DOCUMENT RESUME

ED 186 436 TM 008 394

AUTHOR Kilian, Lawrence J.
TITLE Cognitive Skills and Processes Involved in the Digit Symbol Test of the WAIS.
PUB DATE Mar 78
NOTE 23p.; Paper presented at the Annual Meeting of the American Educational Research Association (62nd, Toronto, Ontario, Canada, March 27-31, 1978).

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Associative Learning; *Cognitive Processes; Higher Education; *Intelligence; Intelligence Tests; Memory; *Nonverbal Tests; Timed Tests; Visual Perception
IDENTIFIERS Wechsler Adult Intelligence Scale

ABSTRACT

In this study, cognitive processes hypothesized to be relevant to the digit symbol task of the Wechsler Adult Intelligence Scale (WAIS) were examined. Fifty-two undergraduate education students were divided into four groups to receive four different treatments. All the students took the digit symbol test, followed immediately by a test of their memory for the nine symbols. Then they were given a verbal paired associate learning test. After that, one group studied codes to help them remember the digit symbol pairs; the second group practiced a letter symbol test; the third group had repeated practice on the digit symbol test; and the fourth group worked on a social studies reading task. After eight minutes, all the students took the digit symbol test again and then a second test of memory for the nine symbols. All four of the groups obtained somewhat higher mean scores on the second administration of the digit symbol test, but there were no significant differences among the four groups in the amount of gain. Possible reasons for this outcome are discussed, and suggestions are made for further research. (Author/CTM)

COGNITIVE SKILLS AND PROCESSES INVOLVED IN THE DIGIT SYMBOL TEST OF THE WAIS* **

Lawrence J. Kilian

Queens College Teacher Corps Project,
New Careers Training Laboratory,
Center for Advanced Study in Education,
Graduate School and University Center,
City University of New York

* Presented at the annual meeting of the American Educational Research Association, Toronto, Canada, March 27-31, 1978.
Session number - 25.22

** I would like to thank Sigmund Tobias, John Carroll and William Estes for comments and suggestions they made on an earlier draft of this paper.

Over the years psychologists have relied upon sophisticated psychometric tests to measure intelligence. Tests like the Wechsler Adult Intelligence Scale and the Stanford-Binet include a wide range of tasks tapping a spectrum of abilities. These tests are very effective in predicting academic performance, but they have not been effective in helping psychologists learn more about the nature of intelligence.

In recent years, there has been a resurgence of interest in the skills and abilities that are present in intelligent people. The work of Hunt and his associates (1975) relating information processing skills to intelligence, and the work of Rohwer (1972) on the role of coding processes in intelligence are but two examples of the trend of investigating the cognitive processes involved in intelligence. Estes (1974) has suggested a particular line of research in which tasks typically included on intelligence tests are analyzed to get some idea of what it is they measure.

The present research will follow the lead of Estes in examining a task on an intelligence test in wide use. The task is the Digit Symbol subtest of the Wechsler Adult Intelligence Scale (1955). In this task the subject is shown an array with nine digits listed on one line paired with nine symbols listed directly below the digits. The nine symbols are: − ⊥ ⊐ L ⊔ O ∧ X = .
The nine digits are repeated in non sequential order in 90 boxes. The subject has 90 seconds to write the symbols in the appropriate boxes.

The Digit Symbol subtest was chosen for study because there is a rather wide difference in opinion about what skills or processes play a role in the task, yet there is no definitive research on the subject.

Review of the Literature

Holt's (1970) edited and revised version of Rapaport, Gill and Schafer (1944-46) Diagnostic Psychological Testing constitutes the most comprehensive discussion of what skills and processes are involved in the Digit Symbol task. The original version of the book was crammed with research data on the meaning of the various subtests of the Wechsler-Bellevue Scale. Holt's revised edition completely eliminated the research aspects of the original edition because of deficiencies in the design of the research reported in it and in the statistical analyses. What remained was a clinical manual for use in the diagnosis of psychological dysfunction. However, the work still contained hypotheses on the psychological processes involved in the various intelligence tasks.

The Digit Symbol task of the WAIS is the same task included in the Wechsler-Bellevue Scale with minor revisions. For example, the number of blank spaces to be filled in was increased from 67 to 90 and the symbol for the digit, 2, was changed from a reversed "N" to an inverted "T".

Rapaport et al. indicated that performance on the task involved visual activity, motor activity, and a learning process. The function of the visual activity is to guide the motor activity and the learning process. The motor activity involves the head and eye movements used in locating the digit symbol pairs in the array and the writing and drawing movements used in the reproduction of the symbols. The learning process consists of learning the digit symbol pairs and learning where to look for the digits and the symbols. Rapaport et al. suggest that the, "learning process is abortive, because of the nonsense connection between the digit and symbol." (Rapaport et al., 1970, p. 156.) Instead they hypothesize that the test measures psychomotor speed which is not further defined except by saying that psychomotor speed appears as a "complex effect of a variety of interesting functions." (p. 157.)

It would seem that the psychological rationale of the Digit Symbol task presented by Rapaport et al. (1970) could stand reexamination for two reasons. First, advances in learning theory over the last thirty years would suggest that merely because the digit symbol pairs are based upon "nonsense" connections, a learning process would not necessarily be abortive. Second, the hypotheses of Rapaport et al. are not based upon research, but upon the observations of the individual authors.

Royer (1971) reported a series of studies on the information processing skills relevant to the Digit Symbol task. His work stemmed from the work of Garner (1962), Clement (1964) and his own work (1966) which established that the processing of spatial orientation information takes a relatively long amount of time when compared to the processing of figural information. As Royer (1971) points out, this topic was of interest because the inability to reproduce correct spatial orientation of figures has long been considered a sign of brain damage.

Briefly, what Royer did was to alter the symbols in the Digit

Symbol task so that the same figure(s) in different spatial orientation were paired with the nine digits. As the spatial orientation demands of the task were increased the scores on the task decreased. It is not doubted here that increasing the spatial orientation demands of a task increase the processing time required to perform a task, however, the question remains: how important is spatial orientation processing in the original task?

Although Royer used the Digit Symbol task, his primary focus was to develop a theory of perception relating the time needed to process visual stimuli to characteristics of the stimuli relative to a hypothesized set of similar figures. Thus his conclusions are primarily relevant to his own perceptual theory and not necessarliy relevant to the cognitive skills and processes involved in the Digit Symbol task.

Royer's line of research points up a methodological problem in trying to establish what skills and processes are involved in receiving a high score on a particular cognitive task. The strategy of using the results of a version of the original task altered along a dimension hypothesized to be important, can, at best, only give a hint of what the original task might involve; and, at worst, it might be totally misleading. In Royer's work, the dimension hypothesized to be relevant, spatial orientation, might have only a limited relevance in the original task. Examining the Digit Symbol task using Royer's criteria for judging the spatial orientation difficulty of the task, only two symbols, those for the three and the five, are rotations of the same figure. The rest of the symbols are clearly distinct figures. Therefore, to conclude that the task measures spatial information processing ability is either premature or ill-advised.

Royer (1971) also investigated whether the motor aspects of the task were relevant: does the actual writing of the symbols play a major role in the task relative to the different sets of symbols he constructed. The procedure used was to have the subjects copy symbols varying in their amount of spatial information. Royer's conclusion was that the motor aspects were not very relevant. However, again his focus was not so much on elucidating the skills involved in the Digit Symbol task as in looking for differences among the different sets of symbols he constructed.

Estes (1974) reviewed Royer's (1971) work in detail and suggested that one might be a bit hasty in concluding that the Digit Symbol task measures spatial orientation processing ability. Estes analyzes the task in the following manner. (Numbers were added by the present author for clarity.)

> At each step in the task the subject must
> 1) inspect the next digit,
> 2) go to the proper location in the table,
> 3) code the information distinguishing the symbol found,
> 4) and carry this information in short term memory long enough to reproduce the symbol in the proper answer box. (Estes, 1974, p. 745.)

Contrary to the thinking of Rapaport et al. (1970) and Royer (1971), Estes hypothesizes that verbal encoding skill plays a major role in success in the task. Estes offers the following reasons:

1) After a symbol is coded, there is no need to look at a

symbol more than once while reproducing the symbol. The code guides the reproduction of the symbol.

2) "It is likely that even within the short time interval involved in the test some individuals will be able to learn some of the digit code associations and thus on many occasions not need to look from the digit to the table at all in order to make the appropriate substitution." (p. 745.)

The present research took as its starting point Estes' speculations on the skill involved in the Digit Symbol task. The first reason Estes cites for concluding verbal encoding skills are an important component of the task was rejected for the following reasons. Estes suggests that if the subject codes the symbol there is no need to ever look twice at the symbol while reproducing it. However, a number of the symbols are very simple figures (the dash (-) and the circle (O), for example) and all are symbols frequently used in our culture for which every subject would have a readily available code. It does not seem likely that very many subjects would have to form new codes so they could reproduce the symbols without looking twice.

Estes' second reason for hypothesizing verbal encoding skills as important, (memorization of the digit symbol associations was an important component in receiving a high score on the task), seemed to hold promise for the following reasons. A subject who was asked to highly overlearn the digit symbol associations was able to achieve a perfect score on the task when instructed to fill in the blanks without looking at the array. Furthermore, contrary to Rapaport et al. informal debriefing of subjects who scored high on the task revealed that they had constructed codes to relate the digit symbol pairs. Estes suggests, for example, that a subject could code the symbol paired with the digit, four, as the letter, "L". However, a number of subjects reported codes which served to not only name the symbols, but served to relate the symbol with the digit by naming both with a single code. For example, one subject coded the symbol for the digit, four, as "the beginning line of a four". Thus the code served as a cue for the digit symbol association.

Now although memorization of the digit symbol pairs outside the test situation can improve performance on the task, the question remained: is it possible for subjects to memorize the digit symbol pairs during the task, given the demands of the task? Examination of the distribution of the digits in the task offered support for the notion that subjects would be able to memorize digit symbol associations as they proceeded through the task. The digits are not distributed in a balanced, random fashion.

The first line of the task has a concentration of the digits, one through four. In the first line the digits, one through three, are used five times each; the digit, two, is used six times; and the digit, four, is used four times. On the other hand, the digit, nine, is not used at all; the digits, six through eight, are included just once; and the digit, five, is used only two times. The concentration of the digits, one through four, at the beginning of the task can be considered massed practice, and lends credibility to the notion that subjects would be able to memorize the digit symbol pairs and thus improve their performance on the task.

Referring back to Estes' description of what is involved in the task, if a subject has memorized a particular digit symbol pair he does not have to:

1) go to the proper location in the table and

2) code the information distinguishing the symbol found.

Thus it was hypothesized that memorization of the digit symbol pairs was responsible for subjects' receiving a high score on the task and that subjects' ability to locate and quickly write the symbols was of limited importance.

Specifically, the following hypotheses were formulated to guide the present research:

1) Subjects would be able to learn the digit symbol pairs while completing the Digit Symbol task.

2) Subjects scoring high on the task will have learned significantly more digit symbol pairs than subjects receiving a low score.

3) Subjects receiving training in the memorization of the digit symbol pairs will score higher on the second administration of the Digit Symbol task relative to a control group.

4) Subjects receiving training in searching for the digit symbol pairs and writing the symbols will not score higher than a control group receiving no such training.

As noted earlier in discussing the methods used by Royer (1971) it is not an easy task to determine what cognitive skills or processes are necessary for receiving a high score on a task. A combined correlational and experimental approach is necessary to cast light on such a problem. The correlational approach is useful in determining, on the negative side, that success on a task and a particular skill or process are not related. However, caution must be employed, when a positive relationship is found, in interpreting a significant correlation. Since we are working in the realm of intelligence it is not uncommon for tasks, outwardly very different, to have high correlations.

The situation is even more complicated on the experimental side. A finding that training in a particular skill or process does not significantly improve performance in a task might mean that the skill trained is not related to the task. On the other hand, it might very well be that the skill practiced is relevant, but it is not susceptible to alteration using a relatively short treatment. Furthermore, the finding that a particular kind of training can increase a subject's score on a task does not insure by itself that subjects completing the task on their own actually use that skill.

In short, extreme caution must be exercised in interpreting the results of a single line of research. Preferably, both a correlational and an experimental approach should be employed and studies using differing materials or tasks should be conducted before definitive conclusions can be drawn.

Method

The fifty two subjects were all undergraduate education students attending an open admissions university. The students were recruited by class with the help of their instructors. Fifty six students from three classes volunteered to serve as subjects in the study. Three subjects were dropped because of a failure to follow directions during administration of the Digit Symbol test and one subject was dropped because he received a faulty test booklet.

All subjects received a test booklet containing the experimental materials. The booklets for the two treatments and the two control groups were randomized before the materials were distributed.

The experimental procedure began with all subjects taking the Digit Symbol test, labeled Digit Symbol I.[1] Correlational examination of the skills and processes hypothesized to be involved in the task was made possible by the administration of the following measures. The number of digit symbol pairs memorized by the subjects during the task was assessed by the Memory Test I. This test, given immediately after the first administration of the Digit Symbol test, listed the nine digits and required the subjects to write the appropriate symbols from memory. Also, to test a subject's verbal encoding ability, a paper and pencil version of the paired associate learning paradigm was used. In this test, labeled Paired Associate Ability, the subjects were given two minutes to memorize a list of twenty word pairs and then they were required to write from memory the second member of each word pair.

Experimental examination of skills and processes hypothesized to be relevant to the Digit Symbol task was accomplished by the formation of two treatment groups and two control groups. The first treatment group, labeled Memory Training, was supplied with codes to help the subjects remember the digit symbol pairs. The codes were selected from codes supplied by subjects (participating in the pilot study) who received a high score in the task. For example, the digit symbol pair, 2 - ⊥ was coded by asking the subjects to recall the song title, "Tea for two", and so the subjects were asked to use the following code, "Upside down T for 2 ".

The second treatment group, labeled Visual Motor Training, was designed to give subjects practice in writing the symbols and practice in searching a visual array to look for the correct symbol pair. The intent in constructing this treatment was to give subjects practice in the above skills without giving the subjects the opportunity to memorize the digit symbol pairs. Therefore, the task used letters instead of the digits. The letter symbol pairs were altered every four lines to preclude subjects completeing the task by relying upon memorization of the letter symbol associations.

The first control group, labeled Control I, was used to give an indication of how much a subject's score would improve with repeated practice on the digit symbol task. The subjects in this group continued working on successive copies of the Digit Symbol test for a total of eight minutes.

The second control group, labeled Control II, was included to serve as a yardstick with which to measure improvement in the other groups. The subjects in this group worked on a social studies task for eight minutes. They read a series of passages and answered questions after each passage.

All the treatments lasted for exactly eight minutes. Shortly after the completion of the treatments the Digit Symbol test was administered again (labeled Digit Symbol II). Digit Symbol II served as the dependent measure. Immediately after the second administration of the Digit Symbol test the Memory Test II was administered to check on the number of digit symbol associations learned after completion of the second Digit Symbol test.

Design

Correlations were computed between the first Digit Symbol test (Digit Symbol I) and the first Memory test (Memory Test I), and between Digit Symbol I and the Paired Associate Ability test. In addition, the effect of the treatments on the dependent measure was assessed by using multiple linear regression techniques to predict the Digit Symbol II score on the basis of the subject's score on the first Digit Symbol test and a series of four vectors representing the subject's group membership.

Results

Subjects received a mean score of 5.94 on the Memory Test I indicating that the subjects, on average, were able to memorize approximately six of the nine digit symbol pairs while completing the Digit Symbol task. However, even though the subjects memorized over half the digit symbol associations, success on the Digit Symbol task was not related to the number of associations learned. The correlation between the scores on the first Digit Symbol test and the Memory Test I was .24 which was not significant at the .05 level. The scores on the Paired Associate Ability test were significantly related to the scores on the Digit Symbol I test, accounting for 20% of the variance with an F value of 9.41 (df 1,49) significant at the .01 level. Table I presents the intercorrelations of the continuous measures used in this study.

A recurring problem of cognitive process research is the establishment of the validity of the various treatments: do the treatments cause the subjects to use or to improve in the intended cognitive process and not others? A crucial difference between subjects as a result of their assignment to the two treatments in this study should be that subjects in the Memory Training group should have memorized all the digit symbol associations by the end of the treatment while the group receiving visual motor training should have learned no additional digit symbol associations by the end of their treatment. In the Memory Training group all but one of the subjects received a perfect score on the Memory Test II and the average gain from pre to post treatment was 3.8 associations. In the Visual Motor Training group the average gain was -.4; the subjects lost from memory, on average, ½ an association. So the validity of the treatments in respect to the critical variable, associations memorized, was established.

The means, standard deviations and the number of subjects in each of the four groups are reported in Table II. There were no interactions among the treatments relative to the pretest scores (Digit Symbol I) and there were no differences among the groups at posttest (Digit Symbol II). F values and degrees of freedom for the critical comparisons are presented in Table III. The score on the first Digit Symbol test was an excellent predictor of a subject's score on the second Digit Symbol test accounting for 61% of the variance.

Discussion

The fact that the first Digit Symbol test accounted for a large proportion of the variance is an indication that the treatments were not differentially effective in altering the score on the Digit Symbol test. This result along with the correlational data allows some conclusions to be drawn about the hypotheses to be tested.

1) It seems evident that memorization of the digit symbol pairs is not responsible for a subject receiving a high score on the task. The first treatment was successful in having the subjects commit the associations to memory. However, given this advantage, they did not score higher than the subjects who did not memorize any additional digit symbol pairs. On the correlational side, there was not a significant relationship between the score on the digit symbol test and the number of digit symbol pairs memorized. Inspection of the scores revealed that some subjects who received very high scores on the Digit Symbol test learned very few digit symbol pairs while some subjects learned a relatively large number of digit symbol pairs and scored poorly on the test. Thus evidence of both a correlational and an experimental nature does not support the hypothesis that the memorization of the digit symbol pairs plays a significant role in a subject receiving a high score on the test.

Thus it seems likely that although the digit symbol associations can be and are learned during completion of the task, subjects apparently use the array to either find or check each answer rather than relying on their memory of the associations. Furthermore, the obtained correlation of .45 between the Paired Associate Ability test and the Digit Symbol test can not be considered as evidence of the primary importance of verbal encoding skills, since it is not unusual for very different tasks measuring various aspects of intelligence to be correlated to such a degree.

2) A decision about the importance of the subject's ability to search for the digit symbol pairs and quickly write the symbols was not possible since the subjects receiving visual motor training did not improve relative to the second control group and a separate test of visual motor speed was not included in this study to be used for correlational purposes. The negative experimental finding in no way rules out that some skills or processes which could be placed under the rubric of visual motor speed are important in a subject receiving a high score on the Digit Symbol task.

Indirect support for this notion is found in the research reviewed and reported by Hunt, Lunneborg and Lewis (1975). They indicated that high verbal subjects are faster in a number of processing skills which might be relevant to the Digit Symbol task. They cite, for example, the work of Sternberg (1970). He finds that high verbal subjects are quicker than low verbal subjects in scanning recently presented arrays from memory. Also Hunt, Frost, and Lunneborg (1973) found that high verbal subjects can access highly overlearned material in long term memory more rapidly than low verbal subjects when dealing with judgments about letters.

It could be that high verbal subjects score high on the Digit Symbol task because they are quicker than low verbal subjects in scanning the array and translating the symbol (or a code for that symbol) into the muscle movements necessary to draw the symbol. On the other hand, it is possible that success on the task might be unrelated to specific psychomotor skills and might be related to strategies used in completing the task: strategies such as not looking back to the array while completing a digit symbol pair which has already been committed to memory.

Conclusion

The author began this research with the hope that verbal encoding skills could be established as an important factor in the Digit Symbol Test of the WAIS. That hope was not realized. It is suggested that various aspects of psychomotor speed and strategies for approaching the task be next examined to determine what, in particular, is responsible for a subject receiving a high or low score on this test.

FOOTNOTE

[1] Ten extra digits were added to the Digit Symbol Test of the WAIS. Thus, the highest possible score was 100 instead of 90. The time limit of 90 seconds was not changed.

REFERENCES

Clement, D. E. Uncertainity and latency of verbal naming responses as correlates of pattern goodness. Journal of Verbal Learning and Verbal Behavior, 1964, 3, 150-157.

Estes, W. K. Learning theory and intelligence. American Psychologist, 1974, 29, 740-749.

Garner, W. R. Uncertainity and Structure as Psychological Concepts. New York: Wiley, 1962.

Holt, R.R. (Ed.) Diagnostic Psychological Testing. London: University of London Press Ltd., 1970.

Hunt, E. G., Frost, N., and Lunneborg, C. L. Individual differences in cognition: A new approach to intelligence. In G. Bower (Ed.) Advances in Learning and Motivation, Vol. 7. New York: Academic Press, 1973.

Hunt, E., Lunneborg, C., and Lewis, J. What does it mean to be high verbal? Cognitive Psychology, 1975, 1, 194-227.

Rapaport, D., Gill, M. M., and Schafer, R. Diagnostic Psychological Testing. Chicago: Year Book Publishers, 1944-1946.

Rohwer, W. D. Jr. Decisive research: A means for answering fundamental questions about instruction. Educational Researcher, 1972, 1, 5-11.

Royer, F. L. Figural goodness and internal structure in perceptual discrimination. Perception and Psychophysics, 1966, 1, 311-314.

Royer, F. L. Information processing of visual figures in the digit symbol substitution test. Journal of Experimental Psychology, 1971, 87, 335-342.

Sternberg, S. Memory scanning: Mental processes revealed by reaction time experiments. In J. Antrobus(Ed.) Cognition and Affect. Boston: Little, Brown, 1970.

Wechsler, D. Wechsler Adult Intelligence Scale. New York: The Psychological Corporation, 1955.

TABLE I

INTERCORRELATIONS OF THE CONTINUOUS VARIABLES

	A	B	C	D	E
Digit Symbol I (A)	1.00	.78	.24	.07	.45
Digit Symbol II (B)	.78	1.00	.26	.09	.42
Memory I (C)	.24	.26	1.00	.31	.38
Memory II (D)	.07	.09	.31	1.00	.28
Paired Associate Test (E)	.45	.42	.38	.28	1.00

TABLE II

MEANS, STANDARD DEVIATIONS, AND NUMBER OF SUBJECTS FOR THE FOUR GROUPS.

	Digit Symbol I			Digit Symbol II		
Group	$\overline{X}$	s.d.	N	$\overline{X}$	s.d.	N
Memory Training	60.9	17.	18	68.5	20.	18
Visual Motor Training	61.4	8.2	11	66.3	15.2	11
Control I	59.7	11.4	11	67.6	11.1	11
Control II	57.3	14.1	12	62.5	17.6	12

TABLE III

DEGREES OF FREEDOM AND F VALUES FOR TESTS OF SIGNIFICANCE*

Tests	df	F values
1. Gp.I - Gp.IV interaction	1,44	.570
2. Gp.II - Gp.IV interaction	1,44	3.230
3. Gp.III - Gp.IV interaction	1,44	.975
4. Gp.I - Gp.IV difference	1,44	.806
5. Gp.II - Gp.IV difference	1,44	3.155
6. Gp.III - Gp.IV difference	1,44	1.203

* The regression procedure used employed a series of 4 vectors (coded using the 1,0 method with a unit vector) to represent the 4 groups. The procedure first tests for interactions among the groups relative to the pretest. The first 3 tests indicate that the slopes of the regression lines are not significantly different from each other. The last 3 tests indicate that there are no significant differences among the groups after pretest differences are controlled for.