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Forward and Backward Digit Span Interaction With Race and IQ: Predictions from Jensen's Theory

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From Jensen's two-level theory of mental abilities (Level I: rote learning and memory; Level II: complex cognitive processing) it was predicted that forward digit span (FDS) should correlate less with IQ than backward digit span (BDS), and age and race should interact with FDS-BDS, with the FDS-BDS difference decreasing as a junction of age and a greater white-black difference in BDS than in FDS. The predictions were substantiated at a high level of significance in large representative samples of white and black children of ages 5 to 12 years, who were given the Wechsler Intelligence Scale for Children (Revised). Socioeconomic differences were found to account for less of the predicted effects than race.

A philosopher of science, the late Imre Lakatos (1970), built his theory of scientific progress on the central idea that the chief criterion for appraising the progressiveness of theories or research programs is whether they can predict novel facts, as contrasted with merely concocting ad hoc interpretations of already established facts. If the predictions seem unlikely or defy common sense expectations, and then are borne out, so much the better for the theory.

In an attempt to apply this criterion to Jensen's two-level theory of mental abilities, we have sought to use the theory to predict some hitherto unknown or unnoticed phenomena—facts about which the theory should yield clear-cut predictions and which are not as clearly predictable from other theories, though they may receive ad hoc explanations after the fact. Whether the predicted facts themselves are or are not of any immediate or practical consequence is irrelevant in this context. The aim is only to test the theory.

The original formulation of the two-level theory stated:

> Level I involves the neural registration and consolidation of stimulus inputs and the formation of associations. There is relatively little transformation of the input, so there is a high correspondence between the form of the stimulus input and the form of the response output. . . . Level II abilities, on the other hand, involve self-initiated elaboration and transformation of the stimulus input before it eventuates in an overt response. . . . The subject must actively manipulate the input to arrive at the output' (Jensen, 1969, pp. 110–111).

A later article (Jensen, 1970a, pp. 155–156) sharpened these definitions:

> Level I ability is essentially the capacity to receive or register stimuli, to store them, and to later recognize or recall the material with a high degree of fidelity. . . . It is characterized by the lack of any need of elaboration, transformation or manipulation of the input in order to arrive at the output. . . . In human performance digit span is one of the clearest examples of Level I ability. . . . *Reverse digit span would represent a less pure form of Level I ability, since some transformation of the input is required prior to output* [italics added]. Level II ability . . . is characterized by transformation and manipulation of the stimulus prior to making the response.

In another article Jensen (1970b, pp. 52–53) notes that the Level I–Level II distinction is not based on a difference in task difficulty per se. The crucial difference involves the complexity of the task's cognitive demands.

Given this conceptualization of the distinction between the two hypothetical classes of abilities called Level I and Level II, it is clear, as Jensen (1970a) first noted, that forward and backward digit span must differ

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in the degree to which they reflect Level I and Level II ability. The ability to repeat a string of digits just as they were heard involves less mental manipulation or transformation than the ability to say the digits in the reverse of the order of presentation—the so-called backward digit span. BDS depends upon the Level I ability involved in forward digit span, but also includes a small but essential element of Level II—transformation of the input prior to the output. Thus variance in FDS and BDS must involve different amounts of Level I and Level II abilities, with BDS reflecting Level II to a greater degree than FDS.

Since, according to the theory, the *g* factor which accounts for most of the variance in standard intelligence tests highly reflects Level II abilities, we then predict that (Hypothesis 1) BDS is more highly correlated with IQ than is FDS.

Jensen (1969, 1971a, 1971b, 1973a, 1974a) has also argued that the magnitude of mean differences typically found between whites and blacks on a variety of mental tests and scholastic performances can be explained in terms of a hypothesized difference in the distributions of Level I and Level II abilities in the two races. Figure 1 depicts the hypothesis in a schematically idealized form. (In reality, tests of Level I and Level II may not be pure measures of these abilities and samples may not always be truly representative of the respective racial groups.) Evidence favoring this hypothesis has been presented in other studies (Jensen, 1971b, 1973b, 1974a, 1974b; Jensen & Frederiksen, 1973). Given this hypothesis in connection with the essential Level I–Level II distinction, we predict that (Hypothesis 2) the mean white–black difference is greater in BDS than in FDS, or stated in statistical terms, there is a Race × FDS versus BDS interaction.

Another prediction from the theory, which is not tested in the present study, is that there should be an interaction of race (i.e., white–black) with visual versus auditory digit span, and the interaction should be magnified under conditions of delayed recall (i.e., about 10–12 seconds after presentation), with mildly distracting stimuli interposed during the interval between presentation and recall. (The precise experimental procedures are detailed by Jensen, 1971c.) Blacks should perform relatively less well on visual than on auditory digit span tests. This prediction is based on the theory, which is supported by many lines of evidence (see Jensen, 1971c), that visual digit span involves transforming or encoding the visual stimuli into an auditory short-term memory storage, while auditory stimuli go directly into the auditory storage without need of transformation. Thus visual memory span would involve slightly more Level II than auditory memory span, and therefore visual span should correlate more than auditory span with IQ. This prediction awaits an experimental test.

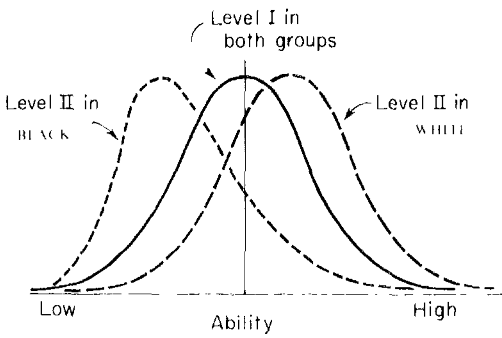

FIGURE 1. Hypothetical distributions of Level I (solid line) and Level II (dashed line) abilities in white and black populations.

Jensen (1969, pp. 115–116) has also hypothesized different growth curves as a function of age, for Level I and Level II, as depicted in Figure 2. It can be seen that the disparity between Levels I and II decreases with increasing age between early childhood and maturity. From this we predict that (Hypothesis 3) there is an interaction between age and FDS versus BDS, such that beyond age 5 years (the lowest age in the present study) the difference between FDS and BDS decreases with age. Since it has also been hypothesized that the Level II (but not Level I) growth curves of whites and blacks increasingly diverge from early childhood to maturity, with whites having the more accelerated curve, we expect to find (Hypothesis 4) a significant triple interaction

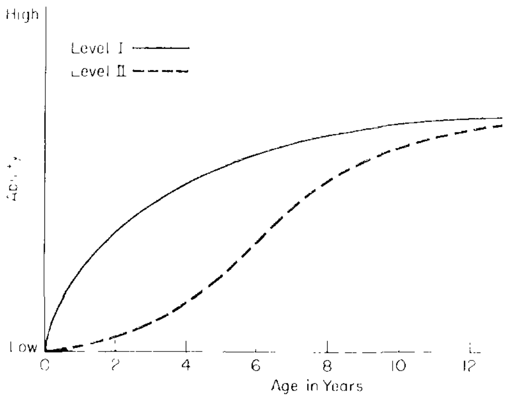

FIGURE 2. Hypothetical growth curves for Level I and Level II abilities.

of Race × Age × FDS versus BDS. Hypothesis 5: the simple interaction of Race × Age follows from the theory, but, as it is based on the combined FDS + BDS scores and is tested against the error term of subjects within race within ages, it should be very difficult to detect in the present study. After all, BDS is a quite impure measure of Level II and could even be much more highly loaded on Level I. All we can be sure of from prior theoretical considerations is that BDS must involve Level II more than does FDS.

METHOD

Subjects

The data of the main study are based on large random and representative samples of white and black children in approximately equal numbers from ages 5 years 0 months to 11 years 12 months in California schools. To achieve the random samples, 98 school districts were selected at random from among all the school districts in California. This sampling was done in such a way that the probability of any school district's being selected was related to the number of pupils of the particular racial group being sampled who were enrolled in that district. Within each district a single school was picked at random, and within each school a boy and a girl were picked at random from each of the grades from kindergarten through six. Thus the largest sample selected from any one school was 14. This entire randomization procedure was applied independently to the selection of the white and black samples, with *ns* of 669 and 622, respectively. Other refinements of the sampling procedure used here to achieve highly representative samples of the child populations in the respective ethnic groups are described in detail elsewhere (Figueroa, 1975; Mercer, 1972). The *ns* by age, race, and sex are shown in Table 1.

Studies supplementing the main study were conducted with large representative samples of white and black elementary school children in two California districts—Bakersfield and Berkeley.

Tests

The Wechsler Intelligence Scale for Children-Revised (WISC-R) was individually administered according to the standard procedures described in the test manual (Wechsler, 1974) by trained psychometrists to all subjects in the main study. The tests for forward digit span and backward digit span are supplementary subscales of the WISC-R. (They are not included in the IQ scores in the present study.) In FDS the tester reads aloud digit series of from three to nine digits, paced at 1 second per digit, and the child is asked to repeat the series. Two trials are given on each series and 1 raw score point is given for each series repeated correctly. BDS has series of from two to eight digits, which the subject must repeat in reverse order, and is scored in the same manner. The BDS test, which follows FDS, includes two unscored practice items to insure that the subject understands the task. The digit span subtests are administered last in the WISC-R battery.

RESULTS AND DISCUSSION

The WISC-R raw scores on FDS and BDS were separately converted to standard scores, each scaled to a mean of 10 and standard deviation of 3 within each 4-month age interval from age 5 years 0 months to 11 years 12 months. With age-standardized scores, the statistical analyses can be applied to the total sample of all ages combined, thus making possible the most powerful tests of the first two hypotheses.

Hypothesis 1 states that BDS is more

TABLE 1
SAMPLE SIZE BY RACE, SEX, AND AGE

Age	White Boys	White Girls	Black Boys	Black Girls
5	41	37	35	32
6	53	52	47	48
7	52	48	44	44
8	43	51	41	42
9	46	47	51	49
10	48	47	45	48
11	53	51	46	50
Total	336	333	309	313
	669		622	

TABLE 2

Correlations of Forward (FDS) and Backward (BDS) Digit Span with Wechsler Intelligence Scale for Children-Revised IQs

IQ	White			Black		
	FDS	BDS	t^a	FDS	BDS	t^a
Verbal	.33	.39	1.38	.28	.40	2.84**
Performance	.22	.28	1.52	.26	.40	3.43***
Full Scale	.31	.38	1.69*	.30	.45	3.61***

[a] Hotelling's t (see Walker & Lev, 1953, pp. 256–257).
* $p < .05$, one-tailed.
** $p < .01$, one-tailed.
*** $p < .001$, one-tailed.

highly correlated with IQ than is FDS. Table 2 shows the correlations of the WISC-R Verbal IQ, Performance IQ, and Full Scale IQ with FDS and BDS in the white and black samples. Hotelling's t test (one-tailed) for nonindependent correlations was used to test the significance of the predicted difference between BDS–FDS (Walker & Lev, 1953, pp. 256–257). The Verbal, Performance, and Full Scale IQs all show higher correlations with BDS than with FDS, in both white and black samples, though the correlational differences are nonsignificant at the .05 level for the Verbal and Performance IQs in the white group.

A corollary hypothesis is that the difference BDS–FDS should be positively correlated with IQ. This was found to be the case, although because difference scores for such short tests are highly unreliable, the correlations between the scaled scores BDS–FDS and Full Scale IQ were found to be low. For whites the correlation is +.06, $p < .05$, one-tailed, for blacks, +.12, $p < .001$. Thus in the black as well as in the white group, the difference between backward and forward digit span is positively correlated with IQ.

It is instructive to look at the correlations of FDS and BDS with IQ when each span is held constant (i.e., statistically partialed out). When this is done, the partial correlations of FDS and BDS with Full Scale IQ are .22 and .31, $t(666) = 2.13$, $p < .02$, one-tailed, for whites and .18 and .39, $t(619) = 4.59$, $p < .001$, one-tailed, for blacks. Thus in both groups BDS is significantly more correlated with IQ than is FDS, in accord with the hypothesis. (The partial correlation between FDS and BDS, holding IQ constant, is .23 for whites and .24 for blacks, a nonsignificant difference, $t < 1$.)

Hypothesis 2 states that BDS shows a greater white–black difference than FDS. Table 3 gives the means and standard deviations of the digit spans and IQs in the black and white samples, and the group differences expressed in σ units (i.e., mean difference/square root of the within-groups variance), to permit direct comparisons. The IQ scales show the approximately one standard deviation white–black difference typically found, with a negligible difference between the Verbal and Performance scales. As predicted, BDS shows a larger (more than double)

TABLE 3

Means, Standard Deviations, and Sigma (σ) Differences Between Whites and Blacks on Digit Span (DS) and IQ

Race	Forward DS		Backward DS		Verbal IQ		Performance IQ		Full Scale IQ	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
White ($n = 669$)	10.75	3.01	11.01	2.99	102.13	14.44	103.99	13.64	103.24	13.79
Black ($n = 622$)	9.98	3.01	9.32	2.97	88.00	13.58	89.63	13.58	87.77	13.07
σ difference	.25		.57		1.01		1.05		1.15	

Note. Digit span scaled scores, $\bar{X} = 10$, $\sigma = 3$.

white–black σ difference than FDS. FDS is less than one-fourth the magnitude of the IQ difference, while BDS is greater than one-half the IQ difference between the races. To test the significance of this interaction of forward and backward digit span with race, an analysis of variance was performed on the scaled scores. The sources of variance in this analysis of variance are: race, subjects within race, Race × FDS versus BDS, and residual (i.e., Subjects × FDS versus BDS within Race). (Since the scaled score means are the same for FDS and BDS, there can be no main effect for digit span; and of course age is eliminated as a factor.) The hypothesis is tested by the Race × FDS versus BDS interaction term, which turns out to be highly significant, $F(1, 1{,}289) = 14.05$, $p < .001$. Thus the second hypothesis is strongly confirmed. An analysis of variance was also performed on the raw scores for digit span, which then includes the factors of age (7 groups in 1-year intervals) and FDS versus BDS, and their interactions. For raw scores, the predicted interaction of Race × FDS versus BDS is highly significant, $F(1, 1{,}276) = 8.38$, $p < .001$.

Hypothesis 3 states that forward and backward digit span interact with chronological age in such a way that the difference between BDS and FDS decreases with age. This prediction is substantiated. The mean raw score differences of FDS–BDS over seven age groups in 1-year intervals from age 5 years 0 months to 11 years 12 months are as follows: 2.71, 2.48, 1.84, 2.14, 2.08, 1.94, 1.77. The analysis of variance shows a highly significant difference among age groups, $F(6, 1{,}276) = 4.04$, $p < .001$. A trend analysis shows that only the linear component of the FDS–BDS difference decreasing with age is significant, $F(1, 1{,}276) = 16.23$, $p < .001$.

Although the triple interaction of Race × Age × FDS vs. BDS predicted in Hypothesis 4 is significant, $F(6, 1{,}276) = 2.22$, $p < .05$, it turns out to be more complex than theoretically predicted. It hardly supports the nature of the interaction predicted in Hypothesis 4, namely, that blacks, relative to whites, should show less convergence of forward and backward digit span with increasing age. The mean FDS–BDS differences at each year of age from 5 years 0 months to 11 years 12 months for blacks and whites are: black: 3.34, 2.67, 1.94, 1.77, 2.06, 2.22, 2.06; white: 2.08, 2.30, 1.75, 2.30, 2.09, 1.66, 1.48; difference: 1.26, .37, .19, −.53, −.03, .56, .59. Since there is no significant linear component in this interaction (as indicated for difference), Hypothesis 4 is not substantiated.

Hypothesis 5, predicting an overall Race × Age interaction, was not borne out. This interaction was nonsignificant ($F < 1$), that is, the races appear roughly parallel in the growth curves of total digit span scores. As noted in the original statement of Hypothesis 5, the present study permits only a weak test of this particular hypothesis, since BDS is an impure measure of Level II ability and the total of the forward and backward span scores represents some unknown combination of Level I and Level II abilities about which no strong prediction is warranted.

Socioeconomic Status

The Level I–II theory was originally formulated in terms of socioeconomic status (SES) rather than race. Because race and SES were confounded in the early studies it was not clear to what degree the theory applied to SES and to race (i.e., white vs. black) independently of one another. A more recent analysis (Jensen, 1974b) of Level I and Level II tests in three social class strata within white and black groups showed that the effects predicted from the Levels theory were significantly borne out for low, middle, and upper SES groups *within* races as well as between races, although the effects were considerably less pronounced for SES than for race. But in that study, race was not considered independently of SES, thus leaving the matter still ambiguous as to whether race makes an independent contribution to the theoretically predicted effects.

A study by Green and Rohwer (1971) of 20 low SES, 20 lower-middle SES, and 20 middle SES black fourth graders reported significant SES differences on forward digit span and Raven's Colored Progressive Matrices (a Level II test); but contrary to prediction from the Levels theory, the SES difference (relative to its standard error) was less on the Raven than on forward digit span.

Therefore, we have examined SES in the present study. SES was determined on the basis of the occupation of the principal wage earner in the child's home, as reported by the child's parent or guardian. The instrument used for classifying subjects by SES is a modification of Duncan's (1961) SES Index, which stratifies SES by percentiles; the modified index groups the percentiles into deciles, thereby categorizing subjects on a 10-point scale from 0 (low) to 9 (high). Duncan's index originally was derived from census data on income and education levels prevailing in the occupations listed in the Classified Index of Occupation and Industries (Duncan, 1961). Other studies have shown the Duncan Index to correlate from .81 to .90 with the Barr scale of prestige ratings of occupations (Duncan, Featherman, & Duncan, Note 1, p. 90). The index runs from unemployed and welfare (0) to high level professional and managerial (9). In terms of other SES scales, Duncan's categories 0 and 1 are generally "low SES," categories 2, 3, 4 are blue-collar "middle-SES," 5, 6, 7 are white-collar "middle SES," and 8 and 9 are "high SES."

The means of the SES Index of the whites and blacks are 5.2 and 2.7, a difference of .97 standard deviation. The Full Scale IQs of whites and blacks at each SES level are given in Table 4. Table 5 gives the corresponding data on forward and backward digit span. The accompanying Figures 3 and 4 make the findings easier to grasp. In accord with the theoretical prediction, the plot for BDS much more nearly resembles that for IQ than does the plot for FDS.

The association of the test variables with race and SES is most clearly seen in terms of correlations, shown in Table 6. The partial correlation of the test variables with SES, independent of race, are as follows: IQ = .28, FDS = .14, BDS = .16. The partial correlations of the test variables with race, independent of SES, are as follows: IQ = .36, FDS = .05 (*ns*), BDS = .18. All but one of the correlations are significant beyond the .01 level. (The standard error of all these *rs* is .03.) The most important point in terms of the theory, however, is that SES (*independently of race*) correlates with IQ and with both forward and backward digit span, and the partial correlations of SES with FDS and BDS do not differ significantly. But, race, independently of SES, shows a quite different pattern: significant correlations with IQ and BDS, but not with FDS. (The difference between the partial correlations of race with FDS and BDS is significant beyond the .01 level; and the difference between the correlations of FDS with SES and with race is significant at the .05 level.) Thus the theoretical prediction of a larger

TABLE 4

MEANS AND STANDARD DEVIATIONS OF WECHSLER INTELLIGENCE SCALE FOR CHILDREN-REVISED FULL SCALE IQ AS A FUNCTION OF SOCIOECONOMIC STATUS (SES) IN WHITE AND IN BLACK GROUPS

SES level	White			Black			White–black difference	*t*
	M	*SD*	*n*	*M*	*SD*	*n*		
0 (Low)	85.00	16.29	25	83.12	13.43	177	1.88	.55
1	93.50	12.89	16	87.50	11.45	54	6.00	1.68
2	97.92	12.45	87	88.51	11.70	145	9.41	5.70**
3	102.98	14.41	51	87.69	12.39	35	15.29	5.19**
4	101.46	9.56	46	88.93	14.20	28	12.53	4.09**
5	103.53	12.73	122	90.73	12.82	88	12.80	7.16**
6	106.82	11.78	49	92.15	10.96	33	14.67	5.77**
7	105.05	11.43	86	94.34	12.54	32	10.71	4.22**
8	111.21	14.24	52	94.70	20.61	10	16.51	2.42*
9 (High)	106.64	13.63	88	88.60	11.94	20	18.04	5.93**

* $p < .05$.
** $p < .01$.

TABLE 5

FORWARD AND BACKWARD DIGIT SPAN SCALED SCORES AS A FUNCTION OF SOCIOECONOMIC STATUS (SES) IN WHITE AND BLACK GROUPS

SES level	White			Black			White black difference	*t*
	M	*SD*	*n*	*M*	*SD*	*n*		
Forward digit span								
0 (Low)	9.52	3.23	25	9.58	3.14	177	−.06	.09
1	9.13	2.78	16	9.81	2.55	54	−.68	.88
2	10.44	2.97	87	9.87	3.11	145	.57	1.39
3	10.47	3.05	51	9.80	2.95	35	.67	1.02
4	10.54	2.46	46	10.21	3.26	28	.33	.46
5	10.44	3.04	122	10.41	2.91	88	.03	.07
6	11.49	3.59	49	10.64	2.63	33	.85	1.24
7	10.67	2.89	86	10.19	2.65	32	.48	.85
8	11.37	2.62	52	9.50	2.42	10	1.87	2.21*
9 (High)	11.36	2.89	88	11.60	3.28	20	−.24	.30
Backward digit span								
0 (Low)	8.16	3.16	25	8.77	3.08	177	−.61	.91
1	10.56	2.39	16	9.19	2.66	54	1.37	1.96*
2	10.56	2.81	87	9.10	3.04	145	1.46	3.71**
3	11.16	3.29	51	9.74	2.87	35	1.42	2.12**
4	11.15	3.18	46	9.54	2.10	28	1.61	2.62**
5	10.82	2.86	122	9.81	2.70	88	1.01	2.61**
6	11.18	2.74	49	9.70	2.77	33	1.48	2.38*
7	11.36	3.07	86	10.13	3.10	32	1.23	1.92
8	11.48	2.88	52	10.30	2.67	10	1.18	1.26
9 (High)	11.35	2.70	88	10.50	3.95	20	.85	.91

* $p < .05$.
** $p < .01$.

group difference in BDS than in FDS is substantiated for race, but not for SES. It is beginning to appear that the Level I–Level II theory may hold more strongly for race (i.e., white–black) than for SES.

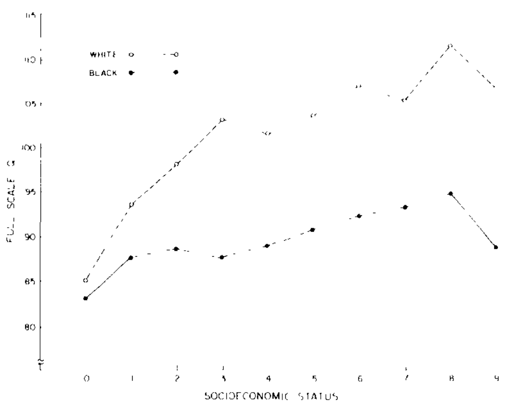

FIGURE 3. Wechsler Intelligence Scale for Children-Revised Full Scale IQ of black (n = 622) and white (n = 622) samples as a function of socioeconomic status as measured on Duncan's Index of SES.

Although it was not formally predicted by the Levels theory, it is noteworthy that the test variables are correlated overall significantly less with SES in the black than in the white sample. The correlations with SES in the white group are as follows: IQ = .49, FDS = .22, BDS = .24; in the black group: IQ = .20, FDS = .12, BDS = .18. (Note that SES is more differentially correlated with FDS and BDS in blacks than in whites.) We have not come across any explanation for the lower correlation between SES and IQ (or other ability measures) in the black population, a finding which is not peculiar to the present study (Loehlin, Lindzey, & Spuhler, 1975, pp. 168–174). The present correlations of SES with IQ and FDS in the black group are just the opposite to the findings of Green and Rohwer (1971). We have more confidence in the present find-

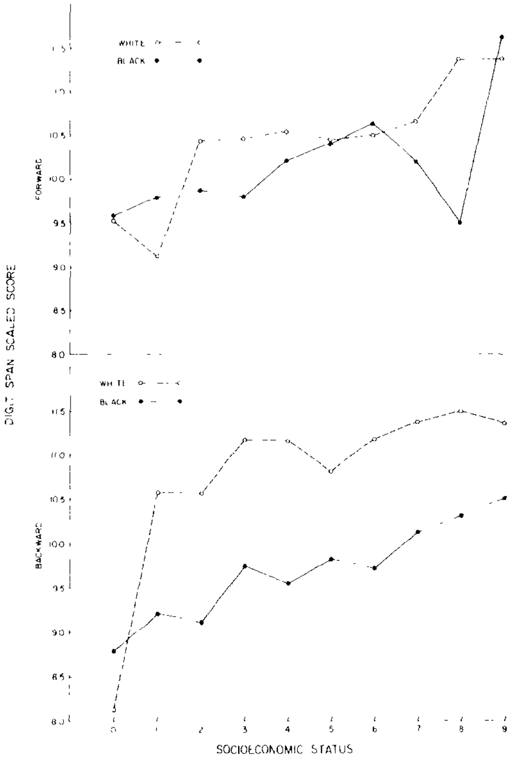

FIGURE 4. Wechsler Intelligence Scale for Children-Revised Forward and Backward Digit Span scaled scores ($\bar{X} = 10$, $\sigma = 3$) of black and of white samples as a function of socioeconomic status.

ing than in the study by Green and Rohwer, which involved only a small ($N = 60$) sample of black fourth graders in three broad SES categories.

SUPPLEMENTARY STUDIES

Anxiety Hypothesis

A possible hypothesis is that the observed effects are the result of greater anxiety or distractability in the black children, which could differentially interfere with performance on forward and backward digit span. If (a) BDS is more adversely affected by anxiety than FDS, and (b) if IQ test performance is also hindered by anxiety, and (c) if blacks are generally more anxious than whites, then we should predict that (a) whites exceed blacks in total digit span, (b) blacks are relatively lower in BDS, and (c) blacks show a higher correlation than whites between digit span and IQ and a relatively higher correlation for BDS than for FDS. This is what was found. The interaction of Age × FDS versus BDS can be predicted from the anxiety hypothesis if we make the additional assumption that anxiety decreases between ages 5 and 12.

So how are we to decide between the Level I–II theory and the anxiety theory in interpreting these results? It has been reported frequently in the clinical literature that anxiety has a greater adverse effect on digit span than on any of the other subtests of the Wechsler scale (e.g., Payne, 1961, p. 233). In fact, a low digit span score, relative to the other Wechsler subscales, is generally interpreted as an anxiety indicator. This being the case, if blacks were more anxious than whites, one should expect blacks' performance on digit span to be among their lowest scores, whereas in fact they do better on digit span than on any of the other subtests which are less affected by anxiety.

Are blacks in general more anxious than whites? In a large sample of school children in grades 4 to 8, Jensen (1973c) found a small but significant white–black difference in the *N* scale of the Junior Eysenck Personality Inventory, which is an anxiety scale similar to and highly correlated with Taylor's Manifest Anxiety Scale. But the whites had the slightly higher score (less than 1 point). Moreover, the *N* scale showed nonsignificant and negligible correlations with verbal and nonverbal IQ in both racial groups. But a review of research on the relationship between anxiety and performance on the Wechsler scales found little consistent evi-

TABLE 6

CORRELATIONS (PEARSON *r*) AMONG VARIABLES

Variable	1.	2.	3.	4.	5.
1. Race[a]		.438	.495	.120	.266
2. Socioeconomic status			.435	.175	.254
3. IQ				.316	.470
4. Forward digit span					.336
5. Backward digit span					

[a] Coded white ($n = 622$) = 1, black ($n = 622$) = 0.

dence of a relationship between digit span and the kind of trait anxiety measured by questionnaires; however, the literature shows quite consistently that digit span performance is related to *state* anxiety (Matarazzo, 1972, pp. 445–446). "State anxiety" (also called "situational anxiety") is anxiety aroused in a specific situation, as contrasted with a more-or-less chronic disposition (called "trait anxiety"). If this is the case, the anxiety hypothesis cannot be properly tested by using a self-report inventory of trait anxiety. There is another possible drawback to scores on a personality inventory: they can be adventitiously correlated with IQ without there being any direct causal connection between the personality trait and intelligence test performance. For example, there is a significant negative correlation between IQ and the Lie scale of the Eysenck Personality Inventory (Jensen, 1973c); and Gough (1953) has devised a "nonintellectual intelligence test" wholly out of personality inventory items which correlate with IQ without any implication that changing the personality traits involved would alter the IQ.

The only satisfactory recourse is to rely on the construct validity of state anxiety for devising a test situation in which the effects of state anxiety should be manifested and then see if the predicted effects are borne out. This was our approach. Reviews of the literature on the effects of state anxiety on test performance (e.g., Matarazzo, 1972, pp. 443–448) suggest that it operates through such mechanisms as emotionality, excitability, inattentiveness, and distractability. The anxious subject's emotions interfere with his giving his full attention to the immediate required task, and his efficiency is thereby reduced. State anxiety therefore especially affects timed tests in which the efficiency of the subjects' mental activity in using the time available is an important aspect of performance.

Our aim, then, should be to administer the very same Level I test, such as forward digit span, under two different conditions, one of which should magnify the interfering effect of state anxiety. In a previous study (Jensen, Note 2) it was found that any enforced delay in the recall of a series of digits resulted in fewer digits being recalled than if recall immediately followed the presentation of the digit series; this was true only if a distracting stimulus was interposed during the delay interval between presentation and recall. Without interposed distraction, subjects use the delay interval for rehearsal and consolidation of the presented material, and this improves recall. Under nondistracting delay in recall, provided the delay is not too long, the short-term memory trace is protected to some degree from "output interference," that is, the loss of the latter part of the digit series as a result of having to recall the first part.

Since state anxiety is manifested as distractability in the test situation, it should act as an interposed interference in delayed recall, and consequently one should predict that the digit span performance of more anxious subjects should benefit less from delayed recall (as compared with immediate recall) than the performance of less anxious subjects. The hypothesis that blacks are more anxious than whites thus yields the prediction that the white–black difference in digit recall should be greater under the condition of delayed recall than under immediate recall.

This prediction was tested on large random samples of white and black children in two California school districts, Bakersfield and Berkeley, henceforth called Districts A and B. The data from the two districts can be viewed as independent replications of the experiment. District A provided a total of 1,852 white and 1,476 black subjects about equally apportioned in Grades 2 through 8. District B provided a total of 2,615 white and 2,134 black subjects about equally apportioned in Grades 2 through 6.

A group-administered FDS test, given by means of a tape recording to insure uniformity of pacing, etc., presented digit series of 4 to 9 digits. Subjects wrote their responses on specially prepared answer sheets. (Each digit recalled in the correct position is scored 1 point. Thus the highest possible score on the test is $4 + 5 + \cdots + 9 = 39$.) Both the immediate and the delayed recall tests were preceded by three practice series of 3 digits each. Every subject received both immediate and delayed conditions. A "bong" signaled the beginning of every series and also the time for recall. In the immediate recall condition the bong always came 1 second after the last digit in the series. In the delayed recall condition the bong came 11 seconds after the last digit. Subjects were required to keep "pencils up" during the interval between the initial and final bongs.

The main digit recall scores and the white–black differences for the two school districts are shown in Table 7. Since all of the differences, though of practically negligible magnitude, are opposite to what is predicted by the anxiety hypothesis, no statistical tests of significance are necessary. In both school districts, the white–black difference is slightly less under delayed than under immediate recall. (The populations in the two districts show marked demographic differences which are undoubtedly related to the absolute size of the white–black differences, but these factors are not relevant to the hypothesis under consideration.) These data, then, contradict the hypothesis that memory span is more affected by anxiety in blacks than in whites.

TABLE 7

MEAN DIGIT RECALL UNDER IMMEDIATE AND DELAYED RECALL CONDITIONS

Race	District A[a] (grades 2–8)		District B[b] (grades 2–6)	
	Immediate recall	Delayed recall	Immediate recall	Delayed recall
White	20.29	20.74	20.80	21.98
Black	19.28	19.78	16.77	18.02
White–black difference	1.01	.96	4.03	3.96

[a] n = 1,852 whites; 1,476 blacks.
[b] n = 2,615 whites; 2,134 blacks.

Task Difficulty

It might be argued that anxiety is aroused specifically by more difficult tasks, regardless of their loadings on Level I and Level II processes. But in Jensen's theory there is an important conceptual distinction between *difficulty* and *complexity*. Complexity implies the need for more mental manipulation and transformation of the input. We may ask, do blacks perform relatively poorly on BDS because it involves more Level II than does FDS, or simply because it is more difficult, in the sense that there is lower probability of success? In this sense a long FDS series is more difficult than a short FDS. If difficulty per se were the cause of the interaction of Race × FDS versus BDS, we should expect a similar interaction between race and short versus long FDS series.

We have looked at this by scoring FDS performance separately for digit series lengths 4, 5, 6 versus series lengths 7, 8, 9 in the records of 100 black and 100 white subjects selected at random from the 11–12 age group of District A. The mean white–black difference for digit series of 4, 5, 6 is .12; for series of 7, 8, 9 the white–black difference is .13. The interaction of Race × Series Length is nonsignificant ($F < 1$). But since the variances of short and long series differ, the white–black differences should be expressed in units of the average standard deviation within each series length. The white–black differences for the short and long series then are .089 and .075, respectively. Though nonsignificant, the race differences are in the opposite direction to the corresponding differences found for FDS and BDS. Therefore, it does not appear that difficulty level per se is a determining factor in the interaction of race and forward–backward digit span.

Race of Examiner

Being tested by a person of a different race from one's own is a conceivable cause of anxiety. Yet studies have failed to demonstrate any significant interaction of Race of Tester × Race of Subject on either intelligence tests or digit memory tests (Jensen, 1974c). To investigate this point specifically for individually administered digit span, which was the case in the WISC-R used in our main study, a black and a white psychometrist individually administered FDS tests with immediate and delayed recall to white (n = 98) and black (n = 80) children taken at random from District B classrooms in Grades 2 through 6, with roughly equal ns in every grade. An analysis of variance was performed within each grade level to test the significance of the Race of Tester × Race of Subject interaction. In every grade the interaction was quite insignificant ($F < 1$). It therefore seems very unlikely that the race of the testers had any significant influence on the WISC-R data of the main study.

General Discussion

Jensen's two-level theory of mental ability gives rise to the predictions that, since backward digit span involves more mental manipulation or transformation of input than forward digit span, BDS should be more loaded on Level II and therefore should be more highly correlated with general intelligence as indexed by IQ; and, since Level II ability is later in developing than Level I ability, the difference between forward and backward digit span should decrease with age over the range from 5 to 12 years. These predictions were fully borne out in large representative samples of white and of black children. In addition, since many studies have shown whites and blacks to differ in measures of general intelligence (e.g., Shuey, 1966), and Jensen has argued that the magnitude of such differences is a function of the degree to which Level II processes predominate over Level I processes in the cognitive demands of the particular test, it was hypothesized that whites and blacks should differ more in backward digit span than in forward digit span. This predicted interaction of race and forward versus backward digit span proved highly significant, and this remained true even when race was considered independently of socioeconomic status. There was no significant interaction of SES (independent of race) with forward versus backward digit span.

Supplementary data were brought to bear on the possibility that this outcome might be due to greater situational anxiety in the blacks. But no evidence for this hypothesis was found in a test situation in which such anxiety, if it existed, could reasonably be expected to have a significant effect. Moreover, a difference in task difficulty per se was shown to be an unlikely explanation of the results. Nor was there evidence of a significant influence of the race of the tester on memory span scores. The interactions of certain other WISC subtests with race might be explained in terms of differences in the experience or cultural background of blacks and whites. But it is difficult to imagine how that kind of explanation would apply to forward and backward digit span.

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