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ABSTRACT

Two studies examined modifiability in intellectual functioning in older adults. The fluid-crystallized theory provided a theory base for the research. (Fluid intelligence follows a normative decline through adulthood, while crystallized intelligence remains stable or even increases.) In the first study thirty subjects (average age 69.2) participated in eight practice (retest) sessions, at which they were administered two tests involving figural relations and induction. Although no external feedback was given during retest sessions, subjects exhibited steady gains between consecutive trials. In the second study fifty-eight subjects (average age fifty-nine) participated in five training sessions on strategies for solving figural relations-type problems. Maintenance of training effects over three posttest periods and generalizability of training across seven measures were used to assess the training. Mean scores for the training group were larger than the control's scores for all seven measures at each posttest occasion. Findings that subjects possessed or were able to generate cognitive strategies useful in improving their fluid intellectual performance and that training effects extended beyond the target ability imply the potential for modifiability in intellectual functioning in middle and later adulthood and suggest that comprehensive theories of intelligence including both potential and normative dimensions of functioning may be particularly important in adulthood. (MN)

Fluid and Crystallized Intelligence--Theory and Research in Later Adulthood

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Fluid and Crystallized Intelligence--Theory and Research in Later Adulthood

Introduction

The major objective of the research I will be discussing has been to examine modifiability in intellectual functioning in adulthood, particularly in later adulthood. It was our position that a theory-guided approach would be particularly useful in examining this issue, and we identified the fluid-crystallized theory as providing a relevant theory base for such research.

Perhaps some brief comments on theory and research on gerontological intelligence would provide a useful perspective (see also reviews by Botwinick, 1977; Horn, 1978; Schaie, 1979). As noted by others in the past, many of our most well known models of psychometric intelligence provide little perspective on developmental change in intellectual functioning across the total lifespan (Baltes & Willis, 1979); at best, they focus on developmental change in the first third of the lifespan. Thus, in comparison with the magnitude of research in childhood, adult intellectual development--including the nature and range of possible developmental change and modifiability--remains relatively unexplored. The limited empirical research on adult intelligence, most conducted within a cross-sectional design, has suggested three themes: 1) Emphasis on individual differences; 2) Examination of normative patterns of intellectual development; and 3) Description of differential patterns of developmental change for various abilities (e.g., verbal, space, etc.). Historically, within the psychometric approach, there has been a predominate emphasis on individual differences. This emphasis in part relates to the use of factor analytic methodology. Whereas in childhood individual differences have been associated with variables such as cognitive style, socio-economic status, sex, and instructional strategies, as well as chronological age, in the study of adult intelligence chronological age has been the primary variable associated with individual differences in intellectual change. As a result, most descriptive research has focused on what was assumed to be age-related decline in intellectual functioning. However, recent longitudinal research such as that conducted by Schaie (1979) suggests that a host of individual difference variables (e.g., cohort, educational level, life style) other than chronological age may be critical to an understanding of intellectual change in adulthood.

A second theme has focused on differential change in adult intellectual functioning (Botwinick, 1977). That is, different patterns of change have been identified for various primary mental abilities. Cross sectional research has suggested a pattern of stability or even increment across the adult years for many verbally-oriented abilities. In contrast, abilities involving psychomotor or speed components as well as novel abstract reasoning show a pattern of earlier decline. Such differential, multidirectional patterns of change in intellectual functioning has led to the predominance of a differential approach to intelligence in the adult years rather than consideration of a global or unitary ("g") perspective of intelligence as some have taken in childhood.

A third theme was, what we considered to be, an almost exclusive concern with a descriptive, normative approach to adult intelligence. In both child and adult psychometric models of intelligence, the primary emphasis has been on studying the individuals average level of functioning or on describing the normative pattern of intellectual development. This descriptive, normative approach to the study of intelligence in childhood has been complemented by cognitive intervention and experimental, manipulative research examining the conditions and range of modifiability in intellectual performance. It would appear that, as advocated by Cronbach, these two complementary approaches (correlational-descriptive, experimental-explanatory) have contributed to more comprehensive theories and models of intellectual functioning in the early part of the lifespan. In contrast, little systematic experimental, manipulative research has been conducted to examine the range of modifiability in adult intellectual performance. Given the significant impact of broad environmental factors such as sociocultural change (as suggested by Schaie's research), it would appear particularly important to examine the range of variability in intellectual functioning which could be effected by experimental paradigms.

We believed it important to conduct such experimental, manipulative research within a theory-guided framework. The fluid-crystallized (Gf/Gc) theory appeared to provide a useful rudimentary theory base for such research. A particular strength of the fluid-crystallized theory was its life-span perspective of developmental change. According to the theory, two broad dimensions of intelligence exhibit differential patterns of normative change across the lifespan. Fluid intelligence (Gf) is said to develop early in the life-span and to follow a normative pattern of gradual decline through adulthood, while crystallized intelligence (Gc) follows a normative pattern of stability or even increment across much of adulthood. As with most psychometric theories, it appeared that the primary emphasis within the Gf/Gc theory has been on *individual differences* in intellectual functioning and chronological age has been the major variable examined in relation to individual differences in intellectual change in adulthood. Moreover, the theory had focused largely on *normative* or average levels of intellectual change in adulthood. A decline in fluid and relative stability in crystallized intelligence had been suggested as normative patterns of long term change; however, in several manuscriptis the theory developers (Horn, 1978; Cattell, 1971) had suggested that such changes may not be universal and apply to all individuals.

It was our perception that little prior empirical research of an experimental nature had been conducted within the theory regarding adult intellectual functioning. Nor had the theory itself dealt extensively or critically with the issue of intraindividual modifiability in intellectual functioning, particularly modifiability in intellectual performance through short-term intervention (training) efforts (see Horn, 1972). Thus, an experimental examination of the range and conditions of modifiability in intellectual functioning, particularly fluid intelligence, was seen as contributing to a more comprehensive model of adult intelligence. The program of short-term experimental cognitive intervention research to be reported was not perceived as a test of the existing fluid-crystallized theory per se. Our emphasis on examining the range of short-term modifiability in fluid performance does not negate the possibility that a normative pattern of decline in fluid intellectual functioning could occur under certain circumstances. Nor did we interpret the theory to necessarily suggest that such decline was irreversible, although with the heavy emphasis on neurological antecedents of fluid intelligence (Horn, 1970; Horn & Cattell, 1967), some readers might reach this conclusion. Rather, it was our position that an experimental as well as normative approach to the study of intellectual aging should be undertaken, as had proved fruitful for earlier portions of the lifespan. Our understanding of normative patterns of intellectual functioning in later adulthood must also be examined in relation to the range of modifiability experimentally producable. Such a perspective may provide useful information regarding potential as well as a normative patterns of aging.

An Examination of Intellectual Plasticity (Variability) in Later Adulthood

In this paper two studies will be reported briefly which are part of an ongoing research program aimed at examining the modifiability of intellectual performance in later adulthood through a cognitive training paradigm.[1] A series of short-term longitudinal training studies focusing on several abilities representing fluid intelligence are being conducted. Within the Cattell-Horn theory of fluid-crystallized intelligence, fluid intelligence is conceived as one of two general dimensions of intelligence, exhibiting a normative pattern of decline in later adulthood (Horn & Cattell, 1967; Cattell, 1971). Our training research seeks to examine the range of modifiability which can be experimentally produced for component fluid abilities and, thus, to assess the modifiability of normative decline in fluid intellectual performance in the elderly.

In the first study to be reported, we examined,the effect of practice (retest) on the range of variability in intellectual performance. Such a study explored intellectual variability under minimal intervention conditions; subjects participated in multiple retest sessions with no instruction on cognitive strategies and no feedback regarding correctness of response. In the second study, subjects received training on cognitive strategies required in solution of the target fluid ability tasks. Training effectiveness was assessed with regard to both durability (maintenance) of training effects and transfer to a theory-based pattern of ability measures.

Research on retest-practice effects. Thirty older subjects ($\bar{X}$ age = 69.2 years, SD = 5.18) participated in eight one-hour retest sessions (Hofland, Willis, & Baltes, Note 1). At each retest session, subjects were administered under standard testing conditions two measures, representing the two fluid abilities of Figural Relations and Induction. The Culture Fair test (Scale 2 and Power Matrices Scale 3; Cattell & Cattell, 1957) was identified from previous research (Cattell, 1971) to represent the Figural Relations ability; the Induction ability was marked by an Induction Composite test including Letter Sets (Ekstrom, French, Harman, & Derman, 1976) Number Series and Letter

Series (Thurstone, 1962) tests. No external feedback regarding correctness of responses was given during the retest sessions.

The mean percentage of correct solutions for each measure was computed for each of the eight retest sessions and is shown graphically in Figure 1. A

Insert Figure 1 about here

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one-factor analysis of variance with repeated measurement across the eight trials was performed on the raw scores for each of the two retest measures. Significant performance gains ($p < .001$) were found across the eight trials for each of the two measures (Figural Relations: $F = 16.81$, $df = 7,203$; Induction: $F = 26.42$, $df = 1.29$). Total improvement in mean scores on both measures was roughly equivalent to one standard deviation. With regard to the performance pattern across the eight sessions, subjects exhibited small, steady gains between consecutive trials. Separate trend analyses for the two measures indicated that only a linear component was significant ($p < .001$). No apparent performance asymptote was reached.

Training research. Modifiability of fluid intellectual performance in the elderly has also been examined as a function of a series of short-term longitudinal training studies each focusing on one target fluid ability. In one such study (Willis, Blieszner, & Baltes, Note 2) involving the target fluid ability of Figural Relations, training effectiveness was assessed by comparing posttest performance of randomly assigned experimental and control groups (Total $N = 58$, $\bar{X}$ age = 69.8, $SD = 5.7$). Experimental subjects participated in five one-hour training sessions focusing on cognitive strategies identified in task analyses to be involved in solution of Figural Relation-type problems.

The two criteria for assessing training effectiveness were durability (maintenance) of training effects over three posttest occasions (1 week, 1 month, 6 months) and transfer (generalizability) of training across a broad battery of seven fluid and crystallized measures. With regard to training transfer, a hierarchical theory-based pattern of transfer was predicted with the largest training effects occurring for the three near transfer measures representing the target fluid ability: ADEPT Figural Relations test (Plemons et al., 1978), Culture Fair test (Cattell & Cattell, 1957), Raven Advanced Progressive Matrices (Raven, 1962). Less or no training effects were predicted for two levels of far transfer, involving far fluid transfer to the fluid ability of Induction and far nonfluid transfer to Crystallized Intelligence and Perceptual Speed. Induction was represented by two measures: ADEPT Induction (Blieszner, Willis, & Baltes, Note 3) and Induction Composite (Ekstrom et al., 1976; Thurstone, 1962) tests. Crystallized Intelligence was marked by a Vocabulary measure (Ekstrom et al., 1976) and Perceptual Speed by the Identical Pictures test (Ekstrom et al., 1976).

The entire data matrix (across treatments and occasions) for each of the seven posttest measures was standardized using the control group's score on that measure at Posttest 1 as the standardization base with a mean of 50 and standard deviation of 10. This standardization procedure was employed to provide a common baseline of performance on each measure to which all other data points for that measure could be compared and to eliminate scale level differences between measures, thus facilitating comparison of transfer effects across measures. A graphic summary of the training and control groups' standardized mean scores for the seven transfer measures, averaged across the three posttest occasions, is shown in Figure 2. Mean scores of the training group were larger than the control's scores for all seven measures at each of the three posttests. The pattern of training transfer is represented by the relative difference between the standardized mean scores for the training and control groups for each measure. Note that the difference between mean scores for training and control groups appears larger for the three near (Figural Relations) measures than for the four far (fluid and nonfluid) measures.

Insert Figure 2 about here

An overall analysis as a general assessment of training effects was performed across all measures and occasions, using standardized scores. That is, a 2 (Treatment: Training, Control) X 3 (Occasion: Posttests 1, 2, 3,) X 7 (Measures) analysis of covariance with repeated measures was conducted using the pretest score on the ADEPT Figural Relations test as the covariate (Table 1). There was no significant difference between training and control groups at pretest. This analysis resulted in a significant Treatment main effect (F [1,54] = 11.81, $p < .001$), and a significant Treatment X Measure interaction (F [6,336] = 2.25, $p < .05$) suggesting differential treatment effects across the seven transfer measures as predicted. A significant Occasion main effect (F [2,112] = 12.00, $p < .001$) was obtained and interpreted as suggesting retest effects common to both training and control groups. A significant Measure main effect (F [6,336] = 3.43, $p < .05$) occurred as a function of differential training and retest effects by measure, given the standardization procedure.

Insert Table 1 about here

Follow-up analyses via the Tukey WSD conducted separately by measure indicated that training and control groups differed significantly on each of the three near transfer measures across posttests: ADEPT Figural Relations (p = .000), Culture Fair (p = .008), Raven's (p = .018). No significant differences between training and control were found for the four far transfer measures separately: ADEPT Induction (p = .151), Induction Composite (p = .16), Vocabulary (p = .138) and Perceptual Speed (p = .122). However, increasing the statistical power by using a repeated measures analysis of covariance on just the four far transfer measures resulted in a significant Treatment main effect (F [1,54] = 4.15, p = .047) for the four far transfer measures.

Discussion

Training research in later adulthood. Findings from both the retest and training studies suggest considerable variability in fluid intellectual performance in later adulthood. In the retest study significant performance increments were found for each of two measures, representing the fluid primary abilities of Figural Relations and Induction. Such retest effects occurred under a minimal practice condition in which subjects received no training or feedback, thus, suggesting subjects possessed or were able to generate on their own cognitive strategies and/or test-taking skills useful in improving their fluid intellectual performance. In the Figural Relations training study a pattern of differential training transfer was found across both fluid and crystallized measures with significant training and transfer effects being established and maintained for the three near fluid transfer measures. Such training effects represent a broad continuum of training transfer within the target fluid ability. Moreover, these training effects were maintained over a six-month period.

Data from the training study also suggests that transfer effects extended, although to a lesser degree, beyond the target ability. The training group's scores on all four far transfer measures at all posttest occasions were larger than those for the control. In our view, such an effect on far transfer measures is less likely to result from ability-specific improvement. Rather, it may reflect generalized, non-ability-specific transfer attributable to situational or ability-extraneous factors (e.g., increases motivation, anxiety reduction) which were accrued as a function of the training treatment but are not intrinsic to performance on the target ability per se. Such non-ability-specific transfer would affect performance on a wide variety of ability measures and would show a general effect across the far transfer measures as was found. The likelihood of non-ability-specific transfer occurring may be greater for educationally and/or test-disadvantaged populations, such as the elderly. It is somewhat difficult to address the issue of such non-ability-specific performance factors (e.g., anxiety, motivation) within factor analytic models of intelligence since interpretation of what a given ability factor means will depend on whether a mentalistic or mechanistic perspective of factors is taken. In the absence of process-oriented models of the fluid and crystallized intelligence factors, it is our position that a nonmentalistic approach is more parsimonious.

Such training research would appear to have important implications for theories of adult intelligence. Most current models of adult intelligence, both within the psychometric and cognitive approach, focus on the normative or average pattern of intellectual aging and do not address the potential for modifiability in intellectual functioning in middle and later adulthood. While most intelligence models in childhood and young adulthood have also focused on normative patterns of development, cognitive training research has examined the range of modifiability of intellectual performance during these age periods. This training research has contributed to more comprehensive models of intellectual development early in the life span. Such training research is needed to supplement current theories of normative adult intellectual development. It is suggested that comprehensive theories of intelligence including both potential and normative dimensions of functioning may be particularly important in adulthood, in light of recent cohort research examining the potential impact of socio-cultural change on adult intelligence.

Footnotes

[1]These studies were conducted as part of a research program entitled the Adult Development and Enrichment Project (ADEPT), supported by a grant from the National Institute of Aging (#5-ROI-AG004403) to Paul B. Baltes and Sherry L. Willis, co-investigators. The focus of ADEPT is the examination of the effect of cognitive training programs on the intellectual performance of older adults. Thanks are due to several research assistants of the project (Steven Cornelius, Marjorie Lachman, Brian Hofland, Vincent Morello, Gail Peck, Manfred Schmitt), its field and training staff (Carolyn Nesselroade, Myrtle Williams), and John R. Nesselroade and Paul A. Games, statistical consultants. Rosemary Blieszner was supported in part by a NIA Predoctoral Traineeship (T32-AG00048).

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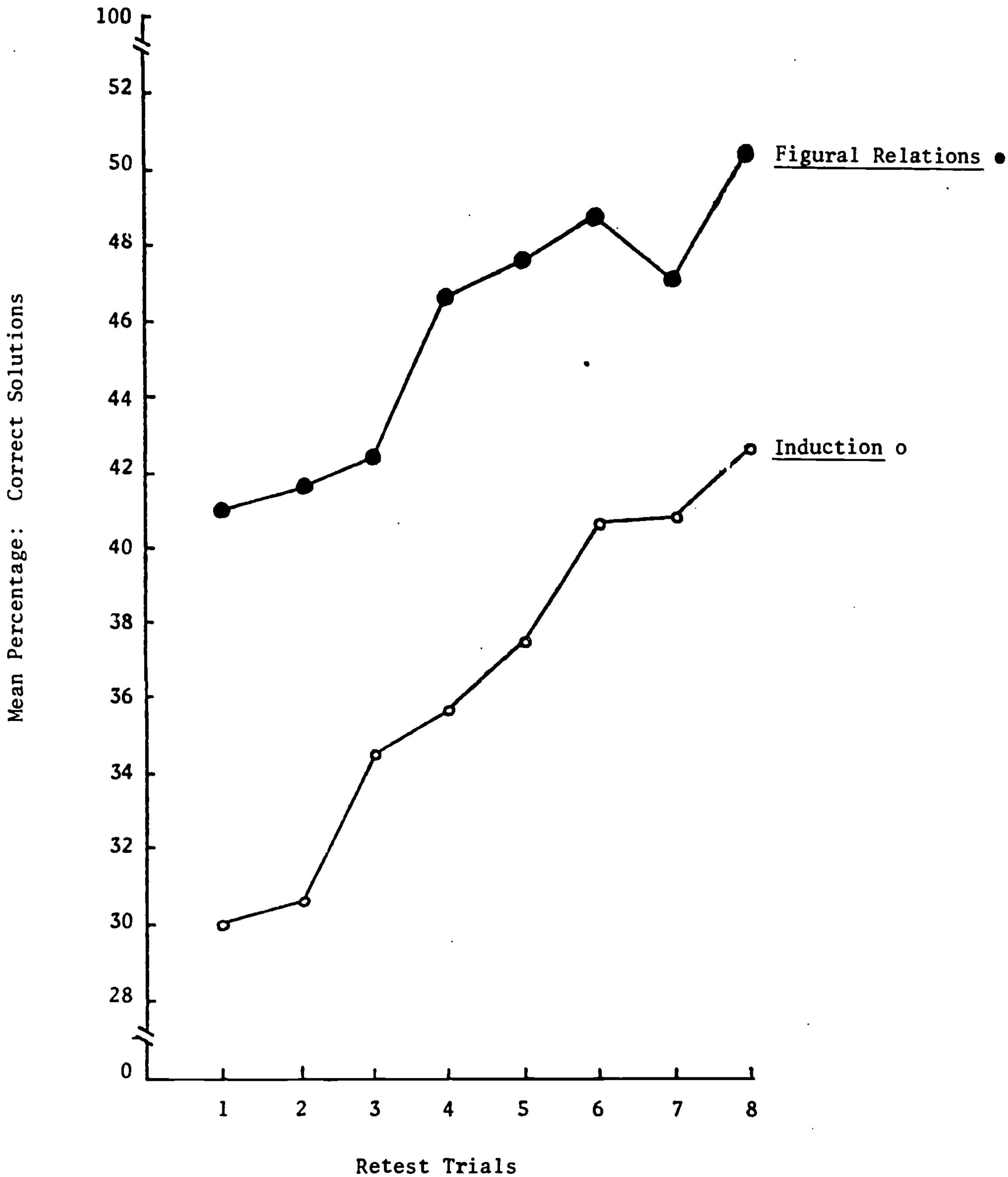
Table 1

Summary of Analysis of Covariance

Source	SS	df	F	p
Pretest	49998.104	1		
Treatment (T)	5652.278	1	11.81	.001***
Occasion (O)	576.175	2	12.00	.001***
T X O	1.951	2	.04	.841
Error	2688.288	112		
Measure (M)	1754.846	6	3.43	.050*
T X M	1152.432	6	2.25	.050*
Error	28694.170	336		
O X M	361.660	12	1.39	.244
T X O X M	244.579	12	.94	.337
Error	14609.660	672		



100
52
50
48
46
44
42
40
38
36
34
32
30
28
0
Mean Percentage: Correct Solutions
Figural Relations ●
Induction o
1
2
3
4
5
6
7
8
Retest Trials

Figure 1

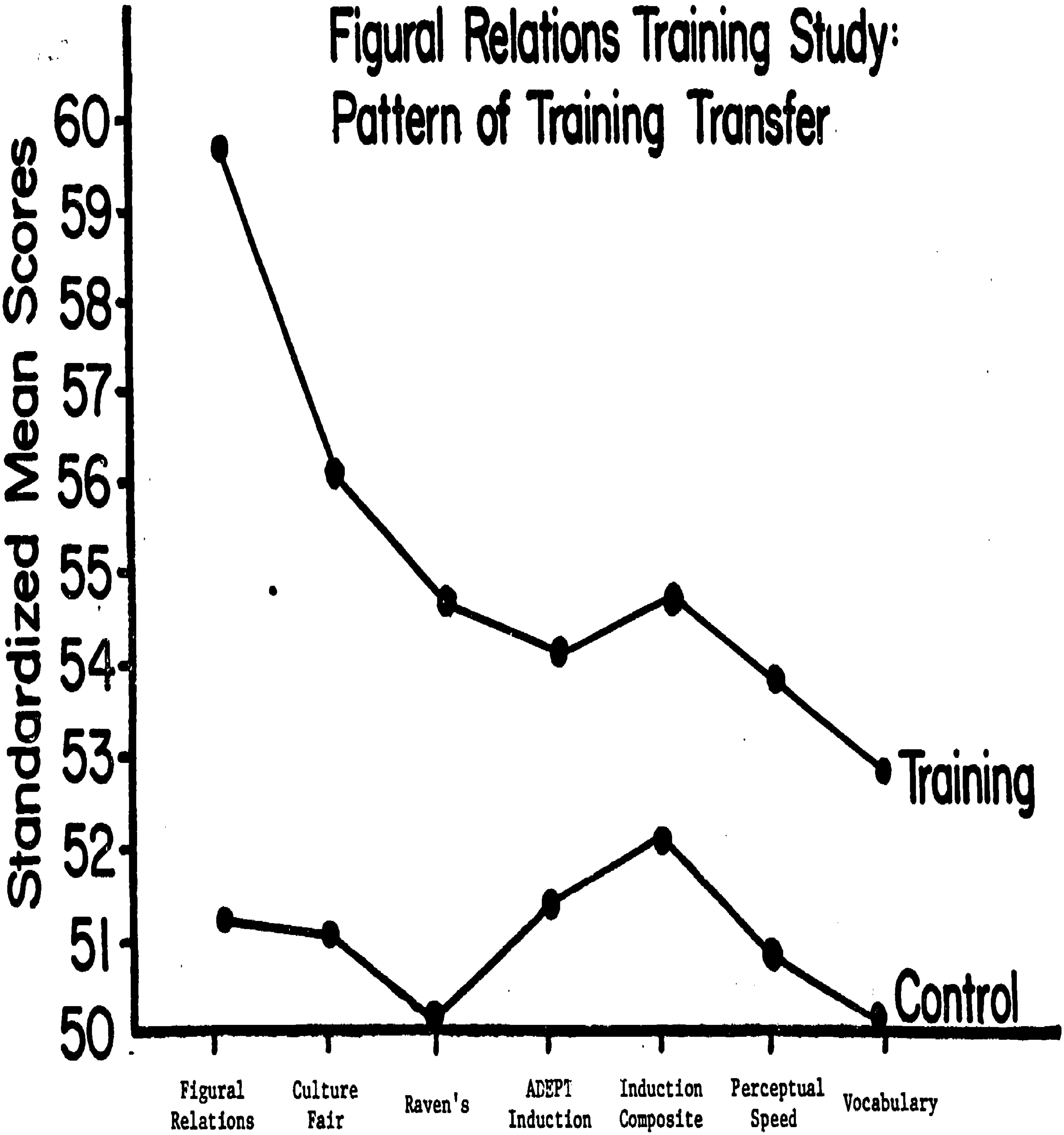

Figural Relations Training Study:
Pattern of Training Transfer
Standardized Mean Scores
60
59
58
57
56
55
54
53
52
51
50
Training
Control
Figural Relations
Culture Fair
Raven's
ADEPT Induction
Induction Composite
Perceptual Speed
Vocabulary

Figure 2.