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Intellectual Training Research in Aging: Modification of Performance on the Fluid Ability of Figural Relations

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The effectiveness of cognitive training on older adults' performance on the fluid ability of figural relations was examined. Posttraining performance of 58 older adults (*M* age = 69.8 years) was assessed on a battery of fluid and crystallized ability measures. A pattern of differential transfer was found with greater training effects to near fluid transfer measures (figural relations). This pattern of training effects was maintained across three posttest occasions, spanning a 6-month period. Significant practice (retest) effects were also obtained for both training and control groups. Retest effects, however, did not follow the pattern of differential training transfer. These findings suggest the continued modifiability of intellectual performance through cognitive intervention across the adult life span.

Although considerable cognitive training research has focused on the age periods of childhood and young adulthood (Glaser, 1978; Levin & Allen, 1976; Wittrock, 1966), comparable research in middle and later adulthood has been meager. This discrepancy reflects not only our society's concentration of formal educational efforts in the first part of the life span but it also reflects early research findings regarding adult intelligence.

Much of the research on adult intelligence has been cross-sectional in design and has typically reported a peak in intellectual functioning in young adulthood, with a normative pattern of decline for some reasoning and perceptual-motor abilities beginning in early middle age (see Botwinick, 1977; Matarazzo, 1972, for reviews). Verbal ability, in contrast, has typically shown a pattern of stability or increment into late adulthood. However, recent longitudinal research suggests more variability in adult intellectual development than traditionally assumed. As shown primarily by the work of Schaie (1979), a peak in intellectual performance for many abilities appears to occur later for current adult cohorts than indicated by cross-sectional research. Moreover, ability decrement begins later and appears less pervasive in current adult cohorts (Botwinick, 1977; Schaie, 1979). In addition, significant cohort differences in intellectual performance have been noted. When cohort-sequential methodologies were applied to longitudinal samples to compare the intellectual performance of adults of different cohorts at the same chronological age, earlier cohorts of adults were found to function at a lower performance level on many abilities than did later cohorts at the same age (Baltes & Schaie, 1976; Schaie & Parham, 1977). Thus, what was interpreted as age-related decrement in prior cross-sectional research may be partially attributable to cohort differences in intellectual functioning. Such cohort differences may indicate the impact of rapid and pervasive so-

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ciocultural change occurring during this century on current older adults' intellectual functioning; the elderly may suffer from considerable cohort-related obsolescence as a function of societal change.

In concert, these recent findings call for an altered perspective of adult intelligence, with emphasis on continued developmental change across adulthood and on the potential impact of environmental factors. Educational policy and practice would appear directly relevant to understanding the role of environmental factors in adult intellectual functioning and the possible cohort-related obsolescence experienced by the current older adult generation (Baltes & Willis, 1979; Havighurst, 1976; Schaie & Willis, 1978). Such factors suggest a rationale for examining the modifiability of intellectual performance in the aged through educational training. Research in this area should contribute information toward the development of life-span educational programming.

Several earlier gerontological training studies have offered support for the modifiability of intellectual performance on a variety of cognitive abilities (e.g., Hornblum & Overton, 1976; Labouvie-Vief & Gonda, 1976; Plemons, Willis, & Baltes, 1978; Schultz & Hoyer, 1976). Most of these studies, however, did not provide a systematic framework for conceptualizing and assessing training effects, particularly with regard to the criteria of training transfer and temporal maintenance of training effects.

The present study examined training effectiveness within a theoretical framework provided by a structural model of intelligence. Several aspects of the study were guided by the particular model of intelligence selected: the target ability for training, conceptual design of the training program, and specification of the pattern of training and transfer effects. Specifically, the theory of fluid and crystallized intelligence provided the conceptual framework for this study. Fluid–crystallized theory is a hierarchical, structural model of psychometric intelligence postulating two broad, second-order dimensions of fluid and crystallized intelligence (Cattell, 1971; Horn, 1970, 1978). These two dimensions are said to show differential, normative patterns of development in adulthood, with fluid intelligence exhibiting gradual decline beginning in early adulthood while crystallized intelligence increases or remains stable across much of adulthood (Horn & Cattell, 1967). The present study examined to what degree short-term educational training could modify the assumed normative deficit in older adults' performance on figural relations, a component of fluid intelligence. Training effectiveness was assessed for a transfer-of-training paradigm and for maintenance of training effects across a 6-month period.

Method

Subjects

Subjects were older adults from several rural communities in central Pennsylvania, who were recruited from community organizations and paid ($2/hour) for participation either individually or by a contribution to their organizations. For all subjects, self-reported health status was good, with no substantial hearing or visual impairment noted.

Of the 69 subjects pretested, 58 (84%: 15 males, 43 females) completed all three posttests. Mean age of these 58 subjects was 69.8 years (SD = 5.7, range = 61–84 years), with no significant sex differences in age. An equal number of training and control subjects completed the study. Comparison of dropouts and subjects completing the study on pretest scores, age, and educational level indicated only significant educational differences, $F(1, 67) = 5.67$, $p < .05$, with dropouts having a higher educational level (M = 13.2 years, SD = 4.4) than the remaining subjects (M = 10.3 years, SD = 3.49).[1]

Design and Procedure

Following a pretest session, subjects were randomly assigned to one of two conditions: figural relations training, and no-contact control. Training began within 1 week of the pretest and involved five 1-hour sessions extending over approximately 2 weeks. Subjects were trained in groups of 4–8 by a middle-aged female trainer. The no-contact control group received the pretests and posttests but no training. Three posttests were administered, approximately 1 week, 1 month, and 6 months after training. Training and control subjects were pretested and posttested together in groups of no more than 12 persons. The pretest session (1.5 hours) involved two tests: the Adult Development and Enrichment Project (ADEPT) Figural

[1] Subject attrition tended to occur early in the study and to be evenly distributed for experimental (n = 6) and control groups (n = 5). The number of dropouts at each test occasion was 7 (Posttest 1), 1 (Posttest 2), and 3 (Posttest 3).

Relations Test (Form A; Plemons et al., 1978) and the ADEPT Induction Test (Form A; Blieszner, Willis, & Baltes, Note 1). A battery of fluid and crystallized intelligence measures (to be described below) was administered at each of the three posttests. Pretests and posttests were conducted by two graduate assistants.

Training Program

The training program focused on the fluid ability of figural relations. Figural relations is characterized as one of the more "pure" primary abilities representing fluid intelligence (Cattell, 1971; Horn, 1970) and is defined by tasks involving the eduction of relations within figural patterns.

The content of the training program was based on a task analysis of the Culture Fair Test (Scale 2; Cattell & Cattell, 1957), previously shown to be a strong marker of figural relations (Cattell, 1971). The Culture Fair Test has four subtests (Figure Series, Figure Classify, Matrices, Topology), each involving a different type of figural relations problem. The task analysis identified relational rules (e.g., size, shape, position) utilized in solving items in each subtest. Training problems were then developed for the most frequently occurring relational rules associated with each subtest. None of the new items were identical to those on the Culture Fair Test.

Each of the first four training sessions focused on one of the four types of figural relations problems (Figure Series, Figure Classify, Matrices, Topology). These sessions included a review of content from the previous session, the trainer's modeling relational rules associated with the problems trained during that session, individual practice with pencil-and-paper training materials, feedback, and group discussion. A fifth training session involved a review of all four types of problems. An adaptation of verbal rule learning, shown to be effective in prior problem solving (Wittrock, 1966) and Piagetian (Beilin, 1976) training research, was the primary instructional strategy utilized.

Assessment of Training Effects

Two major criteria were used in assessment of training effects. The first criterion focused on training and transfer effects within a theory-based measurement paradigm; the second focused on maintenance of training and transfer effects across three posttest occasions (1 week, 1 month, 6 months).

Training transfer. Training and transfer effects were assessed at each posttest occasion with a broad battery of fluid and crystallized measures (see Table 1). A hierarchical, theory-based pattern of transfer was predicted across these measures. The predicted transfer pattern follows both from the Cattell–Horn theory of intelligence (i.e., empirical factor-loading patterns) and the level of similarity of the transfer measures to the training program content.

Near and far levels of training transfer were assessed.

Table 1
Transfer Assessment Battery: Figural Relations Training Study

General intelligence dimension	Primary mental ability	Predicted transfer pattern and marker measures	Source
Fluid	Figural relations	Near-near transfer	
		ADEPT Figural Relations Test (Form B)[a]	Plemons et al., 1978
		Near transfer	
		Culture Fair Test (Scale 2, Form A)	Cattell & Cattell, 1957
		& Power Matrices (Scale 3, Form A, 1963 ed.; and Form B, 1961 ed.)	Cattell & Cattell, 1961, 1963
		Near transfer	
		Raven's Advanced Progressive Matrices (Set II)	Raven, 1962
	Induction	Far fluid transfer	
		ADEPT Induction Test (Form B)[a]: Letter Sets, Number Series, Letter Series	Blieszner et al., Note 1
		Induction Composite Test: Letter Sets, Number Series, Letter Series	Ekstrom et al., 1976; Thurstone, 1962
Speed	Perceptual speed	Far nonfluid transfer	
		Identical Pictures	Ekstrom et al., 1976
Crystallized	Verbal comprehension	Far nonfluid transfer	
		Vocabulary (V-2)	Ekstrom et al., 1976

Note. ADEPT = Adult Development and Enrichment Project. The terms *Fluid, Speed,* and *Crystallized* refer to general intelligence dimensions. All measures were included at Posttests 1, 2, and 3. More complete information on tests and their factorial structure is contained in Baltes, Cornelius, Spiro, Nesselroade, and Willis (1980).
[a] ADEPT Figural Relations and Induction Tests (Form A) were administered at pretest.

Near transfer was examined across three measures of figural relations. Two levels of far transfer (far fluid, far nonfluid) were assessed. The most direct measure of near transfer, the ADEPT Figural Relations Test (Form B), was developed in earlier pilot research (Plemons et al., 1978) and involved test items based on the relational rules identified in the task analysis described for the training program. The two other tests of figural relations were the Culture Fair Test (Scale 2, and Power Matrices, Scale 3; Cattell & Cattell, 1957, 1961, 1963), and the Raven's Advanced Progressive Matrices (Raven, 1962).[2] The Culture Fair Test was the next-nearest transfer measure, involving both the trained relational rules and additional rules not included in training. The Raven matrices represented a more difficult level of the figural relations ability, involving distractors as well as more complex rules. Inclusion of three tests marking figural relations permitted examination of a broad continuum of within-ability (figural relations) transfer.

The first level of far transfer was to the fluid intelligence dimension of induction, another "pure" fluid ability, factorially distinct from figural relations at the primary ability level (Horn, 1970). Two measures of induction were included. The Induction Composite measure involved three published tests: Letter Series and Number Series (Thurstone, 1962), and Letter Sets (Ekstrom, French, Harman, & Derman, 1976). The ADEPT Induction measure included three tests patterned after those in the Induction Composite measure (Blieszner et al., Note 1).

The second level of far transfer was to two nonfluid dimensions, Crystallized Intelligence and Perceptual Speed. Within the fluid–crystallized theory, Crystallized Intelligence and Perceptual Speed were considered to have different developmental antecedents and to be factorially distinct from fluid intelligence. Crystallized intelligence was represented by a marker test of Vocabulary (V-2; Ekstrom et al., 1976), and Perceptual Speed was represented by the Identical Pictures test (Ekstrom et al., 1976).

Maintenance of training effects. The second major assessment criterion examined the maintenance of training and transfer effects across the three posttest occasions (1 week, 1 month, 6 months). Temporal maintenance of training effects was critical if training was interpreted to represent modification of the level of functioning on the target ability. The immediate posttest included in many training studies was considered insufficient to assess the stability of training effects; thus, the assessment design involved three posttests across a 6-month period.

However, the repeated posttesting involved in assessment of training maintenance was predicted to result in strong practice (retest) effects for a test-naive population such as the elderly. Such practice effects have been demonstrated both in prior training research with the elderly (Plemons et al., 1978) and in current research on practice (Hofland, Willis, & Baltes, in press). Retest effects resulting from practice in test taking per se must be distinguished from transfer effects attributed to training. In contrast to training effects, retest effects were predicted to be general in that they would be exhibited by both experimental and control subjects and would occur for all or most transfer measures but would not show the differential transfer pattern predicted for training. The differentiation between training and practice effects is important for an ability-specific interpretation of training.

Results

No significant difference existed between training and control groups on the two pretest scores: ADEPT Figural Relations Test, $F(1, 56) = .018, p > .05$; ADEPT Induction Test, $F(1, 56) = .255, p > .05$.

Results of the study are presented with regard to training and transfer effects, temporal maintenance of training effects, and practice effects. 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 ($M = 50, SD = 10$). This procedure was employed for two reasons: (a) It provided a common baseline of performance on each measure to which all other data points for the measure were compared and (b) it eliminated scale-level differences between measures and thus facilitated comparison of transfer effects across measures.

Transfer of Training

Table 2 shows the training and control groups' mean standardized scores and standard deviations for the seven transfer measures for each posttest. A summary of the training and control groups' mean standardized scores averaged across posttests is shown in Figure 1. The pattern of training transfer is represented by the relative difference between the mean standardized scores for the training and control groups for each measure. Note that the difference between mean scores for training and control groups is larger for the three near (figural relations) transfer measures than for the four far (fluid and nonfluid) transfer measures.

To obtain an initial assessment of training effects, an overall 2 (treatment: training, control) × 3 (occasion: Posttests 1, 2, 3) × 7 (measure) analysis of covariance (ANCOVA) with repeated measures was conducted (Table 3). The ANCOVA was used to reduce

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[2] Due to the length of the posttest battery, only the odd-numbered items of Raven's Advanced Progressive Matrices (Set II) were administered.

Table 2
Mean Standardized Scores and Standard Deviations on Seven Transfer Measures for Training and Control Groups for Three Posttest Occasions

	Occasion					
	Posttest 1		Posttest 2		Posttest 3	
Measure	Training	Control	Training	Control	Training	Control
ADEPT Figural Relations						
M	59.0	50.0	61.1	51.4	59.1	52.5
SD	10.4	10.0	11.7	11.1	12.6	10.7
Culture Fair						
M	55.9	50.0	57.4	51.2	55.2	51.9
SD	10.4	10.0	10.6	12.0	10.6	10.5
Raven						
M	54.3	50.0	54.2	50.6	55.6	50.0
SD	9.9	10.0	11.4	12.3	10.4	10.6
ADEPT Induction						
M	52.6	50.0	54.2	51.9	56.0	52.7
SD	10.8	10.0	10.2	11.2	11.2	10.0
Induction Composite						
M	53.0	50.0	56.3	53.8	55.5	53.0
SD	10.2	10.0	12.5	11.0	11.1	11.7
Identical Pictures						
M	52.5	50.0	53.9	51.9	55.0	50.6
SD	9.5	10.0	11.3	9.2	10.2	8.7
Vocabulary						
M	52.8	50.0	53.0	50.1	52.9	50.1
SD	9.1	10.0	9.4	9.8	9.0	10.2

Note. ADEPT = Adult Development and Enrichment Project. All data points for each measure were standardized with the control group's Posttest 1 scores as base ($M = 50, SD = 10$). For the training and control group, $n = 29$ each.

the large individual differences within training and control groups often found in aging research. The covariate was the pretest score for the nearest transfer measure (ADEPT Figural Relations Test). This overall analysis resulted in a significant treatment main effect for training. In addition, the significant Treatment × Measure interaction indicated differential treatment effects across the seven transfer measures. The significant occasion main effect was interpreted as primarily reflecting practice effects, common to both training and control groups. A significant measure main effect involved the summation of differential training and retest effects, given the standardization procedure used in which all data points were standardized with reference to the control group's scores at Posttest 1.

Following this overall analysis, training and transfer effects were examined more specifically at two levels. First, the pattern of differential training transfer across the seven measures was assessed by a series of orthogonal planned comparisons. Second, transfer effects at the individual test level were examined. In Table 4 a summary of the orthogonal planned comparisons is shown. For the Treatment × Measure and

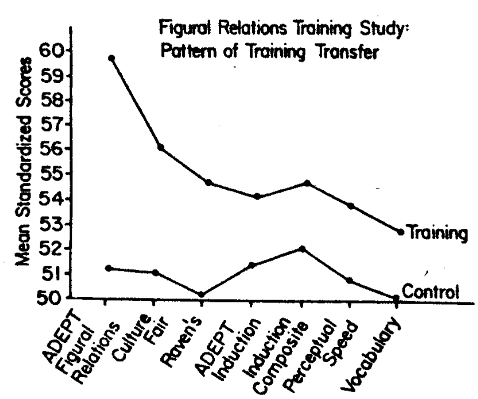

Figure 1. Mean standardized scores on seven transfer measures for training and control groups averaged across three posttest occasions.

Table 3
Summary of Analysis of Covariance and Orthogonal Planned Comparisons

Source	*SS*	*df*	*F*
Pretest	49,998.104	1	
Treatment (T)	5,652.278	1	11.81**
Occasion (O)	576.175	2	12.00**
ψ_1	574.705	1	23.94**
ψ_2	1.468	1	.06
T × O	1.951	2	.04
Error	2,688.288	112	
Measure (M)	1,754.846	6	3.43*
T × M	1,152.432	6	2.25*
ψ_3	1,013.324	1	11.87**
ψ_4	1.477	1	.02
T × M residual	137.632	4	.40
Error	28,694.170	336	
O × M	361.660	12	1.39
T × O × M	244.579	12	.94
ψ_5	11.790	1	.54
ψ_6	2.190	1	.10
T × O × M residual	230.599	10	1.06
Error	14,609.660	672	

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

Treatment × Occasion × Measure comparisons, differential weights were assigned to each measure. The three levels of near (figural relations) transfer were weighted according to their conceptual relatedness to the training program.

In Table 3 a summary of the results for these planned comparisons is presented within the context of the 2 × 3 × 7 ANCOVA. Two planned comparisons (ψ_3, ψ_4) of the Treatment × Measure interaction were conducted. Comparison ψ_3 indicated that the predicted pattern of greater training transfer to near than to far transfer measures was significant ($p < .001$). Follow-up contrasts conducted separately for the training and control groups indicated a significant effect, $F(1, 292) = 22.05$, $p < .001$, for the training but not for the control group. To examine whether a pattern of further differential transfer also existed within the four far transfer measures, Comparison ψ_4 was conducted, contrasting the two far fluid transfer measures with the two far nonfluid transfer measures; this comparison was not significant.

Examination of training effects separately by measure was conducted via the Tukey WSD Method. Training and control groups differed significantly on each of the three near transfer (figural relations) measures, across posttests: ADEPT Figural Relations Test ($p = .001$), Culture Fair Test ($p = .008$), Raven's matrices ($p = .018$). No significant differences between training and control were found for the four far transfer measures separately: ADEPT Induction ($p = .151$), Induction Composite ($p = .16$), Perceptual Speed ($p = .122$), Vocabulary ($p = .138$). However, increasing the statistical power by using a repeated-measured ANCOVA conducted 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 as well.

Maintenance of Training Transfer

To examine whether the pattern of dif-

Table 4
Summary of Orthogonal Planned Comparisons

	Measure (M)							Occasion (O)			Treatment (T)	
Comparison	ADEPT FR	CF	R	ADEPT I	IC	IP	V	1	2	3	Training	Control
O												
ψ_1								2	−1	−1		
ψ_2								0	1	−1		
T × M												
ψ_3	3	2	1	−1.5	−1.5	−1.5	−1.5				1	−1
ψ_4	0	0	0	1	1	−1	−1				1	−1
T × O × M												
ψ_5	3	2	1	−1.5	−1.5	−1.5	−1.5	2	−1	−1	1	−1
ψ_6	3	2	1	−1.5	−1.5	−1.5	−1.5	0	1	−1	1	−1

Note. ADEPT = Adult Development and Enrichment Project; FR = ADEPT Figural Relations; CF = Culture Fair; R = Raven; I = ADEPT Induction; IC = Induction Composite; IP = Identical Pictures; V = Vocabulary.

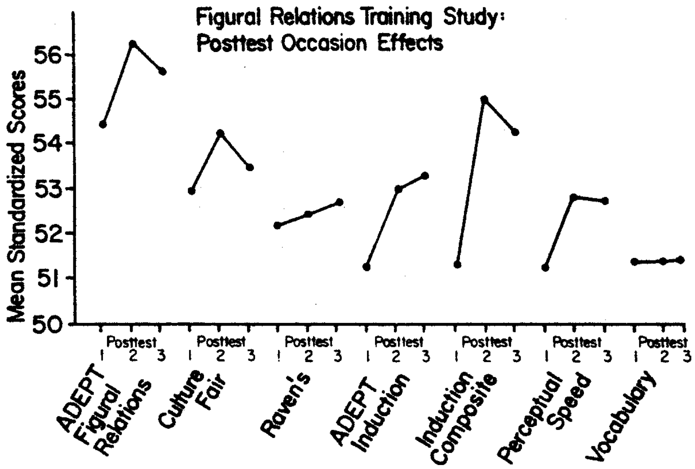

Figure 2. Mean standardized scores for seven transfer measures at three posttest occasions.

ferential training transfer indicated by Comparison ψ_3 was maintained at each posttest occasion, two comparisons (ψ_5, ψ_6) of the Treatment × Occasion × Measure interaction were conducted. Neither comparison was significant, indicating that the predicted pattern of training transfer did not vary between occasions but was maintained across posttest occasions over 6 months.

Practice Effects

Due to the test naivete of elderly subjects, strong practice effects were predicted across posttest occasions. Such retest effects would be common to both training and control groups and would be reflected in an occasion main effect. Two comparisons (ψ_1, ψ_2) of the occasion main effect were conducted. Only Comparison ψ_1 was significant (p = .001), suggesting strong retest effects across treatment and measure levels from Posttest 1 to the average of Posttests 2 and 3. Comparison ψ_2 indicated the absence of significant retest effects between Posttests 2 and 3. Although the Occasion × Measure interaction was not significant, there appeared to be a trend toward differential practice effects by measure. Figure 2 presents a summary of the occasion effects separately by measure. Note, however, that the occasion effects do not follow the same differential pattern as predicted for training transfer.

Discussion

Training and Practice Effects

A theory-based cognitive training study with older adults was conducted, with emphasis on a differential pattern of training transfer and maintenance of training effects across multiple posttests. The predicted pattern of differential training transfer was established and maintained, with significant effects for the three near transfer measures (ADEPT Figural Relations Test, Culture Fair Tests, and the Raven's matrices). Such training effects represent a broad continuum of training transfer within the target ability (figural relations). The significant effects obtained to near transfer measures are in agreement with prior training research for children and young adults (Levin & Allen, 1976; Wittrock, 1963). Moreover, training effects were maintained over a 6-month period. The literature on long-term maintenance of training effects is limited, and thus the extent to which such a finding is corroborative of past research with younger subjects needs further exploration.

The data also suggest that transfer, to a lesser degree, occurred beyond the figural relations ability. Two levels of far transfer assessed in the study involved far fluid transfer to another fluid ability (Induction) and far nonfluid transfer to perceptual speed and crystallized intelligence abilities. The training group's scores on all four far transfer measures at all posttest occasions were higher than those for the control group. Second, although training effects were not significant for the far transfer measures separately, an ANCOVA on the combined four measures indicated a significant treatment main effect ($p < .05$). In our view, such an effect may reflect generalized, non-ability-specific transfer attributable to situational or ability-extraneous factors (e.g., increased test wiseness, response speed, and anxiety reduction). Such effects could have accrued as a function of the training program but were not intrinsic to performance on the target ability (figural relations) per se. The literature on non-ability-specific transfer effects is limited, since most training transfer paradigms have focused on ability-specific transfer (Royer, 1979). However, the likelihood of non-ability-specific transfer occurring may be greater with educationally and/or test-disadvantaged populations, such as young children, the retarded, and the elderly (Baltes & Willis, 1981; Baltes & Willis, in press).

The considerable practice effects occurring across posttest occasions and represented in the analyses as occasion effects are of further interest. Practice effects were differentiated from ability-specific training effects in that they occurred for both experimental and control groups and did not follow the predicted differential pattern of training transfer. The magnitude of such practice effects has been noted in prior training research with both young and older-adult populations (Hofland et al., in press; Sarnacki, 1979; Wing, in press; Wittrock, 1963). Practice effects provide additional support for the modifiability of intellectual performance, since they occur as a function of a very limited, no-feedback retest condition. Moreover, the magnitude of such retest effects and their occurrence over a wide variety of ability measures suggests that considerable caution is required in interpreting single-occasion assessment of test-naive populations, such as the elderly.

Aging and Training Research

The findings of this study, in conjunction with prior gerontological training research (see Willis & Schaie, in press, for review), offer support for the effectiveness of educational training programs in modifying the intellectual performance of older-adult populations. Such training research, therefore, has significant implications both for theories of adult intelligence and for educational policy.

First, current models of adult intelligence 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 (Willis & Baltes, 1980). Although intelligence models in childhood and young adulthood have also typically focused on normative (average) patterns of intellectual development, cognitive training research has examined the range of modifiability of intellectual performance during these age periods. This training research has contributed to a more comprehensive theory of intellectual development early in the life span, involving both potential and normative ranges of intellectual development (Brown & French, 1979). Examination of the range of modifiability in intellectual aging is similarly needed to supplement current theories of normative adult intellectual development. Comprehensive theories of intelligence, including both potential and normative (average) dimensions, may be particularly important in adulthood given recent cohort research regarding the potential impact of sociocultural change on adult intelligence. Moreover, training research may provide insight into the determining factors or mechanisms of intellectual aging. Evidence from educational training research supports the interpretation that the cohort-related obsolescence experienced by current generations of older adults may indeed be a major factor in the lower level of functioning of some of today's older adults.

Second, with regard to educational policy, the effectiveness of cognitive training research in later adulthood provides empirical support for the growing emphasis on a lifelong learning approach to education (Dave, 1976; Knox, 1977; Schaie & Willis, 1978). A wide range of social issues, including our society's changing age structure, mandatory retirement, and the threat of rapid technological obsolescence, argue persuasively that educational efforts cannot continue to be concentrated in the first quarter of the life span. A life-long approach to learning is required. However, such an approach requires the assumption that learning capacity extends across the life course. Training studies, such as this one, provide support for the modifiability of intellectual performance across the life span. However, much more research, examining training effects with regard to a variety of cognitive abilities and instructional strategies, is required to provide a satisfactory theoretical and empirical base for a life-long approach to education.

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