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Modifiability of Fluid Intelligence in Aging: A Short-Term Longitudinal Training Approach[1]

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The aim of this study was to examine to what degree fluid intelligence can be modified in aged subjects. The effectiveness of a cognitive training program designed to enhance one primary component of fluid intelligence, Figural Relations, was assessed by comparing the posttraining performances of 15 experimental and 15 control subjects (mean age: 69; age range 59-85) using a transfer paradigm and three posttraining assessments conducted approximately 1 week, 1 mo, and 6 mo following training. The post-training performance of the two groups was compared on three near (fluid intelligence) and one far (crystallized intelligence) transfer measures. A hierarchical pattern was predicted with the magnitude of training effects ordering themselves in descending order from near to far transfer measures. The training program was successful in enhancing performance on the fluid-nearest measure on all three posttests and for the next fluid-near measure on the first posttest. In addition, significant retest effects resulted which, however, were neither task-specific nor hierarchically ordered, but general and therefore indicative of ability-extraneous factors, such as test sophistication. The findings contribute to a position implying that intellectual performance in old age is more modifiable through short-term behavioral intervention than traditionally assumed.

IT has been suggested by recent reviews of the literature on adult and gerontological intelligence that a biological decrement model of intelligence may have been overemphasized (Baltes & Labouvie, 1973; Barton et al., 1975; Jarvik & Cohen, 1973). In addition to data on cohort differences (Nesselroade et al., 1972; Schaie et al., 1973; Schaie & Strother, 1968), challenging evidence from learning-based intervention research (e.g., Hoyer et al., 1973; Labouvie-Vief & Gonda, 1976; Baltes & Baltes, 1977) is beginning to provide support for the view that adult and gerontological intelligence is more modifiable than traditionally assumed (Baltes & Baltes, 1977; Baltes & Schaie, 1976).

The available evidence on the effectiveness of training programs on intellectual performance in older persons, however, is not yet rich in terms of number of studies. This is particularly true if such evidence is judged to require a theory-based approach to intervention design and the criterion of time generalization or training maintenance. For example, a particular theoretical framework of intelligence would allow assessment of transfer of training effects to a theoretically related network of intellectual abilities. Moreover, the training program content and procedures need to be sufficiently described so that conceptual relationships between the treatment and the criterion measures can be adequately examined. Finally, the maintenance of training effectiveness or its time generalization needs to be assessed over extended periods of time rather than only immediately following training as is true for most cognitive intervention work in gerontology.

The purpose of the present study is to examine training effectiveness within such a refined theoretical and assessment framework. Cattell and Horn's (Horn, 1970, 1972b; Horn & Cattell, 1967) theory of fluid-crystallized intelligence is used as a conceptual framework permitting both a systematic definition of cognitive intervention targets and of transfer of

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training dimensions. In addition, training effects are assessed not only immediately following training but over a 6-mo period. A byproduct of the study is a potential contribution to the theory of fluid-crystallized intelligence itself in that the study explores to what degree short-term experiential-educative factors can modify the assumed normative deficits (Horn, 1970) in fluid performance during advanced age. Such information is important since many researchers view the Cattell-Horn theory of intelligence (particularly its fluid component) as having primarily trait-like features. Trait-like behavior is usually assumed to be rather resistant to short-term environmental intervention.

METHOD

Figural Relations Training Program

Fluid intelligence is represented by primary factors such as Figural Relations, Memory Span, Induction, and Associative Memory (Horn, 1968; Horn & Cattell, 1967). The key component, Figural Relations, was chosen for training in the present study, as it is one of the most "pure" factorial indicants of fluid intelligence (Horn, 1968, 1972a; Horn & Cattell, 1967). The Figural Relations factor is defined by tasks which require the subject to identify relations between figures in a pattern and to produce one element missing from the pattern (Horn, 1972b). Exemplary tests measuring Figural Relations are Figure Series, Figure Classify, Matrices, and Topology (Horn & Cattell, 1966).

As a first step toward developing the training materials, a task analysis of the marker test items from the Cattell-Horn measures for Figural Relations (Horn, 1966; Horn & Cattell, 1967) was undertaken to determine the relational rules involved in solving Figural Relations items and the frequency with which they occur. Relational rules most frequently found in marker test items were used in developing materials included in the training program since these rules were considered to be most prototypical of Figural Relations tasks. It was considered impractical to utilize all relational rules represented in the marker tests due to time limitations and the possibility of cognitive overload for subjects. None of the items constructed for use in training was identical in form to those items contained in the Figural Relations Diagnostic Test or the Cattell-Horn battery.

Training consisted of eight practice sessions on Figural Relations-type items. The general format for a typical training session included: (a) review of content from previous sessions; (b) introduction of new material with modeling of rule-based task solutions by the instructor; (c) individual practice on new material with immediate feedback; and (d) group discussion of practice items, including identification of solution sets. The training materials consisted of small booklets containing examples illustrating specific relational rules and practice sheets to be completed by the subjects.[3]

Each training session was approximately 1 hour in length and was administered twice weekly for 4 weeks. The subjects met in five separate groups, each group always consisting of the same three individuals, in the home of one of the group members. All sessions were supervised by the same instructor, herself an older adult, and by an instructor's aide. At the end of each session, the subjects and instructor were asked to fill out questionnaires designed to provide an immediate evaluation of the clarity and difficulty of the lesson.

Assessment of Fluid and Crystallized Intelligence

A list of the transfer tasks is presented in Table 1. Training effectiveness was assessed both with regard to the training program itself and its effect on a hierarchical set of transfer measures. The use of transfer measures is considered to be crucial in such research. The structure of the transfer system used follows both from the Cattell-Horn theory of intelligence (that is, the empirical factor loading patterns) and the degree of similarity of the transfer measures to the training program content (Figural Relations).

Ordered from near-near to far-far transfer, the transfer tasks were, first, the *Figural Relations Diagnostic Test,* which was specifically constructed for this study to serve as a direct assessment of performance on the subgroup

[3] A copy of the training program can be obtained from Sherry L. Willis at the address given in the second footnote. Additional training programs for the fluid factors of Induction and Memory are currently in preparation and in the piloting stage.

Table 1. Transfer Tasks: Primary Factor Represented, Source, and Relation to the Fluid-Crystallized Dimensions.

Secondary Factor Represented	Primary Factor Represented	Transfer Task	Source
Fluid Intelligence	Figural Relations	Near-Near: Figural Relations Diagnostic Test	Present Study
		Near: Cattell-Horn measures of Figural Relations (Cattell II)	Horn & Cattell, 1966
	Induction	Far: Letter Sets	French et al., 1963
		Far: Number Series	Thurstone & Thurstone, 1949
Crystallized Intelligence	Verbal Comprehension	Far-Far: Vocabulary Tests (V-1 and V-2)	French et al., 1963

Note: The prediction was that training would affect transfer test performance in descending, hierarchical order and that, if training was only of the general-performance rather than fluid-competence kind, training would affect all transfer measures equally.

of relational rules presented in training. It is the most direct assessment of transfer of training effectiveness and, therefore, was considered to be a near-near transfer task. None of the items, however, are identical in form to items from either the Figural Relations Training Program or the Cattell-Horn measures of Figural Relations.

The Figural Relations Diagnostic Test consists of two parallel forms (A and B), each containing 42 items distributed over four timed subtests administered in the following order: Figure Series, Figure Classify, Matrices, and Topology. One of the two parallel forms of the Figural Relations Diagnostic Test was administered in counter-balanced order to all subjects (with the exception of two subjects who erroneously received the tests in the order B, B, A, B) across the four assessment occasions (Pretest, Posttests 1, 2, & 3).

Using a student population ($N = 115$), analyses of Forms A and B to determine interitem consistency yielded alpha coefficients of .78 for Form A and .76 for Form B, and a correlation of .81 was obtained between Forms A and B. In addition, a correlation of .66 was obtained between the Figural Relations Diagnostic Test, Forms A and B combined, and the Cattell-Horn measures of Figural Relations.

A second transfer measure was the *Cattell-Horn Tests of Figural Relations,* considered to be a near transfer task since it is one of the "pure" markers for fluid intelligence and includes the relational rules used in the Figural Relations Training Program, plus additional rules and combinations of rules not covered in training. The Cattell-Horn battery consists of five timed subtests administered in the following order: Figure Series, Figure Classify, Matrices Power, Matrices Speed, and Topology (Cattell, 1957; Horn & Cattell, 1966).

A third set of transfer instruments consisted of *Induction* measures (Thurstone & Thurstone, 1949; French et al., 1963). While equally as pure an indicator of fluid intelligence as Figural Relations, Induction is not identical with the Figural Relations factor; it is considered to be a separate primary factor, measuring a different aspect of fluid functioning. The Induction measures were considered to be the third closest in similarity to the training program (far transfer).

A fourth set of transfer measures was represented by tests of *Verbal Comprehension* (French et al., 1963). As Verbal Comprehension is considered to be an ability defining crystallized intelligence, the measures representing it were considered to be the farthest away in similarity from the training program (far-far transfer).

Subjects

Thirty-seven individuals residing in the community were initially pretested on the Figural Relations Diagnostic Test. Pretest scores were grouped into 5 clusters in order to attain matched pretest performance within each cluster. This necessitated a reduction in sample size to 30, with those 7 subjects whose pretest scores were at the top and bottom of the range being dropped. Subsequently, within the five clusters, subjects were randomly assigned to Training and Control groups within the possibilities of administrative requirements (i.e., the subjects' time schedules and their proximity to training locations). Of the 30 subjects included in the core study, 27 were female and 3 male, with an age range from 59 to 85 years and a mean age of 69.5 years. The mean educational level of the participants was 11.95 years. There was no difference in mean ages or educational level between the experimental and control participants.

Design and Procedure

The design involved a pretest-posttest control arrangement with two experimental conditions: (1) Figural Relations Training and (2) Control. Eight days following pretesting with the Figural Relations Diagnostic Test, the Figural Relations Training Program began. The training subjects received eight training sessions (two 1-hour training sessions per week for 4 weeks), while the control subjects received no training.

Within a week following the last training session, Posttest 1, consisting of all four sets of transfer measures, took place. Posttest 2, consisting of the same transfer measures, was administered approximately 4 weeks later.

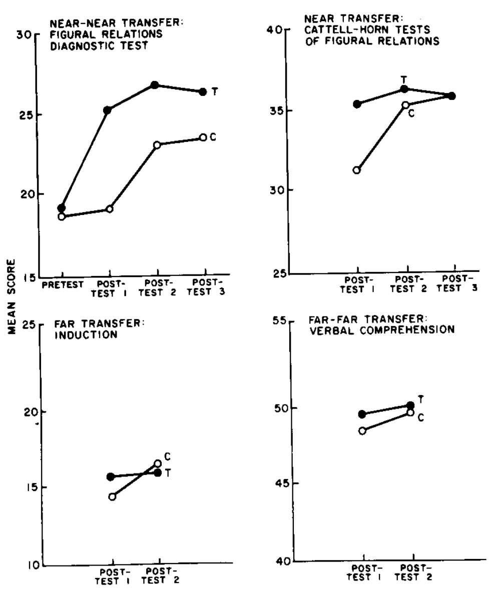

Fig. 1. Mean score on all transfer tasks for the training and control groups on all occasions of measurement. Training (T), O Control (C). Based on analysis of covariance designs, significant differences were obtained between the two experimental groups for the Figural Relations Diagnostic Test ($p < .05$) on all three posttests and, on Posttest 1, for the Cattell-Horn measures of Figural Relations ($p < .05$).

Both Posttests 1 and 2 consisted of two separate testing sessions, 1 to 2 days apart, with the Figural Relations Diagnostic Test and Induction measures being administered in Session 1 and the Cattell-Horn measures of Figural Relations and Verbal Comprehension measures in Session 2. Posttest 3 occurred, on the average, 23 weeks following Posttest 2 and consisted of one testing session in which the observation was restricted to the two near transfer measures. The two far transfer measures were omitted because assessment of earlier posttest performance had resulted in no transfer of training effects. Accordingly, only the Figural Relations Diagnostic Test and the Cattell-Horn measures of Figural Relations were administered at Posttest 3.

RESULTS

A summary of the raw mean scores of the two experimental groups on all measures for each occasion of measurement is illustrated in Fig. 1. In addition, Table 2 presents summaries of the repeated measures analyses of covariance conducted separately for each measure. The analyses of covariance used performance on the pretest (Figural Relations Diagnostic Test) as the covariate because complete random assignment had not been possible. Note, however, that the two groups did not differ significantly in pretest scores on the Figural Relations Diagnostic Test.

Overall-Analysis of Transfer of Training

In order to obtain a first overall assessment of the existence of significant effect patterns,

Table 2. F-Values from Analyses of Covariance Separately for Each Dependent Variable.

Source	Measure			
	Figural Relations Diagnostic Test	Cattell-Horn Measures of Figural Relations	Induction	Verbal Comprehension
Condition (C)	4.69*	0.89[a]	0.06	0.00
Occasion (O)	5.91**	5.68**	2.83	4.27*
C x O	1.70	2.53	1.45	0.76

* $P < .05$
** $p < .01$
[a] When an analysis of covariance is performed separately for each occasion, a significant condition main effect ($p < .05$) is obtained for the Cattell-Horn measures of Figural Relations at Posttest 1.

an overall analysis was performed on all four transfer tasks for Posttest sessions 1 and 2. Some researchers would opt for a multivariate analysis of variance in order to accomplish this goal. We decided against the use of multivariate analysis because, for theoretical reasons, we wanted to keep the four transfer measures intact rather than producing a multivariate composite. Therefore, we conducted a 2 (Condition: Training and No-Training), by 4 (Transfer Measures), by 2 (Occasion: Posttest 1 and 2) analysis of variance. Since we judged scale-level differences between the four transfer measures to be irrelevant for our purpose, we standardized each of the transfer measures for the entire data matrix (across occasions and groups) to a mean of 50 and a standard deviation of 10.

This overall-analysis of variance revealed a number of significant effect patterns, all suggesting that reliable statistical differences were contained in the data. There was a significant Occasion main effect ($F = 18.69$, $df = 1/28$, $p < .01$), a significant Condition by Occasion interaction ($F = 4.62$, $df = 1/28$, $p < .05$), and a trend toward a Training Condition by Transfer Measure interaction ($p < .06$). This pattern of significant outcomes indicates that the separate analyses of the training effect patterns (described below) can be conducted within a framework of inferential confidence.

Analyses for Each Task Separately

After establishing evidence of systematic effect patterns in the preceding overall-analysis, analyses were undertaken to examine training effects as reflected by each task separately. Using the pretest (Figural Relations Diagnostic Test) as the covariate, repeated measures analyses of covariance were performed for each transfer task (summarized in Table 2). The key findings are represented in Fig. 1 in raw-data form. Analyses for the Figural Relations Diagnostic and Horn-Cattell battery are based on Posttest 1, 2, and 3. Analyses for Induction and Verbal Comprehension are based on Posttest 1 and 2.

Figural Relations Diagnostic. — For the near-near transfer measure, the Figural Relations Diagnostic Test, the repeated measures analysis of covariance revealed a significant Training Condition main effect ($p < .05$), indicating that the Figural Relations Training Program was effective in enhancing the performance of the training group over that of the control group on the most direct measure of training effectiveness. It is important to note that this training effect held true for all three posttests extending over a period of 6 mo.

Cattell-Horn Figural Relations Battery. — For the near transfer measure, the Cattell-Horn measures of Figural Relations, analysis of covariance revealed a significant Occasion main effect ($p < .01$) showing performance increments over occasions for both groups. A trend toward the predicted Training Condition by Occasion interaction ($p < .09$) was further analyzed by means of analysis of covariance performed for each of the posttest occasions separately. These analyses revealed a significant difference between the two experimental groups for Posttest 1 ($p < .05$).

Induction and Verbal Comprehension. — For the two far transfer measures, Induction (fluid-far transfer) and verbal Comprehension (crystallized far-far transfer), analyses of covariance revealed no significant Condition (training) main effect or significant interactions. This is an important finding since the theory-based strategy for intervention suggested that smaller or no training effects should be obtained for measures with increasing distance (based on theory and similarity to training program) from the Figural Relations factor. A significant main effect on Occasion ($p < .05$) was obtained for Verbal Comprehension, again indicating an occasion-correlated increase in performance.

CONCLUSIONS

Training Effects

Both training and retest (occasion) effects are evident in the present data. The Figural Relations Training Program enhanced the performance of the experimental group over that of the control group on the most direct measure of training, the Figural Relations Diagnostic Test, on all three posttests (extending over a total period of 6 mo). In addition, if one is willing to place confidence in the post hoc analysis as we do because of the pattern of outcomes, a significant training effect was obtained on the first posttest for the near transfer measure, the Cattell-Horn measures of Figural Relations. Certainly the results are consistently suggestive in the predicted direction, although one might have hoped for more lasting training effects on the closest transfer measures. It is possible that more lasting transfer to these transfer measures would have occurred had the training program been broader in scope, involving a larger number of relational rules and combinations of rules, or alternative treatment packages (e.g., Labouvie-Vief & Gonda, 1976).

Of equal importance is the general retest effect pattern. In line with earlier data presented by Furry and Baltes (1973) and Hoyer et al. (1973), strong retest gains were evident in the present study for three of the four tasks. These retest effects, however, are of the general rather than measure-specific (hierarchically ordered) kind and, thus, suggest the operation of general test-taking performance variables beyond the effectiveness of ability-specific training itself; such general test-taking performance improvements are often interpreted as being due to increases in test sophistication. In this sense, the findings on the general nature of retest effects give further credibility to our theory-based approach. Training effects were fluid intelligence-related and, therefore, transfer measure-specific. Retest (or test sophistication-type) effects, on the other hand, are not related to a specific dimension of psychometric intelligence and, therefore, their effect pattern is general.

Fluid Intelligence and Aging

Both the training effects and the general pattern of retest effects support the modifiability of fluid abilities in the elderly. The enhancement of fluid functioning which resulted via short-term behavioral intervention speaks for the notion that environmental-experiential factors can play an important role in determining, not only crystallized, but also fluid intellectual performance in the elderly. This conclusion and the findings of the present study are supported by the results of other learning-based intervention research (Hoyer et al., 1973; Labouvie-Vief & Gonda, 1976) and in line with recent suggestions that a biological decrement model of intelligence is not sufficient (Baltes & Labouvie, 1973; Barton et al., 1975; Jarvik & Cohen, 1973). The results of the present study, then, indicate that alternative interpretations to the traditional irreversible decrement notion must pay more attention than is usually the case to the degree to which experiential factors and changing environmental variables operate in determining intellectual performance in the elderly.

In contrast to previous interventive research, the present study is particularly supportive of the above conclusions as it is the only gerontological study known to the authors which is based on a theory-guided and structural-model approach of psychometric intelligence and involves a 6-mo longitudinal follow-up. Of particular relevance in the present data is that not only were training effects obtained, as in earlier work, but that these effects followed a pattern which was predicted on the basis of a structural model of intelligence; in addition, that the training effects were maintained for a period of 6 mo on the nearest transfer measure. Specifically, a hierarchical pattern of transfer of training effects speaks for the fact that the training led to an enhancement of basic intellectual processes underlying the Figural Relations factor rather than to a general enhancement of fluid-extraneous, performance (test sophistication) variables.[4] Had only performance-related behavior components been affected by training, one would have expected a general and comparable improvement in performance on all transfer tasks, rather than the hierarchical pattern of transfer of training effects which resulted.

SUMMARY

The present study had two interrelated objectives. The primary objective deals with research into the modifiability of fluid intelliggence performance in aging. The secondary objective is to contribute to a better understanding of the processes which mediate the development and maintenance of fluid intelligence. These objectives were examined by means of a cognitive training study. This training study was designed with a focus on transfer

[4]One of the reviewers raised the question of whether the training program involved a transformation of the validity of the near-transfer tasks from fluid into crystallized components. The present design is not oriented toward a comprehensive assessment of this question. However, an examination of the correlational matrices of the transfer measures (separately for the two experimental groups and the posttest occasions) does not suggest the reviewer's interpretation to be likely. Contrary to the suggested expectation, the Posttest 1 correlation between the Cattell-Horn measures of Figural Relations and Verbal Comprehension did not differ for the experimental and control group. On the contrary, the Posttest 1 correlation between the Cattell-Horn Figural Relations scores and Induction (another fluid measure) is higher in the experimental ($r = .74$) than in the control ($r = .37$) group. This finding, on a correlational level, gives further credence to our interpretation that the training program indeed affected fluid components of cognitive functioning. In line with the reviewer's suggestion, it is important to recognize, however, that future research needs to attend to transfer of training effects on both the level of average performance as well as the level of correlational patterns.

of training within the fluid-crystallized theory of intelligence and a concern with longitudinal maintenance of training over a 6-mo period.

The effectiveness of short-term cognitive intervention in modifying fluid intellectual functioning was examined in older adults with a mean chronological age of 69 and an age range from 59 to 85. The intervention program involved eight training sessions, focusing on Figural Relation ability, one of the primary components of fluid intelligence. Dependent criterion measures included tests from both the fluid and crystallized domain of intelligence.

Posttraining performance of 15 control and 15 experimental subjects was assessed utilizing a transfer of training paradigm with three posttest occasions, occurring approximately at 1 week, 1 mo, and 6 mo following training. Since the Cattell-Horn model of fluid and crystallized intelligence is postulated to be a structural model of intelligence, it was hypothesized that a hierarchical pattern of transfer would occur with the magnitude of training effects ordering themselves in descending order from near to far transfer measures. The order of transfer measures was based on their location in the multidimensional, factor analytic space provided by the fluid-crystallized theory and by their similarity to the content of the training program. The four transfer measures included in the assessment battery (listed in descending order of expected transfer of training effects) are: Figural Relations Diagnostic Test, Horn-Cattell Figural Relations Battery, Induction Measures, Verbal Comprehension Measures.

Significant training effects were shown for the fluid-nearest transfer measure (Figural Relations Diagnostic Test) on all three posttest occasions and for the second most fluid-near transfer measure (Horn-Cattell Figural Relations) on the first posttest. Significant retest effects were also evident for both the experimental and the control group for three of the four assessment measures. Retest effects, however, did not follow a hierarchical pattern of transfer as was true for the fluid improvement due to training. Such general retest effects would seem to be indicative of ability-extraneous performance variables, such as test taking sophistication.

The results suggest that fluid intelligence may be subject to more modifiability through short-term experiential intervention in aging than the theoretical features of the trait-like model imply. Moreover, the findings suggest that intellectual functioning in aging exhibits more plasticity than traditionally assumed. In the past, plasticity was primarily evident in non-fluid measures and in large interindividual and intercohort differences. The present study adds to these earlier findings plasticity in fluid performance resulting from short-term experiential training within a given age/cohort.

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