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ABSTRACT

Six studies were performed investigating the relationship between digit span (DS) capacity and other memory and problem solving tasks: (1) Ss were administered a DS test, an aurally presented mental addition test, a similar multiplication task, and a written timed division test. DS correlated only with the second; (2) Ss were required to interchange mentally the letters in the corners of a square. This task did not correlate with DS; (3) free recall of series of 10 two-digit numbers did not correlate with DS; (4) Ss were presented multiple series of two-digit numbers, from five pairs up to 10 pairs. DS correlated highest using sets of six and seven number pairs; (5) the relationship between DS and memory for visual patterns was examined; with no correlation; (6) the relationship between DS and verbal memory was investigated using the immediate recall, recall after one presentation of a series, vocabulary, and DS. The first three tests correlated significantly with each other while DS did not correlate significantly with any of the three. It was concluded that a DS test measures a narrow ability which does not play a significant role in most other problem solving tasks. (Author/CJ)

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Final Report

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The Relationship Between Memory Span, Long-Term Memory and Problem Solving

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U.S. DEPARTMENT OF
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SUMMARY

Six studies were performed investigating the relationship between digit span (DS) capacity and other memory and problem solving tasks. In the first study the Ss were administered a DS test, an aurally presented mental addition test, an aurally presented mental multiplication task, and a written timed division test. DS correlated only with the mental addition task which required the Ss to remember long numerical problems. DS did not correlate significantly with the mental multiplication task although this latter task did require the Ss to store the products of some calculations while other calculations were being performed. The second study used a task in which the Ss were required to mentally interchange the letters in the corners of a square. Although a number of interchanges had to be successively performed which required recalling the results of previous interchanges, this task did not correlate with DS. In study 3 free recall of series of 10 two-digit numbers, which is much greater than span, did not correlate with DS. Study 4 involved multiple presentations of series of two-digit numbers. On trial 1, five two-digit numbers were presented. On trial 2, the same five plus a sixth two-digit number was presented. On trial 3 seven were presented, trial 4 eight, trial 5 nine, and trial 6 ten. DS correlated highest with trials 2 and 3 and the correlation dropped to zero on later trials. The relationship between DS and memory for visual patterns was examined in study 5. The visual pattern test involved flashing a 13 dot pattern on a screen for .2 seconds and then asking the Ss to reproduce the pattern. The visual pattern test did not correlate with DS. The final study investigated the relationship between DS and verbal memory. The tests used in the study were: 1) Immediate verbatim recall of long sentences; 2) Recall of 30 cartoon captions after one presentation; 3) Vocabulary; 4) DS. The first three tests correlated significantly with each other, indicating a verbal ability or verbal memory factor. DS did not correlate significantly with any of the three. It was concluded that a DS test measures a very narrow ability which does not play a significant role in most other problem solving and retention tasks.

INTRODUCTION

Some form of a digit span (DS) test has been included on many intelligence tests (e.g. Wechsler, 1944), and intuitively DS might be expected to correlate with a number of other cognitive abilities. For example, George Miller (1956) makes the following observation about reasoning:

> We cannot think simultaneously about everything we know. When we attempt to pursue a long argument, it is difficult to hold each step in mind as we proceed to the next, and we are apt to lose our way in sheer mass of detail.

Although Miller's description does not necessarily imply the existence of a correlation between DS and reasoning, it certainly does suggest the possibility of a correlation.

Short term memory as measured by DS could also be important to long term storage and retrieval. A stronger or longer impression in short term memory might make entrance into long term memory more probable or stronger. Also, being able to keep more cues in immediate attention might make information retrieval from long term storage more probable.

The present paper reports a series of studies investigating the correlations between DS and a number of problem solving and memory tasks. In all studies the Ss were students at Cal State, Hayward.

DS and Problem Solving

STUDY 1

In a previous paper (Whimbey, et al, 1969) a correlation of .67 was reported between DS and an aurally presented mental addition task. The items of the mental addition task were of the following type: add 3A, 2B, 5C, and 3D to 4A, 2B, and 8D; the answer being 7A, 4B, 5C, and 11D. The digits were presented by tape recorder at a 2 digits/second rate and the S was not allowed to write anything but the answer.

To investigate the relationship further the present study used the following four tasks:

1. DS test. Consisted of 30 series of numbers varying between five and nine digits in length. The series was presented at 2 digits/second and each was followed by one of six words. The S was required to listen to the series, look up a letter corresponding to the word on a reference sheet, write the letter, and then attempt to write the series. Credit was given for a series only if it was recalled completely correctly in order. The DS test and its rationale are described in more detail in a previous publication (Whimbey & Leiblum, 1967).

2. Mental Addition (MA) test. Identical to the 30 item test used previously (Whimbey, et al, 1969) and described briefly above, except that the digits were presented at a 1 digit/second rate. The slower presentation rate allowed the Ss more time to rehearse the items subvocally during presentation.

3. Mental Multiplication (MM) test. Consisted of 25 aurally presented 2 digit x 2 digit, 2x3 and 3x1 multiplication problems. The Ss were only allowed to write the answer for each problem.

4. ETS Division (DIV) test (French, et al, 1963). This is a highly timed, written test of simple division.

The correlation among the four tests, for 38 Ss, are presented in Table 1.

TABLE 1

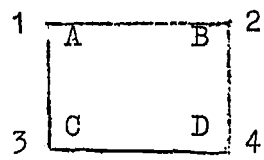
		1	2	3	4
1.	DS		.41	.12	.04
2.	MA			.76	.67
3.	MM				.75
4.	DIV				

The near zero correlation between DS and MM is especially interesting. Each problem of the MM test involved the presentation of only four or five digits and therefore storage of the problem itself would not tax memory span greatly. However, in performing the multiplications some products had to be stored mentally while other operations were being performed. For example, in multiplying 76 x 45, the product of 6 x 45=270 had to be stored mentally while the remainder of the problem, 7 x 45, was recalled and the product 7 x 45=315 was obtained; 210 and 3150 then had to be added mentally to obtain 3420. Apparently, storing mentally generated products and performing mental operations does not depend on DS memory capacity.

In a follow-up study six new Ss who scored high on the DS test and six scoring low, were administered the MA test individually. After each item of the MA test was presented the S was required to attempt to recall the item verbally. If the item was not recalled perfectly, it was re-presented until it was recalled, and only then was the S allowed to perform the addition mentally and write the answer. Although there was appreciable variance in the MA scores, there was no significant difference between the groups. This result again indicated that performing mental operations, and storing the results of the operations, did not put a load on DS capacity.

STUDY 2

This study also investigated the importance of DS capacity in thinking and problem solving. A test with 32 items of the following type was used:



A and B change places, then A and C change, then B and C change, then D and A change. What letter is in each of the following corners?

corner 1__ corner 2__ corner 3__ corner 4__

The items were presented in written form and the original figure presented above was available for perusal. However, all of the interchanges had to be performed and retained mentally; only the final answer was written. The 32 items involved between three and five interchanges, and were administered with a 35 minute time limit.

The interchange test and the DS test were administered to 40 Ss. The interchange test had separately timed halves reliability of .82 but the correlation with DS was only .07.

Retaining the new positions of the letters after each interchange appears to be the most difficult part of the interchange test. The complete lack of correlation with DS, however, indicates that the memory capacity measured by the DS test is a different ability than the memory used in storing the interchanges.

DS and Other Memory Measures

STUDY 3

In a previous study (Whimbey, 1968) DS was found to correlate .71 with free recall of a supra span series of two-digit numbers. The free recall task consisted mainly of six and seven two-digit number series so that the series was just barely greater than span. This was investigated further in the present study using a free recall test consisting of 15 series of 10 two-digit numbers presented aurally at a two-digit number/second rate. The Ss were instructed to listen to each series of 10 numbers and to then recall and write the numbers in any order. The score was the number of two-digit numbers recalled, summed over the 15 series.

The free recall test correlated -.06 with DS in a sample of 34 Ss indicating that when a supra span series is much greater than span, span capacity no longer effects recall.

STUDY 4

In an attempt to maximize any influence of DS capacity in the learning of a supra span series over a number of presentation trials, a supra span test was used in which the series was gradually increased in length. On trial 1 five two-digit numbers were presented aurally. On trial 2 the same five numbers were presented along with a sixth two-digit number. Trial 3 presented seven numbers, trial 4 eight numbers, trial 5 nine numbers, and trial 6 presented ten numbers. The Ss were given six page answer booklets. After each presentation they wrote the numbers in any order as well as they could recall them and then turned the page before the next trial. A total of 12 series were presented in this manner. This presentation procedure was based on results of a pilot study which indicated that when a constant length supra span series was presented aurally for a number of trials some Ss only tried to learn the first four or five numbers on trial 1 and then gradually added one or two numbers on subsequent trials. This strategy tended to be more effective than trying to learn the whole series on every trial. The presentation procedure used in the present study eliminates this source of task-specific individual difference variance.

Thirty-five Ss were tested with both the DS test and the supra span series test. Six scores corresponding to the six presentation trials were obtained for each S by summing the number of numbers correctly recalled on each trial, over the 12 series. The correlation of DS with the successive trials were: trial 1, r=.31; trial 2, r=.63; trial 3, r=.55; trial 4, r=.2; trial 5, r=.09; trial 6, r=.14.

The low correlation of DS with trial 1 resulted from lack of variance with only five two-digit numbers. Six two-digit numbers presented on trial 2 did allow the high DS Ss to score higher than low DS Ss. But as the numbers of digits increased on successive trials the relationship with DS decreased.

STUDY 5

In a previous study (Livson & Krech, 1956) a short term visual memory measure correlated .54 with Wechsler vocabulary in a sample of 22 Ss. To investigate the relationship of these variables to DS a study was conducted using the following four variables:

1. Wechsler Vocabulary (WV) group administered with response written.

2. ETS Vocabulary (ETSV) test (French, et al, 1963) consisting of 36 four choice alternative items.

3. DS test.

4. Visual Memory (VM) test described in greater detail in the original publication.(Livson & Krech, 1956). Basically, it consisted of flashing a pattern of 13 dots on a screen for .2 seconds. The dot pattern was formed by placing 13 dots in a 5x5 grid. Ss had a 5x5 grid answer sheet and tried to recall and reproduce the pattern immediately after presentation. Forty different patterns were used for the entire test; some of the patterns formed simple symmetrical figures like an inverted U, while others were complex and asymetrical. In the present study the Ss were tested in groups of 10 by presenting the VM test on movie film whereas in the original study the Ss were individually tested.

The intercorrelation of the four tests with 30 Ss are presented in Table 2.

TABLE 2

	2	3	4
1. WV	.74	.19	.18
2. ETSV		.20	.08
3. DS			.24
4. VM			

The only statistically significant correlation is between the two vocabulary tests. The non-significance of the correlation between DS and the immediate recall of visual patterns indicates that there is very little, if any, overlap between the abilities involved in the two tasks. This finding contrasts with the well established fact that aurally presented digit span and letter span correlates significantly with visually presented digit span and letter span (French, et al, 1963). The contrast corresponds to Guilford's (1967) distinction between figural and symbolic material.

The correlation between visually and aurally presented DS has been confirmed by the present investigator in two studies. In one study DS series were presented one digit at a time by movie film. In another study the whole series was printed on a card and shown to the S. In both studies, the visual presentation correlated significantly with the aural DS test.

The lack or correlation between DS and immediate recall of visual patterns was replicated in another study, using a somewhat different visual pattern memory test. The visual pattern test consisted of flashing a 4x4 grid onto a screen twice. Each time, between one and four of the boxes were filled and the filled boxes were different for each of the grids. Together, between four and seven boxes were filled. The S was instructed to watch the two grids appear on the screen and then to recall and blacken the filled-in squares on a 4x4 grid answer sheet. The total test had 28 items.

In a sample of 36 Ss this visual pattern test had a reliability of .76 but correlated only .18 with DS.

STUDY 6

The relationship between verbal memory and DS was investigated in a study using the following tests:

1. DS.

2. ETS Vocabulary (ETSV) described above.

3. Immediate Sentence Recall (ISR) consisting of 30 long sentences, selected from non-technical books.. Ss task was to write each sentence verbatim immediately after it was presented and the score was the number of words correctly recalled.

4. Cartoon Caption Recall (CCR) consisted of presenting the captions of 30 Dennis the Menace cartoons aurally, while the respective cartoon pictures were viewed. After all 30 were presented the S was required to view each of the cartoons individually and to write each caption verbatim. The score was the number of words correctly recalled.

The four tests were administered to 51 Ss in groups of 10 and the correlations are presented in Table 3.

TABLE 3

	1	2	3	4
1. DS		-.04	.23	.21
2. ETSV			.50	.64
3. ISR				.66
4. CCR				

The high correlations among CCR, ISR and vocabulary might be regarded as a verbal memory or verbal knowledge factor. The correaltion of CCR with vocabulary is especially interesting since Dennis the Menace uses a very simple vocabulary. However, DS memory appears to bear no relationship to this general verbal capacity since none of the correlation with DS are statistically significant.

CONCLUSION

The results of the present series of studies are in agreement with the results of other experiments. Wechsler (1944) has reported a correlation of .51 between DS and full scale I.Q. However, this is based on the full range of I.Q., including the feebleminded. Wechsler goes on to say (p. 83) that his experience indicates that DS is a good indicator of intelligence only at the lower level; among normal adults it is a very poor measure.

Baumeister and Bartlett (1962) found DS to be a major factor in a factor analysis of a group of tests administered to retardates; numerical ability tests also loaded highly on the factor. Study 1 of the present paper indicates that DS memory is not a component of numerical ability among normal young adults. The factor obtained by Baumeister and Bartlett may reflect differential acquaintance with, and understanding of, numbers among the retardate group.

In previous studies (Whimbey 1968) DS was found to relate to scores on an aurally presented verbal analogies test and to an aurally presented syllogistic reasoning test <u>only</u> when the problems were presented quickly and without any instructions in mnemonic devices. In conjunction with the present studies, the results indicate that DS capacity is not a component of reasoning or problem solving ability per se. If some type of attention span does play a significant role in reasoning ability; it is a different attention span than that involved in a DS test.

Regarding the relationship of DS to other retention tasks, the type of quick, verbatim recall involved in DS loses its importance as other processing and integrating activities become involved. Visualizing information, forming mnemonic connections, and the activities involved in rehearsal and multiple presentation all reduce the importance of DS capacity.

Although the DS test may be useful for diagnosing various levels of retardation and other clinical syndromes, it is apparently unrelated to general problem solving, information processing, and retention among normal young adults. Good DS capacity appears to be useful only in the immediate recall of unrelated, quickly presented material w[illegible] is close to span length, between approximately five [illegible]ht units.

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