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MEMORY SPAN: A REVIEW OF THE LITERATURE

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Although many researches have been undertaken in the field of memory span, both by experimental psychologists and by those in the field of mental testing, there has been no attempt to summarize or to systematize the findings of the investigators who have studied the various aspects of this subject. This paper has been undertaken with that end in view.

I. HISTORY OF MEMORY SPAN TESTS

(1) *Early Anecdotes.* Stories of exceptional individuals have probably been told since the beginning of time, and reports about memory spans of such individuals are not lacking. There was a blind Swiss, for example, who was reputed to have been able to repeat a series of 150 numbers, either forwards or backwards, after a single hearing (91)! Other anecdotes are in the literature (8, 44, 47, 91, 130), but there was no real attempt at controlled observation, and none of the early writers realized the significance of what they had heard of or observed.

(2) *Nineteenth Century Studies of Memory Span.* In 1870, Oliver Wendell Holmes, in addressing the Phi Beta Kappa Society of Harvard University, said, ". . . in uttering a series of unconnected words or letters before a succession of careful listeners, I have been surprised to find how generally they break down, in trying to repeat them, between seven and ten figures or letters; though here and there an individual may be depended on for a larger number . . ." (61). Holmes, however, made no formal experiments on the phenomenon.

Sixteen years later, William James (70) wrote of "the present, . . . merely a dividing line between the past and the future . . .," but he did no

¹The writer wishes to express his indebtedness to Miles Murphy and Francis Irwin of the Department of Psychology, University of Pennsylvania, for their aid in compiling a bibliography for this summary.

experimental work on the problem. In the same year, Jacobs (68), an English philosopher, wrote, "There is . . . a certain number of syllables up to which each person can repeat . . . after only once hearing; and it is probable that this number varies with different persons." In 1887, he made the first formal experiment on "prehension" (69), discovering that the ability increased with age. Galton (48), in the same journal, noted that inmates of institutions for the feeble-minded possessed lower prehension ability than did the normal children tested by Jacobs. In 1888, Burnham (21) summarized some of these results in his comprehensive paper on memory.

From this time on, memory span research was more common. The most important work in the field since 1890 will be reviewed here, not primarily from the historical standpoint, but from the aspect of logical organization. If the reader be interested in historical summaries including some of the work on memory span, he is referred to the review by Burnham (21), and those by Young (144), Kuhlmann (78), Wylie (142), and McGeoch (87).

II. WHAT IS MEMORY SPAN?

To define memory span, one must examine the question from two viewpoints, the functional and the structural.²

(1) *Functional Aspect.* Functionally, Binet (8) has defined prehension as "the maximum number of digits retained after a single hearing." But the definition, of course, need not be restricted to the use of digits. Humpstone (65) broadened this definition when he described memory span as "the ability to grasp a number of discrete units in a single moment of attention and to reproduce them immediately." Leaming (80) elaborated upon this: "It [memory span] appears to measure the number of discrete units over which the individual can successively distribute his attention and still organize them into a working unit." Watkins (133) stated that immediate memory ". . . is the capacity to repeat impressions which have not entirely disappeared from consciousness, the expression following immediately upon the impression." Strong (125) defined it as "a line of successive presents."

To generalize, memory span refers to the ability of an individual to reproduce immediately, after one presentation, a series of discrete stimuli in their original order. Practically any sort of material may be presented, such as digits, letters, words, and sounds, and almost any sense organ or combination of sense organs may be used to receive the impressions. Both of these variables will be discussed under subsequent headings.

(2) *Structural Aspect.* A structural definition of memory span is difficult to give, for one immediately is faced by the distinctions between the prerequisites for memory span, and the actual processes involved. Although an intact sense organ, an afferent tract, a central projection area, efficient association fibers, and a certain degree of attention are all involved, as Smith (119) points out, these terms do not describe the processes actually involved in memory span.

Processes of attention are involved, as McCaulley (86), Gundlach, Rothschild, and Young (56), Cattell (28), T. L. Bolton (16), Johnson (72), and

² "Functional" in the sense of external or extrinsic behavior; "structural" in the sense of the processes involved (the intrinsic aspect).

others indicate. Certainly the subject must be able to distribute his attention over the series of stimuli, and concentration of attention is needed so that the mental processes may continue in the direction started. But the range or span of attention is distinct from memory span. Hunter (66) shows that attention span and memory span are alike in involving only one presentation of the stimulus, but that they differ in temporal duration of the stimulus. "If the stimulus is presented for one-fiftieth of a second, the experiment is classified as one on attention, whereas with longer exposure times, the behavior is classified as . . . memory." Motor aspects of attending are evident in the receipt of instructions and in the postural response of getting ready, as well as in the receptive attitude during the presentation of the series. Much may be said for the suggestion (56) that memory span be renamed "set."

"Associability" is also required in memory span. This term, originated by Humpstone (63, 64, 65), refers to the ability of the subject to group the series of elements together: to perceive relationships among the series in order to better reproduce them.

Still another process involved in memory span is that of imagery (20, 86, 97). The subject, in order to be able to reproduce the series presented, must be able to image the series. But memory span is not an after-image. Richet (110), as early as 1886, compared the memory span with the sensory after-image. He recognized that there was a difference, but believed the two to be comparable. According to common psychological belief, it is generally held that the sensory after-image depends upon activity not only in the brain, but also in the sense organ. Humpstone (64) actually calls memory span an after-image.

The actual reproducing of the series of stimuli involves the process of memory (28, 86). If the individual possessed no memory at all, reproduction of the series would be impossible. But Binet (8), in 1894, was probably the first specifically to point out that there was a difference between memory and memory span. Fernberger maintains (41) that memory span and memory are different in the length of time over which reproduction is possible. Memory span is transitory; memory is fairly permanent. In addition, the amount of material involved in memory span is ordinarily much less than the amount of material involved in memory. W. G. Smith (119) showed that memory span may be good and memory bad, or vice-versa, thus offering further proof that the two are distinct. Reproduction of the series also involves certain other "reproduction factors," such as language ability and arithmetical proficiency.

Now although memory span is dependent on all of the above functions, it seems clear that it is not any one of them (20, 64, 123). The question of whether the ability is dependent or independent is closely related to the present discussion, and hence is the next topic.

III. IS MEMORY SPAN A GENERAL ABILITY?

(1) *Introduction.* A few workers (20, 63, 65, 97) regard memory span as an independent ability. Such attention factors as observation, distribution of attention, and description, and such reproductive factors as language ability, memory, and arithmetical efficiency may also be involved (20). Humpstone's independent

ability tested is "associability," or, ". . . the ability to grasp and associate a number of discrete units of perception in a definite order" (65). Memory and imagination are involved, but memory span itself is a specific ability.

Binet also holds that memory span is an independent ability (12), but that the ability tested is the "capacity for effort." This view assumes that memory span is a general⁸ ability, and accordingly, that the type of material used or the sense organ or organs through which the material is received should have no effect either on the number of discrete units reproduced by the individual, or on the standing of the individual in relation to others tested for memory span.

(2) *The Type of Material.* There is practically no limit to the type of material that can be used in such a test.

Ideas, sentences, objects, pictures, noises, words, paragraphs, diagrams, and syllables are only a few of the many types of material that have been used, though as Bronner, Healy, Lowe, and Shimberg point out (19), the use of digits has preëmpted the field. For a discussion of the various types of material that have been used, the reader is referred to Jacobs (69), Travis (128), Calhoon (25), Lumley and Calhoon (82), Humpstone (65), Terman (126), Terman and Merrill (127), Cattell (28), Squire (121), Whitley (136), and Whipple (135).

It has been found that the type of material used in the test does definitely affect the results secured. In general, experimental results indicate that the most difficult material to reproduce is nonsense syllables, then letters, then digits, sentences and related words (25, 66, 82, 121, 132, 136). Bourdon (18) found that letters were easier for children to repeat than other materials; all materials were found to be of the same difficulty for subjects of from 14 to 20. The order indicates that at least two factors are involved in making some materials easier than others: familiarity with the material and "associability."

If all of the material used produced the same results relatively, the standing of the individuals in the group would not be affected by the type of material used. If the standing of the individuals in the group is affected by the type of material used, other factors remaining constant, we should expect a correlation of significantly less than 1.00 between results secured by use of different materials.

⁸ That is, the same ability is said to be operating through the media of different sense organs and with different materials.

Henmon (60) secured the highest correlation coefficients for memory spans as ascertained for different types of materials when he reported a coefficient of .77 between "memory" for syllables and "memory" for numbers, and found the same correlation between "memory" for nouns and for syllables. Memory span as tested by nouns and numbers correlated only .20. Abelson (2) secured intercorrelations of from .34 to .66 for different types of material. Calkins (26) found that concrete objects produced higher memory span scores than did verbal stimuli, such as words. Fischler and Albert (42) were the first to treat this problem statistically. These investigators secured intercorrelations of from —.38 to .47 for different types of material. As a result of their experiment, they concluded that immediate memory was apparently not a general ability. They admit, however, that their results may be due to the fact that the same subject is attentive in one test, inattentive in another.

In none of these studies was there careful control of all experimental conditions. Thus, additional and more careful work is needed before conclusions can be drawn.

(3) *The Sense or Senses Through Which the Impression is Received.* The sense or senses through which the impression is received also appear to affect the memory span score as secured by the clinical or experimental test. The material may be presented through almost any sense organ or combination of sense organs.

It has been found that in general, for example, the adult will have a greater memory span with the visual than with the audito-vocal method, but that the child's score is higher with audito-vocal than with visual presentation (1, 59, 83, 103). Kirkpatrick (75) reported that visual presentation produced higher scores for immediate reproduction than did auditory or actual presentation of objects before the eyes.

The sense organ which receives the impression does, according to experimental results, make a definite difference in memory span score, at least in terms of the number of units reproduced. If the standing of the individual in relation to others is changed by results on memory span as attained through different sense organs, other factors remaining constant, correlations between the results should be significantly less than 1.00. But again, the experiments were not carefully controlled. Davis (37) found a correlation coefficient of only .49 between visual and audito-vocal presentation results. Hao (57) reported the coefficient to be .39 between visual and auditory presentation.

If the material is presented visually, successive or simultaneous presentation may be used. Münsterberg and Bigham (93), and Gates (53), found that adults profited more through simultaneous presentation, although Warden (132) reported that his college students profited more through successive presenta-

tion, and when movement was involved in the presentation, scores were even higher. Hawkins (59) verified the results of Münsterberg and Bigham (93) and Gates (53), and further reported that children secured higher scores through the use of successive rather than simultaneous presentation.

The memory span apparently increases as the number of sense organs through which impressions are received increases, except where distraction may occur, as in the results of Smedley (116).

Jones (74) found that a method of combining as many sense organs as possible was superior to any other method. This was said to be due to the fact that there are certain "visual," "auditory," and "motor" types of individuals. When all the possible sense organs are stimulated, each subject has the fullest possible advantage in the method of presentation. Münsterberg and Bigham (93) found that a series presented to 2 senses at the same time is much more easily reproduced than if given only to sight or to hearing. Smedley (116) concluded that the audito-visual-articulatory and the audito-visual-hand-motor memory were superior to visual presentation, which was superior to the audito method, but Chambers (31) could not substantiate this order.

Nichols (96) early demonstrated the possibility of using the tactual receptors for testing memory span, though Nichols had little idea of such an application of his work. The fact that memory span can be tested through the medium of any sense modality makes the Knox Cube Test a particular type of memory span test. In the Knox Cube Test, 4 blocks in a row are tapped by the examiner in a given order; the subject is then asked to tap the blocks in the same order. Obviously this comes under the functional definition of memory span, being simply a new method of presenting the stimuli. Davis (37) recognized this test as a type of memory span when he ran correlations with the results of the Knox Cube Test and results of memory span for digits.

(4) *Summary.* Results indicated in the 2 preceding sections show that substantially different spans are secured depending upon the type of material used, and the sense or senses through which the impressions are received. From all the evidence available, however, it would appear that memory spans for different types of material may be specific spans, rather than different aspects of a general span. Likewise, it appears quite probable that the memory span for each sense organ or combination of sense organs is a specific span. But the whole question is far from settled and is open for a real experimental attack, since it is more than possible that differences are due to inaccuracies in the methods rather than intrinsic differences in the mental processes involved.

For example, if the results obtained by methods using different materials could be freed of differences in the subjects' acquaintance with the materials, there might be no differences in relative results. This possibility is to be discussed further under a subsequent heading.

And again, if subjects who had practiced equally with the different sense organs could be obtained, results secured through different sense organs might give the same relative rankings for individuals. But there is a strong possibility that the imaginal endowment, as well as the imaginal type, would still affect the memory span, as Jones (74) suggests.

IV. FACTORS WHICH AFFECT MEMORY SPAN

There are a number of factors which definitely affect memory span; the effects of practically all of these factors have been investigated in statistical and experimental studies. Some of the factors are extrinsic, or present in the testing situation itself. These factors, if not carefully controlled, cause the memory span test to be statistically unreliable. Other factors are intrinsic in the individual, and it is these factors which are the basis of "true" memory span.

Though numerous factors affect memory span, the test is one that shows surprisingly high reliability. Results obtained by different investigators show that the reliability coefficients for memory span may be as low as .28 (15), or as high as .93 (22). Table I summarizes the reliability coefficients secured by different investigators for the more common methods of testing memory span.

TABLE I
RELIABILITY COEFFICIENTS REPORTED FOR MEMORY SPAN

Investigator	Audito-Vocal for Digits	Visual for Digits	Audito-Visual for Digits
E. B. Bolton (15).....	.28		
D. Mitchell (90).....	.44, .47 ⁴		
Hao (57).....	.52	.83	
Garrett (49).....	.80	.68	
Davis (37).....	.74	.84	
Wyatt (141).....		.76	
Burt (22).....		.70, .93 ⁵	
Abelson (2).....			.73, .70 ⁶

Reliability coefficients for other types of memory span reported in the literature vary from .70 (2) to .81 (141). Both the figures summarized in the table, and the data indicated in the preceding paragraph lead to an important conclusion regarding the use of memory span tests. The range of figures indicates that the extrinsic factors *can probably* be controlled carefully enough to make the test a reliable one.

⁴ Two figures secured by use of two methods of scoring.

⁵ Burt (22) secured the first figure with elementary school students, the latter with preparatory school students.

⁶ Abelson's first figure was secured with girls, the second with boys.

A. Extrinsic Factors

(1) *Characteristics of the Material That is Used.* The characteristics of the material used will definitely affect the memory span score.

If, for example, the material is all closely related, it will be much more easily reproduced. This relationship of the material is called by Calhoon (23) the "coefficient of associability." In the use of digits, the figures must be so placed that none are in their natural or reverse order. There must be an avoidance of rotation, or of any numbers suggesting addition, subtraction, division, or multiplication (Brotmarkle, 20). Binet and Simon (11) state that no numbers which follow one another must be used beside each other. T. L. Bolton (16) and Bourdon (18), in their experimentation, were sure to ascertain that no digit came in its accustomed order, and that no digit was repeated. Terman (126) was not so careful in this respect in his 1915 revision of the Binet Test, but has taken greater care in his 1937 revision of the scale (127). Xilliez (143) analyzed the effect of the relation of the digits to one another, and noted that a negative interval (the interval is the difference between 2 digits which follow one another; it is positive if the second is larger, negative if the first is larger), is inferior, in terms of recall, to a positive interval. To summarize, the units of the series must not be presented in a manner that would facilitate groupings through the apperceptive background of the subject.

In addition, the units of the material must not be presented in groups. If the visual method is used, the material should be presented either one unit at a time (successive presentation), or all units at the same time (simultaneous presentation), for grouping would make it too simple for the subject to secure a memory span above his "true" one. Brotmarkle (20) and others emphasize the importance of the control of grouping. Chamberlain (30) has experimentally demonstrated that recall is stronger when the objects are presented in groups. However, even when grouping is eliminated in the presentation of the material, subjective grouping often occurs.

The material used should have approximately the same degree of familiarity for all subjects. Calhoon (23) and Whitley (136) both stress the fact that apperceptive background should be equalized for all subjects, as far as possible.

All of the subjects should have the same degree of familiarity with the items in the series. Do not, for example, test a child by the digit method if that child has never been taught numbers, for all available norms have been secured with the use of subjects acquainted with numbers.

(2) *Rhythm of the Presentation of the Material.* Closely related to the problem of presenting the stimuli in groups, is the presentation of the stimuli in rhythmic fashion. Most investigators point out that

the stimuli used in testing memory span should be presented with as little rhythm as possible (11, 18, 119, for example).

Probably the only experimental study of the effect of varying rhythm on memory span has been undertaken by Adams (3). Adams varied the rhythm in presenting a series of digits by using trochaic, iambic, dactylic, anapestic or amphibrachic rhythm, or no rhythm at all. He reported that his subjects (elementary psychology students at the University of Michigan) had higher memory spans in general when rhythm was used than when no rhythm was used. The effect of the different types of rhythm depended upon the sex of the individual, the females doing best with anapestic rhythm, the males with dactylic.

The fact that the introduction of rhythm into the presentation of the series of units does increase memory span is further verified by the results of those investigators interested in the "rhythmic span," in which the units are presented in rhythmic fashion (see 122, 124, for example). The effect of rhythm is to group the units in the series, again enabling the individual to secure a span higher than his "true" one.

(3) *Rate of Presentation of the Stimuli.* The speed with which the stimuli are presented has an effect on the memory span score attained. Terman (126) and other psychologists set the best rate of presentation of digits at a rate of slightly faster than 1 per second, while Lightner Witmer, in instructing clinical psychologists at the University of Pennsylvania, expressed his belief that the "natural rate of discharge" (the speed best adapted to the individual) should be used.

Actual experimental investigation also indicates that the speed of presenting the stimuli affects the score. Peatman and Locke (100) experimentally showed that the best rate of presentation for digits by either the audito-vocal or visual method was one digit per two-thirds of a second to one digit per second.

In the auditory digit test, Brotemarkle (20) believes that a rapid increase in the rate of presentation will result in an increase in score. Lumley and Calhoun (82) found that a decrease of speed enabled children of the seventh and eighth grades to raise their scores, but that in the other grades tested (third to twelfth) there was no consistent effect on performance. Other experimenters have found that a faster rate of presentation adversely affected memory span performance (56, 107). One investigator (Bergström, 6) reported that rate of presentation of the stimuli had no effect on the attained memory span.

Once again, a conclusion about the effect of the variable cannot be reached. Different research workers make various reports. More carefully controlled and standardized work is essential.

(4) *The Method of Scoring the Responses.* The method of scoring the responses also has an effect upon the apparent memory

span of the individual. Variations in scoring are common; scarcely two investigators have scored alike.

In the audito-vocal memory span for digits, for example, Terman (126) gave the individual 2 or 3 trials on any particular series, depending upon its length, and the subject was given credit for that length if one of the series was reproduced correctly. Starr (122) gave credit if 2 of 4 series were reproduced correctly at a given length. Humpstone (65) gave one trial at each level where the series was arranged in lengths varying from 3 to 10 digits. Credit was given for the longest series correctly reproduced. M. H. Young (145) showed that the number of trials given affects memory span attained. When a child was given 3 chances instead of 2 (with one series necessarily correct for credit), 55% of the subjects increased their span by one.

In the determination of reverse memory span, Starr (122) gave 4 chances at each length, and 2 of the 4 had to be correct reproductions for credit to be given. Terman (126) gave 2 or 3 chances at each level, and only one had to be correct. In the visual memory span for digits, Humpstone (65) gave only one chance at a series of given length, and to get credit, that series had to be absolutely correct.

Most investigators take the point of view that an incorrect series should not be scored at all. As Bergström (6) points out, if errors in a series longer than the span attained are scored, the true memory span is not ascertained. Other investigators feel, however, that all of the reproductions should be considered (55, 133).

Krueger and Spearman (77) take account of errors in their novel technique of scoring. They correlate the subject's reproduced series with the original stimulus series by use of Spearman's "footrule method." Thus the greater the error of the subject, the lower will be the correlation coefficient. Other methods of scoring errors are many and complicated, but these schemes and techniques will not be discussed in this paper.

(5) *Fatigue of the Subject.* Fatigue may be another extrinsic factor affecting memory span performance. Though the few investigators mentioning the effect of fatigue on memory span do not differentiate between mental and physiological fatigue and boredom, this does not immediately exclude their observations from consideration, though it does make them much less valuable. Hao (57) and Whitley (136) both believed fatigue to be a factor in their results, but Smedley (116) probably delayed experimental work on the problem when he pointed out that if one attempted to test the effect of fatigue, the subjects are apt to gain more through practice than they lose through fatigue.

As throughout the field of memory span investigation, more careful work is needed before the effects of fatigue can be conclusively shown.

(6) *Time of Day.* The time of day apparently is another extrinsic variable which produces differences in memory span. From

the available data, there is no way of telling whether the observed variations in memory span during the day are due to mental or to physiological fatigue, or boredom, or to some other factors not even considered as a possible cause. It is for this reason that the variable is considered under a separate heading.

Marsh (84) found wide individual variations in the time of day at which greatest efficiency appeared in memory span performance, while Winch (138) found that efficiency was greatest in the forenoon. Gates (50, 52) substantiated Winch's results, and Laird (79) extended them to conclude that the performance reaches its low point about 10:00 P.M., when there is an "end spurt."

Though the causes of such variation are not clear, the implication for clinical psychologists is clear. In order for the subject to perform in his best possible manner, the test should be made in the forenoon.

(7) *The Attitude of the Subject.* Since the attitude of the subject is another important factor ordinarily within the control of the experienced examiner, it too is listed here as an extrinsic factor. Too many excellent chapters have been written on the technique of establishing rapport with the subject for the present writer to go into detail. For such a discussion, the reader is referred to almost any current text on intelligence testing.

It will be sufficient to mention work in which the attitude of the subject has been found to have a definite effect on the memory span attained. Bronner, Healy, Lowe, and Shimberg (19) and Hao (57) report that the personal attitude of the subject definitely affects results, and Squire (121) found the use of pictures effective in testing the memory span of children, for it increased their interest.

(8) *Distraction.* Naturally enough, one would expect that the greater the distraction present in the situation, the poorer would be the performance of the individual, and this is actually the case (92, 117, 134). The reason for this effect is apparent. Inasmuch as attention is one of the processes involved in the successful functioning of memory span, if the processes of attention are directed towards some other stimulus, they cannot operate effectively in the memory span function. Distractions must be kept at a minimum for reliable results, as Lumley and Calhoun (82) indicate.

(9) *Practice.* Practice on the part of the individual is another extrinsic factor affecting the apparent length of the memory span. Although it is now commonly assumed that the memory span is a congenital ability (65, 116), investigations reveal that a temporary increase in memory span score will result from practice.

Gundlach, Rothschild and Young (56) and Ide (67) found that some individuals' memory span scores were increased, those of others not visibly affected by practice. Winch (137) and T. L. Bolton (16) reported marked improvement with practice on the part of their subjects. Foster (43), experimenting with 6 different materials, stated that there was a definite practice effect in his subjects, but that the gain was specific, and limited to the particular type of material used. This is probably further evidence that memory span is not a general ability, but is specific for different types of material.

The greatest practice effects on memory span thus far have been demonstrated by Martin and Fernberger (85), who discovered that the memory span of one individual increased 47%, that of another 36%, after periods of practice spread over several months. Foster's (43) subjects gained from 6% to 44%.

Dallenbach (35) and Gates (54) were interested in determining the permanence of the practice effect reported. Dallenbach, after training subjects for a period of 17 weeks, observed a practice effect 41 weeks after the drill had been discontinued. Gates trained a group of subjects over a period of 78 days (spread over 5 months) and at the end of training, this group had raised its average memory span by 2 digits. After 4½ months of no practice, the group had fallen back to its original average.

Reed (108), however, claims that practice effects are negligible, and Whipple (134) experimentally found that if adaptation and assimilative devices are held constant, there is no practice effect. We must conclude, nevertheless, that practice does have an effect on memory span score as it is now commonly obtained by experimental or clinical methods. The reasons again are fairly obvious, and are so well discussed by Foster (43) that a detailed discussion is unnecessary. Foster believes gains to be due to (1) confidence and effort, (2) familiarity with the material, (3) learning to distribute the attention effectively, and (4) efficient methods of work and organized procedure.

(10) *Subjective Grouping of the Units in the Series.* It has already been noted that presenting the units in the series of stimuli by any method of grouping or rhythm will enable the subject to secure a higher memory span than he would otherwise have. Often the subject himself is entirely responsible for grouping the units, and may thus increase his apparent memory span. In Martin and Fernberger's study (85) it was noted that any memory span over 5 was secured through subjective grouping of the units. Oberly (98) found that the memory span limen, as indicated by grouping on the part of the subjects, was from 6 to 13.8 units.

It is certain that subjective grouping will increase the memory span of the individual and thus contribute to the unreliability of the method. The many cases of unusual immediate memory are probably explained by such grouping, though in the case of some individuals, this grouping is merely a matter of associating some of the units in the series with others.

F. D. Mitchell's report of Inaudi (91; also reported by Binet, 8), who correctly repeated 42 digits on one occasion, and his report of the blind Swiss

who repeated 150 digits, are of this order. Even the famous Dr. Finkelstein, who appeared on Ripley's "Believe It or Not" program (111) could not have repeated the 15 digits he did on that occasion except through some method of grouping or meaningful association.

(11) *Temporary Pathological Condition of the Individual.* Some temporary pathological conditions of the individual will detrimentally affect memory span score. If the pathological condition is a permanent one, it may then be classed as an intrinsic factor, beyond the control of the examiner.

Kohnsky (76), controlling practice effects, found that pupils, several months after having dental treatment, increased their memory span scores. Paulsen (99) found, after equalizing for practice effects, that subjects who had been suffering from intestinal toxemia increased their memory span scores after treatment for the condition. These results, though apparently definite, need confirmation before final conclusions can be drawn. If the results are confirmed, we are probably justified in assuming that such temporary states have some adverse effect on the processes involved in memory span, making them less efficient. Another temporary pathological condition of the individual is that of hypnosis. P. C. Young (146) found no differences in "digit span" or "memory span" under hypnosis from that in the waking state, but his terms are not well defined and his conclusions thus have little significance.

(12) *Effect of Drugs.* Drugs may also produce a temporary condition which will affect memory span results. Since drugs produce a toxic state, the condition could well be included under the previous heading. Froeberg (45) and Hull (62) found a loss in memory span performance in non-smokers after smoking. Hull found that the habitual smokers showed a very small loss in efficiency due to smoking. From these facts Hull decided that habituation appeared to have produced a partial tolerance for tobacco with regard to its effect on the memory span. The explanation of the effect of drugs on memory span is obvious. The toxic states produced adversely affect mental processes, and through so doing, decrease the memory span score attained.

B. Intrinsic Factors

In addition to the factors here called "extrinsic" (but only extrinsic in that they are largely within the control of the examiner, and if not properly controlled, tend to produce an erroneous memory span), there are also certain "intrinsic" factors affecting memory span. It is these in which the psychologist is primarily interested. These intrinsic factors are those within the individual which work to produce his "true" or permanent memory span.

(1) *Age of the Individual.* The age of the individual is a factor which definitely affects memory span.

Memory span has been found to increase with age by a number of investigators (8, 19, 27, 38, 40, 42, 56, 63, 69, 80, 121, 137). Norms for various age levels have been secured by McCauley (86), Lumley and Calhoun (82), M. Murphy (95), Starr (123), Smedley (116), and Terman (126, 127).

It should be pointed out that if the mental age of the individual does not increase, the memory span will not. So far as is known, memory span increases along with intelligence up to a similar age.

At what age does memory span cease to develop?

Carpenter (27), in using subjects from 6 to 14 years of age, reported a consistent improvement from year to year. Fischler and Albert (42) found an increase of memory span to adulthood. Kuhlmann (78) claimed that memory span increased up to maturity, but neither Fischler and Albert nor Kuhlmann interpret their terms. Wessley (135, p. 176) found that the maximal memory span occurred at the age of 12 to 14, while Smedley (116) and Chambers (31), although finding a general increase with age, found no particular age at which memory span was maximal. Bourdon (18) reported that maximal efficiency occurred at the age of 14. Hao (57) placed the age at 13 or 14 for girls, 15 or 16 for boys.

A few investigators claim that memory span increases to a point somewhere between the sixteen- and twenty-six-year level, though a large number of workers believe that memory span remains constant after the individual reaches a point somewhere between 12 and 16 years. Once again, the investigators have used such diverse methods of administration and scoring, and such different material, that the results are scarcely comparable. It is not surprising that no definite conclusion can be reached regarding this and other points in question.

(2) *Sex of the Individual.* Sex may be another intrinsic factor affecting the memory span; there is some disagreement on this point.

Burt (22), T. L. Bolton (16), Gates (51, 52), Kirkpatrick (75), and Woolley (140) all reported consistent superiority of the females in memory span tests. Gundlach and his coworkers (56), testing memory span with flashing lights, observed only a very slight superiority of the females over the males. Lodge and Jackson (81) and Travis (128), however, using prose passages to test memory span, report the superiority of females over males.

No significant sex differences in memory span have been observed in children of kindergarten age (67), at the six-year level (38), in primary school children (30, 137), and in children in general below the age of 15 (31). Fischler and Albert (42), testing for audito span with digits, consonants, and phrases as material, and for visual span with forms and pictures, found no significant sex differences, either in children or in adults.

Adams (3) reported a slight superiority of men over women in forward memory span for digits, presented by the audito-vocal method. Chambers (31) noted a superiority of males over females above the age of 15, and Watkins (133) reported a superiority of boys over girls in memory span ability. Dallenbach (35, 36) found that when mental age was held constant, males consistently surpassed females in "visual apprehension."

Thus we can reach no conclusion as to the rôle of sex in memory span. All we can do at this time is to note that sex may be a factor. Again, the methods used are so different that results vary.

(3) *Race of the Individual.* Recent investigations indicate that the race of the individual is another factor which may affect memory span. Apparently the Chinese are superior to the whites, who may be in turn superior to the Negroes. Data concerning the memory span of other racial groups have not yet been reported. Hao (57), and Pyle (106) observed that Chinese children were superior to white children in immediate memory. Pyle (105) also found that negro children were definitely inferior to white children in rote memory. Clark (33), however, observed his negro subjects to be superior to the whites. The results here are purely exploratory, and need further confirmation, but at least there is some evidence that there are race differences in memory span.

(4) *Permanent Pathological Condition of the Individual.* When the physical condition of the individual becomes permanently modified, the memory span has been found to be lower than that for a normal individual.

Epilepsy is such a condition; W. G. Smith (117), as early as 1905, reported the inferiority of a group of epileptic subjects to normal subjects in memory span, while Ninde (97) substantiated this conclusion with a study of 2,000 epileptics.

Smith (119) also reported, in another article, that normal subjects were definitely superior in memory span to those in a pathological (insane) group. Pintner and Paterson (102) found that deaf children, as a group, had abnormally poor memory spans. They concluded that this was due to the lack of auditory experience. Bond and Dearborn (17), testing auditory "memory" for different types of material, reported that normal subjects were distinctly superior to the blind subjects they tested from the Perkins Institution. But Hayes (58) failed to substantiate this report when it was found that the blind subjects were superior to normal individuals in memory for auditory digits, but that for other types of material and methods of presentation, superiority of the blind or the normal group varied with the age group tested.

Apparently a pathological condition of the individual may operate to improve memory span; at least certain pathological cases demonstrate unusual memory spans, whether or not this is due to the

pathological condition. Barr (4) discusses Kitri, an "idiot savant" with echolalia, who repeated, after the first hearing, words and accents correctly in English, French, German, Spanish, Italian, Japanese, Latin, Greek, and Norwegian. Tredgold (129) tells of an imbecile who could repeat verbatim a newspaper he had just read.

These cases are not demonstrations of "true" memory span, for the individuals apparently reproduce the materials through some form of a memorial image.

V. CORRELATION OF MEMORY SPAN AND INTELLIGENCE AND WHAT IT MEANS FOR THE MEMORY SPAN AS A CLINICAL TEST

(1) *Relation Between Forward Memory Span and Intelligence.* Earliest observations of the relation between memory span and intelligence were made by Jacobs (69), who noted that pupils who stood high in class tended to have high memory spans, while Smedley (116) corroborated this report. Early experiments with feeble-minded individuals pointed to the same fact—that memory span was directly related to intelligence (48, 72).

Early estimates of intelligence placed those with high memory spans near the head of the list (18, 22, 78, 137). Later investigators on the subject made use of the correlation coefficient and more objective measures of intelligence. Table II summarizes the coefficients secured between memory span and intelligence by various investigators using different types of forward memory span.

TABLE II
CORRELATIONS REPORTED BETWEEN MEMORY SPAN AND INTELLIGENCE

Investigator	<i>Auditory Presentation</i>			
	Digits	Sentences	Commissions	Nouns
Abelson (2) ⁷		.45, .18	.53, .65	.18, .19
Clark (33)	.03			
Garrett (49)	.21			
Wissler (139) ⁸	.16			
	<i>Visual Presentation</i>			
	Digits	Letter Square	Nonsense Syllables	
Garrett (49)	.18			
Wyatt (141)		.18		.59

⁷ Abelson's first figure represents results with girls, the second figure his results with boys.

⁸ Wissler correlated auditory memory for digits with class standing rather than with intelligence.

This table shows that there is some relation between memory span and intelligence, and other results further indicate this relationship.

A contrast of results, probably reflecting differences between the 2 sets of subjects in intelligence, are those of Terman (126) and McCaulley (86). Terman sets the audito-vocal memory span for the normal six-year-old at 5 digits, whereas the backward children tested by McCaulley secured a modal span of only 4 digits. Starr (123) reported that the retarded, sub-normal, and low defective children all tested below normal in memory span. Squire (121) also found retarded children to be inferior in memory span. Bingham (13) and Humpstone (63) found that college students in general had higher memory spans than average adults, as tested by other investigators.

All of these findings indicate a definite relation between memory span and intelligence. But at the present time, results are so varying in nature that the true degree of correlation between the two is impossible to predict. Terman, both in his original revision of the Binet Test (126) and in his recent revision (127) feels certain enough of the high degree of relationship to include memory span tests throughout the scale.

(2) *Relation Between Reverse Memory Span and Intelligence.* Bobertag (14), in 1911, was the first to suggest the reverse memory span test. Little work has been done up to the present time in making use of the reverse span, except for placement in the 2 Stanford revisions of the Binet Test (126, 127). Fry (46) has been the only worker to run correlations between the reverse memory span and intelligence. He secured a coefficient of .75 for reverse audito-vocal digit span and intelligence (as measured by Army Alpha). This is higher than any correlation secured between forward span and intelligence.

(3) *Value of the Memory Span Test as a Diagnostic Measure.* The results of a memory span test, then, are ordinarily indicative of the level of intelligence of an individual. Binet and Henri (10), A. M. Jones (73), Ninde (97), Leaming (80), and others place memory span ability at the base of all intellection. Starr (123) states that memory span "expresses the index of proficiency of all the mental competencies involved." Ninde says, "It goes without saying that a certain degree of associability is essential to all intelligent behavior and it is of special value in the development of the intellect" (97).

Most research and clinical workers agree that the value of the memory span test lies in its clear differentiation of the upper and lower groups of the distribution (Brotemarkle, 20; Starr, 123;

Chambers, 32). There is too much overlapping at the middle and at the extreme upper end of the distribution of age and diagnosis. Most clinical workers place more value in low spans than in high spans. Opinions of clinicians in regard to "critical spans" are of interest. In the forward memory span, a normal child of 5 or 6 should have a span of 2 or more (Easby-Grave, 38). A forward span of 5 is taken as a prerequisite to do high school work, while an even higher span is probably a prerequisite to do more advanced work (Leaming, 80). Other "critical spans" are listed by Sherman (114), Ninde (97), and McCaulley (86).

The memory span test as an indication of the individual's intelligence has several clinical advantages. Ninde (97) points out that it is simple and easy to administer. It does not place an emphasis on language ability, nor is it a long, extended test which is apt to tire the individual. Witmer believes that it is one of the most significant clinical tests, and Starr (122) states that "it is without doubt one of the most valuable tests employed for diagnostic purposes."

But its very simplicity is one of the dangers of the memory span test. The inexperienced examiner is apt not to follow specifically the particular directions which he is using. In addition, the scoring must be done precisely according to the method used in securing the norms which the worker is using. There are so many additional extrinsic factors affecting memory span that if careful clinical conditions are not observed, the results may be meaningless.

Another danger is that the investigator may place too much significance on the memory span test. Bronner, Healy, Lowe, and Shimberg (19) think that the importance of the memory span test has been greatly overemphasized. Of course a memory span test alone should never be used for diagnosis; the results on the memory span test are merely suggestive, and should always be supplemented by other test results and by qualitative observation.

VI. SUMMARY

Though 146 references are listed in the bibliography, it is appalling to note how little real knowledge there is in the field of memory span. Practically all of the questions raised in the present paper have to remain unanswered; many researches have been undertaken, but few facts have been proved.

It has been pointed out throughout the paper that the primary causes for this state of affairs are the widely diverse methods of administering the test, the many kinds of materials used, the different

groups of subjects used, the methods of scoring, etc. The question of whether or not memory span is a specific ability is essential; the effect of other factors cannot be answered until this is determined. For if memory span is a specific ability, it seems obvious that investigators using different materials and methods can expect only to get different answers to the same questions.

Probably the one thing most experimenters do agree on is a functional definition of memory span. But for other questions there are all sorts of answers. We do not know whether memory span is a specific or a general trait. We are sure that memory span is affected by certain extrinsic and by certain intrinsic factors, but we are not sure just what to include under each list, since all sorts of results have been claimed for any one variable.

Oddly enough, however, the test has been shown to have a fairly high reliability, and clinical investigators think enough of it seldom to omit it in an examination. It is favored by clinical investigators because of its close relation to intelligence (which has been fairly definitely shown), its simplicity, its brevity, and its lack of emphasis on language ability.

But, nevertheless, the whole field is wide open for a real experimental attack, for there is not a single aspect of the subject which is a closed chapter.

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