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ABSTRACT

One hundred and sixty-two subjects of three age levels were tested to examine the relationship between crystallized and fluid abilities and three problem solving tasks varying in the abstractness/concreteness of their stimuli and emphasis on past experience. These dimensions have been used by Davis to distinguish between Type "O" and Type "C" problem solving. Predictions regarding problem solving made from the crystallized-fluid intelligence theory of Horn and Cattell were supported only in the elderly group of subjects. Between factor relationships supported a reintegration of abilities in old age, contrary to crystallized-fluid theory predictions made on the basis of previous research. Results suggested that a reinterpretation of age-related trends in ability-performance relations is warranted emphasizing the roles of cohort specificity and individual differences in such relationships. (Author)

Age Differences in Relationships Between Crystallized and Fluid Intelligences and Problem Solving

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Abstract

One hundred and sixty-two subjects of three age levels were tested to examine the relationship between crystallized and fluid abilities and three problem solving tasks varying in the abstractness/concreteness of their stimuli and emphasis on past experience. These dimensions have been used by Davis to distinguish between Type "O" and Type "C" problem solving. Predictions regarding problem solving made from the crystallized-fluid intelligence theory of Horn and Cattell were supported only in the elderly group of subjects. Between factor relationships supported a re-integration of abilities in old age, contrary to crystallized-fluid theory predictions made on the basis of previous research. Results suggested that a reinterpretation of age-related trends in ability-performance relations is warranted emphasizing the roles of cohort specificity and individual differences in such relationships.

Horn and Cattell state that two general types of intelligence exist, each with its own unique ontogenetic pattern of change. Fluid intelligence (Gf) is tied to the neurophysiological status of the organism. After increasing until adolescence, these abilities show a constant cross-sectional decline from approximately age 20 on, the rate of this decline increasing with age. Crystallized abilities (Gc) develop initially as a function of fluid factors and are said to be later due to acculturation effects. These abilities show a constant increasing pattern of growth prior to a slight decline before death.

Davis (1966) subdivides problem solving into two varieties. In Type "O" problems, the subject has formed few preexperimental associations and begins with overt trial and error behavior to test various responses. The subject <u>then</u> covertly, in serial fashion, tests each response alternate, one of which eventually meets solution requirements. These problems are more abstract and unfamiliar and scoring is usually continuous as in the case with switch-light, probability learning and concept identification tasks. Type "C" problems involve response outcomes which, due to pre-experimental trial and error learning, are known to the subject. They can be tested covertly prior to problem solution. More concrete, familiar materials are used and scoring is all-or-none in nature. Representative Type "C" tasks would include anagrams, water-jar, arithmetic, or "insight" problems.

The hypothesized relationship between Type "C" performance and Gc had as a primary basis the literature associating vocabulary level and anagram problem solving (Mendelsohn et al., 1972). A Type "O" performance/Gf relationship should also be substantial due to 1) the nature of Gf, 2) the cross sectional decrements obtained with both Type "O" tasks (Arenberg, 1973) and Gf (Horn and Cattell, 1967), and 3) the relationship suggested between Gf and Type "O" performance in the problem solving literature (Arenberg, 1973;

Wetherick, 1964, 1966). It is thus because Type "C" tasks and Gc both centralize the role of past experience and Type "O" problems and Gf both show similar cross-sectional trends, deemphasizing past learning, that these basic hypotheses were made. In addition, statements by Horn (1974) and Cattell (1971) would seem to suggest such a pattern of ability-learning relationships.

Ontogenetic considerations led us to predict that as Type "C" performance, relative to Type "O" tasks, increases across age levels (or fails to decline), the difference in correlation between crystallized ability and Type "C" performance versus that between fluid ability and Type "C" performance should increase. Differences in correlation between Gc versus Gf and Type "O" performance should likewise increase with age. For younger subjects, we would expect less of a difference in these relationships than for older subjects due to the differences in Gf/Gc correlations in each age group.

Alternatively, the proposed relationship between Gc and anagram solving could be questioned if the ability to "unscramble" or "process" an anagram is seen as important as providing the correct solution word in determining performance. One could also associate Gc and proficiency on tasks that are somewhat abstract (a characteristic of Type "O" tasks) if, as Bourne (1966) has noted, the ability to deal with abstract concepts is derived from the use of language.

Three groups (n=54) of subjects varying in age were tested, the age range being 17-26, 39-51, 59-76. Equal numbers (27) of males and females comprised each group.

The tasks measuring fluid intelligence (Gf) were Cattell's Culture Fair Matrices, WAIS digit span, and the common word analogies and letter series portions of the Gf-Gc sampler (Horn, personal communication, 1975).

Crystallized intelligence (Gc) was assessed by the WAIS Information and

Vocabulary subtests and the multiple choice vocabulary and abstruse word analogies portions of the Gf-Gc Sampler (Horn, personal communication, 1975).

Three problem solving tasks, varying in terms of their degree of concreteness/abstractness and emphasis on past experience, in keeping with Davis' Type "O"-Type "C" dichotomy, were utilized.

The task employed as a Type "C" problem was the anagram task. Thirty anagrams equally distributed with respect to difficulty as determined by normative solution times were utilized. Dependent variables were number of anagrams correct and time to solution (within a 30-minute limit) for the list of anagrams.

Arenberg's (1968) "poisoned foods" (PF) problem was selected as a task containing elements of both Type "C" and Type "O" problems. It consisted of a "concept" ("lived" as a negative instance or "died" as a positive instance) which was the poisoned food to be identified. Each "instance" (meal) contained three attributes (meat, beverage, vegetable) each taking three values (lamb, steak, veal; milk, tea, coffee; beans, peas, corn).

The Type "O" problem was a unidimensional concept identification (CI) task, with three values (red, green, blue; square, circle, triangle; two, three, four) being used from each of three dimensions (color, form, number). Each Type "O" problem employed a modified reception paradigm. Dependent variables were in each case 1) trials to criterion, 2) errors (incorrect identifications) prior to criterion, and 3) time to criterion. When this criterion of ten correct identifications was reached or if either problem was not solved within 108 trials, testing was terminated.

Subjects were tested individually in one session, if possible. A 2-hour per day limit on testing was utilized and the order of presentation for all tasks was counterbalanced. Except for the time limit on the anagram task, no tests were speeded in the present study.

Table 1 shows the Hotelling t valu s across age to express the difference in correlation between 1) Gc and problem solving versus 2) Gf and problem solving. For the young three pairs of correlations differed significantly. In the middle aged, only two pairs of correlations were found to be significantly different. For the oldest subjects, a lone pair of correlations was found to differ significantly.

A multiple stepwise regression analysis (Table 2), treating Gc and Gf as independent predictor variables, and each measure of problem solving as the dependent, or criterion variable was also utilized. Independent variables were entered on the basis of stepwise inclusion.

It can be seen that the second independent variable in no case explained a significantly greater proportion of variance in conjunction with the first independent variable above that accounted by the first independent variable alone. For the youngest group (17-26), Gc accounted for a major proportion of the variance (relative to that explained by both Gc and Gf) in 1) time for completion of the anagram task, 2) errors to criterion in the poisoned foods task, and 3) all concept identification task variables. Gf accounted for the most variance in 1) number of anagrams correct, and 2) trials and time to criterion in the poisoned foods task.

For the middle aged (39-51), Gc alone explained the most variance in all dependent measures with the exception of 1) number of anagrams correct and 2) time for completion of the anagram task.

For the elderly (59-76), fluid ability explained the most variance in all dependent variables with the exception of number of anagrams correct.

Significant age declines were found for all poisoned foods and concept identification task variables, but not so for the anagrams task ($U_{2,2,159}$= .983, $p >$.

An overall age difference existed for fluid intelligence ($F_{2,159}=53.85$, $p < .01$) but not so for crystallized ability ($F_{2,159}=1.88$, $p > .05$).

Crystallized and fluid abilities were highly intercorrelated in the young ($r = +.61$, $p < .01$) and old ($r = +.73$, $p < .01$). Each of these correlations was significantly higher ($p < .05$) than that in the middle aged ($r = +.37$), suggesting a reintegration of abilities in late adulthood.

The correlational analyses by age did not fully support the predicted relationships. Numbers of pairs of independent correlations decreased, rather than increased, with age. The lack of a difference in correlations between Gf versus Gc, and number of anagrams correct in the middle aged and elderly does, however, support a two-stage interpretation of anagram problem solving (Hunter, 1959; Johnson, 1966). Bourne's (1966) hypothesis linking language and abstract thought received support in the young adult and middle aged groups.

The stepwise regression analyses do lend some support to the predictions regarding intelligence-performance relations in the elderly. Gc accounted for an increasing amount of variance (relative to Gf) with age in Type "C" problems where no age declines were found. Gf accounted for more variance (relative to Gc) in problems (Type "O") that were more abstract, placing less importance on pa experience, where significant age declines were observed. However, the h Gf relationship in the elderly must be considered when evaluating this da a.

 the middle aged, however, there is little support regarding the predicted contribution of Gc and Gf to problem solving. For all Type "O" task variables, crystallized, (not fluid) ability, (as our extrapolations from the Ho -Cattell theory predicted) accounted for the most variance.

The results do not support those of Cunningham and Clayton (1973) and Cunningham, et al. (1975) who argued that because Gc has as its prerequisite earlier Gf, progressively less increase should be observed in the Gc factor late in life relative to a fairly rapid decline in Gf. Correlations between Gc and Gf increased in the elderly, relative to those in middle age, contrary to the Cunningham et al. (1973, 1975) findings. It is important to note that this aspect of Gc/Gf theory was one which played a major role in formulating the present hypotheses.

Cunningham et al. (1975) have compared their results to those of Raven (1948) and concluded no cohort differences to exist in relationships between abilities. However, substantial differences in Gf/Gc correlations were obtained in the present study, when compared to those of Cunningham et al. (1975) in the young ($Z = 3.56$, $p < .01$), and the old ($z = -1.66$, $p < .05$), suggesting such a cohort effect.

In addition, the Type "O"-Type "C" distinction of problem solving appears to have gained some support due to the differing cross-sectional trends obtained in each task category. The abstractness/concreteness differential in stimuli between the poisoned foods and concept identification tasks, however, was not supported.

Several limitations should be kept in mind. The results may be specific to this set of anagrams (Johnson, 1966). The Davis distinction, largely derived from a sample of laboratory tasks, may have limited applicability to other types of more applied problem solving. The Gf-Gc Sampler, comparatively new, had not yet been employed with different age groups in adulthood.

Lastly, these learning-ability relationships may not be static, and may change as a function of stage of learning (Baltes & Labouvie, 1973).

The present results do however, seem to raise some questions regarding the validity of age related predictions in problem solving, made on the basis of derivations from the Horn and Cattell theory of intelligence. This points up, as Baltes and Labouvie (1973) have noted, not only the role of differential changes in age functions for different ability and performance variables, but also the contribution of individual differences within cohorts regarding ability-performance relationships.

TABLE 1

HOTELLING t VALUES FOR DIFFERENCES BETWEEN CORRELATIONS INVOLVING INTELLIGENCE AND PROBLEM SOLVING BY AGE

Correlation of:	Young (n=54)		Middle (n=54)		Old (n=54)	
	Correlations	t	Correlations	t	Correlations	t
Gf[1] • Anagrams Correct	.6366**	-3.03*	.2362*	-.037	.4811**	.19
Gc[1] • Anagrams Correct	.3370**		.2309*		.5038**	
Gf • Time-Anagrams	-.2924*	-.06	-.1594		-.0671	.49
Gc • Time-Anagrams	-.2992*		.7400[2]**	10.86**[3]	-.0183	
			(.1026)			
Gf • Errors-PF Task	-.0752	1.90	-.2325*	-.21	-.4468**	2.18*
Gc • Errors-PF Task	.1533		-.2933*		-.2537*	
Gf • Time-PF Task	-.2354*	2.20*	-.2387*	-.19	-.4247**	.67
Gc • Time-PF Task	.0378		-.2693		-.3720**	
Gf • Trials-PF Task	-.2357*	2.46*	-.2289*		-.4933**	1.44
Gc • Trials-PF Task	.0545		.6100[2]**	6.96**[3]	-.3573**	
Gf • Errors-CI Task	-.1382	-1.38	-.0086	1.36	-.3773**	1.64
Gc • Errors-CI Task	-.3005*		-.2043		-.2264*	

TABLE 1 (cont.)

Correlation of:	Young (n=54)		Middle (n=54)		Old (n=54)	
	Correlations	t	Correlations	t	Correlations	t
Gf · Time-CI Task	-.1621	-.64	-.0126	-.38	-.3378**	.82
Gc · Time-CI Task	-.2474		.0536		-.2516*	
Gf · Trials-CI Task	-.1947	-1.10	-.0332	-1.38	-.3392**	.82
Gc · Trials-CI Task	-.3184*		-.2370*		-.2527*	

*p ∠ .05

**p ∠ .01

[1]Gc - crystallized intelligence

[1]Gf - fluid intelligence

[2]η coefficients

Corresponding Pearson r is below each η in parentheses

[3]F ratios computed for testing η versus r

TABLE 2

REGRESSION ANALYSES OF RELATIONSHIPS BETWEEN INTELLIGENCE AND PROBLEM SOLVING VARIABLES BY AGE

Group	Young (n=54)			Middle (n=54)			Old (n=54)		
Variable		R^2	F		R^2	F		R^2	F
Anagrams - Correct	1) Gf	.40526	.336	1) Gf	.05579	1.34	1) Gc	.25381	1.97
	2) Gf+Gc	.40916		2) Gf+Gc	.07991		2) Gc+Gf	.28171	
Time - Anagrams	1) Gc	.08950	1.11	1) Gf	.02540	1.61	1) Gf	.00450	.101
	2) Gc+Gf	.10892		2) Gf+Gc	.05529		2) Gf+Gc	.00649	
Time - PF Task	1) Gf	.05543	2.96	1) Gc	.07250	1.28	1) Gf	.18039	.528
	2) Gf+Gc	.10720		2) Gc+Gf	.09520		2) Gf+Gc	.18892	
Trials - PF Task	1) Gf	.03758	2.62	1) Gc	.07528	1.07	1) Gf	.24340	
	2) Gf+Gc	.08467		2) Gc+Gf	.09435		2) ______[2]		
Errors - PF Task	1) Gc	.02351	2.46	1) Gc	.08604	.636	1) Gf	.19961	.696
	2) Gc+Gf	.06840		2) Gc+Gf	.10416		2) Gf+Gc	.21042	
Trials - CI Task	1) Gc	.10139		1) Gc	.05610	.913	1) Gf	.11508	
	2) ______[2]			2) Gc+Gf	.07278		2) ______[2]		

TABLE 2 (cont.)

Group Variable	Young (n=54)			Middle (n=54)			Old (n=54)		
		R^2	F		R^2	F		R^2	F
Time - CI Task	1) Gc	.06120	.012	1) Gc	.00287	.061	1) Gf	.11410	
	2) Gc+Gf	.06142		2) Gc+Gf	.00407		2) ______[2]		
Errors - CI Task	1) Gc	.09027	.016	1) Gc	.04173	.269	1) Gf	.14237	.293
	2) Gc+Gf	.09338		2) Gc+Gf	.04678		2) Gf+Gc	.14729	

[1]Gc - Crystallized Intelligence

Gf - Fluid Intelligence

[2]Blanks represent no additional contribution (.001 of variance) by the second independent variable over the first.