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A study of the relationships between measures of fluid and Piagetian intelligence

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Abstract

Francis Galton (1869) was the first to suggest the scaling of human general intelligence, distinguishing fourteen grades ranging from the most illustrious and eminent to imbeciles and idiots. He sought to show that such intelligence was mainly hereditarily determined, although he was awe.re that most brilliant individuals were reared in intellectually stimulating environments. Charles Spearman, an officer in the British Army and a man of great military tradi tion, likewise became interested in the nature of intelligence. Comparatively late in life he became a professor at the University of London, where he built a world-famous psychological research center. Spearman asked himself whether intelligence should be considered a single entity rather than a grouping of apparently unrelated abilities, as had been thought to be tho case by the test makers near the turn of' the century, most notably Alfred Binet. The originator of factor analysis, Spearman proposed in 1927 that all individuals possess a general intelligence factor (called g) in varying amounts. A person would be described as bright or dull depending upon the amount of g. Accordingly, Spearman felt the g factor to be the major determinant of performance on intelligence test items.

A STUDY OF THE RELATIONSHIPS BETWEEN MEASURES OF FLUID AND PIAGETIAN INTELLIGENCE

A Research Paper

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James Ray Hurley

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A STUDY OF THE RELATIONSHIPS BETWEEN MEASURES OF FLUID AND PIAGETIAN INTELLIGENCE

Chapter 1

The Problem

Francis Galton (1869) was the first to suggest the scaling of human general intelligence, distinguishing fourteen grades ranging from the most illustrious and eminent to imbeciles and idiots. He sought to show that such intelligence was mainly hereditarily determined, although he was aware that most brilliant individuals were reared in intellectually stimulating environments. Charles Spearman, an officer in the British Army and a man of great military tradition, likewise became interested in the nature of intelligence. Comparatively late in life he became a professor at the University of London, where he built a world-famous psychological research center. Spearman asked himself whether intelligence should be considered a single entity rather than a grouping of apparently unrelated abilities, as had been thought to be the case by the testmakers near the turn of the century, most notably Alfred Binet. The originator of factor analysis, Spearman proposed in 1927 that all individuals possess a general intelligence factor (called g) in varying amounts. A person would be described as bright or dull depending upon the amount of g. Accordingly, Spearman felt the g factor to be the major determinant of performance on intelligence test items.

A later researcher, Louis Thurstone (1938), objected to Spearman's g factor by stating that intelligence could be broken down into a number of primary abilities. To isolate these abilities Thurstone applied the method of factor analysis to

results from a large number of tests employing many different types of items. Those test items which were found to best represent each of the supposed basic factors were used to form new tests, and these tests were then given to another group of subjects and the intercorrelations reanalyzed. After a series of like studies, Thurstone stated that seven primary abilities were revealed by his tests. He summarized these abilities as in the table below.

ABILITY	DESCRIPTION
Verbal comprehension	The ability to understand the meaning of words, vocabulary tests represent this factor.
Word fluency	The ability to think of words rapidly, as in solving anagrams or thinking of words that rhyme.
Number	The ability to work with numbers and perform computations.
Space	The ability to visualize space-form relationships, as in recognizing the same figure presented in different orientations.
Memory	The ability to recall verbal stimuli such as word pairs or sentences.
Perceptual speed	The ability to grasp visual details quickly and to see similarities and differences between pictured objects.
Reasoning	The ability to find a general rule on the basis of presented instances, as in determining how a number series is constructed after being presented with only a portion of that series.

(Hilgard, Atkinson, Atkinson, 1975, p. 409)

In the preface to his classic book Primary Mental Abilities, Thurstone states, "As far as we can determine at present, the tests that have been supposed to be saturated with the general common factor divide their variance among primary factors that are not present in all the tests. We cannot report any general common factor in the battery of fifty-six tests that have been

results from a large number of tests employing many different types of items. Those test items which were found to best represent each of the supposed basic factors were used to form new tests, and these tests were then given to another group of subjects and the intercorrelations reanalyzed. After a series of like studies, Thurstone stated that seven primary abilities were revealed by his tests. He summarized these abilities as in the table below.

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analyzed in the present study."

If Thurstone's abilities are truly independent, one would not always expect individuals who score high in one or more abilities to score high in the remaining abilities. Unfortunately, for Thurstone, subjects who score high on the reasoning factor also score high on the number, verbal, and word fluency factors. In fact, the reasoning factor seems to be very similar to Spearman's g, leading Freeman in 1962 to suggest that Thurstone's primaries may be only particular cultural expressions of a single ability factor. Thurstone's inability to obtain results indicative of independent factors led him to conclude that in addition to primary abilities there is a second-order general factor.

Concurrent to the consideration of a general factor in intelligence was the effort of Jean Piaget and his coworkers at the Rousseau Institute and the Centre International d'Epistomologie Genetique, both in Geneva, Switzerland. Piaget has come to regard intellectual development as proceeding in definite stages rather than as a continuous process. The stage concept implies that the course of development is divided into step-wise levels with clear-cut changes from one stage to the next. These stages follow one another in an orderly sequence, the transition from one stage to the next involving a process of integration, whereby the behavior from earlier stages is integrated into the next, along with new elements. While environmental factors may speed up or slow down development, the sequence of stages is not changed.

As outlined by Sund (1976), the first two Piagetian stages are the sensorimotor and the preoperational, while the last two, which are of particular interest in this study, are the concrete and formal operational stages. In the concrete stage the individual is capable of logical thought, achieves conservation of number, mass, and weight, can classify and order objects, and understands some relational terms. The formal operational individual can think in abstract terms, follow logical propositions, and reason by hypothesis. He is able to isolate the elements of a problem and systematically explore all the possible solutions. The formal thinker is also concerned with hypothetical and ideological problems. Considering all possibilities, working out the consequences of alternate hypotheses, and confirming or denying these consequences is the essence of formal thought. The third stage is called concrete as, although the individual might use abstract terms, he does so only in relation to concrete objects. Not until the final stage of development is the individual able to reason in purely symbolic terms.

Piaget (Piaget and Inhelder, 1964) believes that what changes in intellectual development are structures, those organized aspects of intelligence which change with age, while functions, general characteristics of intelligent activity, remain the same. Individuals do not inherit structures, as these emerge in the course of development, but intellectual functions are inherited.

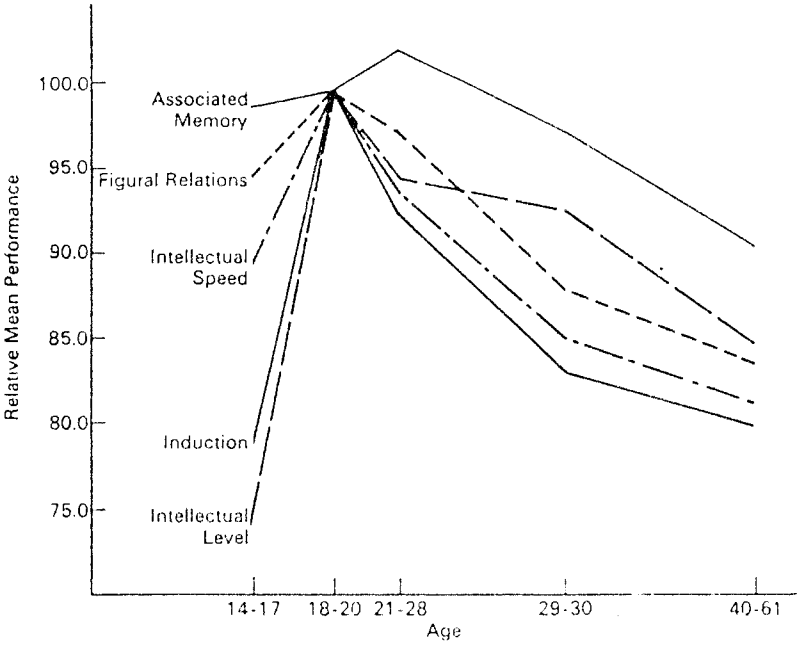
The dual nature of the inherited function and the acquired structure, although perhaps overshadowed by Piaget's descriptive

behavioral taxonomy, is similar to the work of Raymond B. Cattell. Cattell (1963) and John L. Horn (Cattell and Horn, 1966) also stress the dual nature of intelligence and believe that the concepts of fluid and crystallized intelligences satisfactorily deal with both the notion of general intelligence, Spearman's g, and factorial intelligence as posited by Thurstone and in greater detail by Guilford (1967). Cattell's crystallized intelligence represents the effect of acculturation on human ability while fluid intelligence is indicative of a pattern of neural-physiological and incidental learning influences. The basic processes underlying fluid intelligence are anlage functions, elementary capacities in perception, retention, and expression. These functions are elementary, yet must be present in some sufficient amount to adequately support higher order thinking. Anlage functions, and thus elements of fluid intelligence, develop relatively independently of arrangements one might make to foster them and are also independent of acculturation.

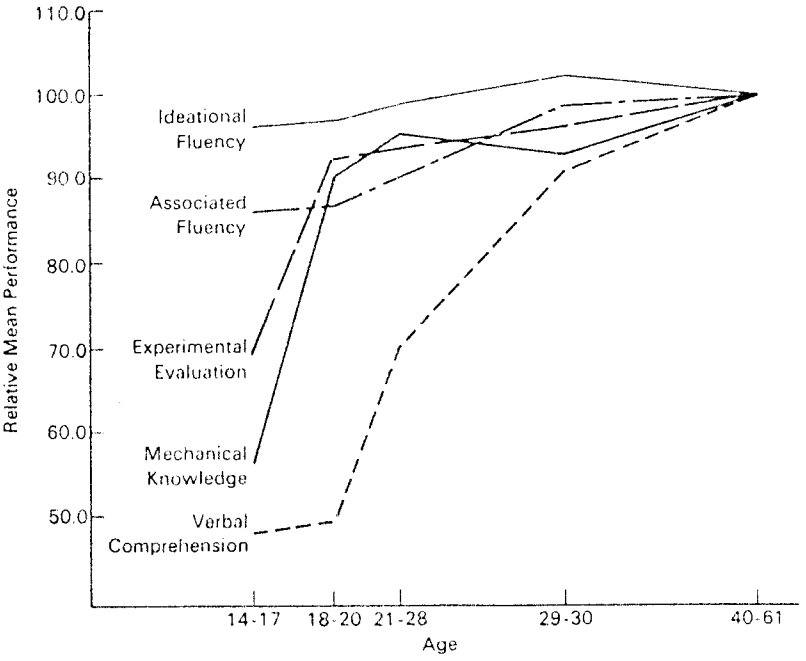
Although the hypothetical composite age curve representing the growth of intelligence from birth to middle age has classically been considered to be a flattened S-curve (Hilgard, Atkinson, and Atkinson, 1975, page 415), the work of Cattell and Horn in the late 1960's and early 1970's indicates that curves are very different for fluid and crystallized intelligence and that the usually accepted curve is a mixture of the two measures. The graphs on the following page (Cattell, 1971, page 168) illustrate the differences between the two sets of abilities.

Age Changes in Fluid and Crystallized General Abilities

(a) Fluid Intelligence Abilities:

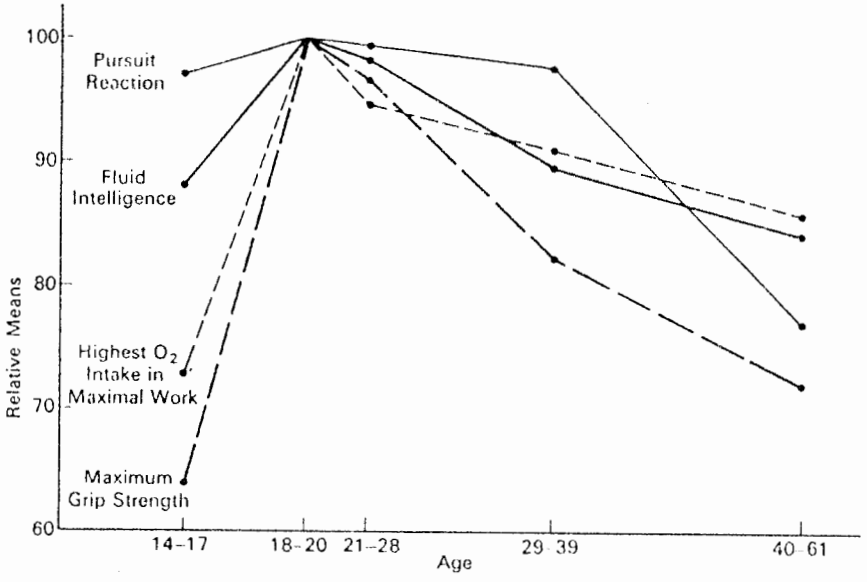


(b) Crystallized Intelligence Abilities



It is observed immediately that elements of crystallized intelligence, reflecting acculturation or wisdom, do not decline with age while fluid abilities fall steadily from a comparatively early age. Cattell considers this to indicate that gf, the element of fluid intelligence, is closely related to biological neural efficiency. Coupled with the fact that almost every known biological index shows a decline from about twenty years of age, illustrated in the graph below (Cattell and Horn, 1966), the parallelism of gf and general biological efficiency measures is quite striking.

Parallelism of Age Change Curves in Fluid Intelligence and General Biological Efficiency (Cattell and Horn, 1966b; Robinson, 1938; Miles, 1942; and Burle, *et al.*, 1953)



Of equal interest is the similarity seen to exist between gf and the levels of Piaget. Attainment of Piaget's top level and maximum achievement of elements of gf chronologically coincide, and the decline in gf abilities parallels the failure of successful application of Piagetian stages to older

adults, as reported by Rubin (1974) and Storck, Looft, and Hooper (1972). Although Piaget rejects any psychometric conception of intelligence, assuming assimilation simply causes a reorganization into existing structures resulting in a chronological retention, Cattell recognizes the analogy and states:

> An enormous amount of discussion- and a very limited amount of psychometric experiment- has been given by Piaget and his followers to the area of acquisition of abilities by learning, with the theory of which we are here concerned. This discussion, beginning with the valuable "naturalistic" observation of problem-solving in small children, has, in the main, failed to integrate with the main stream of quantitative experimental psychometric research, for lack of a methodological sophistication.....It has also taken virtually no account of the role of gf in making the perception of certain relations possible, which produces the well-documented correlation of acquisition of the more advanced tools with constitutional level on gf. The most disabling lack of perspective, however, has occurred in implicitly considering the gains of the child in these experiences as an increase in his "general ability"- as some general power in the child himself without regard to their being tied up in a specific relation to a specific environment. (Cattell, 1971, p. 315)

It is the purpose of the proposed study to explore the relationships between measures of fluid intelligence and

performance on Piagetian tasks.

Statement of the Problem

The purpose of this study was to examine student scores on two measures purporting to measure fluid intelligence, Raven's Progressive Matrices and Cattell's IPAT Culture Fair Intelligence Test, in view of the students' Piagetian level as assessed by Anton Lawson's Classroom Test of Formal Operations. The conceptual groundwork laid in the introduction above tends to indicate that the quantity under scrutiny in all three measures is similar. It is therefore hypothesized that 1) older, formal operational thinkers will exhibit a greater degree of fluid intelligence than younger, concrete operational thinkers, and 2) younger, formal operational thinkers will likewise illustrate a greater measure of fluid intelligence than older, concrete operational thinkers. The relationship of Piagetian intelligence to gf will then be established independently of the age of the subjects in the test group.

Importance of the Problem

If it can be sufficiently demonstrated through numerous and repeatable studies that the Piagetian and fluid intelligence theories have common elements, a quasi-biological interpretation of Piaget's observations will be possible. Consideration of inclusion of elements of fluid intelligence (associated memory, figural relations, intellectual speed, and induction) and crystallized intelligence (ideational fluency, associated fluency, experimental evaluation, mechanical knowledge, and verbal comprehension) into curricula at the most appropriate

and efficient time might then be possible. Furthermore, if fluid and Piagetian intelligences are similar, a reassessment of psychometric procedures should be undertaken. Educators should certainly be aware that perhaps standard measures of intelligence measure only one set of abilities, neglecting those skills which are relatively independent of environmental impact.

Assumptions

The underlying assumption in a study of this nature is that a test requiring adaptation to new situations is a measure of fluid ability, and that crystallized skills (gc) will be of no particular advantage. For individuals not at complete biological maturity, as was the case with the subjects in this study, it was also assumed that individual differences in the difference between gc and gf were reflected mainly as variations in fluid ability. Divergence of crystallized abilities was presumed minimal due to the similarity of the school experience of the subjects.

It should also be mentioned that with all comments regarding gf and gc, reference is being made to general factors in a broad array of fluid and crystallized abilities, rather than to any single ability.

Limitations of the Study

Some question has arisen in recent years as to whether construction of a test independent of acculturation is possible (Eells, 1951). Hilgard, Atkinson, and Atkinson (1975) point out that a study of rural Nigerian children in which it was concluded that lack of familiarity with pictorial representation

resulted in consistently poor performance, whereas identical tasks utilizing physical objects presented no difficulty to the subjects. Cattell (1971), however, points to success with his test for Chinese, Indian, European, American, Australian, and Japanese populations, and provides data indicating successful statistical isolation of a gf factor. In the table below (Cattell, 1971, page 487), note that data is listed for the Raven's test also.

Loadings (Saturations) When General Factor is Defined by Varied Collection of Intellectual Ability Measures

Test	*Presumed*[1] *gf*	*Presumed Cryst. Intell. or Educ. Factor*
IPAT Culture-Fair (Scale 2A)	.75	
Rav. Progressive Matrices	.71	
Lorge-Thorndike Fig. Class.	.58	
Lorge-Thorndike No. Series	.55	
Lorge-Thorndike Fig. Anal.	.74	
Holz-Crowder Fig. Ch.	.50	
Holz-Crowder Series	.46	.21
Holz-Crowder Spatial	.40	
Occupat. Status Parent	.25	
Home Index	.25	.21
Reading Vocabulary	.34	.74
Reading Comprehension	.50	.62
Arith. Reasoning	.46	.34
Arith. Fundamentals	.45	.44
Language	.42	.59
Spelling	.20	.62
Laycock	.68	.51
Cal. Test Ment. Matur. Spatial	.61	
Cal. Test Ment. Matur. Logical	.66	
Cal. Test Ment. Matur. Number	.64	.20
Cal. Test Ment. Matur. Verbal	.46	.66

[1] On 271 Canadian Grade 7 boys and girls. Rotation, not fully for simple structure, by R. S. McArthur and W. B. Elley, The reduction of socioeconomic bias in intelligence testing. *British Journal of Educational Psychology*, 1963, 33, 107-119. Correlations below .20 omitted.

LOADINGS IN DIFFERENT ANALYSIS, TOGETHER WITH CORRELATIONS WITH ACHIEVEMENT AND SOCIAL STATUS OF PARENTS[2]

Test	*g loading*	*Soc. Status*	*Achiev. Tests*
IPAT Culture-Fair	.79	.24	.35
Raven Matrices	.78	.23	.41
Lorge-Thorndike Fig. Class.	.58	.15	.31
Lorge-Thorndike No. Series	.55	.19	.41
Lorge-Thorndike Fig. Anal.	.74	.26	.39
Lorge-Thorndike Total	.75	.27	.47
Holz-Crowder Series	.46	.31	.49
Holz-Crowder Fig. Ch.	.52	.22	.39
Cal. Test Ment. Matur. Non-Lang.	.62	.18	.38
Cal. Test Ment. Matur. Lang.	.58	.41	.66
Cal. Test Ment. Matur. Total		.38	.65
Laycock Intelligence Test	.68	.35	.64

(Cattell, 1971, p. 488)

Perhaps a culture fair test is impossible in principal- an individual's performance may always be affected by cultural background regardless of the nature of the test. A degree of faith in the test instruments appears justified, however, and any success of this study was understood to be limited by any element of culture-unfairness.

Definitions of Terms

For the purposes of the proposed study, the following definitions are made:

1) Fluid intelligence, or gf, is taken to be a neural-physiological entity determining proficiency in associated memory, figural relations, intellectual speed, and induction, and is that factor which is measured by Raven's Standard Progressive Matrices and Cattell's IPAT Culture Fair Test.

2) Crystallized intelligence, or gc, is taken to be a broad array of cultural factors determining proficiency in ideational fluency, associated fluency, experimental evaluation, mechanical knowledge, and verbal comprehension. It is assumed that the two evaluative tools mentioned contain a negligible assessment of gc.

3) Concrete operational thinkers are operationally defined as those individuals who achieve a score of 6-11 on Lawson's Classroom Test of Formal Operations.

4) Formal operational thinkers are operationally defined as those individuals who achieve a score of 12-15 on Lawson's Test of Formal Operations.

5) The term "younger" is applied to subjects drawn from the 9th grade.

6) The term "older" is applied to subjects drawn from the 12th grade.

In this study the independent variable will be concrete vs. formal thought (as this consideration is of a nominal nature), the moderator variable under consideration will be age (younger vs. older), and the dependent variable is performance on the Raven's and Culture Fair tests.

Chapter 2

Review of Related Literature

The basic premises of Piaget's theory are presented in his book The Origins of Intelligence in Children (1952) and Piaget and Inhelder's The Growth of Logical Thinking from Childhood to Adolescence (1958). Additionally, Sund (1976) has authored a multimedia program, Piaget for Educators, which utilizes the learning cycle (exploration, concept introduction, and concept application), an extension of Piagetian theory, to introduce the theory to teachers. In his article "The Development and Validation of a Classroom Test of Formal Reasoning", Lawson (1978) explains in detail the content and development of the examination used in this study. Lawson and Nordland (1976) also present a review of several of the Piagetian tasks contained in the Lawson test.

Those not familiar with the theory of fluid and crystallized intelligence are referred to Cattell's book Abilities: Their Structure, Growth, and Action (1971), his article "Theory of Fluid and Crystallized Intelligence: A Critical Experiment" (1963), Cattell and Horn's "Refinement and Test of the Theory of Fluid and Crystallized General Intelligences" (1966), and Horn's "Organization of Abilities and the Development of Intelligence" (1968). Cattell and Horn continue the development, refinement, and defense of their efforts in the articles "Check on the Theory of Fluid and Crystallized Intelligence with Description of New Sub-Test Designs" (Cattell and Horn, 1978) and "Are Culture Fair Intelligence Tests

Possible and Necessary?" (Cattell, 1979).

A similarity previously noted between the Piagetian and fluid intelligence theories was the regression of abilities of the aged. Age differences in primary mental abilities are illustrated by Cattell and Horn (1966), while Hooper, Fitzgerald, and Papalia (1971) in their article "Piagetian Theory and the Aging Process: Extensions and Speculations" note that "Piagetian logical functioning is potentially subject to qualitative disorganization and regression with advancing years." Rubin (1974) concludes from his studies on egocentrism that "the combined effects of increasing neural decrement and decreasing activity within the environment lead to cognitive regression" or, in Piagetian terms, structural disintegration.

A startling lack of literature exists purporting to show similarity between the two theories as they might be applied to adolescents. Storck, Looft, and Hooper (1972) examine interrelationships between Piagetian tasks and traditional tests of cognitive abilities in mature and elderly adults, while Rubin, Brown, and Priddle (1978) do the same for elementary school children. Carlson, Dalton, and Fagal (1977) also have performed an investigation of somewhat limited scope. It is therefore hoped that the study undertaken may in some minute way contribute to further understanding in this area.

Chapter 3

Design of the Study

Subjects

In order to achieve the greatest possible critical mass for the study, as many individuals as possible were placed into the appropriate criterion groups (Younger Concrete, Younger Formal, Older Concrete, Older Formal) by first administering Lawson's Test of Formal Operations. The Raven's test and Cattell's IPAT were then administered on consecutive days. In order to facilitate computations done in the analysis of variance, equal numbers of individuals were placed into the appropriate groups. A total of 80 students were involved in the study, 20 per criterion group.

The younger students were drawn from three classes of freshman general science, an elective course (although virtually all of the freshman students fulfill their one-year science requirement with this class). The older students were drawn from elective classes in senior English and it was assumed that since the different classes were designed for all levels of student ability, variations in IQ, ability, and sex would equalize within the framework of the original group criteria. Subjects who participated in the research might best be described as "selected volunteers", as the researcher was in a position of authority over them. It was assumed that this relationship had no bearing on the experimental outcome as the evaluative instruments are not of an opinion or survey nature.

Experimental Design

The following design was decided upon as Concrete vs. Formal

may be considered a nominal independent variable, Younger vs. Older as a nominal moderator variable, and scores on the Raven's test and Cattell's IPAT as interval dependent variables.

	C	F
Y	01,02	03,04
O	05,06	07,08

C= Concrete thinkers
F= Formal thinkers
Y= Younger students
O= Older students
01,03,05,07= Raven's scores
02,04,06,08= IPAT scores

The hypotheses are now restated as:

1) the scores 07 and 08 will significantly differ from the scores 01 and 02,

and 2) the scores 03 and 04 will significantly differ from the scores 05 and 06.

Data Analysis

As the independent and moderator variables are nominal while the dependent variables are interval, the appropriate statistical tool is analysis of variance. (Tuckman, 1978) A two-factor analysis of variance was performed twice, once for the Raven's scores and again for the Cattell scores. Such analysis clarifies the action and interaction of the variables on the dependent measures. Additionally, independent means t-tests were conducted to more directly address the two hypotheses listed above.

Description of Instruments to be Used

Determination of Piagetian level has traditionally been made by personal interview, so the development of a classroom test was a welcome departure from special materials and time-consuming methods. Lawson's test is a composite of several techniques, many authored by Piaget himself, and is reported

by Lawson (1978) to have a reliability of .86 utilizing Cronbach's Alpha Coefficient, a modification of the KR-20 formula for scalable items. Test-retest correlation coefficients obtained from various groups range from .48 to .78. To assess face validity, Lawson submitted his test for consideration to a panel of six Piagetian researchers, and they responded unanimously that the test was appropriate. Convergent validity is established by item utilizing Pearson product-moment coefficients and factorial validity is established by principal components analysis. Individuals interested in the details of the test construction are referred to Lawson (1978).

In the guide to administering his test, Raven (1977) reports a test-retest reliability of .83 to .93, varying with age. For the sample considered in this study the reliability is .93. Raven cites additional studies illustrating that scores on the test reach a maximum for subjects at about age 14, remain constant for ten years, and then begin to decline uniformly. This pattern is taken to indicate that fluid abilities decline. Raven's statistics were generated from samples obtained in England in the 1930s but he states, "For comparative purposes the SPM is now used internationally, and no revision of it has yet appeared necessary." (Raven, 1977)

In a review of Raven's test, Lemke and Wiersma (1976) report that the test has a .79 loading on the gf factor and essentially zero loadings on all other factors, indicating that the test is homogeneous in content. This tends to lower the criterion validity, since the item correlation is high, but the construct validity is therefore high. They also state

that the test may not correlate with tests which may contain cultural bias, although they indicate a correlation of .86 with the Terman-Merrill scale.

In the handbook accompanying his test, Cattell (1960) presents extensive data outlining its reliability and validity, and the concerned reader should avail himself of this information. Originally normed on a sample of 3140, Cattell lists over thirty studies which favorably review his test with correlations with gf consistently near .8. Additionally, Buros (1959) views the test favorably in The Fifth Mental Measurements Yearbook. Cattell points to his sub-test format as advantageous to that of Raven's single format and rejects as useless any correlations with intelligence tests which evaluate mainly crystallized abilities while citing a correlation of .73 with other recognized tests of general ability. Test reliability is listed as .84-.94 test-retest for four undergraduate samples (N=400) and .82-.95 split-half on three undergraduate groups (N=367).

Chapter 4

Results

Application of the technique of analysis of variance yields the following results.

Table 1 Analysis of Variance of Raven's Scores by Piagetian Level and Age

Source	df	MS	F	p
Total	79	--	-	-
Piaget	1	720.00	27.33	< .001
Age	1	84.05	3.19	< .05
Piaget X Age	1	42.05	1.60	n.s.
Error	76	26.34	-	-

Table 2 Analysis of Variance of IPAT Scores by Piagetian Level and Age

Source	df	MS	F	p
Total	79	--	-	-
Piaget	1	5412.00	26.77	< .001
Age	1	2761.20	13.66	< .001
Piaget X Age	1	387.30	1.92	n.s.
Error	76	202.19	-	-

Preliminary conclusions drawn from the analyses of variance are:

1) Piagetian level significantly affects performance on both the Raven's and the IPAT measures. In both cases significance is observed at the .001 level.

2) Age significantly affects performance on both the Raven's and the IPAT measures. Significance is observed at the .05 level for the Raven's and at the .001 level for the IPAT.

3) No interaction exists between the variables Piagetian level and Age on either the Raven's or the IPAT measures.

While analysis of variance clarifies the action and interaction of the independent and moderator variables on the dependent variable, in order to more directly address the hypotheses that 1) Older Formal thinkers outperform Younger Concrete thinkers, and 2) Younger Formal thinkers outperform Older Concrete thinkers, independent means t-tests were performed. The results of these tests are presented in Table 3.

Table 3 Independent Means t-Test Results

Hypothesis	df	t	p
$\overline{OF} > \overline{YC}$ (Raven's)	38	5.16	<.001
$\overline{YF} > \overline{OC}$ (Raven's)	38	2.35	<.025
$\overline{OF} > \overline{YC}$ (IPAT)	38	7.40	<.001
$\overline{YF} > \overline{OC}$ (IPAT)	38	0.93	n.s.
$\overline{YF} > \overline{OC}$ (revised IPAT)	37	1.61	<.1

Preliminary conclusions drawn from the t-tests are:

1) Older Formal thinkers significantly outperform Younger Concrete thinkers on both dependent measures.

2) Younger Formal thinkers significantly outperform Older Concrete thinkers on the Raven's measure but not on the IPAT. Significance is observed on the IPAT measure, however, if one extreme score (IQ 162) is discounted.

Discussion of Results

The superiority of the Formal thinkers over the Concrete thinkers on both measures of gf is firmly established ($p < .001$) and supports the contention that individuals in the higher Piagetian level possess a greater amount of gf. If gf is considered a strict function of Piagetian level, however, the significance of age on performance ($p < .05$ for the Raven's and $< .001$ for the IPAT) is difficult to explain. Why should Older Concrete thinkers outperform Younger Concrete thinkers on tests which claim no crystallized component if Piagetian level is, in fact, determined by gf? Examination of the following figures clarifies this problem.

Figure 1 Raven's Scores as a Function of Piagetian Level and Age

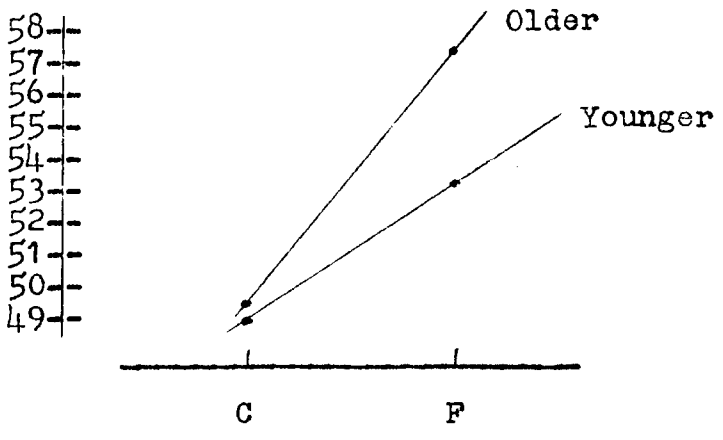
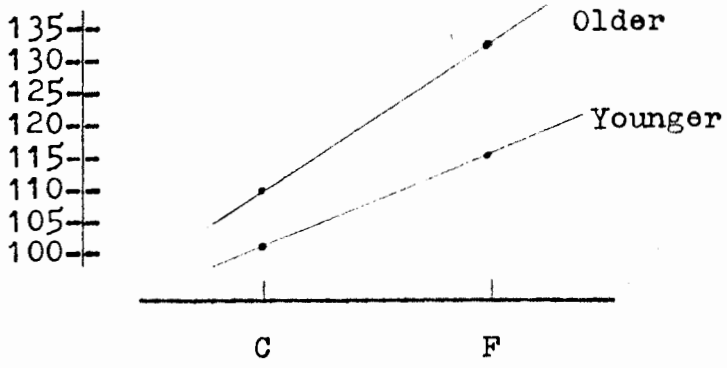


Figure 2 IPAT Scores as a Function of Piagetian Level and Age



It is readily observed that the variance becomes statistically significant due to the superiority of the Older Formal thinkers over the Younger Formal thinkers. The Older Concrete thinkers have not significantly outperformed the Younger Concrete thinkers. Again, however, the question of age arises. Why have the Older Formals outperformed the Younger Formals? If faith is placed in the tools of measurement of gf, i.e., if their crystallized content is negligible, one possibility would be to attribute the superiority to neural maturation, supportive of Cattell's attempt to relate intellectual development to physiological development. In compiling data for analysis, a confusing situation is encountered, however, in that Cattell's last age group entry in his normed tables is "13.9-adult"! (see Appendix) If such neural differences exist from early to late teen years, should there not be different entries? Perhaps allowing the older adolescents to dominate the younger within the group is Cattell's argument for positing neural maturation, but use of such tables to illustrate intellectual decline in the aged presents perhaps insurmountable difficulties. The Raven's data continues to age 65 so no such problem would occur, however a ceiling effect is observed in

the Old Formal group (25% of the group received perfect scores), accounting for the lower level of significance ($p < .05$ for the Raven's as compared to $p < .001$ on the IPAT) on the Age variable.

While Tables 1 and 2 report no significance on the Piaget X Age interaction, it should be reported that interaction did exist on both dependent measures near the .2 level. Figures 1 and 2 illustrate the differential action of Age while Figures 3 and 4 show the same for Piagetian level.

Figure 3 Raven's Scores as a Function of Age and Piagetian Level

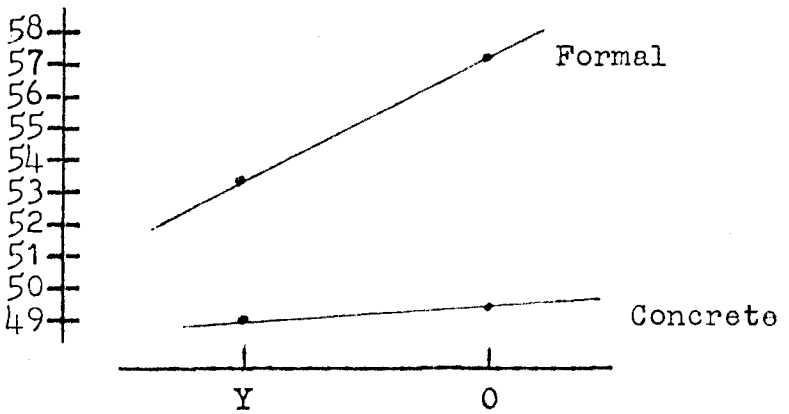
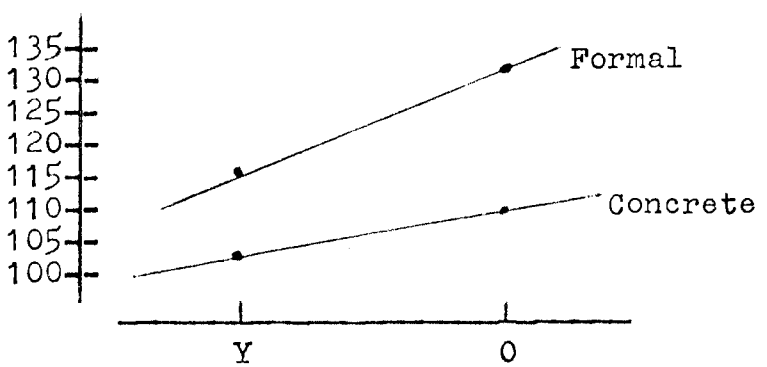


Figure 4 IPAT Scores as a Function of Age and Piagetian Level



Figures 3 and 4 illustrate that once an individual moves from the Concrete to the Formal level, his intellectual development is accelerated as he matures over and above what is observed had such a transition not occurred. Again, while Cattell's theory is perhaps only mildly supported, it certainly is not refuted.

The t-test results isolate cells of the experimental design to directly address hypotheses about different groups. Hypothesis 1 listed in the Chapter 3 Experimental Design section, i.e., Older Formal students will significantly outperform Younger Concrete students, is supported at the .001 level on both dependent measures. Such an hypothesis is made to insure that both measures yield an anticipated result. The crucial t-test is that which responds to Hypothesis 2, that Younger Formal thinkers will outperform Older Concrete thinkers. From Table 3 it is observed that the hypothesis is supported at the .025 level for the Raven's test, while the IPAT test yields a non-significant result. Included in the Older Concrete group, however, is an IQ score of 162, nearly four standard deviations above the mean score of 100 (for the norm group), and more than three standard deviations above the cell mean! Discounting this one individual and computing a revised t yields significance at the .1 level for the IPAT measure.

Discussion of the data would be incomplete without subjective comment on the three measures employed in this study. The Lawson Test of Formal Operations seemed to adequately differentiate the Concrete from the Formal thinkers, while definite problems occurred with both the Raven's test and the IPAT.

As previously mentioned, a definite ceiling effect was observed in the Raven's results. Of the five sets of twelve matrices, only the fourth and fifth seemed to discriminate. Although there is an Advanced Matrices Test, the 1977 Raven's manual indicates that the Standard Progressive Matrices is the appropriate test for the age group included in this study. Additionally, scores must still be compared to normative data obtained four decades ago in England. The 1977 manual presents more recent data only for ages 5.9 to 11.9 years.

While the Cattell examination was found to adequately discriminate between the four test groups, questions arise in observing some of the extremely high IQ scores. A score of nearly four standard deviations above the mean, tha 162 previously mentioned, should be nearly impossible to achieve. Also, the mean of the Older Formal group is two standard deviations above the mean. Of the twenty individuals contained in this cell, all but one would be screened as gifted according to most current definitions! Again, while an advanced scale exists for this measure, it is recommended only for "college students... and (use) with other individuals considered generally higher in ability." (Cattell & Cattell, 1959) If this study is to be repeated, consideration should be given to using advanced scales for both the Raven's and the IPAT tests.

Chapter 5

Discussion

William of Ockham, the most influential scholastic thinker of the fourteenth century, stressed in his writings that "entities must not be multiplied beyond what is necessary." (Courtenay, 1977) Known as Ockham's Razor, this principle, that the simplest theory which fits the facts of a situation should be selected, has become the goal of research. Newly obtained data must either take its place within the framework of current theory, or revision of theory must be undertaken to accommodate the data. Kuhn (1979) notes that the difficulties encountered in attempts at reduction are revealing of the ambiguities that exist within theories, and that attempts to overcome the difficulties contribute to clarification of new strategies for development of theory. Horn (1968) also argues that "future research should be directed toward bringing together results from studies pertaining to process and development, on the one hand, and results on structure (or correlational patterns) among performances in ability tests, on the other hand." It was the purpose of the present study to explore the relationships between fluid and Piagetian intelligences to see if scores obtained on measures of fluid intelligence are dependent on Piagetian level. If the descriptions of behavioral development can be statistically substantiated by the work of Cattell, perhaps the two theories can complement one another in providing a more scientific interpretation of the complexity of human intelligence.

This study indicated that the gf factor of fluid intelligence is closely related to Piagetian level- formal operational thinkers were found to possess more of this postulated quantity than concrete operational thinkers. Determining whether such coexistence is causal or coincidental is beyond the scope of this research effort, however. Also, while the technique of analogy employed in this study may be less direct than other research methods, attempts at combination of the two theories are justified if significant and numerous similarities are identified. While the Newtonian synthesis rendered the work of Kepler, which itself was a synthesis of the efforts of Brahe, to be of secondary importance, the impact of Kepler's three laws is not lessened, nor would it be reasonable to maintain Kepler's efforts as separate and distinct from those of either Brahe or Newton. Piaget and Cattell are not in competition and if their efforts are concurrent, each should support the other. The descriptive taxonomy and the quasi-biological interpretation both have their place in the study of intelligence. Horn (1968) supports this contention by stating:

> For too long there have been too many invidious comparisons of work stemming from these sources, the implication sometimes being that one approach had the inside road to truth while the other was patent nonsense. When stated thus bluntly, of course, such extreme positions can be rejected rather easily. Nevertheless, there has been precious little cross-reference in the two major streams of research here indicated. Fortunately, many

signs point toward removing communication barriers between these two. In this sense the gf-gc theory, with its emphasis on bringing factor-analytic research on abilities into the context of developmental and process theories, is just one among several aspects of a Zeitgeist.

While it is tempting to search for immediate uses to which a theory might be put, the development of either of the two theories with which this study concerns itself may be only partial. No one knows how to move an individual from the concrete to the formal stage, or even if facilitation of such movement is possible. Duckworth (1979), an associate of Piaget, notes that "Piaget's own view is that such development takes time and cannot be hastened. Simply telling children the truth about something cannot make them understand it." Similarly, Glaser and Resnick (1972) state "Progress from one stage to the next depends on maturational changes so that training is most effective if it occurs when the child is ready." Gauld (1979) suggests that "Piaget's is not an adequate framework to provide the kind of detail needed by classroom teachers...". Furthermore, he believes that "in the long run the development and coordination of schemes has to take place in the student's mind and so, to some extent (possibly to a large extent), is out of the teacher's control. It may not occur at all." While Duckworth considers diagnosis of intellectual level to tailor individual instruction to be an impractical goal, Martin (1980) claims success in such a use of theory in his article "A Piagetian Approach to Teaching

Physics". Additionally, Lawson (1978) believes that development of intelligence theory will benefit formal thinkers who have been mistakenly placed into remedial programs. Likewise, the factor "gf" is only a postulated construct and even if it could be isolated as a real quantity, could it be produced, nurtured, or manipulated, perhaps to enhance development of formal thinking? If one could literally bottle and sell gf, even knowing the outcome of its consumption, would marketing of such a substance be desired?

The physicist is familiar with the concept of introducing energy into a system. In pushing a child on a swing, force applied only at specific times will facilitate maintenance of the activity. Blindly and randomly extending the arms to push the child on the swing will produce no desired effect and will most likely produce some undesireable ones. So too, perhaps the work of Piaget and Cattell addresses itself more to what cannot be done than to what can. Attempts to produce the formal thinker or to increase gf may be philosophically misguided, as perhaps Robert Graham ("Superkids?", 1980) is in his attempt to breed genius. Inclusion of the appropriate elements of fluid and crystallized intelligences at the most efficient time may be the only educational product of either theory. Increasing such efficiency, or manipulating the level of fluid intelligence may not be possible. Duckworth, in her article "Either We're Too Early and They Can't Learn It or We're Too Late and They Knew It Already", explains that whatever the state of development at a given moment, the child may or may not even think of bringing higher capacities to

bear on a problem. She believes that the real issue for educators should be when and how does anyone think of bringing higher levels of thought into play.

This research study can, at best, stand as a minimal contribution to the research yet to come in clarifying the relationship of the work of Piaget to that of Cattell. As noted previously, if this study were undertaken again, more advanced measures of gf might clarify the results. An additional consideration would be to treat transitional individuals as separate from the concrete group. (Piaget (Sund, 1976) has postulated a transitional phase between the concrete and formal levels. The present study considered such individuals to be concrete.) Studies of the loss of neural efficiency in the aged are also potential sources of increased understanding of the development and decline of intellect. Cattell and Horn (1966) suggest that understanding the aged might be aided by conceiving their mental abilities to consist of gf and gc, which are affected in different ways by different influences.

References

Buros, O. K. The Fifth Mental Measurements Yearbook. New Jersey: The Gryphon Press, 1959.

Carlson, J. S., Dalton, S., & Fagal, R. E. A comparison of the predictive validity of a measure of general intelligence and a Piaget-derived test relative to an achievement examination in high school chemistry. Educational and Psychological Measurement, 1977, 37(4), 999-1003.

Cattell, R. B. Abilities: Their Structure, Growth, and Action. Boston: Houghton Mifflin, 1971.

Cattell, R. B. Are culture fair intelligence tests possible and necessary? Journal of Research and Developmental Education, 1979, 12, 3-13.

Cattell, R. B. Theory of fluid and crystallized intelligence: a critical experiment. Journal of Educational Psychology, 1963, 54(1), 1-22.

Cattell, R. B., & Cattell, A. K. S. Handbook for the Culture Fair Intelligence Test. Champaign, Ill.: Institute for Personality and Ability Testing, 1959.

Cattell, R. B., & Horn, J. L. Age differences in primary mental ability factors. Journal of Gerontology, 1966, 21, 210-220.

Cattell, R. B., & Horn, J. L. Check on the theory of fluid and crystallized intelligence with description of new subtest designs. Journal of Educational Measurement, 1978, 15, 139-164.

Cattell, R. B., & Horn, J. L. Refinement and test of the theory of fluid and crystallized general intelligences. Journal of Educational Psychology, 1966, 57(5), 253-270.

Courtenay, W. J. William of Ockham. The World Book Encyclopedia. Chicago: Field Enterprises Educational Corporation, 1977.

Duckworth, E. Either we're too early and they can't learn it or we're too late and they know it already. Harvard Educational Review, 1979, 49, 297-312.

Eells, K. Intelligence and Cultural Differences. Chicago: University of Chicago Press, 1951.

Galton, F. Natural Inheritance. London: Macmillan and Co., 1869.

Gauld, C. F. Physics teaching and cognitive functioning: a neo-Piagetian perspective. Physics Teacher, 1979, 17, 513-518.

Glaser, R., & Resnick, L. B. Instructional psychology. Annual Review of Psychology, 1972, 23, 207-276.

Guilford, J. P. The Nature of Human Intelligence. New York: McGraw-Hill, 1967.

Hamilton, V., & Vernon, M. D. (ed.). The Development of Cognitive Processes. London: Academic Press Inc., 1976.

Hilgard, E. R., Atkinson, R. C., & Atkinson, R. L. Introduction to Psychology. New York: Harcourt Brace Jovanovich, Inc., 1975.

Hooper, F. H. Piagetian theory and the aging process: extensions and speculation. Aging and Human Development, 1971, 2(1), 3-20.

Horn, J. L. Organization of abilities and the development of intelligence. Psychological Review, 1968, 75(3), 242-259.

Inhelder, Barbel, & Piaget, Jean The Growth of Logical Thinking from Childhood to Adolescence. New York: Basic Books, 1958.

Inhelder, Barbel, & Piaget, Jean The Growth of Logic in the Child. New York: Norton, 1964.

Kuhn, D. Application of Piaget's theory of cognitive development to education. Harvard Educational Review, 1979, 49, 340-360.

Lawson, A. E. The development and validation of a classroom test of formal reasoning. Journal of Research in Science Teaching, 1978, 15(1), 11-24.

Lawson, A. E., & Nordland, F. H. The factor structure of some Piagetian tasks. Journal of Research in Science Teaching, 1976, 13(5), 461-466.

Lemke, E., & Wiersma, W. Principles of Psychological Measurement. Chicago: Rand McNally College Publishing Company, 1976.

Martin, D. R. Piagetian approach to teaching physics. Physics Teacher, 1980, 18, 34-38.

Piaget, Jean The Origins of Intelligence in Children. New York: International Universities Press, 1952.

Raven, J. C. Guide to the Standard Progressive Matrices. London: H. K. Lewis & Co., 1977.

Rubin, K. H. The relationship between spatial and communicative egocentricism in children and young and old adults. Journal of Genetic Psychology, 1974, 125, 295-301.

Rubin, K. H., Brown, I. D. R., & Priddle, R. L. The relationships between measures of fluid, crystallized, and

Piagetian intelligence in elementary school-aged children. Journal of Genetic Psychology, 1978, 132(1), 29-36.

Spearman, C. E. The Abilities of Man, Their Nature and Measurement. New York: Macmillan and Co., 1927.

Storck, P., Looft, W., & Hooper, F. Interrelationships among Piagetian tasks and traditional measures of cognitive abilities in mature and aged adults. Journal of Gerontology, 1972, 27, 461-465.

Sund, Robert Piaget for Educators. Columbus: C. E. Merrill, 1976.

Superkids? A sperm bank for Nobelists. Time, March 10, 1980, 49.

Thurstone, L. L. Primary Mental Abilities. Chicago: University of Chicago Press, 1938.

Tuckman, Bruce Conducting Educational Research. New York: Harcourt Brace Jovanovich, Inc., 1978.