

MEMORY SPAN AND THE SKEWNESS OF THE SERIAL-POSITION CURVE*

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Three experiments were performed to test the hypothesis that the skewness of the serial-position curve is determined, at least in part, by memory span. Expt. I showed that the degree of skewness of the serial-position curve is positively related to the length of the subject's immediate memory span. Memory span for sequences of colour-forms was determined for 47 subjects (university students). Eleven subjects with the highest span (HS) and 11 subjects with the lowest span (LS) were compared in the serial learning of a 9-item list of colour forms. The HS group produced significantly more skewed serial position curves both for overt errors and for failures to respond than did the LS group. Expt. II investigated the effects of prolonged practice on serial learning. Three subjects each learned a different 9-item list of colour-forms every day for 4 weeks (20 days). Practice increased the ease of serial learning to the point that the entire list could be comprehended within the subjects' memory span. There was a corresponding increase in the skewness of the serial-position curve as a function of amount of practice. Expt. III tested the hypothesis that a list of items for which subjects have a relatively long memory span would produce a more skewed serial-position curve than would a list composed of items for which subjects have a relatively short memory span. Forty subjects each learned a 12-item list of single letters (in a random order) and a 12-item list of 3-letter nonsense syllables. As predicted, the list composed of single letters produced a significantly more skewed serial-position curve than did the list of nonsense syllables.

I. INTRODUCTION

One of the problems of explaining the bow-shaped serial-position curve concerns the typical skewness of the curve. The skewness, with the maximum errors past the middle of the list, is greatest for short lists and decreases as the number of items in the list increases. The bow shape of very long lists (usually 16 or more items) appears almost symmetrical about the middle position (McGeoch & Irion, 1952, p. 123).

The first writer has proposed a theory of serial learning in which the skewness of the serial-position (SP) curve is related to immediate memory span (Jensen, 1962*a*). The aspects of this theory which are relevant to the present paper may be summarized briefly as follows: (a) When a series of items can be reproduced perfectly after one presentation, the number of items in the series defines the subject's memory span for these items under the particular conditions of presentation. When the number of items presented exceeds the subject's memory span, the additional items interfere with the retention of the items that fall within the subject's span and the subject recalls fewer items after a single presentation than if the list had not exceeded his memory span (Woodworth & Schlosberg, 1954, pp. 705-6). Also, the longer the list, the greater is the effect of this interference. (b) If the subject cannot learn the entire list within one trial, that is, if the list exceeds his memory span, he learns it piecemeal in n trials. Consequently some items are learned sooner than others. (c) The SP curve results from the fact that the units of the serial list are learned in a fairly definite order as a function of serial position. The determinants of this order are as yet not fully understood, but it is hypothesized that the units of the list are built-up,

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integrated, or 'attached' around an anchor point, which is usually the first item or items learned on the first presentation of the list. On successive trials new items are attached to the anchor point in a forward and backward direction, so that, for example, the items of a 9-item series would be learned as follows:

Position of item: 6 7 8 9 1 2 3 4 5
 Order of learning: 9 7 5 3 1 2 4 6 8

or

Position of item: 1 2 3 4 5 6 7 8 9
 Order of learning: 1 2 4 6 8 9 7 5 3

This simple model, which is easily generalized to lists of any length, predicts quite well the peak of the SP curve for errors and the degree of skewness of lists of various lengths (Jensen, 1962*a*). The errors at each position of the SP curve are directly proportional to the rank order of learning. (*d*) It is hypothesized that the skewness of the SP curve for a list of a given length is determined in part by the subject's memory span for the type of material composing the list and by the conditions of presentation of the list. The longer the subject's memory span, the more items that are learned in the forward direction from the anchor point. Thus, a subject with a very short memory span would learn a 9-item list as follows:

Position of items: 1 2 3 4 5 6 7 8 9
 Order of learning: 1 3 5 7 9 8 6 4 2

A subject with a long memory span, on the other hand, would learn the same series as follows:

Position of items: 1 2 3 4 5 6 7 8 9
 Order of learning: 1 2 3 5 7 9 8 6 4

Since the theory states that the errors (overt errors plus omissions) made at each position before the entire list is mastered are directly proportional to the rank order in which the items are learned, it can be seen from these two examples that the curve corresponding to the longer memory span is the more skewed; that is, when the memory span is longer the last positions are learned relatively later and a greater proportion of the total errors occur in the last half of the list.

The present experiments attempt to test this aspect of the theory which relates skewness of the SP curve to memory span. Other aspects of the general theory of serial learning (see also Jensen, 1963) are not discussed here, since they are not directly relevant to the memory span hypothesis.

This hypothesized relationship between memory span and serial learning is not new. Lepley (1934, ch. v) found that when subjects learned twelve different lists, the only systematic effect that practice had on the shape of the SP curve was to produce greater skewness. With an increasing amount of practice, the peak of errors moved further toward the end of the list, and the percentage of total errors in the first half of the list decreased. The most pronounced effect of practice was, of course, to increase the over-all speed of learning, but this increase was greatest in the first

part of the list, with the consequent increase in skewness of the SP curve. This increased skewing might be explained in terms of the memory span hypothesis, since it has also been shown that memory span is increased by practice (Gates & Taylor, 1925).

Lepley found also a difference between low I.Q. 7th-grade boys and high I.Q. 11th-grade boys in serial learning (Lepley, 1934, ch. vi). Not only were the older, superior boys (mean mental age = 19 yr. 2 mo.) faster learners than the younger boys with low I.Q.'s (mental age = 12 yr. 5 mo.), but the SP curve of the superior group was significantly more skewed than that of the low I.Q. group. Since the two groups very likely differed in memory span (Digit Span norms for the Wechsler Intelligence Scale would indicate a difference of at least 2 to 3 digits (Wechsler, 1944, p. 222), this finding also lends support to the memory span hypothesis. The same phenomenon was reported by Barnett, Ellis & Pryer (1960), who compared the SP curve produced by adolescents with high I.Q.'s (120-139) with the curve produced by adolescents with low I.Q.'s (40-59). The curve of the high I.Q. group was significantly more skewed than that of the low I.Q. group.

Since memory span is known to be correlated with mental age, our hypothesis would also predict that the skewness of the SP curve should increase as a function of age among children of normal intelligence, with the increase in skewness becoming asymptotic at about age 18 or 19, the age beyond which memory span does not increase appreciably. This prediction has been borne out in an experiment by Postman & Jensen (1963), in which groups of normal, 4th-, 7th-, and 10th-grade children and of university sophomores, with mean ages of approximately 9, 12, 15 and 19, respectively, learned 12-item lists consisting either of words or of nonsense syllables. As predicted, the SP curves of the four age-groups yielded significant differences in skewness, both for words and for nonsense syllables. A quantitative index of skewness was shown to increase as an approximately linear function of age.

Malmo & Amsel (1948) compared the SP curves of patients suffering functional and organic memory loss (severe and bilateral frontal gyrectomy) and those of normal subjects. The SP curves of the patients were more symmetrical about the middle position than was the curve for the normal subjects, and the patients made significantly more errors in the first half of the list. Though Malmo & Amsel interpreted their results in terms of anxiety-produced interference, their findings are clearly in accord with the memory span hypothesis, since anxiety-produced interference also adversely affects the subject's memory span (Siegman, 1956).

Deese & Kresse (1952) found that the SP curves for failures-to-respond and for overt errors differ in shape. The failures rise to a maximum at about the middle of a 12-item list and show very little decrease in the positions beyond the middle. The overt errors, on the other hand, form a bow-shaped curve almost perfectly symmetrical about the middle position. The composite of the two curves forms the typical skewed, bow-shaped SP curve for total errors. To explain these findings Deese & Kresse suggested a two-factor theory. 'A factor of associative inhibition would be indicated by the intra-list intrusions [overt errors], and a second factor, that might be identified with either the notion of response-induced inhibition or the *immediate memory span* [our italics], would be indicated by the failure-to-respond curves' (1952, p. 202).

Since the experiments we have reviewed did not include the independent measurement of the memory span and are therefore merely suggestive of our hypothesis, the present experiments were conducted specifically to investigate the role of memory span in serial learning. The relationship between individual differences in memory span and the degree of skewness of the SP curve was examined in Expt. I. Expt. II was concerned with the effect that prolonged practice in serial learning has on the skewness of the SP curve. It was presumed that practice would increase memory span, at least for the kind of items being practised, and that, in accordance with our hypothesis, the increase in memory span would influence the skewness of the SP curve. Expt. III tested the hypothesis that materials for which subjects have a relatively long memory span, when learned as a serial list, would produce a more skewed SP curve than would materials for which subjects have a relatively short memory span.

II. EXPERIMENT I

Method

Subjects. A class of 47 college juniors and seniors in an introductory educational psychology course served as subjects.

Memory span test. In order to minimize the verbal associations that arise in using nonsense syllables, meaningful verbal materials, or digits, the content of the memory span test consisted of geometric shapes in various colours, viz. squares, triangles and circles, coloured red, yellow and blue. Thus there were three shapes in each of three colours, making nine different stimuli in all. The serial learning task consisted of the same set of stimuli, since it was desired to measure memory span and serial learning in the same medium.

The subjects were instructed that they would be shown a sequence of stimuli on the screen at the front of the room. The stimuli were 4 in. in size on the screen and were of vivid colour. There were from 3 to 7 stimuli in each sequence, but the number appearing in any sequence was determined randomly and was thus unpredictable by the subject. However, the same length of sequence was never presented twice in succession. The stimuli were presented one at a time at a 2 sec. rate. The subjects were told the nature of the stimuli as well as the fact that the same shape or the same colour would never appear consecutively. Subjects wrote their responses in the form of initial letters (e.g. BC for blue circle). Guessing was allowed. After all subjects had recorded their responses, the next sequence was presented. Each sequence was a different random order. In all, there were three presentations each of sequences having either 3, 4, 5, 6, or 7 stimuli. The subjects sat one seat apart and were proctored to make sure they did not record their responses until after the sequence had appeared.

Serial learning. The 11 subjects with the highest memory span and the 11 subjects with the lowest span were tested individually in the serial learning task. The subjects were instructed to learn by the anticipation method a series of 9 stimuli presented at a 3 sec. rate. The same sequence was repeated, with a 9 sec. intertrial interval, until the subject correctly anticipated all nine items in the series. Subjects were told that the stimuli were exactly the same as those used in the memory span test; the same rule held that the same shape or colour would never appear adjacently in the series. The stimuli appeared on a screen 12 ft. in front of the subject. The series was always preceded by three small dots as the signal to anticipate the first item. The subject responded by saying 'blue triangle', etc. Three different serial orders were used, with each group of 11 subjects divided 4, 4, 3.

Results

Memory span. Memory span was defined as the longest series the subject could recall perfectly after a single presentation. Since there were three sets each of 3, 4, 5, 6, and 7 items, the subject's memory span score was the mean of the three longest lists he recalled perfectly. The reliability of this score, as determined from the

intraclass correlation among the three sets, was 0.57. The mean span for the entire group ($N = 47$) was 2.51, s.d. 1.47. From this group were selected the 11 subjects with the lowest memory span score and the 11 subjects with the highest. The mean span for the Low Span Group (LSG) was 0.55, s.d. 0.50; for the High Span Group (HSG) the mean span was 4.48, s.d. 0.41. The difference between the means of the LSG and HSG is reliable ($t = 19.22, P < 0.001$).

Serial learning. The HSG required fewer trials to attain the criterion of mastery than did the LSG, though the difference is not statistically significant (Table 1a).

Table 1. Means of high and low memory span groups on serial learning variables

Variable	High span		Low span		<i>t</i>
	<i>M</i>	s.d.	<i>M</i>	s.d.	
(a) Trials to criterion	13.5	5.5	18.1	6.8	1.64
(b) Percentage of overt errors in first 4 positions	37.8	9.4	46.8	13.5	1.72*
(c) Percentage of failures in first 4 positions	14.3	8.8	23.8	9.1	2.33**
(d) Percentage of all errors that are failures-to-respond	47.7	25.3	58.3	13.9	1.16

* $P < 0.10$. ** $P < 0.05$.

Fig. 1 shows the mean number of trials to attain successive numbers of correct anticipation per trial. The left side of the figure shows the rates of learning the first four positions in the series (positions 1-4); the right side shows the rates of learning the last four positions (positions 6-9). The data of these curves were subjected to an analysis of variance, shown in Table 2. It can be seen that the HSG learned the first part of the list significantly faster than the LSG and that the two groups differ hardly at all in the rate of learning the last part of the list. This difference in rate of learning the two parts of the list is reflected in the skewed appearance of the SP curve. The difference between the HSG and LSG shows up even in the first learning trial, though not to a statistically reliable degree, since the within-groups variability is quite large on single-trial data. But the first-trial data are wholly consistent with the over-all results. For example, on the first trial the HSG had a total of 30 correct anticipations, of which 19, or 63%, occurred in the first four positions, while the LSG produced a total of 25 correct anticipations, of which only 13, or 52%, were in the first four positions. The peak of errors on the first trial was at position 4 for the LSG and at position 6 for the HSG. On the first trial the total number of anticipations *consecutively* correct from the beginning of the series was 15, or 50% of all correct anticipations, for the HSG; LSG had 10 (40% of all correct responses) consecutively correct anticipations.

The SP curve for *overt* errors, all of which were intralist intrusions, is shown in Fig. 2. Since we were interested primarily in the shape of the SP curve, the curves in Figs. 2 and 3 were obtained by determining the percentage of errors (or failures) made at each position by each subject and then obtaining the mean for all subjects in each group. Thereby every subject is weighted equally in the mean curve and the

areas under the curves are the same for both groups. The only possible difference is in the shape of the curve. The percentage of all overt errors occurring in the first four positions provides a rough index of the degree of skewness. The HSG and LSG differ in this measure (Table 1*b*).

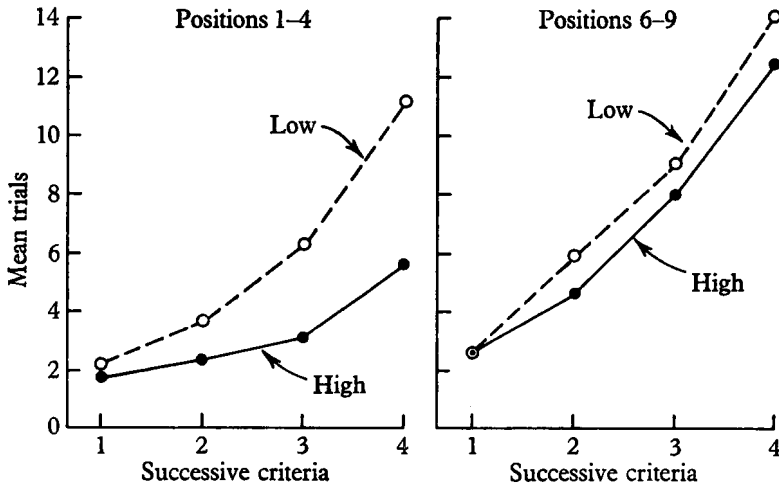


Fig. 1. Mean number of trials to attain successive numbers of correct anticipations per trial for the first 4 serial positions (positions 1-4) and for the last 4 positions (positions 6-9).

Table 2. *Analysis of variance of trials to successive criteria for positions 1-4 and positions 6-9*

Source	D.F.	Positions 1-4		Positions 6-9	
		M.S.	F'	M.S.	F'
Memory span (MS)	1	147.73	7.52*	0.56	< 1
Criteria (C)	3	175.79	—	467.80	—
Subjects within groups	20	19.64	—	41.99	—
MS × C	3	27.21	6.21**	9.53	1.06
Error	60	4.38	—	8.98	—

* $P < 0.05$. ** $P < 0.001$.

Fig. 3 shows the SP curves of mean percentage of failures-to-respond. As was the case in the Deese & Kresse (1952) study, the curves for failures-to-respond are much more skewed than those for overt errors, and this is true for both the HSG and LSG. However, the skewness was again greater for the HSG. There is a significant difference between the groups in the percentage of all failures that occur in the first four positions (Table 1*c*). The greater skewness of the SP curves of the HSG is not attributable to the HSG having a larger percentage of failures among its total errors, for, in fact, the LSG had a larger number of failures in proportion to overt errors than did the HSG, although this difference is not statistically significant (see Table 1*d*).

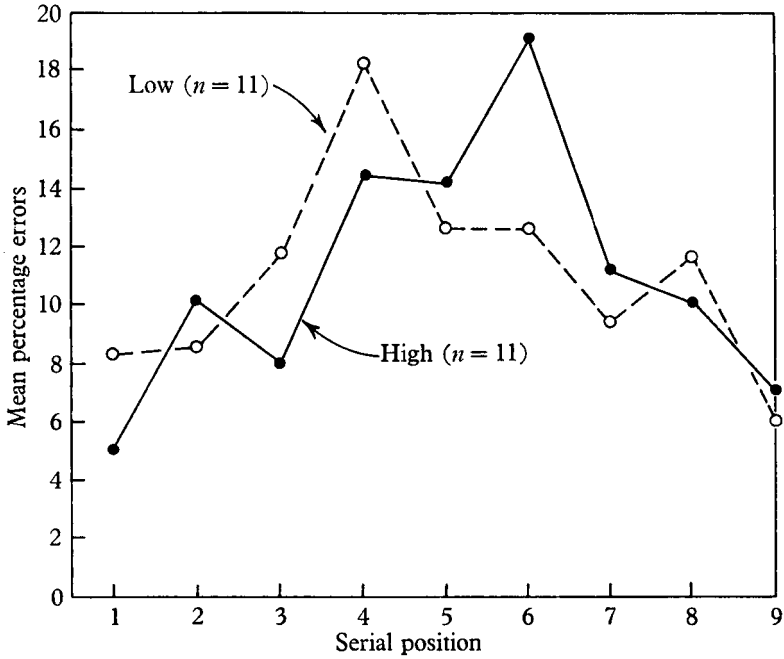


Fig. 2. Serial-position curves showing the mean percentage of overt errors at each serial position for subjects with high or low memory span.

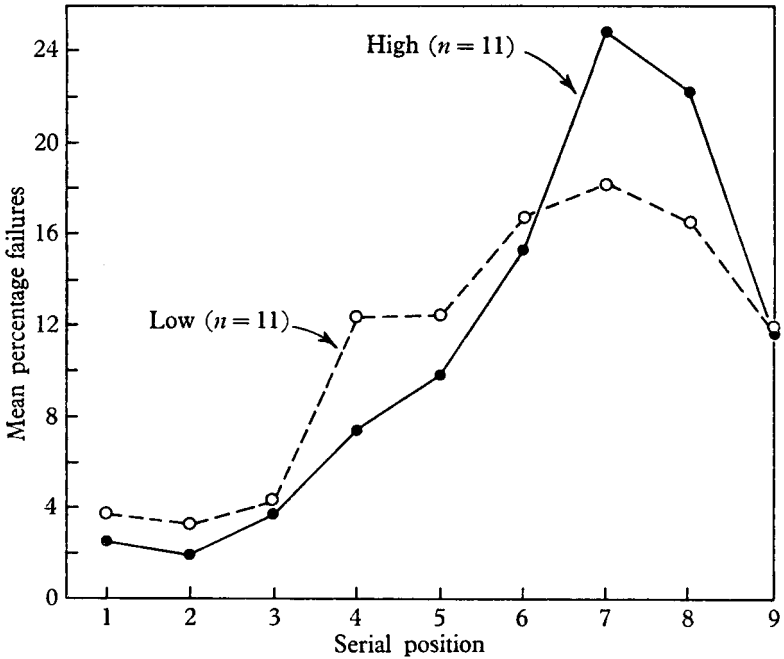


Fig. 3. Serial-position curves showing the mean percentage of failures-to-respond at each serial position for subjects with high or low memory spans.

III. EXPERIMENT II

Method

Subjects. Three women students (one senior and two graduates), ages 20, 21, and 22 volunteered as subjects.* As was later discovered, they were not the ideal subjects for the purposes of this experiment, since they all were exceptionally fast learners and started out with highly skewed SP curves. Consequently there was little room for additional practice in serial learning to make much difference. All three subjects were above the 95th percentile on the American Council on Education Psychological Examination, a test of scholastic aptitude. Their only knowledge concerning the purpose of the experiment was that we were investigating practice effects in serial learning.

Procedure. The subjects learned, by the anticipation method, a different serial order of nine coloured forms each day of the week (i.e. 5 days) for 4 consecutive weeks. Thus there were 20 days of practice in all. The serial learning materials and procedure were the same as in Expt. I. The general instructions were given to the subjects only the first day and on each succeeding day they were merely reminded that their task was the same as the day before except that they had to learn a new order of the stimulus items. Twenty random orders of the stimuli were used, with the one restriction that the same shape or the same colour would never appear adjacently in the series. The order in which the lists were given to the subjects each day was random for each subject. The subjects always attained a criterion of one perfect trial. They were required to guess when in doubt, rather than omit response. In order to get information about improvement in their guessing ability, the subjects were required to anticipate each stimulus item on the very first presentation. (These first-trial guessing data were not included in the analyses of the serial learning or in the SP curves.)

Results

Rate of learning. The most obvious effect of practice was to increase the rate of learning. The mean trials-to-criterion on the first day's serial list was 7.67, which is about 1 S.D. below the mean of college students learning these kinds of lists in previous experiments. The mean trials-to-criterion during each of the 4 weeks were 4.9, 2.7, 2.5, and 2.1, respectively. This decrease in mean trials-to-criterion is significant beyond the 0.01 level ($F = 16.74$, D.F. = 3, 6). The over-all decrease in total errors from the first 2 weeks to the second 2 weeks of practice is evident in Fig. 4. There were also significant individual differences in learning rate. The mean trials to criterion for each of the three subjects were 3.9, 3.0 and 2.4. The differences between these subjects' means are significant beyond the 0.05 level ($F = 7.95$, D.F. 2, 6).

That memory span increased with practice may be inferred from the fact that by the final week all subjects were able, part of the time, to recall the entire list after a single presentation. It appears that after 3 to 4 weeks of practice the subjects became able to comprehend the 9-item series within their immediate memory span. In the fourth week, for example, one subject recalled perfectly one of the lists, and two subjects each recalled three lists, after a single presentation. This one-trial learning never occurred during the first week of practice and occurred only once in the second week.

Serial-position effect. Our chief concern, of course, is the effect of practice on the SP curve. To obtain fairly reliable curves, the data of weeks 1 and 2 (days 1-10) were combined for comparison with the combined data of weeks 3 and 4 (days 11-20).

* We are grateful to Joanne Clason, Arlene Rustin, and Ida Yamamoto for so faithfully and uncomplainingly submitting to this ordeal.

These SP curves, expressed in terms of the total number of errors in each position, are shown in Fig. 4. (Because of the negligible number of failures-to-respond among the three subjects in Expt. II, we have not distinguished between failures and overt errors but have simply labelled them all as *errors*.) In general, after 2 weeks of practice, the first 3 or 4 positions appear almost equal in difficulty, and the peak of errors has moved one position toward the end of the series. To obtain a quantitative measure of the degrees of skewness, we have used, as in Expt. I, the percentage of

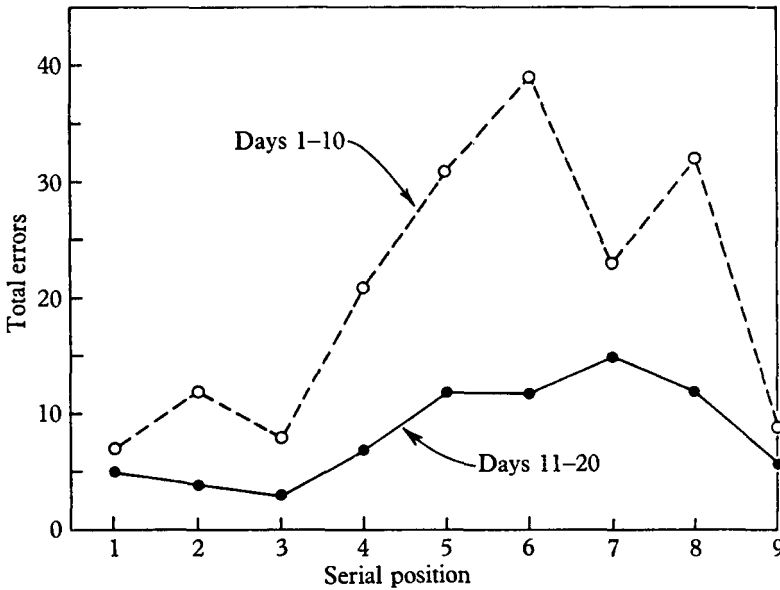


Fig. 4. Serial-position curves of total errors made during the first two weeks of practice (days 1-10) and during the second 2 weeks (days 11-20).

all errors that occur in positions 1-4. Degree of skewness is, of course, inversely related to this percentage. The mean percentages of errors in positions 1-4 in each of the four weeks of practice are shown in Fig. 5. The geometric mean (G.M.) of the percentages is presented in addition to the arithmetic mean.* Since the over-all errors decreased markedly with practice, the percentage of errors in positions 1-4 tends to fluctuate considerably from day to day and in the last 2 weeks their distribution was very positively skewed. In such a case, the G.M. would seem better to represent the trend of the data. The percentage data shown in Fig. 5 were subjected to analysis of variance, which required that the percentages be transformed to $\log(x + 1)$ to achieve homogeneity of variance from week to week. The between weeks main effect, tested against the weeks \times subjects interaction, is significant beyond the 0.05 level ($F = 5.84$, D.F. = 3, 6). Reliable individual differences in the degree of skewness of the SP curve are indicated by the significant between subjects effect ($F = 7.64$, D.F. = 2, 6, $P < 0.05$).

* Since zero cannot enter into the computation of the G.M. 1.00 was added to all the original percentages.

Guessing tendencies. Inspection of the first-trial data, in which every response was a sheer guess, indicates that changes in the subjects' guessing tendencies over the 4 weeks probably worked against our hypothesis, viz. that, with increasing practice, the preponderance of errors would gravitate more and more to the last half of the list.

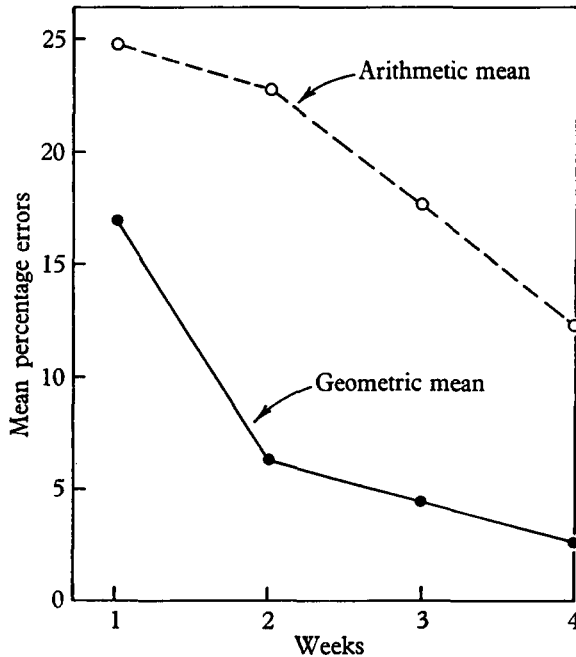


Fig. 5. Mean (arithmetic and geometric) percentage of total errors occurring in serial positions 1-4 (of a 9-item list) as a function of weeks of practice.

There was a small, non-significant improvement in guessing over the weeks. The mean number of correctly guessed anticipations during the first 2 weeks was 3.9; during the second two weeks it was 4.3. Of greater importance in terms of our hypothesis, however, is the fact, that, with practice, the subjects improved in guessing correctly the last two or three items of the list. By the time they were halfway through the list they seemed to remember which items had appeared previously and did not use them in making their guesses. The effect, of course, was to make the guessing probabilities of the last items considerably higher than those in the first half of the list. In the first-trial guessing during the first 2 weeks, 59% of all errors occurred in positions 1-4; during the second 2 weeks 62% of the errors occurred in positions 1-4. If it is assumed that the subjects' guessing strategy carried over the learning trials, this would seem to have worked against our hypothesis that practice would result in a decrease in percentage of errors in positions 1-4. The hypothesis was borne out, however, despite this counteractive effect of the subjects' guessing tendencies.

IV. EXPERIMENT III

While the previous experiments show that individual differences in memory span as well as the improvement of ability in serial learning as a result of prolonged practice affect the skewness of the SP curve, a further question remains: Do different materials for which subjects in general have longer or shorter memory spans produce SP curves that differ in skewness? This question cannot be satisfactorily answered by the inspection of the SP curves found in the literature on serial learning, mainly for four reasons: (a) subjects across various studies are not of comparable learning ability; (b) the conditions of learning, such as instructions, presentation rate, distribution of practice, etc., are not comparable across various studies; (c) little or nothing is known concerning subjects' memory span for the different materials generally used in serial learning experiments; and (d) SP curves as generally plotted confound a number of factors, making the comparison of different curves quite ambiguous with respect to our present hypothesis (see Jensen, 1962*b*). It was necessary, therefore, to carry out an experiment specifically to determine whether or not different material for which subjects have a relatively long memory span produce a more skewed SP curve than do materials for which the memory span is relatively short.

Method

Subjects. Forty students in an introductory course in educational psychology served as subjects.

Procedure. Each subject was required to learn two serial lists of 12 items each. The criterion was one errorless trial. One list (for long memory span) was composed of single letters (*A* to *L*); the other list (for short memory span) was composed of 3-letter trigrams (*bot, com, dal, est, fac, mul, nop, pim, rel, tis ven, zin*). To average out any specific interaction between items and positions, the items were presented in a different random order for every one of the 40 subjects. Half the subjects learned the letter list first and half learned the trigram list first. Subjects were tested individually and were given the standard instructions for learning by the anticipation method; they pronounced the syllables. The items were automatically projected on a screen at a 3 sec. rate with a 6 sec. intertrial interval. (The apparatus used in these experiments is described in detail elsewhere (Jensen, Collins & Vreeland, 1962). The first item of the list was always preceded by a green light of 3 sec. duration which served as the signal to anticipate the first item.

Results

The number of errors (overt errors plus omissions) in the first half of the list (positions 1-6) and in the second half of the list (positions 7-12) were determined for each subject for the letter list and for the trigram list. These data were subjected to an analysis of variance. The over-all skewness effect was highly significant, with a greater number of errors in the second half of the series than in the first half ($F = 36.82$, D.F. = 1 and 39, $P < 0.001$). Of course there was a large difference in the over-all difficulty of the two lists, the mean trials for letters and for trigrams being 4.63 and 11.29, respectively.

The test of the memory span hypothesis, however, is the lists \times halves interaction, which proved significant beyond the 0.01 level ($F = 8.17$, D.F. = 1 and 39). The letter list produced a significantly more skewed SP curve than did the trigram list. The percentage of the total errors in the first half of the list (positions 1-6) was 34.4

for letters and 37.3 for trigrams. Though the absolute difference does not seem great, it is fully significant as shown by the analysis of variance. Also in accord with the memory span hypothesis is the fact that the mean number of consecutively correct responses from the beginning of the list on trial 1 (i.e. the first anticipation trial) was 3.34 for the list of letters and 1.54 for the trigrams. The correlated t test (by the direct difference method) shows these means to be significantly different beyond the 0.001 level ($t = 4.12$, D.F. = 39).

V. DISCUSSION

In Expt. I a relationship was found between individual differences in memory span and the degree of skewness of the SP curve. Expt. II, in which subjects practised serial learning until the entire list could be comprehended by the immediate memory span, revealed a progressive increase in skewness as a function of practice. The latter finding was originally made by Lepley (1934, ch. v), using 12-items lists of nonsense syllables. Since Lepley used different syllables in each of the 12 lists learned by his subjects, the practice effect on the serial learning *per se* was probably somewhat obscured by the subjects' having to acquire the responses anew on each successive list. In the present experiment, on the other hand, all the learning was limited to serial order. It is known from previous experiments with our colour-form stimuli that subjects are able to name all the items comprising the list even before the first presentation, since the nature of the items is described in the experimenter's instructions to the subject. Under these conditions, however, the subjects' guessing strategies may have obscured to some extent the hypothesized relationship between span and skewness.

Expt. III showed that skewness is not only a function of individual differences in memory span for a given material but also of differences in memory span for different kinds of material composing the serial list.

Probably a greater degree of relationship between skewness and individual differences in memory span, and between skewness and amount of practice, would have been obtained had we selected subjects from a more heterogeneous population than our upper-division college group. Both our High span and Low span groups, for example, probably produced quite skewed SP curves as compared with what might be found in a less select and less fast-learning population. Mentally retarded subjects with a very small memory span, if they can learn a serial list at all, might be expected to produce SP curves having almost no skewness.

Also, a short list of, say, 6 or 7 items, might reveal a greater association between memory span and skewness, since as the number of items in the serial list increasingly exceeds the subject's memory span, there is probably a corresponding increase in retroactive inhibition of the first part of the list. If there were a negligible correlation between memory span and susceptibility to the effects of retroactive inhibition, lists that greatly exceed the memory span would tend to obscure the effects of memory span in determining the shape of the SP curve. In very long lists of, say, 14 or more items, we would expect individual differences in memory span to be reflected only slightly in the shape of the SP curve. The soundness of such a prediction depends, of course, upon the nature and degree of relationship between the subject's memory span and the degree of decrement in the subject's span which results, presumably from interference, when items are presented in excess of the subject's maximal span.

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