Age Changes in Perceptual Speed: A Seven-Year Longitudinal Study

K. Warner Schaie

The Pennsylvania State University

Paper presented at the

Cognition and Aging Conference

May 9, 1987

Atlanta, Georgia

Abstract

Previous studies of perceptual speed have shown substantial decline in this ability during old age. Cross-sectional studies also suggest that this decline may occur earlier than for other abilities. However, thus far longitudinal data have been reported only for older subjects. This paper presents cross-sectional data from the Seattle Longitudinal Study for 1621 subjects first assessed in 1977 as well as 628 subjects first assessed in 1984. In addition 838 subjects were followed over the 7-year interval between these data collections. Subjects covered the adult age range in 7-year age intervals from age 25 to age 88. Markers of perceptual speed were the "Identical Pictures" and "Finding A's" tests from the ETS Kit of Factor Referenced Tests. Cross-sectional and longitudinal data are presented at both observed variable and latent construct levels. Cross-lagged correlations are examined to consider the importance of perceptual speed in predicting later performance on other abilities (e.g., Inductive Reasoning, Spatial Orientation, Number, Word Fluency).

Age Changes in Perceptual Speed: A 7-Year Longitudinal Study

K. Warner Schaie

The Pennsylvania State University

One of the most consistently documented age-related finding is the decline in speed of performance. Although examined mostly within the framework of simple and complex reaction time studies (cf. Birren, Williams, & Woods, 1980; Salthouse 1985a), decline in speed of performance on virtually all tasks is assumed to be a universal phenomenon (cf. Salthouse, 1985b). Speed of performance and age has also received ample attention within the information-processing framework (e.g., Berg, Hertzog, & Hunt, 1982; Hertzog, Carter, & Hunt, 1982). The separate role of speed within the psychometric framework of intelligence, however, still remains somewhat controversial. Most of the primary mental abilities have generally been defined as slightly speeded power tests. However, a specific primary ability, usually called <u>Perceptual Speed</u> has been identified and is included in the most comprehensive catalog of operational definitions for the psychometric framework (Ekstrom, et al., 1976). Previous studies of measures of perceptual speed have shown substantial decline in this ability during old age. Cross-sectional studies also suggest that this decline may occur earlier than for other abilities. However, thus far longitudinal data have been reported only for older subjects (e.g., Cunningham, in press). Moreover, it has been argued that level of performance on perceptual speed may be predicted of the course of age changes in other mental abilities (Witt & Cunningham, 1979).

This paper presents cross-sectional data from the Seattle Longitudinal Study for independent samples assessed at two points in time (1977 and 1984), as well as longitudinal data across a 7-year interval for individuals covering the adult age range from the twenties to the eighties. The purpose of our analyses is to determine whether cross-sectional differences in perceptual speed (at the test and factor levels) over or underestimate longitudinally observed changes (cf. Schaie, 1983, in press a). To investigate this question seriously it is also necessary to consider the effects of experimental mortality (attrition) and testing on the longitudinal data (cf. Schaie, 1977, in press b). Cross-lagged correlations are then used to seek to replicate the Witt and Cunningham findings and to determine whether rate of change in perceptual speed is predictive of changes on other variables. That is, we want to know to what extent change on the substantive abilities may be accounted for by behavioral slowing. Finally we regress perceptual speed upon the Primary Mental Abilities, and examine the patterns of cross-sectional age differences and longitudinal age changes for the residualized ability scores.

Method

Subjects. Study participants were subjects who had originally been obtained by a random draw from a Pacific Northwest Health Maintenance Organization over the age range from 22 to 84 years of age. Included in the present analysis are 1839 individuals. Of theses, 1421 subjects first received the speed measures 1977 and 628 new subjects were added in 1984. Longitudinal data are available for 838 subjects who were tested on both occasions. All subjects were community-dwelling individuals in good health. The sample is predominantly white and is a good cross-section of the upper 75% of the socio-economic spectrum.

Measures. The measures represented in the present analysis are as follows: The two measures of perceptual speed are the Identical Pictures test, which requires subjects to match a stimulus stick figure from a set of four multiple choice figures, and the Finding A's test which requires cancellation of words that contain the letter "a." Both tests come from the ETS Kit of Factor-referenced tests (Ekstrom et al., 1976). The five Primary Mental Abilities are Verbal Meaning a recognition vocabulary test; Spatial Orientation, a measure involving visual rotation in two-dimensional space; Inductive Reasoning, a letter series task involving the identification of rules; Number, a measure of simple arithmetic skill using addition checks; and Word Fluency, a measure of recall vocabulary. The ability tests are adaptations of the work of the Thurstones (1949; Schaie, 1985).

Procedure. The tests were administered as part of broader psychometric batteries which in 1977 extended over 2 1/2 hours and in 1984 were expanded to a 5 hour battery. All subjects were tested in small groups using one examiner and one proctor.

Results

All measures were scaled into T-Scores form (M = 50, SD = 10) using as a base a large set of first test administrations of the perceptual speed measures (N = 1839) and the primary mental abilities (N = 2812). Derived scores for the latent variable of Perceptual Speed were obtained, using regression weights from the factor analysis of the entire multiply-marked psychometric abilities (Schaie, Willis, Jay, & Shapur, 1987). All data are presented in 7-year age/cohort intervals across the range of mean ages from 25 to 81 years.

Age patterns

As would be expected highly significant age differences were found for both measures of perceptual speed (see Figure 1). The age progression is virtually linear for identical pictures, with the oldest group approximately 2 SDs below the youngest. The age difference slope was somewhat steeper in 1977 than 1984. At first test significant negative age differences were observed by age 46. For the 1984 sample there was a significant difference between ages 25 and 32, but further significant negative differences did not occur until age 53. The magnitude of age differences for

Finding A's is similar. For this measure, however, peak performance was shown at age 32, with significant negative age differences occurring by age 46 as well. For this variable virtually all sub-samples performed at a lower level in 1984.

Insert Figure 1 about here

The discrepancies between the 1977 and 1984 alert us to the likely presence of cohort effects. We determined their magnitude by assessing the performance difference for sub-samples at first test matched by age. Figure 2 shows the cumulative cohort effects (given the assumption that period effects from 1977 to 1984 were negligible). Cumulative effects are charted from a base cohort born in 1896. Note that a peak is reached for finding A's for the 1910 cohort with a virtually linear negative pattern thereafter, and a negative cohort difference of approximately 1 SD favoring the oldest over the youngest cohort. By contrast, Identical Pictures shows a positive cohort gradient until 1931 with a linear negative pattern thereafter. Because of the concave cohort pattern, however, the difference between the oldest and youngest group is less than 1/2 SD, but again the younger cohorts appear to be comparatively slower.

Insert Figure 2 about here

We next present longitudinal data obtained by taking mean differences within each cohort from 1977 to 1984. These changes are then corrected for experimental mortality and effects of practice (cf. Schaie, 1983, in press b). Figure 3 shows the longitudinal gradients thus obtained which are quite similar for the two measures and suggest profound linear age decrement in perceptual speed beginning with our youngest sample. Because of the cohort trends favoring the older individuals, longitudinal findings in this case indicate even greater age decrement than would be suggested by the cross-sectional findings. The magnitude of the decrement is in excess of 2 SDs.

Insert Figure 3 about here

Similar data are shown in Figure 4 for the factor scores on the derived latent variable of Perceptual Speed. Cross-sectional findings for the two data sets differ primarily in that the slope for the 1977 study is somewhat steeper than for the 1984 study. The longitudinal gradient (again corrected for attrition and practice effects) suggests fairly linear age decrement somewhat greater than that shown by the cross-sectional data that accelerates after the fifties and amounts to almost 2 1/2 SDs from 25 to 81 years of age.

Insert Figure 4 about here

Individual Differences

The impressive longitudinal average age decrements, however, do conceal the fact that there are wide individual differences with decline in perceptual speed being much greater for some than the averages would suggest, while others do not change at all, or even improve their performance. Figure 5 contains scattergrams plotting the amount of drop against cohort membership (Cohort 2 = age 88; cohort 10 = age 32). As can be seen, the correlation of magnitude of drop over 7 years with age/cohort membership is quite small, suggesting that while age may not be a good predictor of individual changes in perceptual speed over time. This point is illustrated further by Figure 6, which charts the proportion of individuals who reliably increase or remain stable over seven years preceding the ages indicated in this figures, employing a 1 SEM confidence interval criterion. Note that throughout the age range covered better than two thirds of each sub-group fails to show reliably measurable decline over a seven-year period. Figure 7 shows the stability data for the latent ability measure. Here the proportion of subjects remaining stable or increasing declines after the sixties are reached, suggesting that more people decline on one but not all of the observed measures as advanced age is reached.

Insert Figures 5, 6 & 7 about here

Effect of Perceptual Speed on the Primary Mental Abilities

We next considered the question whether speed accounts for the correlation between age and abilities, or whether age accounts for the correlation between speed and abilities, by computing the relevant partial correlations. These are reported in Table 1. Results are essentially replicated over the two independent samples of individuals tested seven years apart. For all five abilities studied, correlations between age and ability are virtually reduced to zero when perceptual speed is partialled out. On the other hand, partialling out age from the correlations between speed and ability, while markedly reducing correlations, still result in statistically significant partial correlations between speed and ability. These data provide limited support for Salthouse's (1985a) specifications of slowing in central processing speed. However, individual differences in perceptual speed are by no means accounted by age alone.

Insert Table 1 about here

As a next step we obtained the residuals for the five primary mental abilities after partialling out the effect of perceptual speed. Residual scores were then rescaled into T-score form (*M* = 50, *SD* = 10) for ease of comparison across abilities. The top part of Figures 8 to 12 contrasts the actual cross-sectional means with the age difference data resulting after the effects of perceptual speed have been removed. The bottom part of these figures contrasts average cross-sectional (i.e., averaged across the 1977 and 1984 studies) and longitudinal age gradients after residualizing for perceptual speed.

Insert Figures 8 to 12 about here

Removing the effect of perceptual speed has rather drastic consequences for the age patterns on the primary mental abilities. For Verbal Meaning the non-speeded age-difference gradient attains a peak at age 60, with a negative age difference of about 1/2 SD to age 81, where performance is still above that shown at age 25. Even more dramatic are the longitudinal estimates. They suggest steep increment (1 1/2 SD) until age 46, with a more moderate but continuing upward trend thereafter. The cross-sectional age trends for Spatial Orientation and Inductive Reasoning remain negative after speed is removed. However, from the youngest to the oldest group, the magnitude of the differences is reduced to about 2/3 SD. Longitudinal data suggest a peak for Spatial Orientation at age 32, subsequent decline to age 53, with a plateau to the seventies (the increment observed to age 81 is probably attributable to sampling fluctuation). For Inductive Reasoning the longitudinal gradient peaks at 39, then declines sharply to age 35, with a subsequent plateau. The longitudinal data for these two abilities, once perceptual speed is removed amount to less than 1 SD.

The speed-adjusted age pattern for Number skill is quite similar to that for Verbal Meaning (note that both these abilities would qualify as measures of crystallized intelligence). The cross-sectional data show positive differences until age 67 with a negative trend of 4/10 SD thereafter; the 81-year olds still above those at age 25. The longitudinal gradient has a sharp positive slope until age 46 with moderate increment continuing until age 74; a total gain of approximately 2 SDs. Finally, for Word Fluency, the cross-sectional trend, after adjusting for perceptual speed, is virtually level over the entire age range. The longitudinal data, on the other hand, show sustained increment until age 53, with steep decrement amounting to just under 2 SDs thereafter.

Cross-lagged Relations Between Perceptual Speed and the Primary Mental Abilities

Our final analysis concerns the question whether base level of performance on perceptual speed is predictive of performance on the mental abilities over time, as proposed by Witt and Cunningham (1979). We computed the cross-lags from 1977 to 1984 in our longitudinal sample, with appropriate corrections for differences in reliability and stationarity (Kenny, 1975). As can be seen from Table 2, cross-lags from perceptual speed to abilities and from abilities to perceptual speed are virtually identical. It is only for the cross-lag from Perceptual Speed to Word Fluency that the Pearson-Filon test reaches significance at the 5% level of confidence.

Insert Table 2 about here

Summary and Discussion

We have presented data on cross-sectional and longitudinal age patterns on tests of perceptual speed and for a derived perceptual score latent variable, that suggest average linear age decrement on this ability over the adult age range from 25 to 81 years. Because of negative cohort patterns for more recent cohorts, cross-sectional data actually tend to underestimate the magnitude of the decline. However, examination of individual differences suggests, that the linear decline shown for the total group is not necessarily characteristic of individuals. The fact that stability over seven years on at least one measure of perceptual speed persists for about 75% of individuals assessed until late in life would suggest that individuals do not decline in a linear fashion, but more likely do so in a stairstep manner in response to quantum changes in the underlying physiological or environmental resources. Indeed, knowledge of an individual's age showed little power for predicting drop in perceptual speed.

As could have been expected from these findings, the cross-lagged correlation analysis, provided only marginal support for the Witt and Cunningham (1979) hypothesis of perceptual speed predicting future level of ability performance. Perceptual Speed had predictive power for future performance only the highly speeded measure of Word Fluency.

When we study the effects of partialling out perceptual speed from five primary abilities, we find that age difference and age change patterns for the residual scores are markedly affected. If perceptual speed is removed there seems to be increment into late life for the residualized scores of crystallized abilities, while the decrement slopes for fluid measures are markedly moderated. Partialling out speed or age from the ability relationships results in limited support for Salthouse's (1985) slowing of processing speed model. However, the differential effects of partialling out speed suggests that a single effects model must be questioned, and that differential cohort patterns in underlying resources may further complicate the speed-ability relationship. It should be noted, however, that the analyses pertinent to this model were conducted over our entire data set representing virtually the entire adult age range. Reexamination of the speed-ability relationship for more limited age ranges may therefore require some qualifications of these conclusions.

References

Berg, C., Hertzog, C., & Hunt, E. (1982). Age differences in the speed of mental rotation. Developmental Psychology, 18, 95-107.

Birren, J. E., Woods, A. M., & Williams, M. V. (1980). Behavioral slowing with age: Causes organization and consequences. In L. W. Poon (Ed.), Aging in the 1980's (pp. 293-308). Washington, DC: American Psychological Association.

Cunningham, W. R. (In press). Intellectual abilities and age. In K. W. Schaie (Ed.), Annual Review of Gerontology and Geriatrics, Vol. 7. New York: Springer Publishing Co.

Dudek, F. J. (1979). The continuing misinterpretation of the standard error of measurement. Psychological Bulletin, 86, 335-337.

Ekstrom, R. B., French, J. W., Harman, H., & Derman, D. (1976). Kit of factor-referenced cognitive tests (Rev. ed.). Princeton, NJ: Educational Testing Srvice.

Kenny, D. A. (1975). Cross-lagged panel correlation: A test for spuriousness. Psychological Bulletin, 82, 997-903.

Salthouse, T. A. (1985a). A theory of cognitive aging. Amsterdam: North-Holland.

Salthouse, T. A. (1985b). Speed of behavior and its implications for cognition. In J. E. Birren & K. W. Schaie (Eds.), Handbook of the psychology of aging (2nd. ed., pp. 400-426). New York: Van Nostrand Reinhold.

Schaie, K. W. (1977). Quasi-experimental designs in the psychology of aging. In J. E. Birren & K. W. Schaie (Eds.), Handbook of the psychology of aging (pp. 39-58). New York: Van Nostrand Reinhold.

Schaie, K. W. (1983). The Seattle Longitudinal Study: A 21-year exploration of psychometric intellligence in adulthood. In K. W. Schaie (Ed.), Longitudinal studies of adult psychological development (pp. 64-135). New York: Guilford.

Schaie, K. W. (1985). Manual for the Schaie-Thurstone Test of Adult Mental Abilities (STAMAT). Palo Alto, CA: Consulting Psychologists Press.

Schaie, K. W. (In press a). Variability in cognitive function in the elderly: Implications for social participation. In A. Woodhead (Ed.), Phenotypic variation in populations: Relevance to risk assessment. New York: Plenum.

Schaie, K. W. (In press b). Internal validity threats in studies of adult cognitive development. In M. L. Howe & C. J. Brainard (Eds.), Cognitive development in adulthood: Progress in cognitive development research. New York: Springer-Verlag.

Schaie, K. W. (In press c). The impact of research methodology on theory-building in the developmental sciences. In J. E. Birren & V. L. Bengtson (Eds.), Theories of aging: Psychological and social perspectives on time, self and society. New York: Springer Publishing Co.

Schaie, K. W., Willis, S., Jay, G., & Shapur, H. (1987). Equivalence of Primary Abilities factor structure across samples ranging from 25 to 81 years of age. Unpublished manuscript, Penn State University.

Thurstone, L. L., & Thurstone, T. G. (1949). Examiner manual for the SRA Primary Mental Abilities Test. Chicago: Science Research Associates.

Witt, S. J., & Cunningham, W. R. (1979). Cognitive speed and subsequent intellectual development: A longitudinal investigation. Journal of Gerontology, 34, 540-546.

Author Note

This research was supported by a research grant (AG04770-03) from the National Institute of Aging. I would like to acknowledge the cooperation of members and staff of the Group Health Cooperative of Puget Sound, the source of our subject population, and the competent technical help of Ann O'Hanlon and Ann Gruber-Baldini who assisted in the data analyses.

Table 1. Raw and Partial Correlations Between Age, Speed and Primary Mental Abilities

	Speed/ Ability	Age Part. Out	Age/ Ability	Speed Part. Out
	1977 Study (N = 612)			
Verbal Meaning	.80	.50	.37	.00
Spatial Orientation	.49	.10	.41	.03
Inductive Reasoning	.71	.25	.53	.03
Number	.36	.14	.09	.02
Word Fluency	.47	.16	.23	.00
	1984 Study (N = 628)			
Verbal Meaning	.86	.50	.51	.00
Spatial Orientation	.55	.10	.47	.02
Inductive Reasoning	.74	.21	.18	.03
Number	.47	.21	.18	.03
Word Fluency	.53	.18	.33	.00

Table 2. Crosslag Coefficients Between Perceptual Speed and the Primary Mental Abilities from 1977 to 1984 (N = 838) Corrected for Differences in Reliability and Stationarity

	PERCEPTUAL SPEED TO ABILITY	ABILITY TO PERCEPTUAL SPEED
VERBAL MEANING	.71	.70
SPATIAL ORIENTATION	.47	.53
INDUCTIVE REASONING	.68	.69
NUMBER	.38	.38
WORD FLUENCY	.50*	.43

*Significantly greater crosslag at or beyond the 5% level of confidence.

Figure Captions

Figure 1. Cross-sectional age differences for the Identical Pictures and Finding A's tests.

Figure 2. Cumulative cohort differences for the Identical Pictures and Finding A's tests.

Figure 3. Estimated longitudinal age changes for the Finding A's and Identical Pictures tests corrected for attrition and practice.

Figure 4. Cross-sectional age differences and longitudinal age changes corrected for attrition and practice for the Perceptual Speed factor scores.

Figure 5. Scattergrams showing distribution of within subject changes from 1977 to 1984 with cohort membership for the Identical Pictures and Finding A's tests.

Figure 6. Proportion of subjects remaining stable or showing increased performance over seven years for the Identical Pictures and Finding A's tests.

Figure 7. Proportion of subjects remaining stable or increasing significantly over seven years on the factor score for Perceptual Speed.

Figure 8. Cross-sectional data residualized for perceptual speed and estimates of average cross-sectional and longitudinal age changes after residualizing for speed and correcting for attrition and practice for the primary mental ability of Verbal Meaning.

Figure 9. Cross-sectional data residualized for perceptual speed and estimates of average cross-sectional and longitudinal age changes after residualizing for speed and correcting for attrition and practice for the primary mental ability of Spatial Orientation.

Figure 10. Cross-sectional data residualized for perceptual speed and estimates of average cross-sectional and longitudinal age changes after residualizing for speed and correcting for attrition and practice for the primary mental ability of Inductive Reasoning.

Figure 11. Cross-sectional data residualized for perceptual speed and estimates of average cross-sectional and longitudinal age changes after residualizing for speed and correcting for attrition and practice for the primary mental ability of Number.

Figure 12. Cross-sectional data residualized for perceptual speed and estimates of average cross-sectional and longitudinal age changes after residualizing for speed and correcting for attrition and practice for the primary mental ability of Word Fluency.

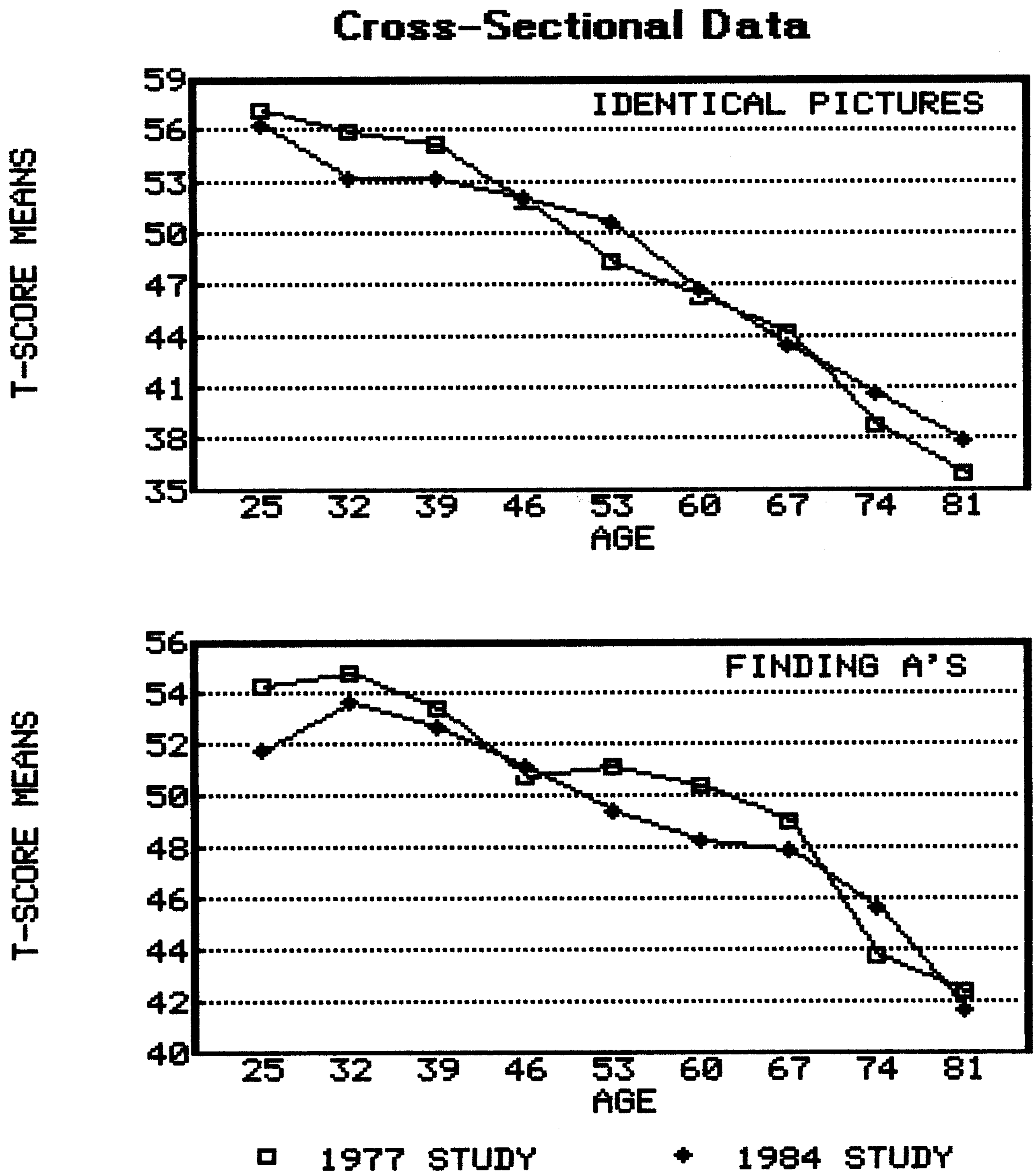
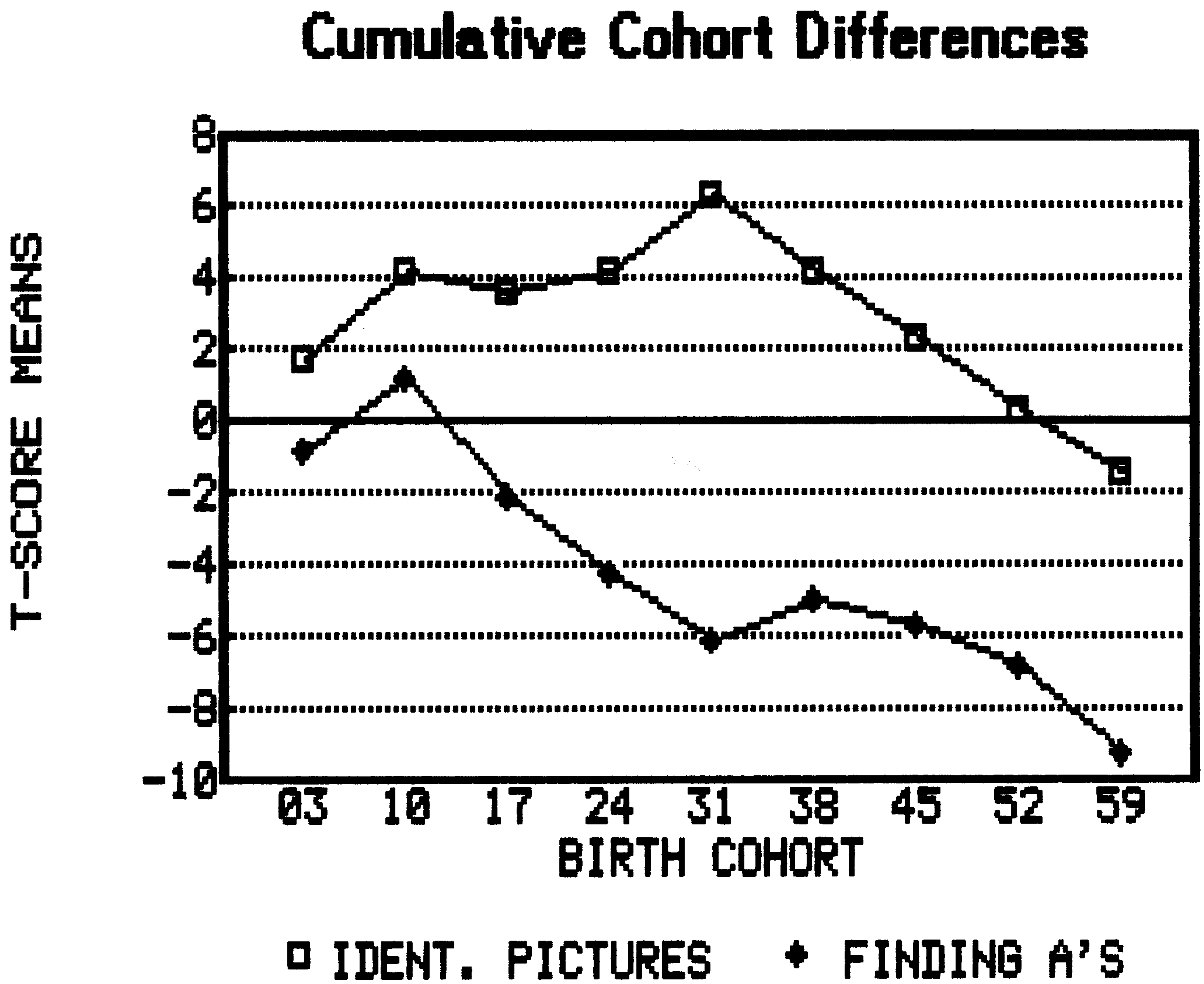

Cross-Sectional Data
IDENTICAL PICTURES
T-SCORE MEANS
59
56
53
50
47
44
41
38
35
25 32 39 46 53 60 67 74 81
AGE
FINDING A'S
T-SCORE MEANS
56
54
52
50
48
46
44
42
40
25 32 39 46 53 60 67 74 81
AGE
1977 STUDY
1984 STUDY

FIGURE 1.



Cumulative Cohort Differences
T-SCORE MEANS
8
6
4
2
0
-2
-4
-6
-8
-10
03 10 17 24 31 38 45 52 59
BIRTH COHORT
IDENT. PICTURES
FINDING A'S

FIGURE 2.

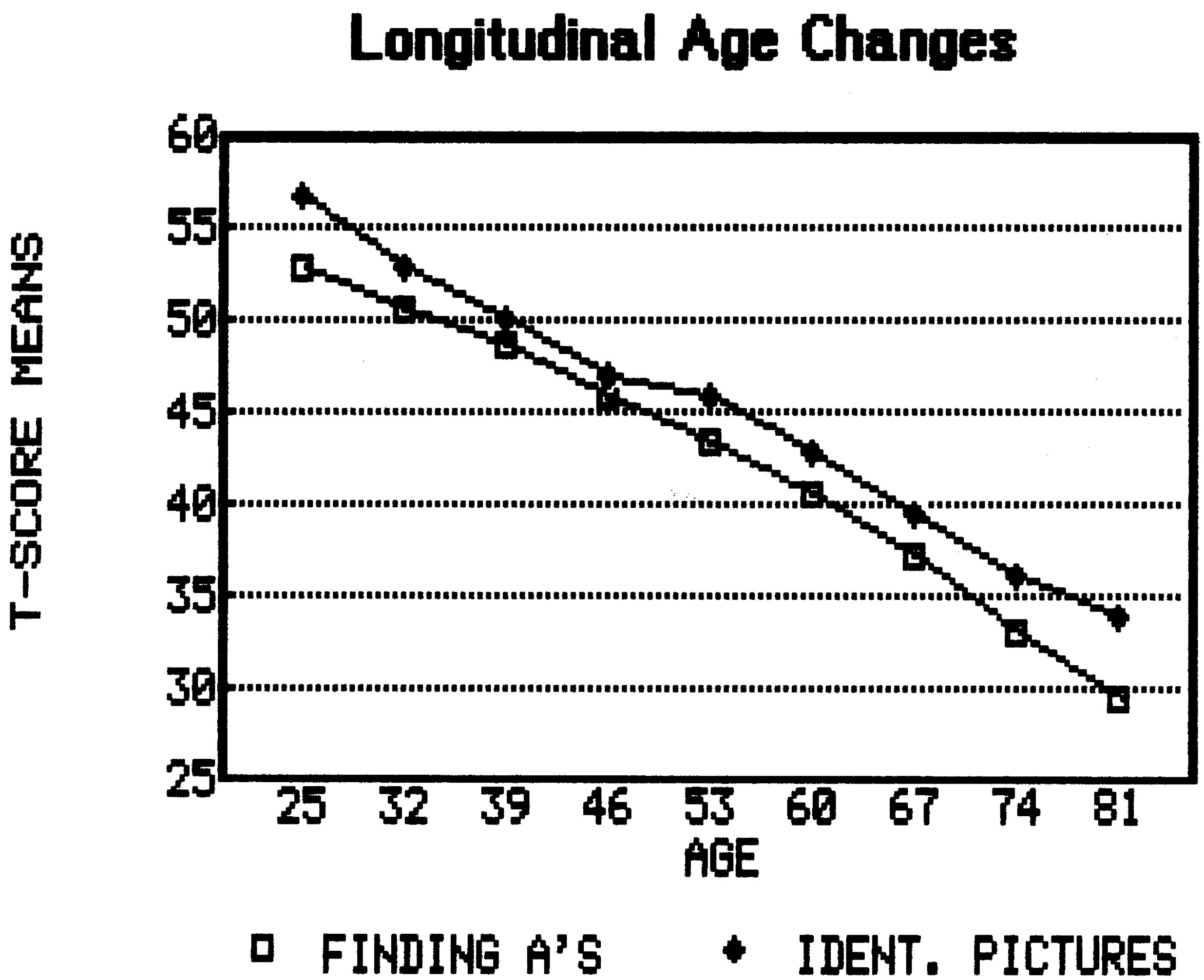

Longitudinal Age Changes
T-SCORE MEANS
60
55
50
45
40
35
30
25
25
32
39
46
53
60
67
74
81
AGE
FINDING A'S
IDENT. PICTURES

FIGURE 3.

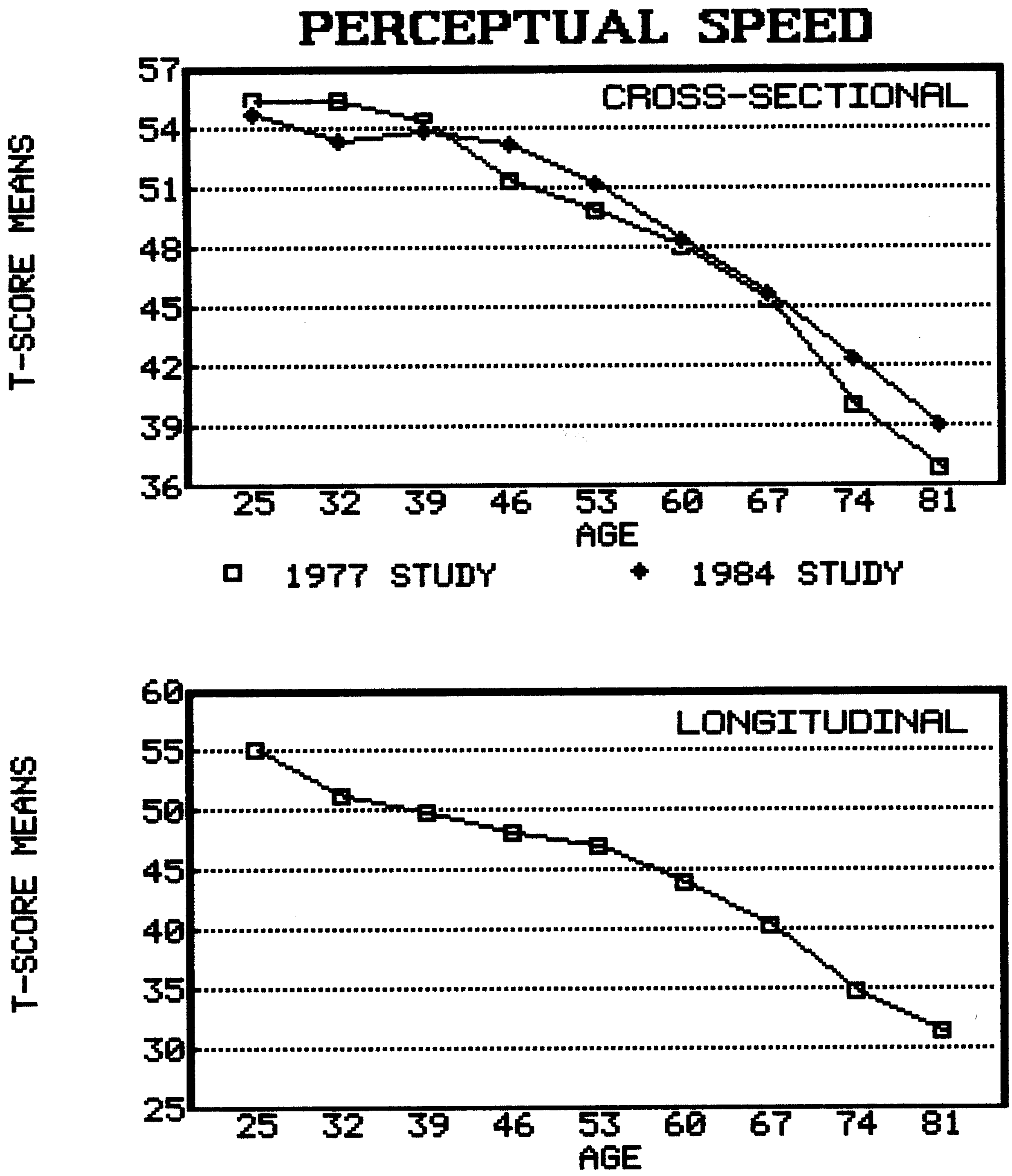

PERCEPTUAL SPEED
T-SCORE MEANS
CROSS-SECTIONAL
57
54
51
48
45
42
39
36
25 32 39 46 53 60 67 74 81
AGE
1977 STUDY
1984 STUDY
T-SCORE MEANS
LONGITUDINAL
60
55
50
45
40
35
30
25
25 32 39 46 53 60 67 74 81
AGE

FIGURE 4.

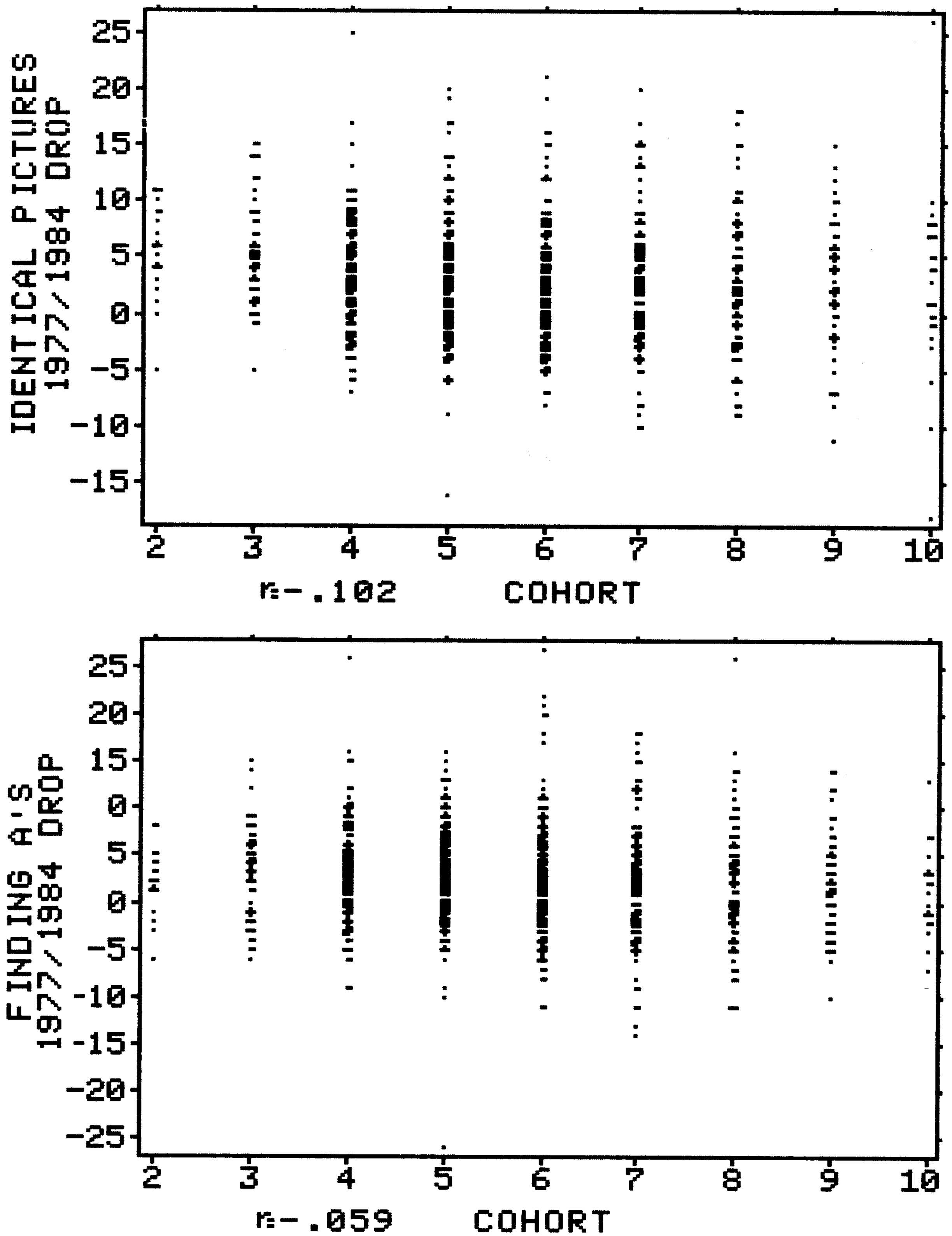

IDENTICAL PICTURES 1977/1984 DROP
25
20
15
10
5
0
-5
-10
-15
2
3
4
5
6
7
8
9
10
r=-.102
COHORT
FINDING A'S 1977/1984 DROP
25
20
15
0
5
0
-5
-10
-15
-20
-25
2
3
4
5
6
7
8
9
10
r=-.059
COHORT

FIGURE 5.

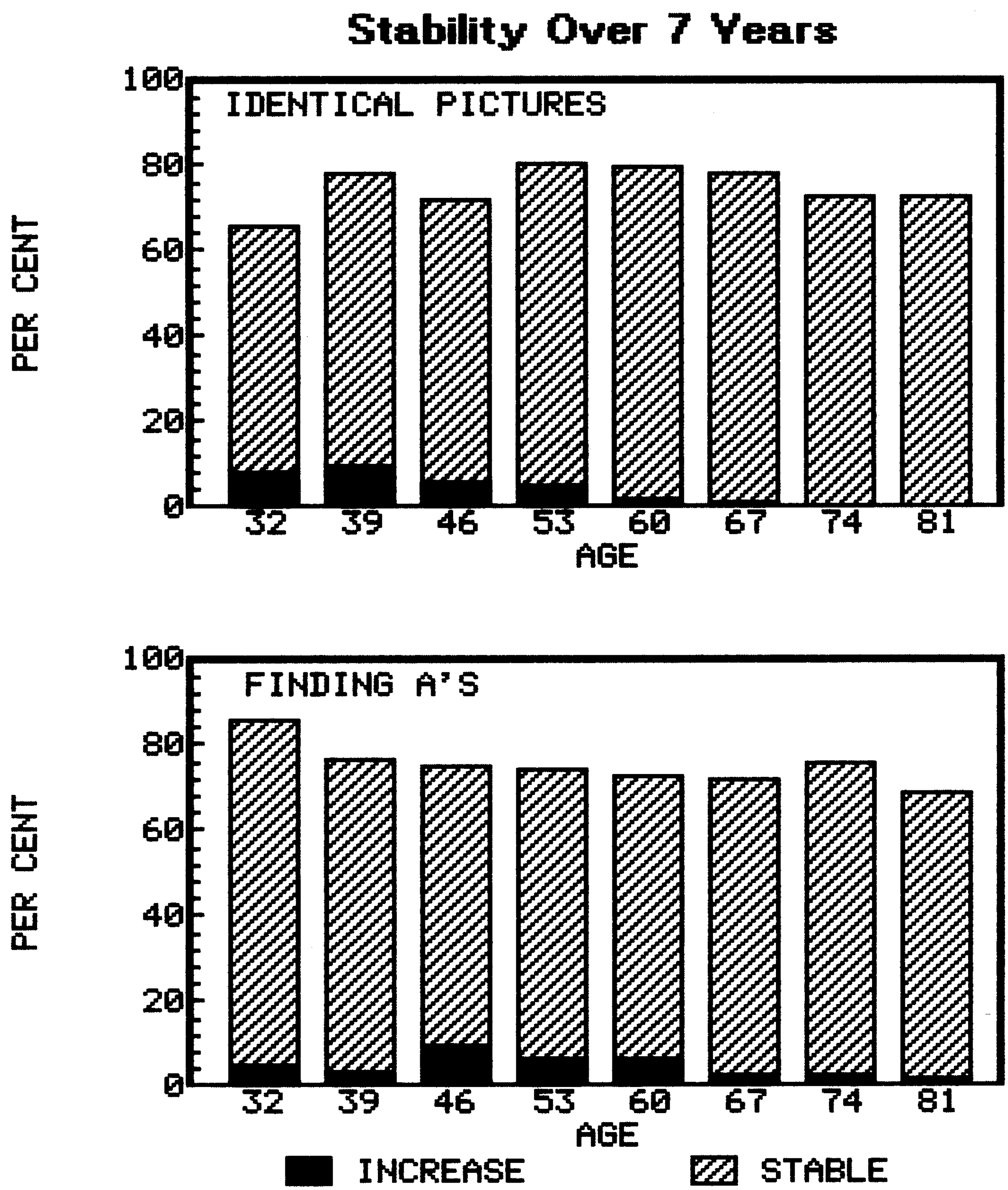

Stability Over 7 Years
IDENTICAL PICTURES
PER CENT
100
80
60
40
20
0
32
39
46
53
60
67
74
81
AGE
FINDING A'S
PER CENT
100
80
60
40
20
0
32
39
46
53
60
67
74
81
AGE
INCREASE
STABLE

FIGURE 6.

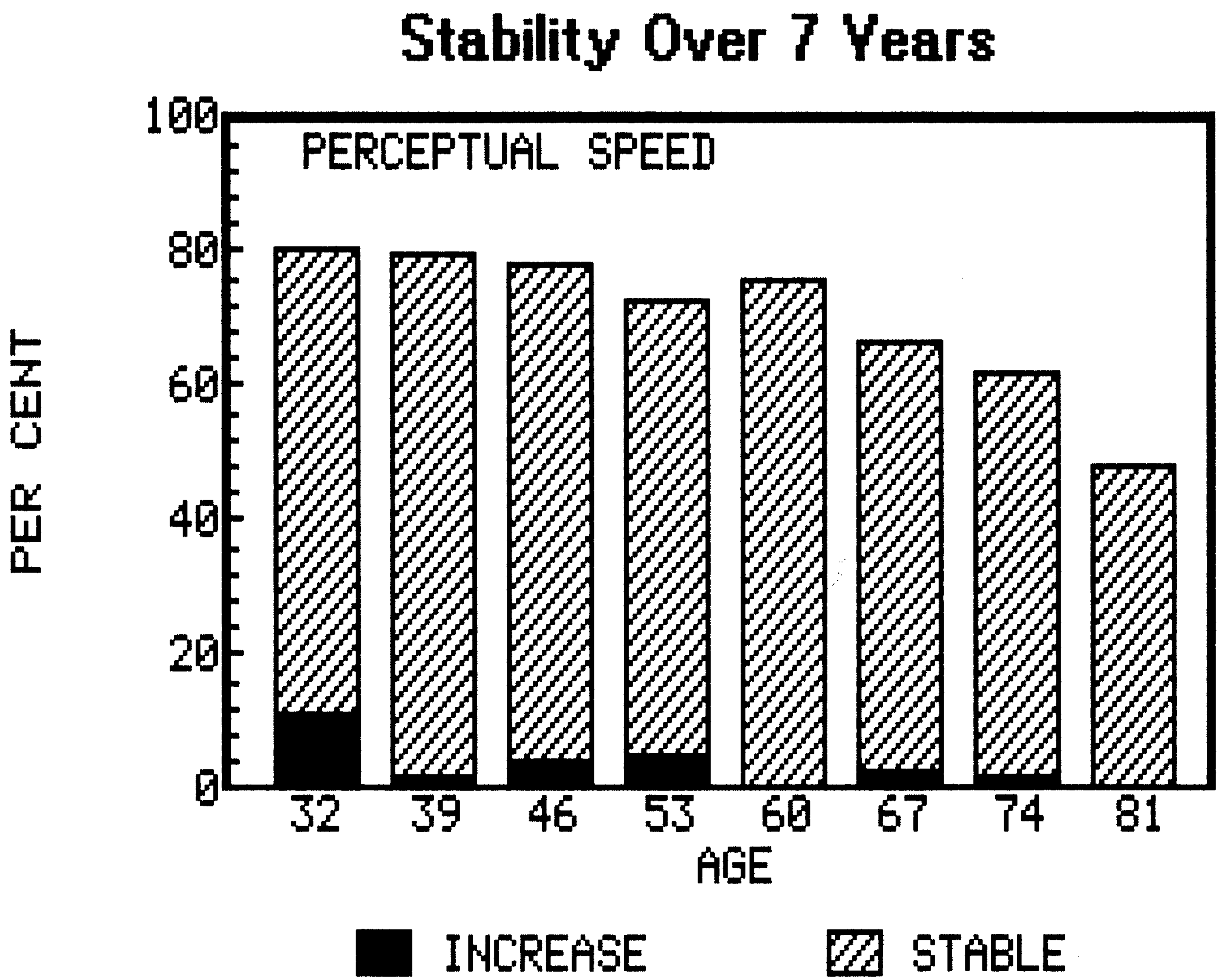
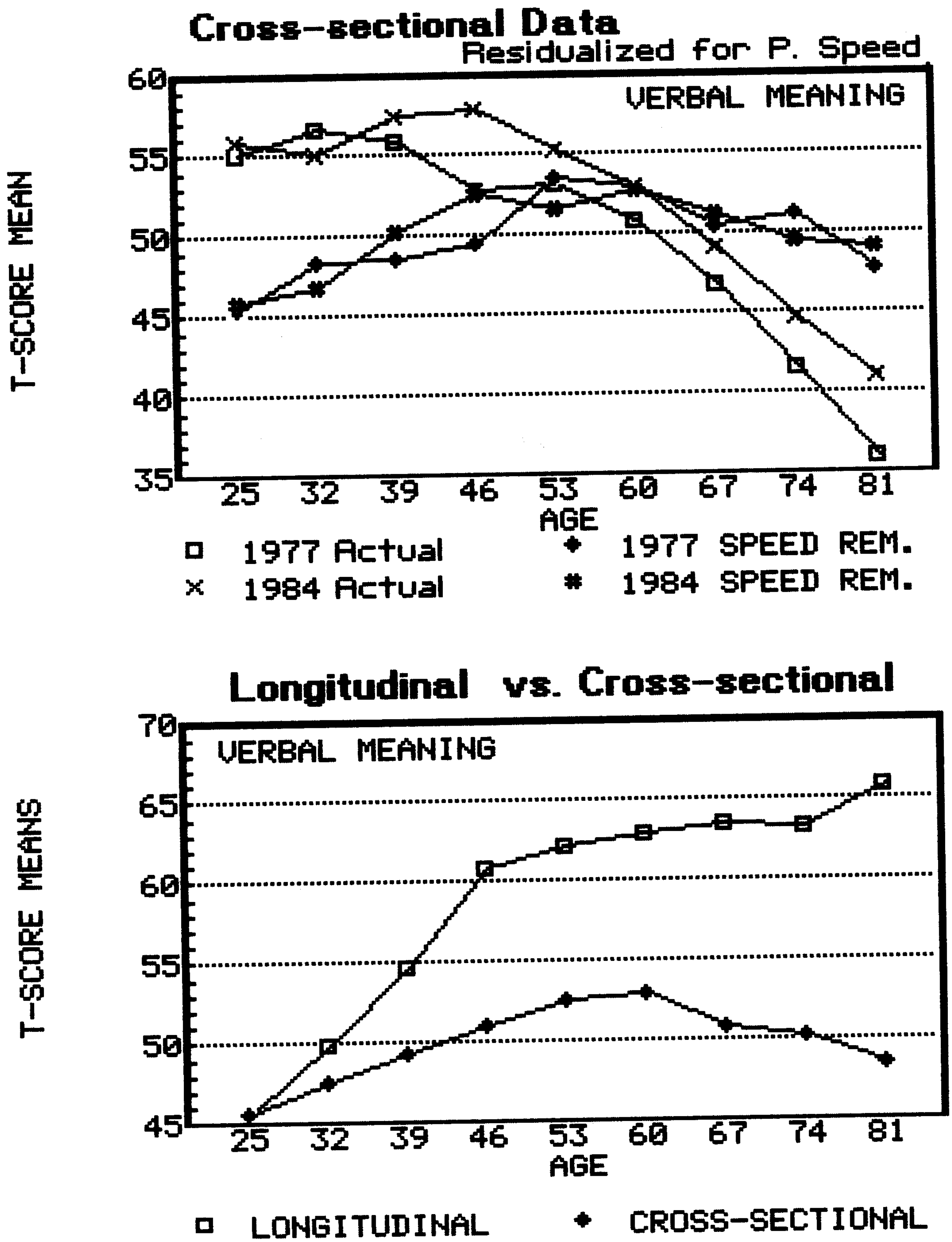
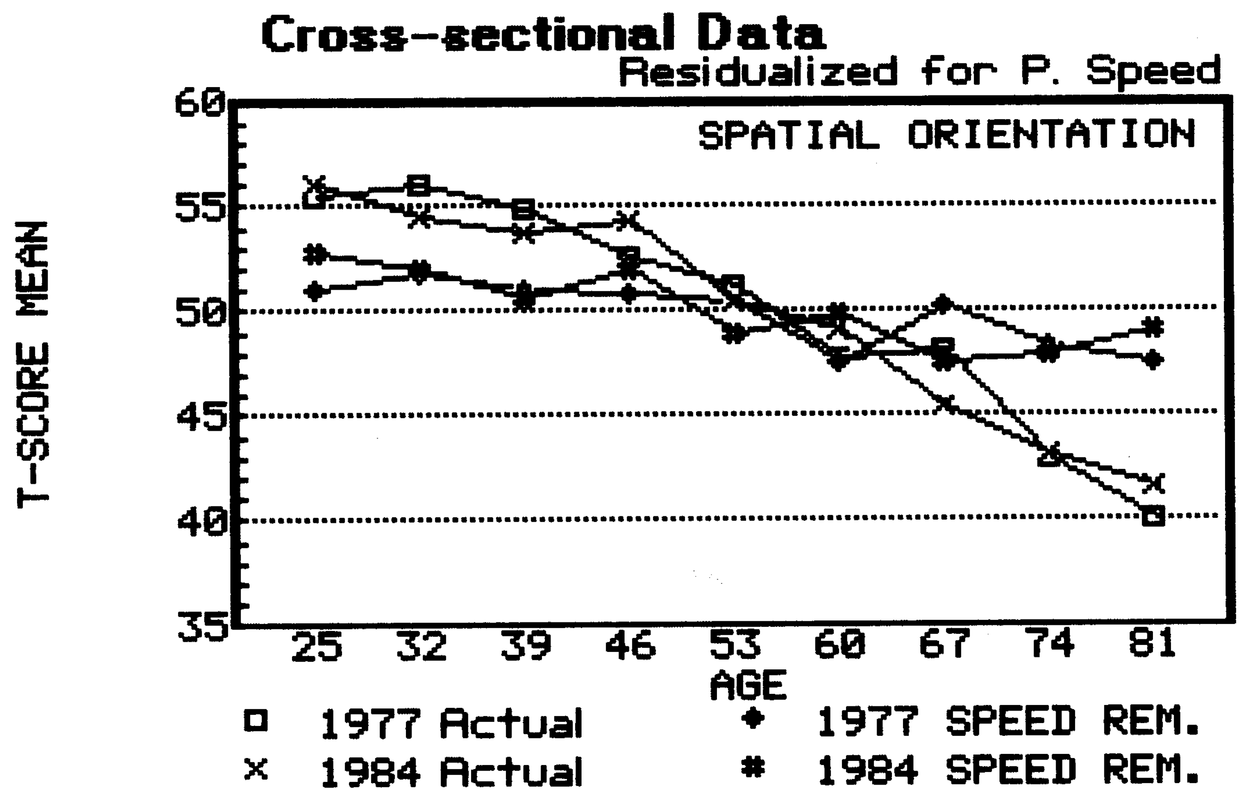

Stability Over 7 Years
PERCEPTUAL SPEED
PER CENT
100
80
60
40
20
0
32
39
46
53
60
67
74
81
AGE
INCREASE
STABLE

FIGURE 7.

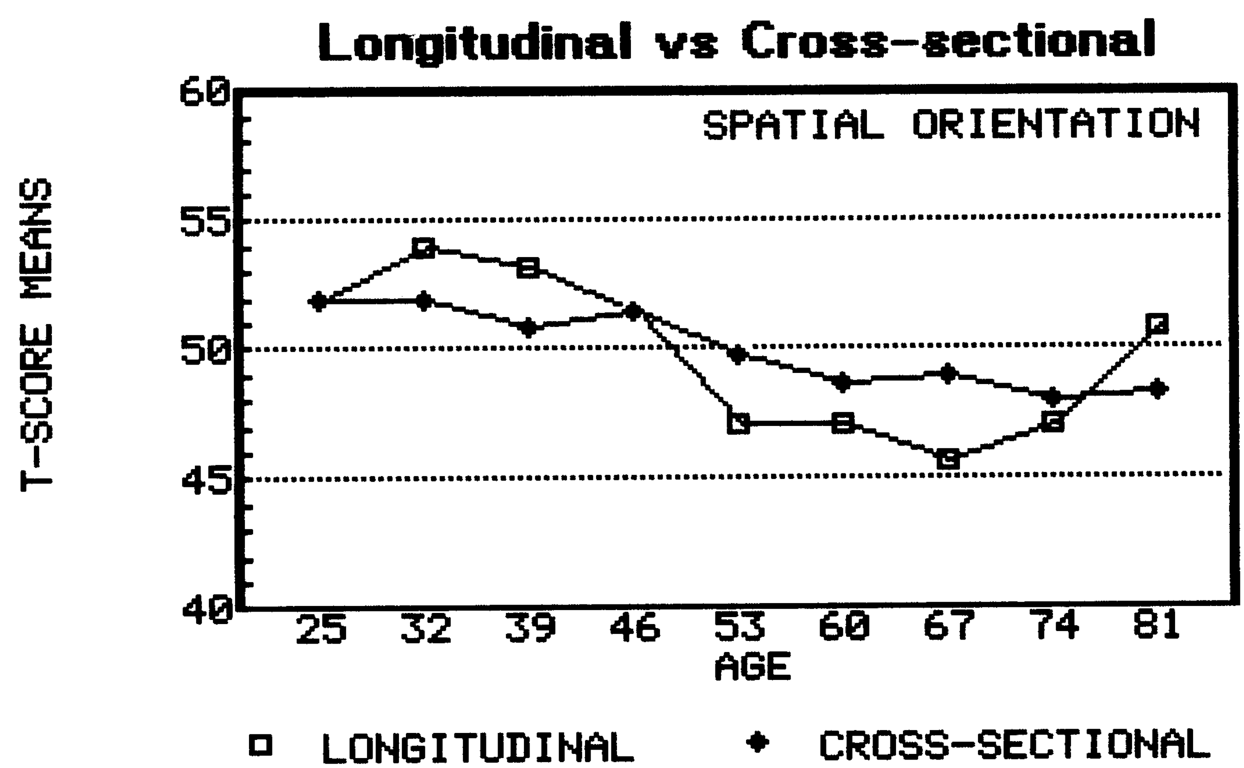


Cross-sectional Data
Residualized for P. Speed
VERBAL MEANING
T-SCORE MEAN
60
55
50
45
40
35
25 32 39 46 53 60 67 74 81
AGE
1977 Actual
1984 Actual
1977 SPEED REM.
1984 SPEED REM.
Longitudinal vs. Cross-sectional
VERBAL MEANING
T-SCORE MEANS
70
65
60
55
50
45
25 32 39 46 53 60 67 74 81
AGE
LONGITUDINAL
CROSS-SECTIONAL

FIGURE 8.

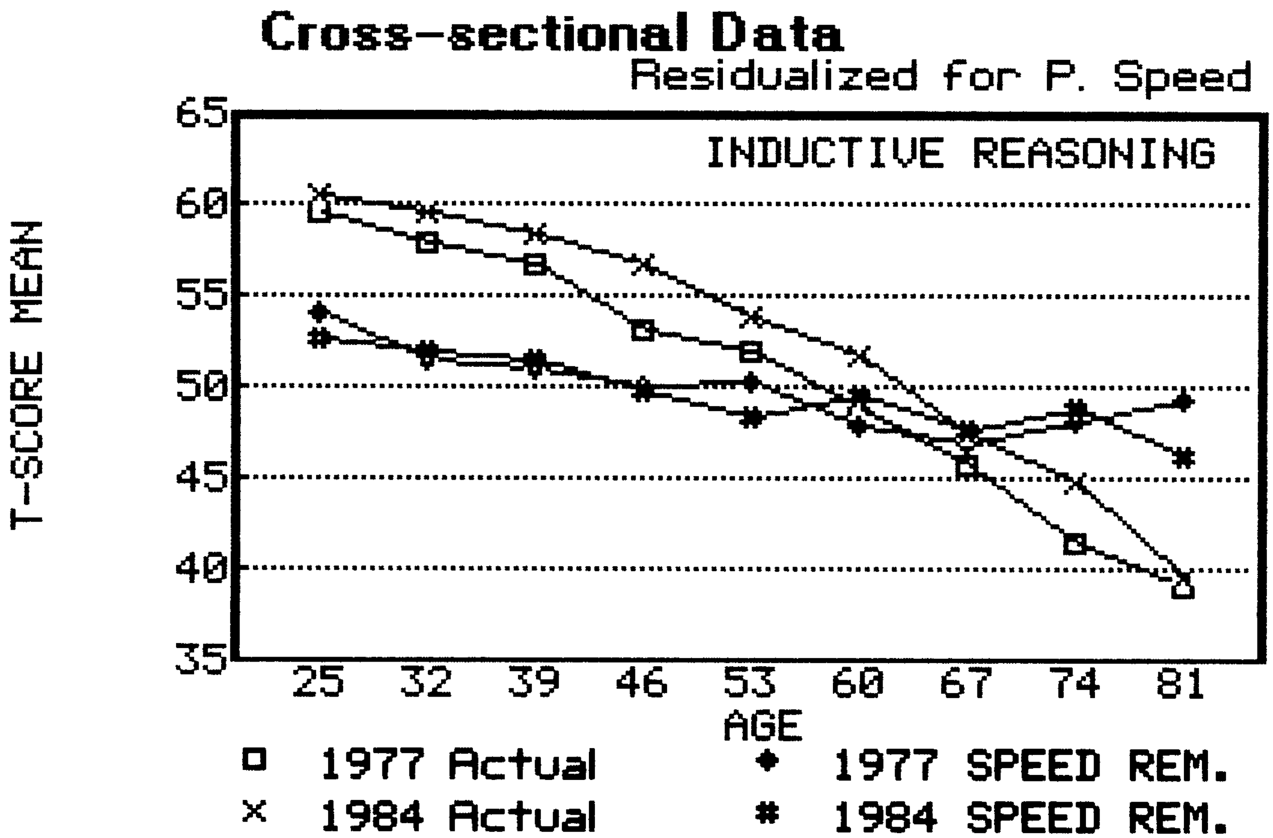


Cross-sectional Data
Residualized for P. Speed
SPATIAL ORIENTATION
T-SCORE MEAN
60
55
50
45
40
35
25 32 39 46 53 60 67 74 81
AGE
1977 Actual
1984 Actual
1977 SPEED REM.
1984 SPEED REM.



Longitudinal vs Cross-sectional
SPATIAL ORIENTATION
T-SCORE MEANS
60
55
50
45
40
25 32 39 46 53 60 67 74 81
AGE
LONGITUDINAL
CROSS-SECTIONAL

FIGURE 9.


Cross-sectional Data
Residualized for P. Speed
INDUCTIVE REASONING
T-SCORE MEAN
65
60
55
50
45
40
35
25 32 39 46 53 60 67 74 81
AGE
1977 Actual
1984 Actual
1977 SPEED REM.
1984 SPEED REM.

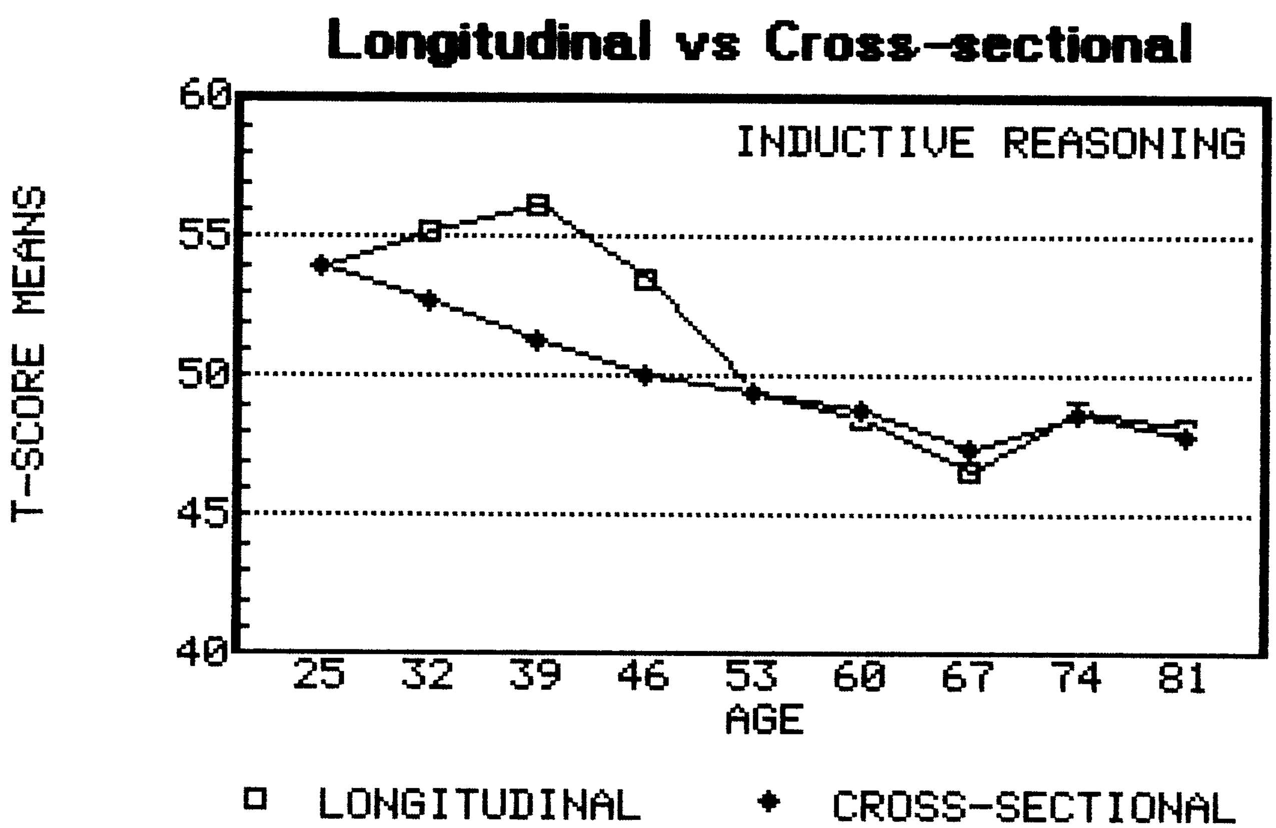
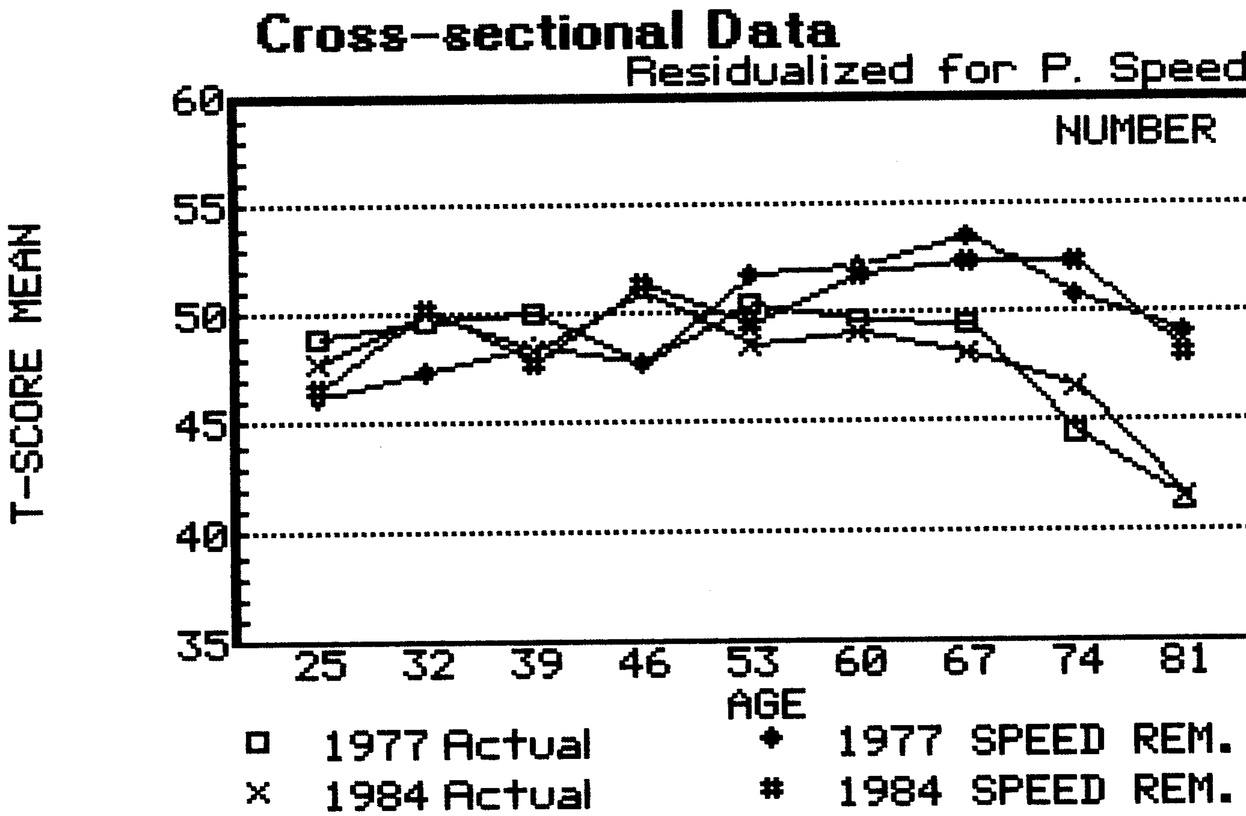
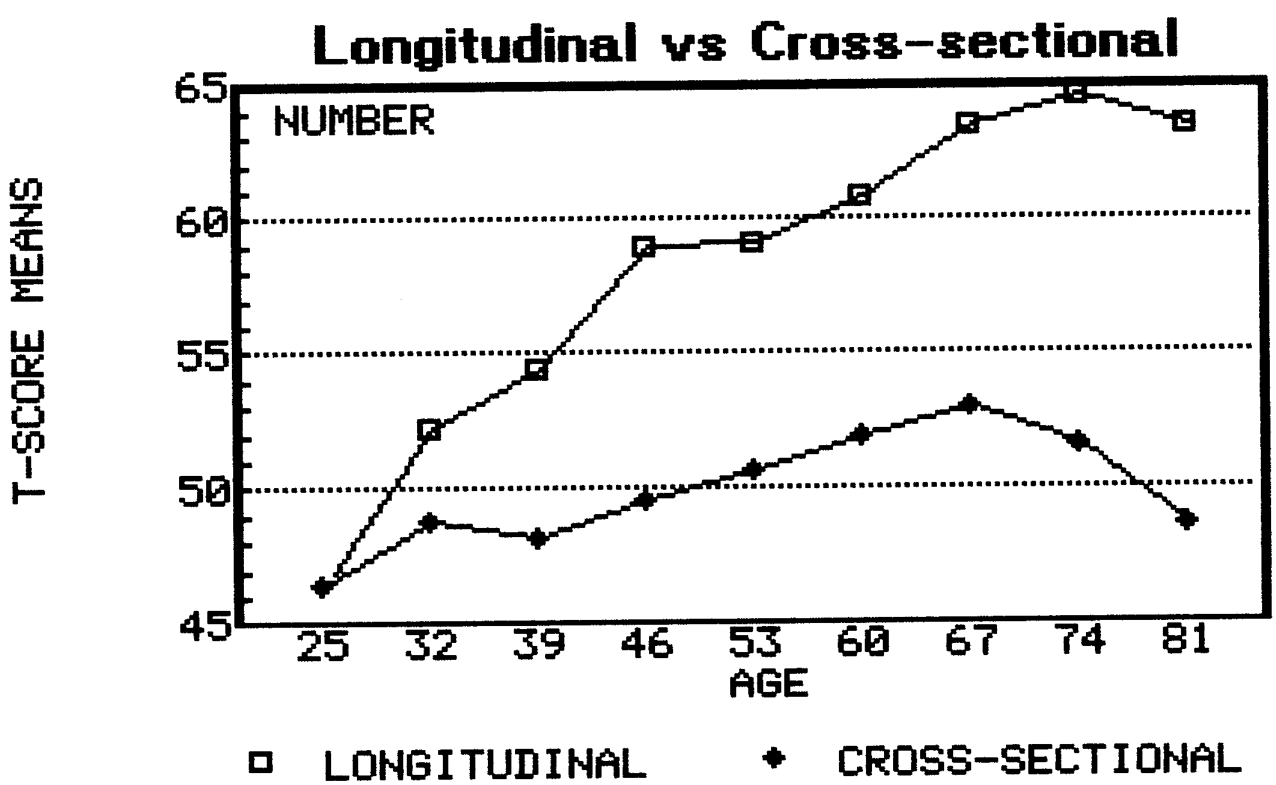

Longitudinal vs Cross-sectional
INDUCTIVE REASONING
T-SCORE MEANS
60
55
50
45
40
25 32 39 46 53 60 67 74 81
AGE
LONGITUDINAL
CROSS-SECTIONAL

FIGURE 10.



Cross-sectional Data
Residualized for P. Speed
NUMBER
T-SCORE MEAN
60
55
50
45
40
35
25 32 39 46 53 60 67 74 81
AGE
1977 Actual
1984 Actual
1977 SPEED REM.
1984 SPEED REM.



Longitudinal vs Cross-sectional
NUMBER
T-SCORE MEANS
65
60
55
50
45
25 32 39 46 53 60 67 74 81
AGE
LONGITUDINAL
CROSS-SECTIONAL

FIGURE 11.

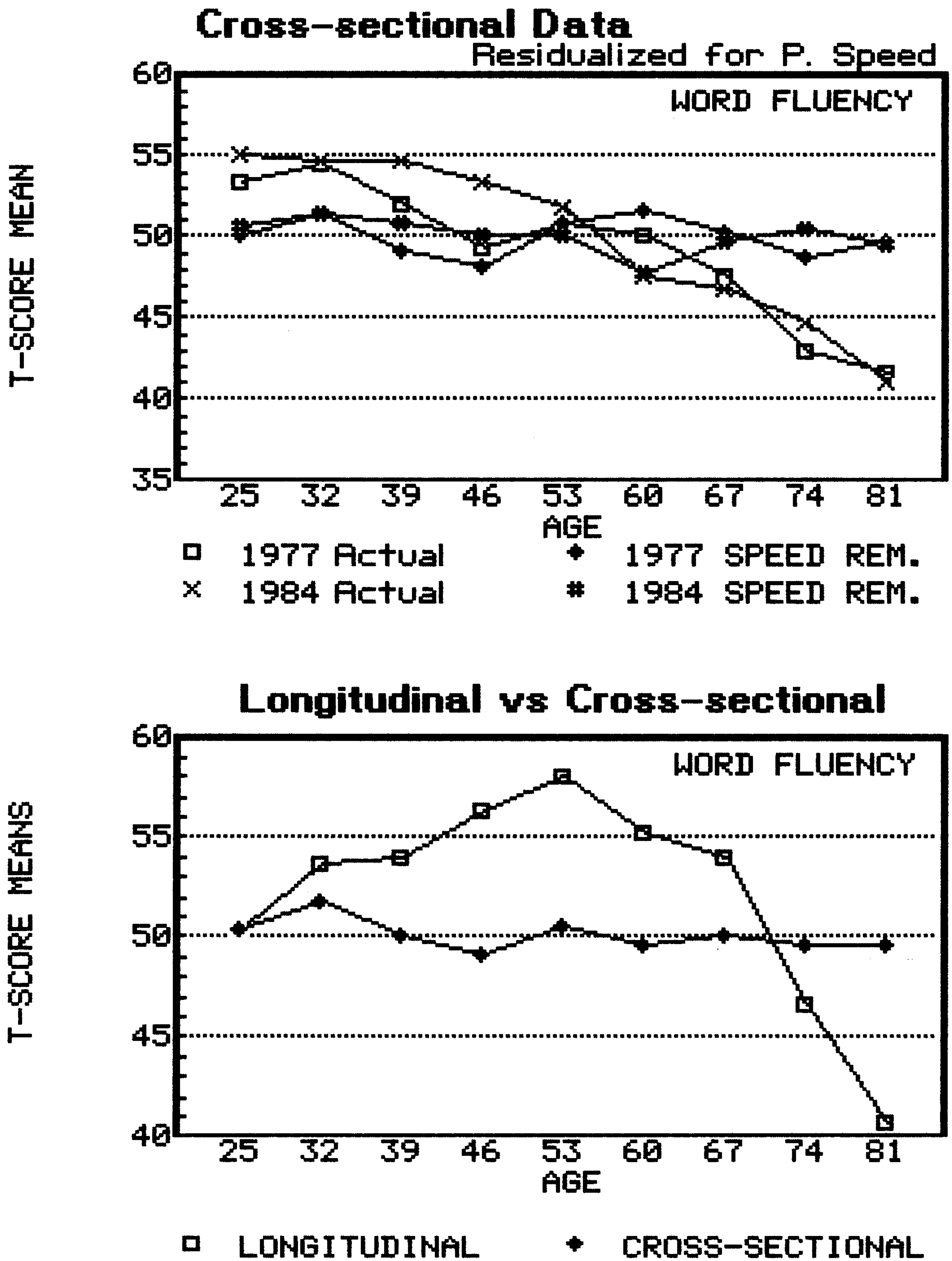

Cross-sectional Data
Residualized for P. Speed
WORD FLUENCY
T-SCORE MEAN
60
55
50
45
40
35
25 32 39 46 53 60 67 74 81
AGE
1977 Actual
1984 Actual
1977 SPEED REM.
1984 SPEED REM.
Longitudinal vs Cross-sectional
WORD FLUENCY
T-SCORE MEANS
60
55
50
45
40
25 32 39 46 53 60 67 74 81
AGE
LONGITUDINAL
CROSS-SECTIONAL

FIGURE 12.