# On the Relationship Between Gf/Gc Theory and Jensen's Level I/Level II Theory

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A sample of 201 high school students was given a battery of 27 ability tests strategically chosen to provide composite measures of 12 primary mental abilities selected to indicate second-order abilities known as fluid intelligence (Gf), crystallized intelligence (Gc), and short-term acquisition retrieval (SAR). Factor analysis of the 12 primaries provided evidence of the Gf, Gc, and SAR dimensions. The SAR dimension is similar to a Level I form of intelligence (LI) and the Gf and/or Gc factors relate to a Level II intelligence (LII) in a theory sponsored by Jensen. Analyses of social class differences in respect to SAR (LI) in contrast to Gf and Gc (LII) did not provide convincing evidence in support of a hypothesis that the social classes differ primarily in respect to LII (Gf and Gc) rather than in respect to LI (SAR).

Those who have followed recent work on Jensen's (1973b, 1974) theory of Level I (LI) and Level II (LII) forms of intelligence and developments of the theory of fluid (Gf) and crystallized (Gc) intelligence (Cattell, 1971; Horn, 1968; 1974, 1976, 1978a; 1979; in press; Stankov & Horn, 1980) might have noticed that memory has come to play a rather similar role in the two theories. In both formulations memory has been relegated to the status of a precursor or a servant of the capacities that are the sine qua non of human intelligence.

In the work on Gf/Gc theory, several

Requests for reprints should be sent to John L. Horn, Department of Psychology, University of Denver, University Park, Denver, Colorado 80208. studies of the factorial structure in a wide variety of ability performances have indicated a broad unity among short-term acquisition and retrieval (SAR) functions (Horn, 1976, 1978a, 1978b; 1980; Horn & Bramble, 1967; Hundal & Horn, 1977; Rossman & Horn, 1972; Shucard & Horn, 1972). It is suggested that this SAR factor represents organization among memory processes that is analogous in some respects to organizations among visualization (Gv) and auditory (Ga) processes. The SAR, Gv, and Ga organizations represent ways in which information is prepared, as it were, for the induction, eduction, and deduction processes of Gf and Gc (Horn, 1978a, 1978b; Horn & Donaldson, 1980). In particular, SAR indicates functions involved in holding information in awareness long enough for it to be processed by the capacities of Gf and Gc.

Jensen (1973b) has performed several factor analyses in which three factors were extracted to suggest that the memory function he had formerly designated as LI intelligence stands apart from factors representing Gf and Gc. Both Gf and Gc are regarded as indicating LII in Jensen's work. The memory function is regarded as pro-

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viding a precondition for expressions of LII, rather in the manner that SAR provides a basis for expressions of Gf and Gc.

Thus it seems that with respect to memory as it relates to major factors of intelligence, there is a similarity between Gf/Gc theory and LI/LII theory. However, the SAR factor of Horn's (1978a) study is considerably broader than the memory factor of the Jensen (1973b) study, and the former is based on a rather different line of research than the latter.

An important feature of the Cattell and Horn developments of a structural theory of intelligence is the aim to build broad concepts on narrower concepts for which there is empirical evidence of unity among different aspects of a function. In particular the aim has been to define Gf, Gc, and other broad dimensions in terms of the primary mental ability factors found among tests (as summarized by Ekstrom, French, & Harman, 1979; French, Ekstrom, & Price, 1963: Guilford, 1967; and Horn, 1972, among others). From this research the SAR factor emerged as a broad dimension involving performances as diverse as those of span memory, serial rote learning, and pairedassociates recognition (Horn, 1978a). In contrast the memory factor of Jensen's empirical studies is hardly any broader than the primary mental ability known as memory span (Ms). In applications and discussions of his theory, however, Jensen has said that LI involves paired-associates memory and serial recall, as well as span memory. In studies that involved no analyses of structure, Jensen used memory tasks of each of these various kinds to identify LI (Jensen, 1971; 1972). Thus it seems that LI represents the same concept as SAR even as it has been defined more narrowly in Jensen's (1973b) studies of structure.

In response to these indications of rapprochement between two theories, the present study was designed to examine the second-order structure among primary abilities in an area in which Gf, Gc, and SAR—that is, LI—might be distinguished. In particular, the aim was to sample primary mental abilities that are indicative of distinct memory processes and examine the structure among these in the context of a sample of the primaries that are indicative of Gf and Gc. This will provide a replication of a basis for regarding SAR (LI) as distinct from Gf and Gc, and will permit examination of some important implications of LI/LII theory.

One important implication derives from Jensen's hypotheses that movement from low to high social/economic status (SES) within an open society is mainly determined by, and racial differences occur mainly in respect to, LII rather than LI. Jensen argued that support for these hypotheses would be indicated by two kinds of findings, namely, (a) large differences between SES or racial groups for LII abilities, small differences for LI abilities; (b) large slope for the regression of LI on LII in samples of high SES or majority-group people, small slope for this regression in samples of low SES or minority-group individuals.

There are many problems with the logic of these hypotheses as well as with obtaining data that can be properly interpreted in accordance with the hypotheses and proposed tests. Several of these difficulties were pointed out by Hall and Kaye (in press), Horn (1976), Humphreys and Dachler (1969), and Humphreys and Fleishman (1974). An exhaustive review of these difficulties will not be attempted here. Instead, the logic of Test (b) above will be accepted (even though it can be questioned), and some of the difficulties in testing this hypothesis will be illustrated.

A major difficulty in providing convincing evidence for the regression-slope hypothesis is associated with problems of obtaining good operational definitions of LI and LII. As noted previously, Jensen has defined LI from one study to the next in terms of rather different memory tests-different in the sense that the tests measure different primary factors, the Ms primary in one case, the associative memory primary (Ma) in another case, and so on. It might be reasonable to use the different tests to represent the same concept, such as SAR, if indeed there is adequate evidence to support a hypothesis that all of the tests measure the same factor. Jensen has not supplied such evidence, however.

More important, although it might be reasonable to use separate marker tests to define a factor to use to seek support for Jensen's hypotheses, it is not necessarily reasonable to do this. Variables of a given factor can have different relationships with outside variables. Given the fact that several variables all define the same factor, it does not follow that each of these will have the same relation to SES. Also, the relation of one of these variables to SES can be nearly the same as the SES relation for a variable of an entirely different factor. Many variables, not just memory variables, can relate to SES with regression slope,  $m_1$ , that is different from an  $m_2$  slope representing the relationship for a measure of LII. Thus, little support for Jensen's theory is provided by results showing that one arbitrary indicant of LI relates to SES in a different way than an arbitrary indicant of LII relates to SES.

Support for Jensen's second hypothesis might be obtained by showing that each indicant of LI has the same relation to SES as each other indicant, and this relationship is different from the relationship for each indicant of LII and each indicant of a host of other factors. Alternatively, evidence might be adduced by first showing that different indicants of LI and LII do indeed define separate factors and then showing that the two factors have different relations to SES. Jensen has not attended to either of these kinds of approaches in his studies designed to produce support for his hypotheses. This is a major weakness.

In accordance with these concerns about LI/LII theory, the present study was designed to provide evidence of the structural distinction between SAR, Gf, and Gc as a basis for then examining the hypothesis that SAR (i.e., LI) has a different relation to SES than either Gf or Gc (i.e., two possible representatives of Jensen's LII concept).

A second problem in examining the Jensen hypothesis pertains to the sampling of subjects at different points along the range of the scales that are used to provide operational definition of the principal variables. As Horn (1976) pointed out, the slope of regression is a function of the correlation and the standard deviations of the variables,  $b_{xy}$  $= r_{xy}(S_y/S_x)$ , so if there is selection of one group relative to another that affects the ratio of standard deviations, the slope will be changed in consequence of the selection (Humphreys & Dachler, 1969). Such selection can occur when there is sampling from the upper part of a distribution in one group and in the midrange of the variable in another group (see Darlington, 1971; Schmidt & Hunter, 1974; and Thorndike, 1971, for a discussion of issues associated with such selection). There is no certain way to escape these kinds of difficulties short of using representative sampling and ratiolevel scales (in which a unit of measure at the extremes is the same as a unit of measure in the middle of a scale). But a somewhat better picture of the plausibility of slope comparison hypotheses can be indicated by sampling from both sides of the midpoints of scales. The present study was designed to provide this more plausible picture.

## Method

## Subjects and Their SES

The subjects were high school students, 14–16 years of age, drawn from six private Catholic schools in the Sydney (Australia) metropolitan area. A total of 201 subjects (109 girls and 92 boys) was obtained.

Schools were used as units of selection to provide a broad and representative range of the SES classes within the city. Only those schools in which students came from within a local area were selected. The school-sampling units were chosen in a way to cover the full range of economic classes from the most affluent to the poorest.

This selection was aided by an extensive study (Congalton, 1969) on status and prestige in Australia. The results from the Congalton study were also used to provide estimates of a subject's SES on the basis of father's occupation. Congalton's 7-point scale of SES was collapsed to provide enough subjects in each of three SES categories to ensure a stable basis for estimating statistics. There were 45 subjects in the high SES group, 75 in the middle SES group, and 91 in the low SES group.

Each principal of the different schools was asked to compare the SES distribution in the subsample drawn from his/her school with the distribution of SES within the school as a whole. Each suggested that the subsample distribution did not differ in any notable degree from the school distribution. In this respect, therefore, the sample would seem to be representative of the population represented by the schools. The private school system in Australia is completely decentralized, however, so it is difficult to estimate how the present sample of private schools differs from the population of all private schools or the population of schools in general. Thus we would not claim that our sample is

Symbol	Primary ability	Tests to measure primary abilities
I	Induction (visual)	Letter Series <sup>a</sup>
		Letter Sets <sup>b</sup>
Ia	Induction (auditory)	Tonal Series <sup>c</sup>
		Chord Series <sup>c</sup>
CFR	Cognition of figural relations	Raven's Progressive Matrices
Ν	Number facility	<b>Addition<sup>b</sup></b>
		Division <sup>b</sup>
		Subtraction & Multiplication <sup>b</sup>
V	Verbal comprehension	Vocabularv <sup>d</sup>
	•	Incomplete Sentences <sup>c</sup>
CMR	Cognition of semantic	Common Verbal Analogies <sup>a</sup>
	relations	Esoteric Verbal Analogies <sup>a</sup>
Ms	Memory span	Auditory Number Span <sup>b</sup>
		Visual Number Span <sup>b</sup>
		Auditory Letter Span <sup>b</sup>
Ma	Associative memory	Low Associated Word Pairs <sup>e</sup>
	-	Word–Number Pairs <sup>e</sup>
		Low Associated Serial Recall
		(free recall of uncategorized
		lists) <sup>f</sup>
Mm	Meaningful memory	High Associated Word Pairs <sup>e</sup>
		Emphasized Word Recall <sup>c</sup>
		High Associated Serial Recall
		(free recall of categorized
		lists) <sup>f</sup>
Fa	Associational fluency	Similar Words <sup>b</sup>
	-	Word Associations <sup>b</sup>
Fi	Ideational Fluency	Topics <sup>b</sup>
		Things Categories <sup>b</sup>
Fw	Word fluency	Word Endings <sup>b</sup>
		Word Beginnings <sup>b</sup>

Primary Abilities and Tests Used to Measure Them

Table 1

<sup>a</sup> Horn (in press). <sup>b</sup> French, Ekstrom, and Price (1963). <sup>c</sup> Stankov and Horn (1980). <sup>d</sup> Adapted from French et al. (1963). <sup>e</sup> Kelley (1964). <sup>f</sup> Jensen and Frederiksen (1973).

representative of any population that can be well circumscribed in other studies. In this respect the sample is no different from the samples of almost all studies in the psychological literature. However, an important feature of the sample is that it contains subsamples all along the SES scale, from high to low.

## Measured Variables

Twenty-seven tests were chosen to measure 12 primary factors. The latter were selected to represent markers for Gf, Gc, and SAR. The tests came from French, Ekstrom, and Price (1963), Jensen and Frederiksen (1973), Kelley (1964), or our previous research (Horn, in press; Stankov & Horn, 1980). Table 1 shows the 12 primary abilities, and the tests used to measure each.

A question at issue is how these 27 tests can indicate the factors of interest, Gf, Gc, and SAR. This is a question that pertains both to measurement of variables and to design for analysis.

One reasonable way to provide evidence for Gf, Gc

and SAR is to first factor among tests at the primary ability level and then factor among the primary factors to produce a second-order solution. A problem with this approach for the present analysis is that with only 27 tests it is not realistic to expect to define the 12 primary factors that are needed to define the second-order dimensions; that is, this is not realistic if one rejects use of Procrustean methods. We have provided good reasons why a researcher should reject use of such methods in applications similar to this one (Horn, 1967; Horn & Knapp, 1973, 1974; Horn & McArdle, 1980).<sup>1</sup>

Recent evidence suggests that several of the primary abilities listed above are most related to a long-term memory factor identified as tertiary storage and retrieval (TSR), which is distinct from SAR, so the col-

<sup>&</sup>lt;sup>1</sup> It should be realized that the cautions represented in these studies are only cautions, not blanket rejections of Procrustean methods. As pointed out in the referenced articles, there are several situations in which Procrustean methods are desirable.

lection of primary abilities really represents four second-order factors, not three. This makes the problem of overdetermining the needed primary structure very unrealistic indeed.

In general, there are simply not enough variables to define an objectively rotated structure involving the number of first-order and second-order factors implied by the sampling of variables. If objectively rotated methods of factoring are to be employed, the approach of factoring at the first order and then at the second order is precluded.

It might be possible to provide dependable results with this approach by using maximum likelihood confirmatory methods (Jöreskog, 1973). These are essentially Procrustes solutions (Horn, 1967) with the added strength, however, that they contain statistical tests of how well the forced fit does indeed fit. However, there are several problems with using these methods that need to be understood much better before one can be confident that results are indeed dependable (Horn & McArdle, 1980).

For these reasons, then, the approach of factoring at the primary level was rejected for the present study, and a third reasonable approach was adopted. In this approach, the evidence of previous research is used as a basis for defining the primary factors as linear composite variables. It is recognized that factors indicate concepts, the operational definition of which can vary somewhat from one study to another. The verbal comprehension primary factor, for example, has been defined in no fewer than 34 studies in the last decade and by a somewhat different configuration of variables in each study. Thus, several different sets of variables could be selected to measure the factor. The listing of variables given above to measure the 12 primary abilities of the present study is only one among many ways in which the concepts represented by these factors can be made operational. No doubt this operational definition is far from ideal, but it does represent one acceptable way of achieving objective indication of the variables of principal interest (Wackwitz & Horn, 1971).

This particular set of primary factors was chosen to overdetermine both Gf and Gc, as well as SAR. Fluid intelligence was expected to be indicated by Induction (visual), Induction (auditory), and Cognition of Figural Relations (CFR) with lesser loadings from Number Facility (N) and some of the memory variables. Crystallized intelligence was expected to be defined by Number Facility (N), Verbal Comprehension (V), and Cognition of Semantic Relations (CMR), with lower loadings coming from Associational Fluency (Fa), Ideational Fluency (Fa), and Word Fluency (Fw), and again, some of the memory variables.

The sampling of memory abilities designed to indicate SAR (i.e., LI) was derived largely from the work of Kelley (1964), McKenna (Note 1), and Jensen (1973b). This work indicated three distinct primary factors among a wide variety of memory tasks, namely, Ms, Ma, and meaningful memory (Mm). These three factors were also found in the work of Guilford and his associates and in a comprehensive study by Hakstian and Cattell (1974).

The work of McKenna (Note 1) was particularly important for purposes of the present study because it indicated a factor of memory for emphasis that may be equivalent to the meaningful memory factor found in Kelley's study. A memory for emphasis test (emphasized word recall) was used in the present study as a marker for Mm.

It should be noted, however, that Mm is generally regarded by researchers on primary abilities as less well established than either of the other two memory primaries. For example, Ekstrom et al. (1979) noted that the evidence in this area is probably best interpreted as indicative of a factor of rote memory of related material. As will be described in the section on procedures, analyses were conducted to examine the premise that Mm represents a form of memory that is distinct from Ms and Ma. It will be noted that this issue is important for considerations of whether SAR (LI) is separate from Gf and Gc.

Recent evidence on structure (e.g., Horn, 1978a) suggests that TSR might be indicated in the data of this study by Fa and Fi, and possibly Fw (although Horn, 1970, has suggested that Fw may not be a part of the factor). It is pushing at the limits of overdetermination, however, to expect to get four factors out of 12 primary ability variables. The TSR factor is underdetermined relative to the constraints originally specified by Thurstone (1947) and recently emphasized in the studies of Horn (1967), Horn and Knapp (1973, 1974), and Humphreys, Ilgen, McGrath, and Montanelli (1969). It would not be surprising, therefore, to find a three-factor solution in which TSR is not defined.

#### Test Administration and Scoring

All tests were group administered. Each testing session lasted two school periods (80 minutes). For each group the sessions occured on 2 days, 1 week apart. The instructions were prerecorded on a SONY TC-133 cassette tape recorder. An overhead projector was used for Test 14. Classroom sizes and seating varied depending on the resources of the school, but each subject sat at the same desk for the two sessions. All French et al. (1963) tests were scored as described in the manual.

As noted previously, questions have been raised in previous research about whether Mm is indeed a separate primary ability, distinct from Ma and Ms. Because the status of Mm was somewhat in doubt and because the marker variables selected to indicate the factor in this study had not been well confirmed by previous research, preliminary analyses were carried out for the purpose of indicating the structure among the nine short-term memory variables.

The intercorrelations among the nine memory variables were factored in accordance with orthogonal Procrustes procedures suggested by Lawley and Maxwell (1964). Three factors were estimated (in accordance with hypotheses of Ms, Ma, and Mm). The Lawley-Maxwell procedures differ from similar procedures embodied in the well-known LISREL program (Jöreskog & Sörbom, 1978) in that the zeros of the target need not remain fixed but can take on small nonzero values in the estimated solution. The zero and nonzero values of the target were specified as shown in Table 2. The solution obtained on the total sample of subjects

		Su	ubsam	ples	_						-		
<b>m</b> 4		Tai	rget m	atrix	P (you	rocrust ng subj	es ects)	(ol	d subje	s cts)	Tot Pr	al samp ocruste	s
no.	Variable	Ms	Ma	Mm	Ms	Ma	Mm	Ms	Ma	Mm	Ms	Ma	Mm
13	Auditory number												
	span	1	0	0	<u>83</u>	-07	-02	<u>90</u>	04	-06	<u>88</u>	-02	-08
14	Visual number			<u>^</u>		^ <b>-</b>		-					~ -
1.5	span	1	0	0	<u>92</u>	-07	-03	$\frac{72}{2}$	28	-17	82	02	07
15	Auditory letter	1	0	0	00	10	00	00	90	90	04	00	0.9
16	span Low accorded	1	U	0	<u>82</u>	-10	09	<u>82</u>	-20	20	<u>04</u>	-09	-03
10	word pairs	0	1	0	04	82	-19	02	67	28	-01	81	06
17	Word-Number	Ū	1	Ŷ	04	02	10	02	<u>01</u>	20	01	01	00
	pairs	0	1	0	-07	79	28	11	73	-25	-03	68	24
18	Low associated					_							
	serial recall	0	1	0	-14	<u>92</u>	-11	-04	84	09	-04	88	-14
19	High associated												
	word pairs	0	0	1	<u>38</u>	<u>49</u>	$\underline{30}$	-09	$\underline{47}$	$\underline{56}$	07	<u>59</u>	19
20	Emphasized word	0	0		0.0	00	00	0.7	00	05	00	00	00
01	recall Utable accepted	U	0	1	03	02	93	07	-08	85	00	-03	<u>98</u>
21	serial recall	0	0	1	19	<u>58</u>	15	-01	<u>82</u>	01	09	<u>65</u>	18

Table 2Factor Patterns for Nine Memory Tests

*Note.* Decimals have been omitted; salients are underlined. Ms = memory span; Ma = associative memory; Mm = meaningful memory.

is shown near the far right in Table 2, under "Procrustes."

It will be noted that the Procrustes solution on the total sample indicates Ms and Ma factors, but the Mm factor is not well defined in terms of requirements such as have been specified by Horn and Knapp (1974) and Humphreys et al. (1969): The Procrustes algorithm tends to direct most of the variance of the factor to emphasized word recall. In this test the subject listens to a paragraph in which 10 of the words have been emphasized by being spoken more loudly than the other words. The hypothesis (McKenna, Note 1) is that the paragraphs provide a meaningful basis for associating the target words in the context of other words, and for this reason the variable should relate to the Mm factor.

One could define the Mm factor using the single test, emphasized word recall. This would be a rather lean factor. It seemed, however, that the factor might be indicated more adequately if particular features of the sampling of subjects were taken into account. In particular, it was noted that high associated word pairs and categorized serial recall would have different relations to meaningful memory in young as compared to older children: A child would need to have acquired a knowledge base of the words before the tests could be expected to represent meaningful word association. On the basis of this reasoning, the total sample was split into subsamples of younger and older children. The sample of younger children was made up of students in Form 3 (average age was 14), and the sample of older children was comprised of students in Form 5 (average age was 16). The factoring was done in the manner described above for both subsamples. The results are shown near the left in Table 2.

The results from these analyses provide some support for using high associated word pairs and emphasized word recall to measure a meaningful memory factor that is independent of Ms and Ma. The factor is not well overdetermined in accordance with the guidelines suggested by Horn (1967), Horn and Knapp (1974), and Humphreys et al. (1969), but it does meet minimum critiera for reasonable definition of a common factor. On this basis meaningful memory was defined as the sum of standard scores on the variables numbered 19 and 20.

Contrary to the claim of Jensen and Frederiksen (1973) that high associated serial recall and low associated serial recall separately define Level II and Level I abilities (respectively), the results of Table 2 indicate that the two variables go together in the one Ma factor. This was true in each of the three separate factor solutions.<sup>2</sup>

Each of the 11 primary abilities, as well as the Mm

<sup>&</sup>lt;sup>2</sup> It is of some interest to notice that the high associated word pairs variable has a high loading on the Ms factor in the subsample of younger children but not in the subsample of older children. This suggests that some of the associations among the words were often not known to the younger children and that therefore these children were forced, as it were, to use simple span memory to retain the words.

factor, was obtained by simple summation of the zscores for the tests that in previous research had been shown to define the factors (as indicated previously in this section). Structural analyses were carried out on the resulting 12 primary ability measures.

## Results

# Analyses

Two kinds of analyses were conducted: (a) factor analyses among measures of primary abilities to provide evidence of Gf, Gc, and SAR and (b) regression analysis and analysis of variance to examine hypotheses pertaining to SES differences. These two kinds of analyses will be described in this order of listing.

Factor analyses. Several methods of extracting factors were tried including truncated principal components, principal axes (communality estimation), maximum likelihood, and image analyses procedures. In all cases, three factors were estimated, this being the number indicated by the root-one criterion. In the image analysis solution orthoblique rotation was employed, whereas rotation in the other solutions was by varimax followed by promax, with power set at 5. The solutions in all cases were similar. There are several theoretical reasons for prefering the image-analysis estimation of Little Jiffy, Mark IV (Kaiser & Rice, 1974), and so the results from application of this program are included along with results from the better known varimax and promax analyses.

There are several problems with the orthoblique subroutine of Little Jiffy, however, the principal one being that it yields correlations among factors that are unrealistically large. Experience in working with these methods indicates that the orthoblique correlations are about .25 higher than the correlations obtained with promax based on varimax (Stankov, 1979) and that promax correlations, in turn, are good estimates of the correlations for the best estimates of population factor scores (Wackwitz & Horn, 1971). This prior experience is verified by the results of the present study.

The intercorrelations among the primary abilities are shown in Table 3. Two factor solutions obtained with Little Jiffy are shown in Table 4. One of these solutions includes the Mm primary factor; the other does not. As mentioned earlier, doubts can be raised about whether Mm is distinct from Ma and Ms. It was of some interest, therefore, to determine how the second-order solution might be altered by eliminating the Mm primary. In both solutions the root-one criterion for the number of factors was adopted.

The first factor is a clearly defined fluid intelligence. The second factor contains high loadings on V, CMR, Fa, Fi, and Fw,

Table 3Correlations Among 12 Primaries

1	2	3	4	5	6	7	8	9	10	11	12
1.0											
381	1.0										
349	470	1.0									
274	341	299	1.0								
208	403	333	368	1.0							
263	474	405	317	634	1.0						
200	124	208	172	317	321	1.0					
120	249	272	285	328	355	317	1.0				
107	182	298	289	206	210	384	561	1.0			
252	329	277	176	542	506	254	313	235	1.0		
206	222	271	133	420	278	232	314	245	356	1.0	
339	417	298	368	604	479	371	303	292	510	422	1.0
	1 1.0 381 349 274 208 200 120 107 252 206 339	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$									

Note. Decimals have been omitted. I = induction (visual); Ia = induction (auditory); CFR = cognition of figural relations; N = number facility; V = verbal comprehension; CMR = cognition of semantic relations; Ms = memory span; Ma = associative memory; Mm = meaningful memory; Fa = associational fluency; Fi = ideational fluency; Fw = word fluency.

				1	2 primari	es					
		Gf			Gc			SAR		11 prin	naries
Variable	VAR	PRO	ORT	VAR	PRO	ORT	VAR	PRO	ORT	Gf	Gc
I Ia CFR -02	$\frac{68}{73}$	$\frac{74}{74}$ $\overline{68}$	$\frac{50}{58}$ $\frac{70}{70}$	12 33 <u>53</u>	-06 19 19	-08 08 00	05 -02 -07	-04 -16 20	02 08 11	$\frac{61}{59}{11}$	$-08 \\ 01 \\ 55 \\ 55 \\ -08 \\ 01 \\ 55 \\ -08 \\ 01 \\ 55 \\ 01 \\ 01 \\ 01 \\ 01 \\ 01 \\ 01$
-02 N V 75	$\frac{60}{25}$	$\frac{62}{03}$	$-\frac{36}{02}$	11 <u>80</u>	-08 <u><math>85</math></u>	00 <u>79</u>	26 12	$20 \\ -04$	14 -06	<u>30</u>	08 03
75 CMR Ms Ma Mm* Fa Fi Fw	$     \frac{38}{03}     15     22     14     03     30   $	23 -13 01 13 -07 -17 12	$     18 \\     -12 \\     -04 \\     04 \\     -06 \\     -11 \\     04   $	67 33 24 04 75 59 70	$     \begin{array}{r}             \underline{66} \\             \underline{28} \\             11 \\             -16 \\             \underline{82} \\             \underline{64} \\             \underline{70} \\         \end{array}     $	$     \begin{array}{r}       57 \\       26 \\       08 \\       -14 \\       \underline{67} \\       \underline{46} \\       \underline{62} \\     \end{array} $	$     \begin{array}{r}         & 11 \\                         $	$-04$ $\frac{56}{75}$ $\frac{89}{-02}$ $18$ $06$	$-05$ $\frac{35}{56}$ $\frac{66}{00}$ $15$ $05$	$     \begin{array}{r}       18 \\       -07 \\       05 \\       -07 \\       -09 \\       04     \end{array} $	
<u></u>				Fact	or interco	rrelations					
Gf	Gf		Gc .52		SAR .33					Gf	Gc
SAR ·	.85 .68		.71		.59					.87	

Factor Pattern Matrices Based on Three Methods of Factoring and Two Sets of Variables

Note. Loadings of .30 or larger have been underlined to indicate saliency. VAR = varimax; PRO = promax; ORT = orthoblique; Gf = fluid intelligence; Gc = crystallized intelligence; SAR = short-term acquisition retrieval; I = induction (visual); Ia = induction (auditory); CFR = cognition of figural relations; N = number facility; V = verbal comprehension; CMR = semantic relations; Ms = memory span; Ma = associative memory; Mm = meaningful memory; Fa = associational fluency; Fi = ideational fluency; Fw = word fluency.

\* Mm dropped out; see text.

Table 4

<sup>a</sup> Promax is above diagonal; orthoblique is below.

and thus may be seen as reflecting the acculturation processes that scholastic success demands. This factor is interpreted as crystallized intelligence. The third factor is a distinct memory factor defined by Ms. Ma. and Mm. It is broader than the memory factor found in Jensen's (1973b) study but corresponds rather closely to the SAR dimension specified by Horn. As anticipated, a TSR factor was not found. The fluency measures that might have defined this factor are here correlated with Gc, as in previous studies (e.g., Horn, 1978a; Horn & Cattell, 1966). LI/LII theory makes no commitments regarding a TSR factor or the fluency measures. It seems likely, however, that these abilities would be regarded as indicative of LII.

As mentioned earlier, it is of some interest to ask if the SAR dimension is indicated if Mm is not included in the analyses at the second order. The second set of results in Table 4 indicates that, indeed, SAR is not sufficiently overdetermined by only Ma and Ms and such other memory variance as may be contained in the other primary abilities of this study. Thus it seems that the minimum conditions for determining SAR are three primary-level memory factors. Such results are consistent with the arguments of Horn and Knapp (1974) and Humphreys et al. (1969). In Jensen's structural analyses only the Ms factor was determined.

If one were not to accept our previous arguments about orthoblique factor correlations being unrealistically high, then serious questions about the independence of factors are raised by the Little Jiffy solutions. Results of relevance for addressing these issues are provided in Table 5. Here

 Table 5

 Average Primary Factor Intercorrelations

Factor	1	2	3
1. Gc	48	29	29
2. Gf	29	35	20
3. SAR	29	20	42

Note. Decimal points have been omitted. Gc = crys-tallized intelligence; Gf = fluid intelligence; SAR = short-term acquisition retrieval.

it is indicated that the average of the intercorrelations among the primary factors that define a particular second-order dimension is in each case larger than the averages of the correlations of the marker primaries with the primaries of other dimensions. As has been pointed out by a number of investigators (e.g., Horn, 1977), the independence of constructs and the independence of operational representations of constructs should not be equated with a condition of zero correlation or even low correlation. For example. Wackwitz and Horn (1971) demonstrated in a simulation study that even if constructs were correlated zero in the population, operational measures of the constructs in a sample will usually be correlated nonzero. As concerns the present study, the theory is that Gf and Gc will be more highly correlated in samples of fairly well-adjusted children that differ notably in age than in heterogeneous samples of adults. Hence, even if the orthoblique correlations are accepted at face value as indicating high interdependence in samples of children, this is consistent with the developmental aspects of the theory. More important, the between-dimensions correlations are low enough relative to the within-dimension correlations to retain a hypothesis that the dimensions are independent.

Analysis of SES groupings. The results from these structural analyses thus provide some indications of the conditions under which an LI, or SAR, form of "intelligence" can be distinguished from major forms of intelligence. In agreement with a considerable amount of previous research, the results indicate that the behaviors that are commonly accepted as indicating intelligence do not fall into a single, LII, factor but instead represent two major sources of variance, namely Gf and Gc. This means that LI/LII theory, as such, specifying only two attributes, probably is not readily supported with simple structure factoring at a given (e.g., second-order) level. The results also indicate that to use the evidence of primary mental abilities to define SAR/LI as a second-order capacity, it is necessary to have at least three memory primaries-if not Mm. then some other memory primary. However, it has been known for many years-at least since the time of Woodrow (1938)that whether memory is defined as a factor or not, it is largely independent of many of the abilities that are most readily accepted as indicating mature human intelligence. Thus general knowledge and the findings of the present study provide a reasonable basis for regarding SAR/LI as separate from Gf-Gc/LII for purposes of considering SES differences.

Within-model measures of the Gf, Gc, and SAR/LI factors were obtained using the Little Jiffy procedures. That is, so-called exact factors scores (Wackwitz & Horn, 1971) were obtained by direct calculation based on the image-analysis/orthoblique solution.<sup>3</sup> These scores were then scaled (over the entire sample), to make the means equal 500 and the standard deviations equal 100.

The Gc, Gf, and SAR means and standard deviations for the three separate SES groupings are shown in Table 6. Here it can be seen that the means for all three factors decrease monotonically from the high to middle to low SES classifications. The differences between the means are, for all factors, significant at the .01 level, as indicated by a one-way analysis of variance: When the F values shown in Table 6 are converted to eta-squares to indicate the proportion of variance in the dependent

<sup>&</sup>lt;sup>3</sup> As pointed out by Wackwitz and Horn (1971), the word *exact* in this context should not be interpreted as meaning that exact factor scores provide a better indication of population, or "true" factor scores than the so-called "inexact" methods for estimating scores. Exact means simply that given a particular factor analysis model, the exact scores are the scores specified in that model, not estimates of these scores. Since the model itself is only an estimate of reality, however, the model scores are only estimates.

variable that is accounted for by the quasiindependent SES variable (best nonlinear fit), it is seen that SES would predict individual differences in any one of the factors with a correlation (nonlinear) of about .25 (the square root of  $r^2 = .0625$ , roughly the average of the three separate eta-squares).

The difference between the Gc correlation (r = .26), which indicates the strongest factor-SES relationship, and the Gf correlation (r = .23), the weakest SES-factor relationship, is neither noteworthy nor significant. Thus Jensen's argument that SES groups do not differ notably in LI abilities but do differ notably in LII abilities finds no support in these results. The factor for which the SES differences are smallest is an indicant of LII according to Jensen's reasoning, and the SES differences for the factor that best represents LI are intermediate between the Gf and Gc indicants of LII. In fact, however, the differences between the SES-factor relationships for SAR. Gf. and Gc are in no case large enough to be of much consequence.

For each of the three factors, the variances for the three SES groups are not significantly different when evaluated by Bartlett's test of homogeneity of variance. It is of some interest to note, however, that the order of the variances for the SES groups is different for SAR/LI than for Gf or Gc. For SAR the variances increase monotonically from low to high SES, and thus are directly related to the order of the means. This appears to be the reverse of what the Jensen hypothesis specifies. For Gf and Gc, the variances decrease monotonically from low to high SES, and thus are inversely related to the order of the means. This result, too, does not seem to be in accordance with Jensen's hypothesis. These facts should be kept in mind as regression slopes are considered.

According to Jensen's hypothesis, the slope of the regression line relating LI and LII should be steeper in upper than in lower SES groups. The results graphed in Figure 1 and summarized in Table 7 are of relevance for considering this statement of the hy-The differences between the pothesis. slopes for the different SES groups are not significant at the .05 level when either Gf or Gc is taken as the indicant of LII. The Fvalues for these tests are shown in Table 7. There are enough degrees of freedom to provide a reasonable test of the critical hypothesis. Earlier formulations of the slope hypothesis were expressed in terms of the differences between the coefficients of correlation, that is, the standard-score slopes. As can be seen in Table 7, these differences are small. Significance tests for the differences do not even approach significance. Moreover, for Gc the order of magnitude of these standard-score slopes is contrary to the order specified in the hypotheses. These analyses, therefore, do not lend support to Jensen's reasoning.

In fairness to Jensen, it should be noted that the raw-score slopes in both cases (for Gf and Gc) decrease monotonically with a decrease in SES, and the slope differences for Gf are close to being significant at the .05 level. Also, one might reasonably evaluate Jensen's hypothesis with models other than the simple regression model that he advocated. In particular, for example, as pointed

		G	ja	G	f <sup>b</sup>	SAI	R¢
SES	N	М	SD	М	SD	М	SD
High	45	542.36	81.03	539.71	91.36	543.17	106.01
Medium	75	501.60	95.90	498.12	98.25	494.05	103.06
Low	81	474.94	105.63	479.57	100.56	481.17	86.33

Table 6Differences Among the SES Groups

Note. In all three analyses, Bartlett's test of homogeneity of variances was not significant. Gc = crystallized intelligence; Gf = fluid intelligence; SAR = short-term acquisition and retrieval; SES = socioeconomic status. <sup>a</sup> One-way analysis of variance (ANOVA) for Gc yielded F = 7.01,  $\eta^2 = .069$ . <sup>b</sup> One-way ANOVA for Gf yielded F = 5.50,  $\eta^2 = .053$ . <sup>c</sup> One-way ANOVA for SAR yielded F = 6.19,  $\eta^2 = .059$ . The degrees of freedom in each case were 2 and 198. The critical value of F at the .05 level is 3.04.



*Figure 1.* Regression lines of Level I abilities (Short-term acquisition and retrieval [SAR], memory) on Level II abilities (fluid and crystallized intelligence). (SES = socioeconomic status.)

out by a reviewer of an earlier draft of this article, Jensen's hypothesis can be regarded as making a directional prediction in regard to the slopes, so one could make pairwise tests with directional alternate hypotheses using the overall error rate. This test suggests significance for Gf.

The following multiple regression model also might be regarded as a reasonable basis for evaluating Jensen's hypothesis:

$$M = b_0 + b_1 g + b_2 S + b_3 (g \times S), \quad (1)$$

where M represents a measure of LI, g represents a measure of LII, and S represents SES. In this formulation, a test of the sig-

Table 7Differences Among Slopes

	SAR	on Gf <sup>a</sup>	SAR	on Gc <sup>b</sup>	
SES	<i>r</i>	Slope	r	Slope	
High	.713	.827	.665	.870	
Medium	.708	.743	.729	.784	
Low	.603	.518	.712	.582	

Note. SES = socioeconomic class; SAR = short-term acquisition and retrieval; Gf = fluid intelligence; Gc = crystallized intelligence.

<sup>a</sup> F(2, 195) = 3.03. <sup>b</sup> F(2, 195) = 2.66.

nificance of the  $b_3$  regression weight for the interaction between g and S might be interpreted as indicating that the level of SES (low to high) needs to be taken into account in predicting LI from LII and S. This is stretching a bit to find a test of the hypotheses (because of its post hoc nature), and it is a very sensitive test indeed (not recommended by Jensen), but with such stretching and given that high sensitivity might be deemed desirable, one can find significance (at the .05 level) for  $b_3$  when Gf is taken as an indicant of LII but not when Gc is used to represent LII (F = 3.20).

These results might thus be interpreted as lending mild support for Jensen's hypothesis. To keep this idea of support in perspective, the reader should note that it derives from only one of the two factors that Jensen regards as indicative of LII, and primarily reflects a finding that the order of variances in relation to the order of the means for SES groups is different for SAR than for Gf and Gc.

# Discussion

These results thus provide limited evidence in support of a hypothesis of a shortterm acquisition and retrieval function that is independent of Gf and Gc. SAR is defined if one accepts that Mm is adequately measured as a primary mental ability in this study and thus can be included as a marker for SAR, along with Ma and Ms, but the dimension is not sufficiently overdetermined by only the latter two markers. Fortunately, the evidence for SAR is not limited to the present study. As noted earlier, 40 years ago Woodrow (1938) made a good case for the distinction between memory and intelligence. The recent work of Horn (1978a, 1978b, in press), Horn and Bramble (1967), and Hundal and Horn (1977) indicates the structural distinction and also points to developmental differences between SAR in contrast to Gf and Gc. The present work can thus be seen as indicating some of the limiting conditions for identifying SAR in distinction from Gf and Gc.

The results provide new perspectives for evaluating Jensen's (1973a, 1973b) statements regarding socioeconomic groups and different levels of intelligence. They indicate that when sampling does not produce a contrast between only one extreme group and a midgroup with respect to the abilities of interest, the differences between SES groups are significant for LI (i.e., SAR) as well as for LII (i.e., Gf or Gc), and the differences between the differences are neither noteworthy nor significant. Similarly, the regression slopes for LI and LII in different SES groups are not notably different. If one goes beyond Jensen's suggestions to find a more sensitive test of what might be implied by his hypothesis, weak support might be claimed. Viewed concretely, this support represents a finding (in these data at least) that the variance on SAR is decreased in lower SES groups compared to higher ones, whereas the variance increases with decrease in SES for both Gf and Gc. This finding may be consistent with Jensen's hypothesis, but it must be evaluated within a frame of reference that includes recognition that the variances are not significantly different when evaluated by Bartlett's rather sensitive test. Overall, therefore, these results do not lend strong support to Jensen's theorizing.

Humphreys and Dachler (1969) and Humphreys and Fleishman (1974) pointed

out that the correlations between indicants of LII and various other ability measures vary considerably and not necessarily (i.e., it has yet to be demonstrated) in accordance with an LI versus LII conception of these abilities. Horn (1976) reiterated this point and noted, too, that the slope of regression lines in different subsamples will depend on the variances of the different measures, and these in turn will be a function of direct and indirect selection with respect to one or more factors (Campbell & Stanley, 1963). When there is selection at the extremes along one factor, there tends to be reduction in variance of that factor and shift in slope as a function of this fact. Horn pointed out that this is a parsimonious interpretation of Jensen's findings pertaining to slope. In the Humphreys-Dachler and Humphreys-Fleishman studies it was pointed out that the same kind of interpretation is reasonable for the interactions that Jensen had interpreted as providing support for his theory. As noted, these investigators stressed the fact that precisely the same kinds of findings can be expected for variables that are not regarded as aspects of LI relative to LII.

The present analyses and results differ from those of Jensen in one notable respect: Groups were selected at both extremes and in the middle with respect to each of the three major factors. This means that selection at one extreme has not occurred. The conditions that Horn and Humphreys cited as parsimonious bases for interpretations of slope differences or interactions do not obtain, at least not to a noteworthy degree, and the between-groups differences turn out to be close to what they predicted.

Similarly, the measurement of SAR (LI) in the present study differs from the measurement of LI in Jensen's work, and this, too, sheds new light on the matter of differences between SES groups. The broad SAR dimension no doubt comes closer to what is regarded as intelligence in most theories than does the narrow Ms factor that had been the operational definition of LI in Jensen's study. It is not unlikely that the SAR of the present study is more reliable (as well as more valid as an indicant of intelligence) than the usual measures of Ms, for there are many extraneous influences that affect memory measurements (see Horn, 1970, 1976, for review). For these reasons, as well as for reasons pertaining to the variances of the measures, substantial between-SES differences for SAR can be expected (as in the present study) when small, perhaps insignificant, differences in Ms were found in Jensen's previous work.

These results suggest that several of the connotations of Level I/Level II theory may be misleading. Interpretations of Level I as a kind of intelligence need to be regarded with particular caution. As Horn (1976) pointed out, many ability factors can be regarded as a kind of intelligence. But little advance in understanding is gained by this assumption if the claim is not closely linked with theory that separates a "form of intelligence" from the forms of primary abilities and second-order functions.

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