.54 (9)	.18
Group											
Cohort											
CoXgrp											
Memory for Names											
Base	59.67	4.74	12.60*	.59	.56	1.06	−.04	.02	−2.11*	11.76 (9)	.23
Group											
Cohort											
CoXgrp											
Visual Closure											
Base	44.78	8.71	5.14*	3.92	.90	4.34*	−.12	.03	−3.77*	28.95 (6)	.00
Group	.78	6.74	.12								
Cohort	−.95	.59	−1.62								
CoXgrp											
Incomplete Words											
Base	58.12	4.26	13.66*	1.23	.52	2.36*	−.02	.02	−1.4	18.64 (9)	.03
Group											
Cohort											
CoXgrp											

(Table 4 continued)

Table 4 Continued

Measures of cognitive function[a]/Level 2 variables	Level 2 models for the Level 1 intercept			Level 2 models for the Level 1 linear age slope			Level 2 models for the Level 1 quadratic age slope			Wald test[b]	
	Parameter estimate	SE	t	Parameter estimate	SE	t	Parameter estimate	SE	t	χ (df)	p
Broad Cognitive Skills											
Base	24.57	6.57	3.74*	2.39	.57	4.20*	−.06	.02	−2.79*	18.4338 (8)	.02
Group											
Cohort	−.56	.37	−1.50								
CoXgrp											

Note. All models estimated by restricted maximum likelihood. Level 1 age variable centered on age=31.
[a] Sample size is 58 for cognitive skill models. [b] See Byrk and Raudenbush (1992, pp. 50–51) for discussion of multiparameter test for trimmed models. [c] 0 for subjects who completed the 10-year study, 1 for those who were lost to follow-up. [d] Age at time of entry into the study minus 31. [e] Cohort × Group interaction.
*p < .05, two-tailed test.

curves as age increases. All four curves indicate an accelerating decline in performance after about age 45, and the decline is faster for those who dropped out of the study (dashed lines indicate GROUP = 1). On the other hand, older cohorts tended to perform better at all ages than did younger cohorts (the thin lines are higher than the thick lines). By about age 55, any advantage due to older cohort status is eliminated by being in the group whose members were unable to complete the study because the curves for the older cohort who were lost to follow-up drop below the curve for the young cohort who remained in the study (the thin dashed line drops below the thick solid line). Our estimates indicate that our data were influenced by a selection effect due to COHORT and GROUP status, but the general shape of the age-specific growth in Community and Personal Living Skills resembled that of the previous three ICAP measures. Change was modest on both Community and Personal Living Skills until the "typical" participant reached about age 45. After age 45, performance declined at an accelerating rate. The overall declines in performance for the best performing individuals were 9% for Personal and 11% for Community Living Skills between ages 31 and 61. The declines for the poorest performing sets were 28% and 32% for Personal and Community Living Skills, respectively (see Figure 1).

Estimated change in performance followed similar growth trajectories for all five ICAP measures. Performance was approximately constant for a typical subject until about age 45. After that age, noticeable declines in performance occurred, and the decline was more rapid as age increased. The overall decline in performance between ages 31 and 61 was about 20%, regardless of the ICAP measure, but the majority of the decline occurred after age 45.

Cognitive Function

The cognitive function growth trajectories implied by the results shown in Table 4 are displayed graphically in Figure 2. One commonality among all six trajectories plotted in this figure were the absence of any effects of GROUP membership. The patterns for those who failed to complete the study were identical to the patterns for those who completed all scheduled measurements in 5 of the 6 plots. The only exception was the pattern for Visual Closure, which had a statistically significant difference in intercepts by GROUP (see Table 4), but
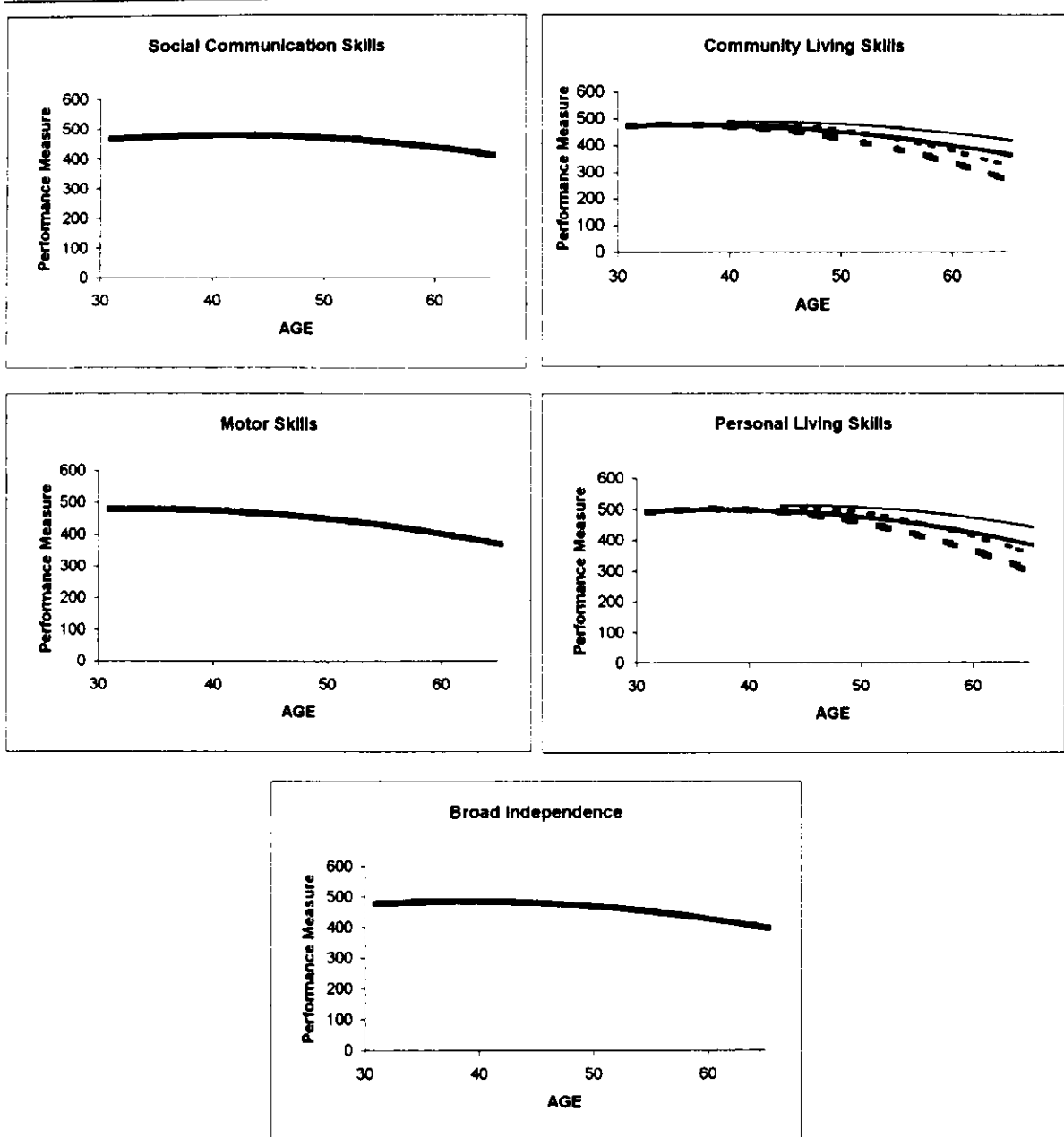
Figure 1 Adaptive behavior trimmed growth models. Dashed lines, GROUP = 1; solid lines, GROUP = 0; thin lines, COHORT = 15; thick lines, COHORT = 0

the difference was so small that it was of no practical importance. No apparent differences in the trajectory of Visual Closure by GROUP is apparent from a visual inspection of its plot in Figure 2. Hence, we conclude that the trajectories of all six measures of cognitive function were essentially unaffected by GROUP differences.

Three of the six measures showed no significant

differences by COHORT or GROUP. Of these, Memory for Sentences declined steadily over the age span of the participants in our study. The decline appears almost linear but actually accelerates over the entire age span. The decline is about 0.33 points/year between ages 31 and 34, but speeds up to a decline of 1.25 points per year between ages 58 and 61. The typical Memory for Sentences score
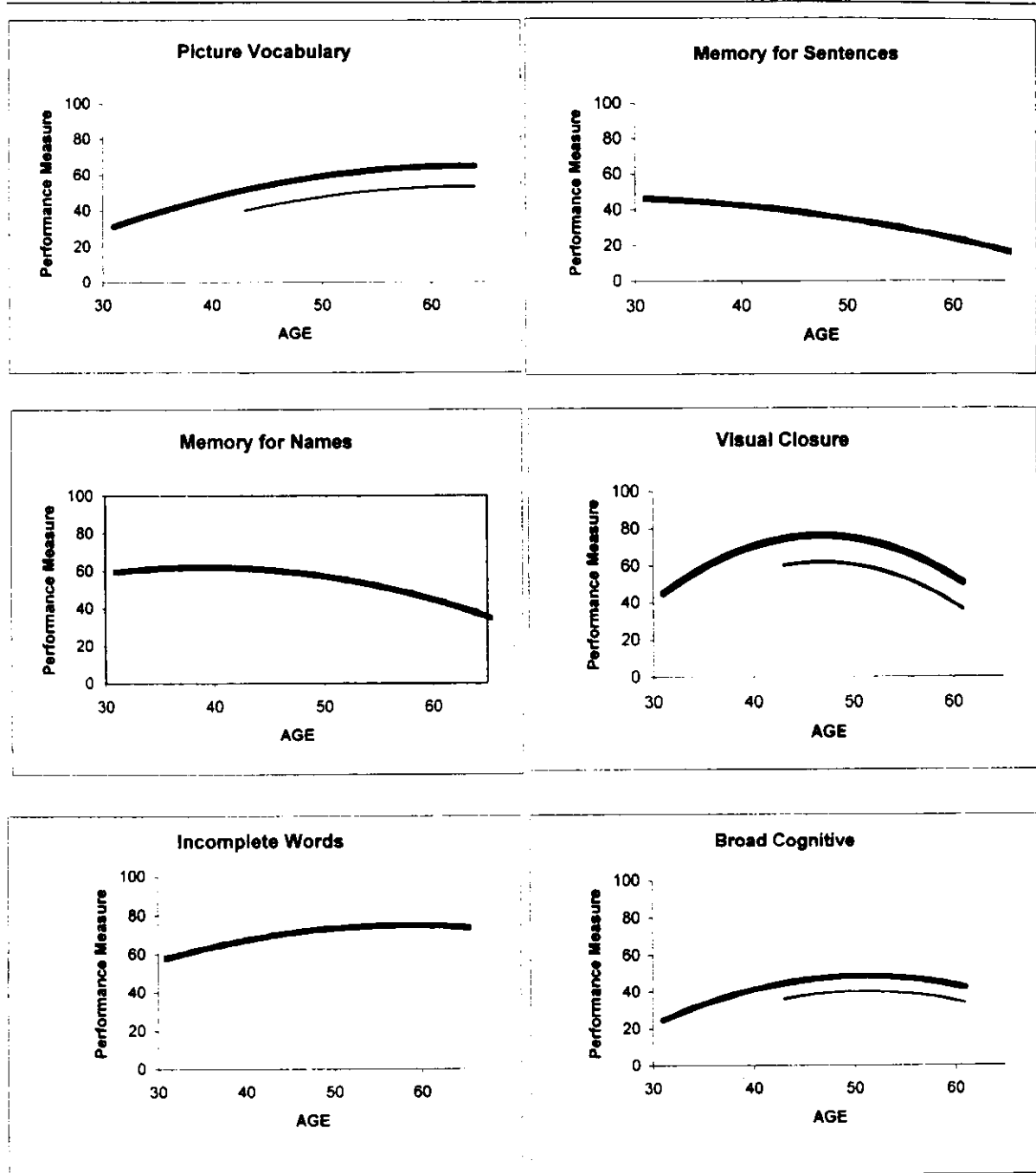
Figure 2 Cognitive function trimmed growth models. Thin lines = COHORT = 15; thick lines, COHORT = 0. GROUP has no effect on these curves.

declined slightly more than 50% between ages 31 and 61.

Memory for Names also declined over the age-span of our participants, and no differences in the trajectories were found for those in different age co-horts or different study completion groups. Unlike Memory for Sentences, however, performance on Memory for Names remained rather constant until about age 45 or so, and then began a decline that accelerated with age. By age 61, the overall decline

in measured Memory for Names was slightly more than 25%.

No differences by GROUP or COHORT were discovered in the trajectory of Incomplete Words, but performance on this measure improved over the age span of the study participants (see Figure 2, bottom-left graph) instead of dropping, as was the case with the two memory measures. Improvement in Incomplete Words scores, which was about 1.1 points per year between ages 31 and 34, slowed to nearly zero between ages 58 and 61.

The three remaining measures of cognitive function—Picture Vocabulary, Visual Closure, and Broad Cognitive—differed by cohort status, and the younger cohorts always had higher scores than did older cohorts. Consider Picture Vocabulary (Figure 2, upper-left corner). The youngest age cohort (corresponding to those who entered the study at age 31) displayed an improvement in Picture Vocabulary scores, whose rate of increase declined until about age 60 at which point a plateau was reached (compare the thick line to the thin one). The average gain in Picture Vocabulary scores for this young cohort was about 2 points per year between ages 31 and 34 but dropped to about .2 points per year between ages 58 and 61. The thick line, which indicates a typical growth curve for a person in the 31-year-old age cohort, is higher than the thin line, corresponding to the 46-year-old cohort, by about 11.5 points. On the other hand, the shapes of the two curves are identical. Younger cohorts always outperformed older cohorts, but the overall gain was large for all cohorts. For example, Picture Vocabulary scores doubled between 31 and 61 for the youngest age cohort. By contrast, the gain for those in the older, 46-year-old cohort was about 43% between ages 41 and 61, a lower but still substantial improvement.

Visual Closure presents a different pattern than any of the previous four measures. Rapid gains at the beginning of the age-span are followed by slowing rates of growth, a plateau at age 47, and a continuously accelerating decline thereafter. Younger cohorts produced better scores than did older cohorts, and the difference between the 31- and 46-year-old cohorts was about 14 points (compare the thick line to the thin one in the middle-right graph in Figure 2). By age 61, the youngest cohorts' scores declined from a maximum of about 75 to 50, a level only about 5 points higher than they were at age 31.

The Broad Cognitive scores present a pattern

similar to that of Visual Closure (bottom-right corner of Figure 2). Increasing scores at declining rates are followed by declining scores at increasing rates. Younger cohorts produced higher scores than did older cohorts at every age. (The difference between the 31- and 46-year-old cohorts was about 8 points.) The scores of the youngest cohort doubled before their decline began and the maximum was reached at about 50 years of age, slightly older than was the case for Visual Closure. The decline between 50 and 61 was modest, about 10% to 12%.

The cognitive function growth curves show more heterogeneity than do the adaptive behavior measures. Memory for Sentences declined throughout the age-span of our participants, whereas the decline in the scores of Memory for Names did not become apparent until they were about age 45. Picture Vocabulary and Incomplete Words scores increased during the age-span and reached plateaus between age 50 and 60. Visual Closure and Broad Cognitive scores increased to a maximum in the late 40s or so and then began a decline. Based on the estimates reported in Table 4, it appears that Memory for Sentences reaches a maximum before age 31, the youngest age in our study. Peak scores varied over the age-span of our participants for Memory for Names (about 39 years), Visual Closure (47 years), Broad Cognitive (51 years), and Incomplete Words (58 years). (The age at the maximum for each curve was calculated using unrounded values corresponding to the figures in Table 4 for the coefficients of AGE and the square of AGE.) The maximum for Picture Vocabulary occurred after age 61. In other words, it is likely that the typical growth curves for adaptive behavior and cognitive function all demonstrate growth to a peak value followed by subsequent decline. The adaptive behavior curves all reached peak values at about age 45, whereas the cognitive function trajectories varied greatly. Four reached peak values within the age-span of our participants, one before the youngest subject (Memory for Sentences), and one appeared to reach a maximum at an age beyond the range of our data (Picture Vocabulary).

Discussion

The estimates of age-related change for adults with Down syndrome reported here demonstrate the complexity of the process and the importance of using analysis techniques that control for selec-

tion factors that can bias estimates. We controlled for the effects of participant loss due to mortality and morbidity, for cross-sectional differences based on entry age into the study, and for changes over a 10-year period of time. In addition, by including an interaction variable for cohort and group membership, we examined the possible confounding of these variables.

Using multi-level modeling, we were able to ascertain the influence of these variables on growth curves. We used a .01 significance level to trim our models to the best fitting model for each of 11 variables. This procedure ensured that we had to have a strong signal from our control variables (COHORT and GROUP) in order to retain them in our final models presented in Tables 2 and 4, thus reducing the potential for false positive findings. Hence, if a cohort or group effect was reported in a final model, we had strong statistical evidence that it was there in these data. For all 11 trimmed growth models, the interaction variable was eliminated based on nonsignificant effects. Also, all 11 trimmed models represent quadratic growth curves that showed the expected performance for adults with Down syndrome across an age range encompassing the 30s, 40s, 50s, and 60s. One advantage of this approach to the study of age-related change is that the resulting models can provide a picture of longitudinal change while also testing for the effects of subject loss, younger versus older cohorts, and the interaction of these two factors. Finally, by graphing our trimmed models, we were able to readily observe and interpret the expected growth trajectories of typical individuals in our study. These models of age-related change demonstrate selected differences that can be expected and described, as suggested by Prasher et al. (1998). We discuss the implications of our findings in each area of performance separately below.

Adaptive Behavior

For participants who were lost to follow-up due largely to morbidity and mortality reasons, decreases in adaptive functioning for Community Living and Personal Living Skills were significantly greater than for those who completed the 10-year study. Older cohorts had higher adaptive functioning in Community Living and Personal Living Skills and their rates of decline were slower. It is possible that our sample represented a "healthy older survivor" selection process. However, the increasing losses in these two areas of adaptive functioning with age

and health complications would not have been unexpected. These findings support results of other researchers who have reported that selective losses are associated with dementia and other health conditions (Prasher, 1995a; Prasher & Chung, 1996; Prasher et al., 1998; Zigman et al., 1987).

Overall performance in three areas of adaptive behavior (Social/Communication Skills, Motor Skills, and Broad Independence) did not show significant group or cohort effects. Performance on these three measures tended to peak around the mid-40s and then showed declines at an accelerating rate into the 60s, thus supporting a picture of expected declines that increase with advancing age. These findings are consistent with those reported by Rasmussen and Sobsey (1994) and Zigman et al. (1987).

Our findings, in general, present a picture of expected declines with age and, further, we were able to identify only two measures for which cohort and group significantly affected performance. These findings provide further elucidation of age-related change, but they fall short of clearly identifying changes that are distinctly associated with dementia or other disease processes in this population. Our knowledge about the status of participants who were lost to follow-up was based on care givers' reports and clients' records. Given the recent debate over clear and unequivocal diagnosis of dementia in adults with Down syndrome (Burt et al., 1998), we are hesitant to draw strong conclusions about losses in Community Living and Personal Living Skills among our group of subjects who were lost to follow-up. We agree with Burt et al. and Prasher and Chung (1996) that additional research is needed to understand onset and progression of disease and associated effects on adaptive functioning.

Our findings extend the results of earlier studies on adaptive behavior losses in adults with Down syndrome and provide additional information (Burt et al., 1995; Devenny et al., 1992; Prasher et al., 1998). Our findings support the need for programs and services that could be designed to prevent functional declines in adults with Down syndrome who are in their 40s, 50s, and 60s. All growth curves for adaptive behavior measures showed an accelerating rate of functional losses after age 45. These findings suggest the need for programmatic interventions that preserve functional independence and active lifestyles throughout the adult years, particularly for those individuals who are in their late 40s, 50s, and

60s. These types of health promotion and health protection programs are not atypical among services provided to the general public, especially adults without disabilities who are in their 50s to 80s. Finally, distinguishing how much loss in adaptive functioning signals the advent of a serious health problem or whether a deterioration in health is the prelude to losses in adaptive behavior is a poorly understood process in this population. Continued longitudinal investigations, such as those by Prasher and colleagues (1998) and Burt et al. (1995), will be instrumental in distinguishing between expected declines in adaptive functioning with age and those that are associated with disease processes in adults with Down syndrome. Our findings provide evidence of those declines that would be expected with age; further investigation is needed to more clearly understand declines that are associated with disease and sensory impairment in this population.

Cognitive Function

In contrast to the adaptive behavior findings, participants who were lost to follow-up did not perform more poorly on the cognitive variables than those who were able to complete the study. Older cohorts performed less well than did younger cohorts on two of the subtests, Picture Vocabulary and Visual Closure, and on the overall Broad Cognitive Index. Such cohort differences are often attributed to educational or other treatment differences that prevail during particular times in history and may reflect improved programming for more recent cohorts.

Growth curves revealed improvement with age on both the Picture Vocabulary and Incomplete Words measures. The Picture Vocabulary measure resulted in improved performance over time for both younger and older cohorts, with older cohorts performing less well when they entered the study than did younger cohorts. Improvement with age in Picture Vocabulary, a measure of acculturation knowledge (or crystallized ability), is consistent with predictions based on the Horn–Cattell theory that crystallized abilities are maintained or improve with age. Of course, this finding may also be interpreted as a practice effect because the same test was given repeatedly at intervals ranging from 10.8 to 28 months. At the least, it is unlikely that such improvement would be shown if major deterioration were taking place. Also, because naming pictures is not an unusual task, practice is less likely to have had a major effect. However, the second

test that showed improved performance, Incomplete Words, which measured auditory processing, was a novel task and may have been more subject to practice effects. Again, it seems unlikely that participants would have been able to benefit from their experience with this task if they were experiencing deterioration in this ability. This finding is consistent with research on normal aging, which has shown this crystallized ability to improve with age and experience through at least the sixth decade of life (Horn, 1982; Horn & Donaldson, 1976). The finding of improvement in Picture Vocabulary in participants with Down syndrome is supported by Hewitt, Carter, and Jancar's (1985) finding of stability in verbal abilities and with Burt et al.'s (1995) finding of stability in picture vocabulary. The cohort effect is likely explained by differences in educational opportunities afforded to younger and older cohorts.

By contrast, the short-term memory measure (Memory for Sentences) declined in both groups and all cohorts over time. This decline would also be predicted by the Horn–Cattell theory, wherein short-term apprehension and retrieval is thought to be vulnerable to decline with age. Persons with mental retardation, in general, have been shown to have poorer short-term memory (Hale & Borkowski, 1991), whereas individuals with Down syndrome perform more poorly than do those with other etiologies on auditory/verbal short-term memory tasks (Marcell & Weeks, 1988). Lott and Lai (1982) found that memory for recent events and short-term visual retention declined in those with Down syndrome over age 35. Varnhagen, Das, and Varnhagen (1987) reported short-term memory deficits in older persons with Down syndrome. Changes associated with typical aging include small, incremental declines in performance on tests of recent memory (e.g., Salthouse, 1991). Thus, our finding of declines in short-term memory function are consistent with previous studies in both aging of individuals in the general population and aging in persons with Down syndrome.

Performance on the long-term memory measure, Memory for Names, remained constant until age 39 and then began to decline. This decline in long-term memory would not be predicted from the Horn–Cattell theory and is not usually found in aging studies of the general population. Devenny et al. (1996) demonstrated gradual declines (<1% per year) in verbal, long-term memory for healthy adults with Down syndrome over the age of 50. Our

subjects experienced an overall decline by age 61 of slightly more than 25%.

Performance on the Visual Closure measure, which assesses visual-processing, showed rapid gains until age 47 and decline thereafter. Younger cohorts performed significantly better than did older cohorts, probably influenced by different educational experiences. No prediction on age pattern for this processing measure could be made based on the Horn–Cattell model, nor is it commonly used in studies of typical aging.

Overall Broad Cognitive scores reveal a picture not unexpected from a composite including both crystallized and fluid abilities, some of which improve with age and others of which decline. Maximum performance was reached at about age 50, and decline was gradual and modest between 50 and 61. This pattern of decline is similar to the pattern seen in studies of typical cognitive aging, except that the decline in those studies does not begin until approximately age 60 (Hoyer, Rybash, & Roodin, 1999).

Based on our findings, it appears that an aging-related decline can be identified in these participants with Down syndrome approximately 10 years earlier than in the general population. On the positive side, however, it is also apparent that different cognitive abilities follow different growth trajectories, with at least two abilities, auditory processing and comprehension knowledge, showing growth well beyond age 50. Overall, our cognitive findings tend to support the Horn–Cattell theory with positive change in acculturation-based skills (crystallized) and decline in those skills more heavily influenced by neurological function (fluid).

Our findings are strengthened by the application of multi-level modeling procedures to estimate age-related changes in function in adults with Down syndrome in their 40s, 50s, and 60s. We avoid the typical analysis strategy of omitting cases with incomplete data, which would have forced us to drop all lost to follow-up participants from the analysis. Rather than drop cases, which would have biased our findings, we provide comparative growth models for the two types of subjects where they were significantly different. The inclusion of the cohort variable allowed us to model age-related differences for younger and older subjects at time of entry into the study. Our data are prospective on individuals. We presented results for a typical individual in our study, but our random-effects models allowed each individual to follow a unique growth trajectory. Hence, our procedure accommodated a cross-sectional sample of individuals to a longitudinal measurement design as typical fixed-effects models cannot. As demographers continue to alert us to sustained growth in the aging and aged populations, the need for an accurate picture of the needs and concerns of adults with Down syndrome as they age will only heighten. We agree with Burt et al. (1995) and Prasher et al. (1998) that longitudinal investigations are the preferred design for studying this phenomenon, even though this kind of design poses considerable methodological challenges. Our study demonstrates that these challenges can be met.

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