

THE RELATION OF THE QUANTITY OF MATERIAL
TO THE PREPARATION STAGE OF THINKING

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By

Richard Earl Lincoln

AN ABSTRACT

Submitted to the College of Science and Arts
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ABSTRACT

Many investigators have attempted to separate the total thought process into a series of definable stages. In 1896, Helmholtz analyzed his own introspections while seeking the solution to an original problem. This investigation led Helmholtz to divide the thought process into three stages. Graham Wallas, in 1926, proposed a subjective analysis of the process into four parts which he termed: preparation, incubation, illumination and verification. D. M. Johnson has investigated the total problem solving episode and for methodological reasons has proposed a serial analysis consisting of two parts, preparation and solution. Many of the factors which influence preparation have been described by Johnson but not all of the variables affecting this period have been sufficiently investigated. One important feature which requires further study is the relation between the preparation period and the amount of task material. This study is an investigation of that relationship.

Numbers were chosen as the task material because they are more easily standardized than are verbal materials. The method consisted of presenting the subject with lists of numbers varying in length from 3 to 11 digits. The subject prepares to retain this list and, when he decides that he is sufficiently prepared, views 10 similar lists only one of which contains all of the digits in the preparation list. The period during which he views the 10 possible lists and selects the correct one is designated as the solution period.

Both the preparation and solution periods are timed. Three methods of exposing the lists were employed: (i) the subjects were permitted to switchback and review the preparation list, (ii) the subjects were allowed only one preparation period, i. e. no switchback, (iii) the subjects were presented with both the preparation and solution lists simultaneously, i. e. complete exposure. Twenty-one subjects were assigned to each exposure group.

The most important conclusion is that the time spent in preparation is a crucial determinant of successful performance. This finding was true for all 9 list lengths. As was expected, all of the performance measures (preparation time, solution time, errors and switchbacks) increase as the list lengths increase. There is a rather sharp increase of errors and switchbacks at about list length 8; this finding is consonant with the memory span experiments. The exposure condition which allows the subjects to switchback to the preparation list results in the best performance of the three groups.

A mechanical model is presented as an expository device to describe the recognition procedure thought to be employed by the subjects.

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INTRODUCTION

The notion that the thought process proceeds through a series of definable stages has been greatly advanced by the published work of Helmholtz in 1896 (6) and Poincaré in 1913 (13). Each of these analyzed his own introspections while seeking the solution to an original problem. The investigations of Helmholtz led him to postulate three well-defined stages of the thought process:

(i) a preparatory period during which the problem was analyzed; (ii) a period of nonproblem directed activity; (iii) the occurrence of a tentative solution, i. e. a period of illumination. To this formulation, Poincaré stated the requirements for a fourth stage of conscious effort.

John Dewey in 1910 (2) stated, "All people at the outset, and the majority of people, probably all their lives, attain ordering of thought through ordering of action." Dewey sought to analyze the reflective reasoning of a disciplined thinker. Dewey's five part analysis consisted of: (i) the occurrence of a problem accompanied by a feeling of perplexity or confusion; (ii) a period of searching for possible solutions, from this the problem emerges more specifically; (iii) the resulting hypotheses or suggestions are integrated into approaches bearing on the problem; (iv) concentration on a possible solution, called the reasoning period; (v) finally, the resultant solution is tested either by overt or covert means.

Graham Wallas in 1926 (15) proposed a subjective fractionation similar to the one earlier proposed by Helmholtz. Wallas' contribution was that he more clearly delineated the phases and assigned

a name to each. He termed the four parts preparation, incubation, illumination and verification. These are described below:

- (a) Preparation--A person voluntarily directs his attention to the successive elements in a problem. Closely associated with this voluntary examination of present phenomenon is the choice of a problem-attitude (Aufgabe).
- (b) Incubation--This stage consists of mental activity in which no conscious or voluntary effort is being directed toward the problem.
- (c) Illumination--This portion of the thought process consists of the sudden "flash" of success. Wallas prefers the term "Intimation" for that moment in this stage when the person is in the state of rising consciousness following the incubation period.
- (d) Verification--The feasibility of the evolved idea is tested and arranged into its exact form.

Poincaré (13) maintains that in the daily stream of thought there is a constant overlap of these four stages as the individual explores different problems. He further contends that in a more-or-less complex problem, the mind may be consciously preparing or verifying one aspect of it, while it is unconsciously incubating on another aspect. Despite this lack of discreteness in the four-part analysis, Wallas contends that the phases are distinguishable from each other in the final result.

Patrick (11, 12), in a series of elaborate experiments, presented objective evidence in support of Wallas' fractionation. Her procedure consisted of requiring the subjects in a standardized

situation to evolve a creative product. She then recorded the manner in which this thought was produced. In the two experiments to be described here she investigated the writing of a poem and the painting of a picture. The subjects in the experimental groups consisted of 55 poets and 50 artists with control groups of 58 non-poets and 50 nonartists. All groups were matched according to intelligence, age and sex. The general procedure consisted of presenting each subject individually with a stimulus, a landscape painting for the poetry group and a portion of Milton's "L'Allegro" for the artist group, the response being to create the appropriate object. The experimenter then observed the performance and wrote down the subject's verbal commentaries as they occurred. Patrick divided the subject's total time into the four appropriate divisions mentioned earlier and attempted to classify the type of activity which was most representative of each. Her results substantiated Wallas' claim that the preparation phase is occupied with "thought changes." The incubation period was unfortunately rather brief; the criterion for incubation was the reoccurrence of an idea or theme in a later stage of the work session. There was substantial evidence of this phenomenon in a majority of the cases. Illumination was assumed to have occurred when the lines of the poem were first written or when the general outline of the picture was observed. The fourth stage, verification, was evidenced by revision, criticism or elaboration.

Although Patrick's experiments were a noteworthy investigation of Wallas' formulation, there are serious limitations which must be considered. Not the least of these limitations is her heavy reliance on the subject's verbatim reports which can hardly be

assumed to adequately reflect the ongoing intellectual process. Also, there was no control for the reliability of classification, since only Patrick did the classifying. Furthermore, the subjects were not allowed sufficient breadth to be truly creative since the experimental session was of brief duration and the task was so definitely stated as to be confining. The merit of the Patrick experiments lies in the fact that a theoretical division of the thought process can be applied to objective experimentation, and that these phases do correspond more-or-less to the observed data.

In contrast to the analytical attempts of Helmholtz, Dewey, Wallas, etc. are the proponents of a more holistic conception of the thought process. Wertheimer (16) prefers to view thinking as a total pattern of intellectual behavior in which the component processes interact or "spill-over" one into the other. Vinacke (14) also defines thinking as an interplay of activities rather than as more-or-less discrete stages.

The information that has been gained about the intellectual activities of the organism suggest that neither of these extreme points of view is entirely correct. The most likely situation is neither complete discreteness nor total inseparability but rather partial overlapping of the various phases. The degree of overlap would be highly correlated with the complexity of the mental activity. It would logically follow from this that any fractionation of the thought process(es) should be directed toward the type of task under consideration. That is to say, if a rather simple mental task were required of a subject, and an analysis made of his operationally inferred intellectual activity, most likely this analysis could be correspondingly less complex than those of Dewey and Wallas.

The results of such a research would provide a system of categories into which the data could be sorted with little ambiguity.

Johnson (8) described problem solving in a general sense and placed particular emphasis on the preparation phase. "Preparation in a dynamic sense is a process, the process of getting ready or adopting a preparatory set, based on present conditions as well as past learning, which controls the subsequent production of pertinent responses." In a later series of experiments, many short problems were studied and a different hypothetical model was put forth. In these experiments a two-part analysis was applied to the problem solving activity; Johnson designated these two phases as preparation and solution. The total activity was limited to two processes for methodological purposes. The aim of these experiments was to more carefully delineate the preparatory activity. The experimental method was to sequentially present the problem material in two steps and then to determine how the dependent variables of accuracy and time were related to the types of material. This serial exposure method was of two types, experimenter and subject paced. The materials involved were verbal analogies emphasizing induction and deduction. Another experiment involved the formulation and reformulation of figure concepts and a similar experiment utilized verbal concepts. The results of these experiments are not especially relevant to the present discussion but mention is made of them to illustrate the diversity of problems to which Johnson's two-part formulation has been applied with successful results. In essence, the investigation of the preparation period yielded the following general statements: the time spent on preparation is closely associated with the instructions about preparation, the nature of the task, the

subject's prior experience with the type of material, the amount of material, the relative difficulty of the previous problems, and a trait which Johnson terms "forethoughtfulness."

Statement of the Problem

Johnson's previous research on the preparation period provides a workable framework within which further experiments can be designed. Many of the factors influencing the nature of preparation have been sufficiently investigated but not all of the parameters of this process have been adequately described.

At this point in the discussion it is necessary to define, in logical terms, exactly what is meant by the term preparation. The essential characteristics of the preparation phase are that it consists of some general processing of the task material. This structuring of the presented material must exert an influence on the production of subsequent solution attempts. The activities the subject engages in during the preparation period are thought to consist of a survey of the material during which some features are assigned saliency and others are viewed as less important. The features that are emphasized are then assembled into a meaningful formulation relative to the expected requirements of the solution phase. The adequacy of this formulation can then be inferred by his subsequent performance during the solution phase.

The present study is an attempt to determine how the quantity of task material is related to the initial preparatory activity. A detailed investigation of this problem seems to be of paramount importance to a complete description of this initial phase. This study is proposed as a parametric investigation of the amount of

material a subject can process and retain for use during the solution period. The procedure to be used is the two-part serial analysis previously employed by Johnson.

An experiment similar to the one proposed was conducted by Johnson (9) with the stimulus material consisting of words. It is difficult to control for stimulus difficulty by using verbal material and it is expected that numbers should yield better data. The use of numbers enables an efficient standardization of stimulus characteristics by minimizing the uncontrolled effects of meaningfulness. The procedure, in some respects, resembles the immediate memory span method introduced by Jacobs in 1887 (7).

In general, the method will consist of presenting the subject with a list of numbers varying in length from 3 to 11 digits (hereafter referred to as list lengths), and allowing him to prepare at his own pace. Then he will view 10 similar lists only one of which has all of the digits contained in the preparation list. The subject's task will be outlined as picking the correct list from the multiple choices.

The experimental design will employ three exposure conditions. The first condition will allow the subject to review the preparation material as many times as he feels necessary to make a correct choice. The second group will be permitted no such review but must make their discrimination after only one preparation period, the length of which is self determined. The third group will be presented with both the preparation and solution material simultaneously, i. e. complete exposure. This last group is included as a check on the authenticity of dividing the total episode into two parts. That is, if comparable data are obtained from the first and third groups, it is

assumed no violence has been done to the recognition process by exposing the two parts serially.

The experimental attempts to determine the limiting capacity of an individual's memory have been many and varied. Gates and Taylor (5) found that the average number of digits that can be reproduced after a single reading by college students is not over 8. The method employed in the present experiment is quite a bit different from that used by Gates and Taylor but this limit of approximately 7 units of stimulus material has been observed by many investigators. Miller (10) applies the concepts of information theory in determining the limiting capacity of memory. His primary assumption is that if the human observer is a reasonable kind of communication system, increasing the amount of input information will result in an increase of transmitted information which will level off at some asymptotic value. Miller terms this asymptotic value the "channel capacity" of the observer. In line with this limiting capacity, he makes a distinction between immediate memory and absolute judgment. The limiting factor in immediate memory is the number of items while in the latter it is the amount of information. Miller cites other studies which provide information about the channel capacities for various sensory attributes such as loudness, taste, pitch, etc. The mean of the channel capacities is about 6.5 categories. Miller concludes from this that there is a finite and rather small capacity for making unidimensional judgments and this capacity is usually in the neighborhood of seven.

The memory span experiments are related to the present experiment in that both are concerned with the limiting capacity of memory. The principal difference is that, in the former time was an

uncontrolled factor, while in the research under discussion it is a main dependent variable. In the first case, the decrement in performance was manifested by an increased error score, while here increased preparation time is the principal measure. This is based on the reasonable assumption that, if a subject is preparing to retain lists exceeding his memory span or channel capacity, he should take more time to do it.

It is expected that a decrement in the subject's performance will occur at about list length 8. This limit is higher than previously reported because of the greater stimulus value of presenting the material visually and permitting the subject to regulate the presentation rate. This sudden performance decrement should be evidenced by an increase in errors at list length 8. Further evidence of this increase in difficulty should be noticed in an increase of preparation time and switchbacks (reviews) for those groups in which these measures are taken.

If the time spent in preparation is as crucial a determinant of successful performance as has been suggested, subjects should spend greater time preparing for those list lengths they answer correctly than for those on which incorrect responses are given. This experiment will provide data to test this expectation.

Since the expected critical value is list length 8, it is assumed that list lengths of from 3 to 11 should provide the necessary range of performance.

METHOD

Apparatus

Since Johnson's previous fractionation of the problem-solving process has proven workable, this experiment employed the same division. The intellectual process under investigation is therefore thought of as progressing serially, and the apparatus to be used will allow the subject to sequentially view the preparation material followed by the solution material. The apparatus was a serial-exposure box consisting of two chambers, separated by a partition and separately lighted. See Fig. 1. The subject faces a half-silvered mirror, 9 1/2 inches wide and 6 1/2 inches high. The back of the box contains a card holder for 5x8 cards so that the list of digits to be retained appears in the preparation chamber and the list of 10 possible responses appears in the solution chamber. A two-position toggle-switch is located directly in front of the subject which allows him to illuminate either chamber at his own pace. A system of lights, relays, interval timers, and clocks is arranged so that the subject can view each side of the box at will. The exposure times taken by each subject are recorded by two Standard Electric Timers with readings possible to 1/100th of a second; the scores, however, were recorded to the nearest 1/10th of a second. Attached to the front of the serial-exposure box is a console containing 10 push-buttons appropriately lettered from A through J. Pushing any one of the buttons automatically opens the circuit thereby darkening the box and stopping the clocks.

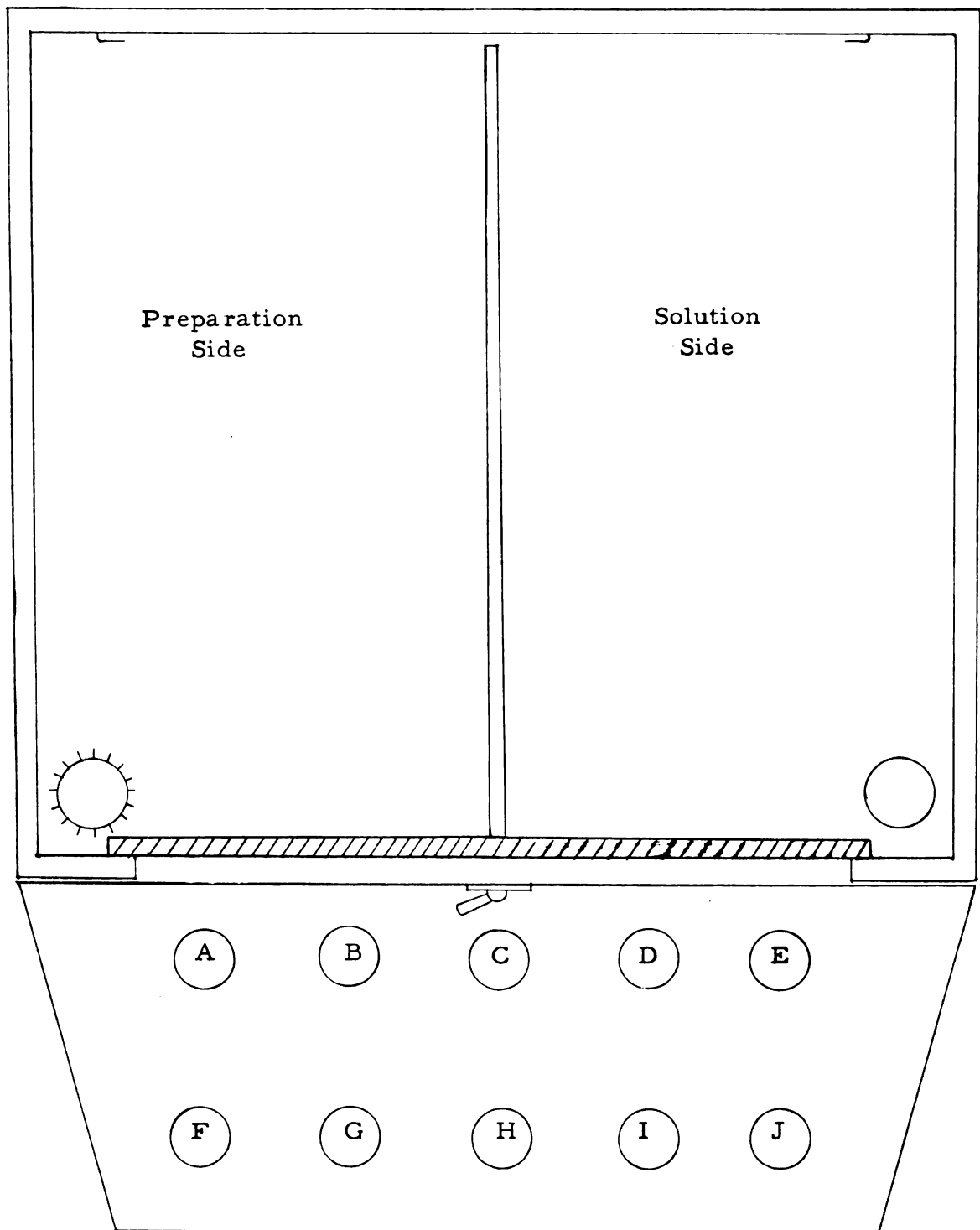


Figure 1. Top view of the serial-exposure box. The console containing the 10 pushbuttons is located directly in front of the subject. The two-position toggle-switch is located in the "start" position, i. e. with the preparation side of the chamber illuminated. The half-silvered mirror is represented by the cross-hatched panel. The brackets of the card holder can be seen at the back of the box.

Stimulus Material

The stimulus material consisted of 45 5x8 cards, 5 cards for each of the 9 list lengths. The list lengths ranged from 3 digits to 11 digits. A table of random numbers was used to construct the initial list on the preparation side; the digits from 0 through 9 were used. From this initial list, the experimenter then constructed 1 correct and 9 incorrect variations. In each of these variations, the digits were always ordered differently than the initial preparation list. Because a table of random numbers was used, most of the initial lists contained repeated digits; this is true of necessity in lists of 11 digits. A table of random numbers was again consulted to determine which of the 10 possible positions, i.e. A through J, was to be designated as containing the correct digits. This randomization was done in an attempt to control for subject position preferences. The preparation list and the 10 solution lists were then typed on an unlined 5x8 index card. This procedure was followed in constructing each of the 45 cards. An example of a card is presented below:

	A	B	C	D	E	F	G	H	I	J
3	4	7	8	2	8	5	1	3	8	1
4	2	6	5	4	3	3	3	4	0	2
1	8	4	4	1	5	1	4	1	3	4
8	1	3	3	3	1	8	<u>8</u>	9	9	8

- correct choice

Procedure

The subjects were 63 undergraduate students enrolled in the introductory psychology course at Michigan State University.

The experimental procedure employed the three exposure conditions mentioned previously. Each group contained 21 subjects, 10 males and 11 females.

The first 42 subjects were alternately assigned to either the Switchback or No Switchback condition. Since the apparatus required changes in the circuitry for the Complete Exposure group, it was necessary to complete the testing of the first two groups before beginning the third.

The exact instructions that were given to each group are presented in the Appendix. The appropriate instructions were typed on 5x8 cards and each subject read them in the same manner as the stimulus cards, i. e. by manipulating the toggle-switch to illuminate the portion of the instructions relating to the preparation and solution sides.

In general terms, the subjects were instructed to examine the preparation list and be ready to pick out the same numbers, in a different group, on the other side of the card. They were also informed that the numbers will not necessarily be in the same order as in the initial list. The solution side of the instruction card contained the information that, although their response times will be recorded, the task is not a test of speed but the primary emphasis is on accuracy. The subjects were then given instructions about whether they will be permitted to switchback or review the preparation list. An example card was inserted into the apparatus and the subject familiarized himself with the mechanics of responding. He was then asked if he had any questions about the operation involved. The entire experimental session usually lasted approximately 50 minutes. When the session was completed, the subject was requested not to

pass on any information about the procedure to those who were scheduled to participate in the experiment.

During the trial session the experimenter recorded the preparation and solution times, as well as the response that was made to each card. At the end of the session each subject was asked to state the method he used in retaining the preparation lists and to offer any suggestions for improving the procedure.

RESULTS

The first step in the data analysis consisted of plotting a frequency distribution of the preparation times for each of the list lengths. This plot indicated that the distributions were not normally distributed, but rather, sharply skewed to the right. This is a not uncommon characteristic of time data in psychological experiments. In order to obtain a more positive test of the skewness, the cumulative distributions were plotted on normal-probability paper. The resultant plot deviated considerably from a straight line, indicating that the populations were not normally distributed (3). Therefore, a suitable transformation had to be performed if parametric statistics were to be used. If the assumptions of homogeneity of variance and normal distribution could be met, the plan of analysis included an analysis of variance. Therefore, an attempt was made to find an appropriate transformation.

Normality of distribution can frequently be enforced on time data by transforming the scores to their reciprocals. However, when each measurement was replaced by its reciprocal and the data then plotted on a frequency distribution, it was observed that this manipulation failed to remove the skewness.

A logarithmic transformation was then considered. The sample means were plotted against their respective standard deviations and appeared approximately proportional, i. e. the plot was approximately a straight line. When the logarithmically transformed data were plotted on normal graph paper the distribution curves appeared uniformly bell-shaped, indicating that the transformation was

successful in removing the skewness. Since the application of analysis of variance requires an assumption of homogeneity of variance of the samples, as well as normal distribution, Bartlett's Test (4) was applied to the preparation times. The 9 list lengths of the Switchback and No Switchback conditions were tested for homogeneity of variance. The "corrected" X^2 of 18.96 was not significant ($df = 17$, $X^2_{.95} = 27.59$), hence the assumption was made that the samples were not heterogeneous in variance.

Figure 2 allows for a comparison of preparation times of the two principal exposure conditions, Switchback and No Switchback. The plotted points were obtained by calculating the mean of each subject's 5 time scores (transformed to logs) at each list length; this was done for each subject and the mean of these 21 means was then calculated. It can be noted from this figure that both groups take approximately the same length of time to prepare. The most interesting aspect of the curves is the crossover between list lengths of 7 and 8 items, i. e. the Switchback group takes less time to prepare for shorter and more time for longer list lengths than the No Switchback group.

An analysis of variance was then applied to the preparation time scores to determine whether there were significant differences between the Switchback and No Switchback exposure conditions. This technique also tests for differences between list lengths as well as a possible interaction effect between exposure conditions and trials. The analysis was performed on the 9 list lengths of the two exposure conditions which were previously tested for homogeneity of variance. Each exposure condition was presented to 21 subjects, giving a 21 x 18 design. In effect, each subject contributed 9 scores

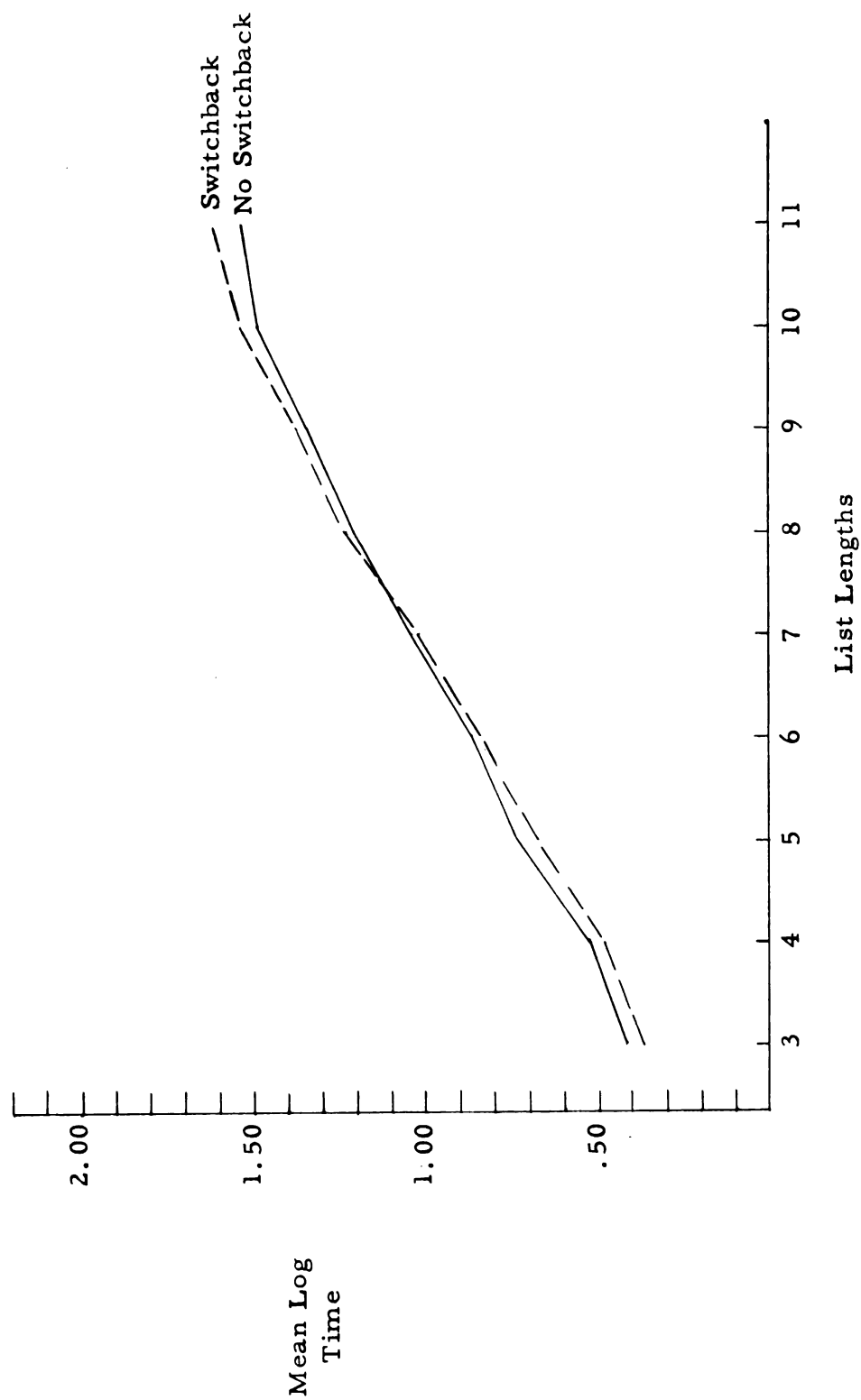


Figure 2. Mean preparation time, Switchback and No Switchback groups.

to the analysis matrix and the method of analysis was of the type for repeated measurements on several independent groups (4).

The results of that analysis are presented below.

Analysis of Variance of Preparation Times for the Switch-
back and No Switchback Exposure Conditions

Source of Variation	d f	Mean Square	F
Between Exposure Conditions	1	.02 ⁺	0.00
Between Ss in same Group	40	1499.02	
Total between Ss	41		
Between List Lengths	8	77733.70 [†]	963.36**
Interaction: Conditions X List Lengths	8	228.63 [†]	2.83**
Interaction: Pooled Ss X List Lengths	320	80.69	
Total Within Ss	<u>336</u>		
Total	<u>377</u>		

** $P < .01$

+ Tested against error term of Between Ss in same group

† Tested against error term of Pooled Ss X List Lengths

There was practically no difference between exposure conditions, as evidenced by the extremely small mean square. The difference between list lengths was highly significant. This was expected since subjects must of necessity take more time to prepare for longer than for shorter list lengths. The significant interaction between conditions and list lengths is interpreted as meaning the exposure condition exerts a differential effect on the 9 list lengths. This may be observed graphically in Figure 2.

Figure 3 allows for a comparison of solution times of the two principal exposure conditions. The data points were obtained in

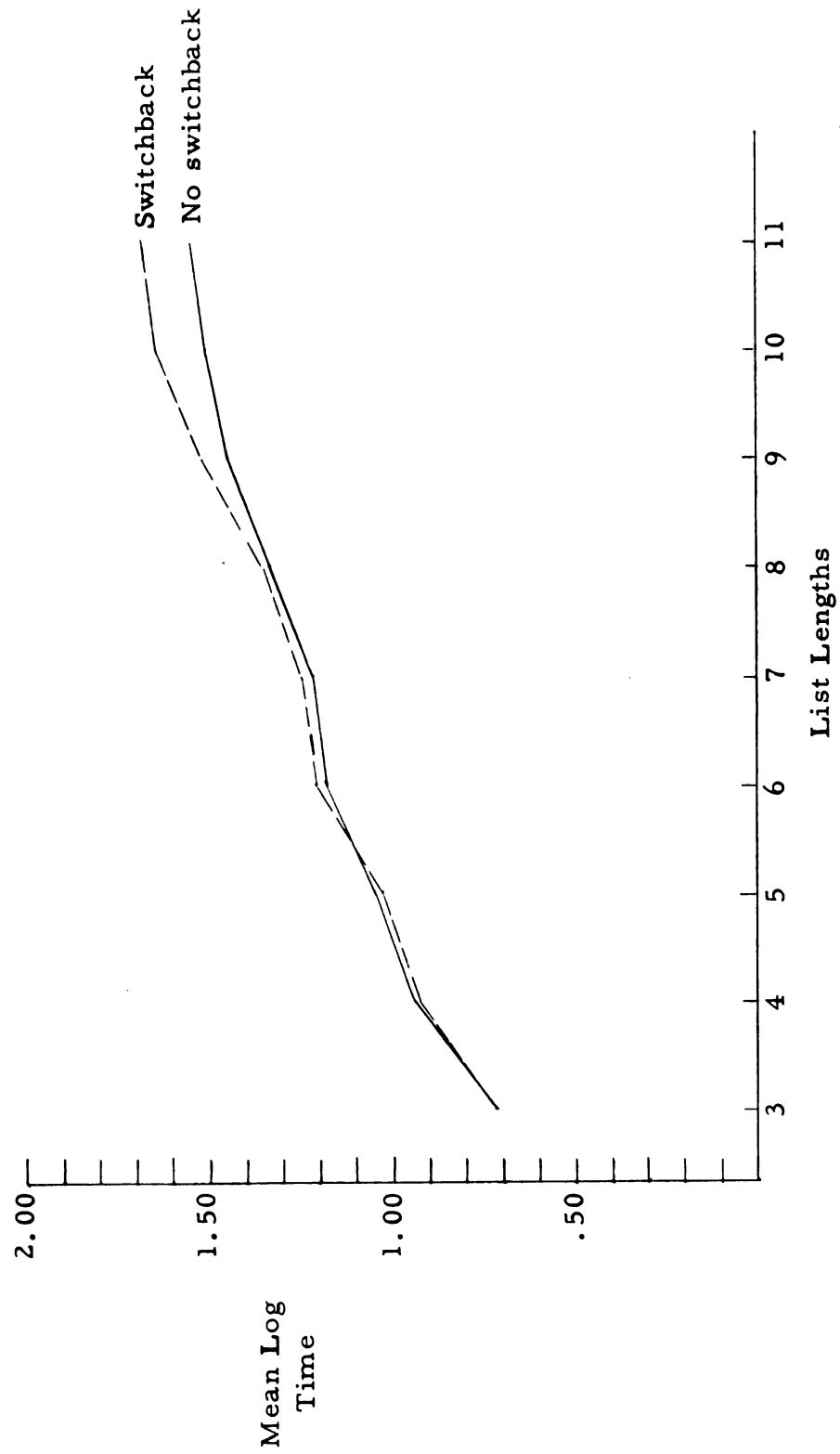


Figure 3. Mean solution time, Switchback and No Switchback groups.

the manner previously outlined for preparation time. It may be seen from this figure that solution time scores are nearly identical for list lengths 3 through 8. The Switchback group took consistently longer solution times for the list lengths of 9 through 11.

The data in this 21 x 18 design were also tested for homogeneity of variance by Bartlett's Test. The obtained X^2 of 41.70 (d f = 17, $X^2_{.95} = 27.59$) was too large to permit the assumption of equal variances. However, it was decided to proceed with the analysis in the hope that pertinent trends may be observed. The results of this analysis are presented below.

Analysis of Variance of Solution Times for the Switchback
and No Switchback Exposure Conditions

Source of Variation	d f	Mean Square	F
Between Exposure Conditions	1	1496.04+	1.75
Between Ss in same Group	40	856.60	
Total between Ss	41		
Between List Lengths	8	38050.70†	275.99**
Interaction: Conditions X List Lengths	8	307.26†	2.29*
Interaction: Pooled Ss X List Lengths	320	137.87	
Total Within Ss	<u>336</u>		
Total	<u>377</u>		

* $P < .05$

** $P < .01$

+ Tested against error term of Between Ss in same group

† Tested against error term of Pooled Ss X List Lengths

As in the previous situation, the difference between exposure conditions is not significant. As expected, the between list lengths F value is highly significant. The interaction term is significant at

the .05 level of confidence, however, since the variances are not equal a conservative analysis requires that this interaction term be lightly regarded.

Figure 4 presents the total errors made by the 21 subjects in each of the three groups. The Switchback group was most accurate, No Switchback was next and the Complete Exposure group made the most errors. This relative superiority was consistently maintained, with few exceptions, over all 9 list lengths. It is worthy of note that the Complete Exposure group was least accurate, i. e. the group that was presented with both preparation and solution items simultaneously, made more errors than the two groups which had to retain the preparation material for longer periods of time. All three curves increased sharply between list lengths of 8 and 9 digits.

Figure 5 is a crucial graph in assessing the role that preparation time plays in this recognition task. It was mentioned earlier in the introductory section of this report that, the time spent in preparing should be intimately related to proficiency in the task. Figure 5 presents the mean correct and incorrect preparation times for the No Switchback group. It may be seen that longer preparation time results in superior performance. No score was determined for list length 3 since there was only one incorrect response.

In order to assert that preparation time is the most crucial component of the process, it is necessary to demonstrate that solution time is not an equally valid predictor of accurate performance. Figure 6 presents support for this assertion. It is shown in this figure that in several instances the mean solution time of the No Switchback group is higher for the incorrect responses.

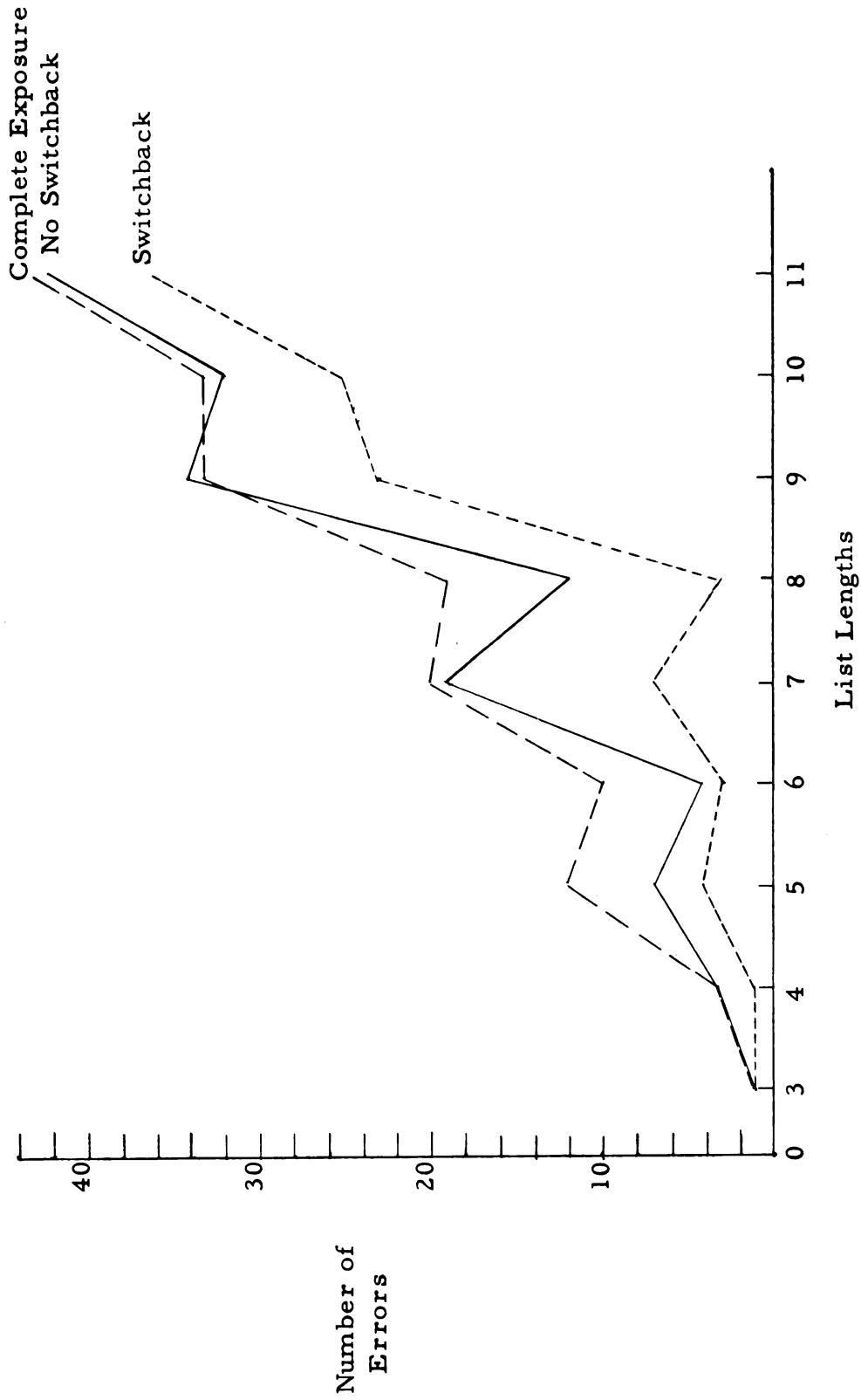


Figure 4. Total number of errors of the Switchback, No Switchback and Complete Exposure groups.

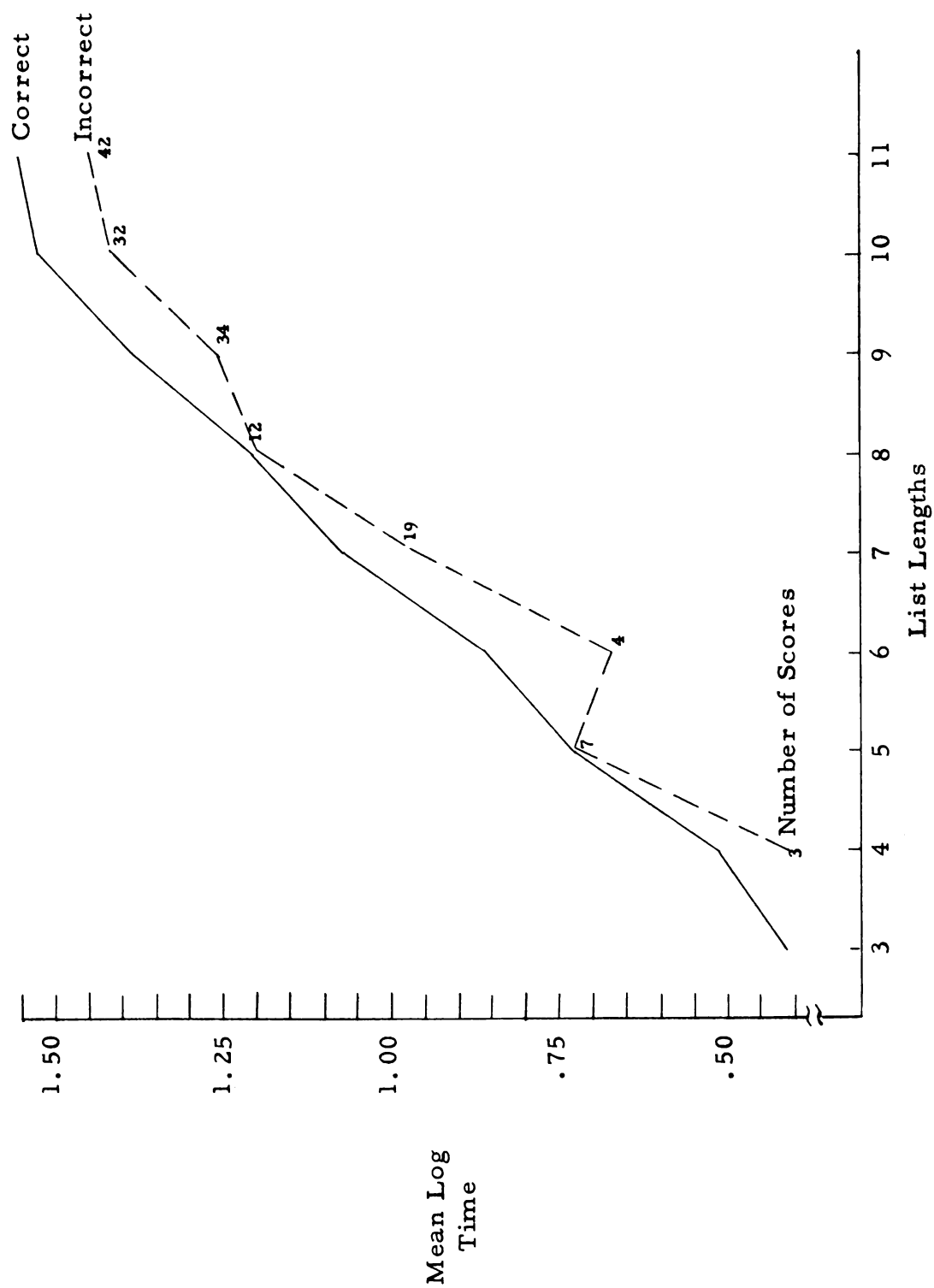


Figure 5. Mean preparation time for correct and incorrect responses, No Switchback group.

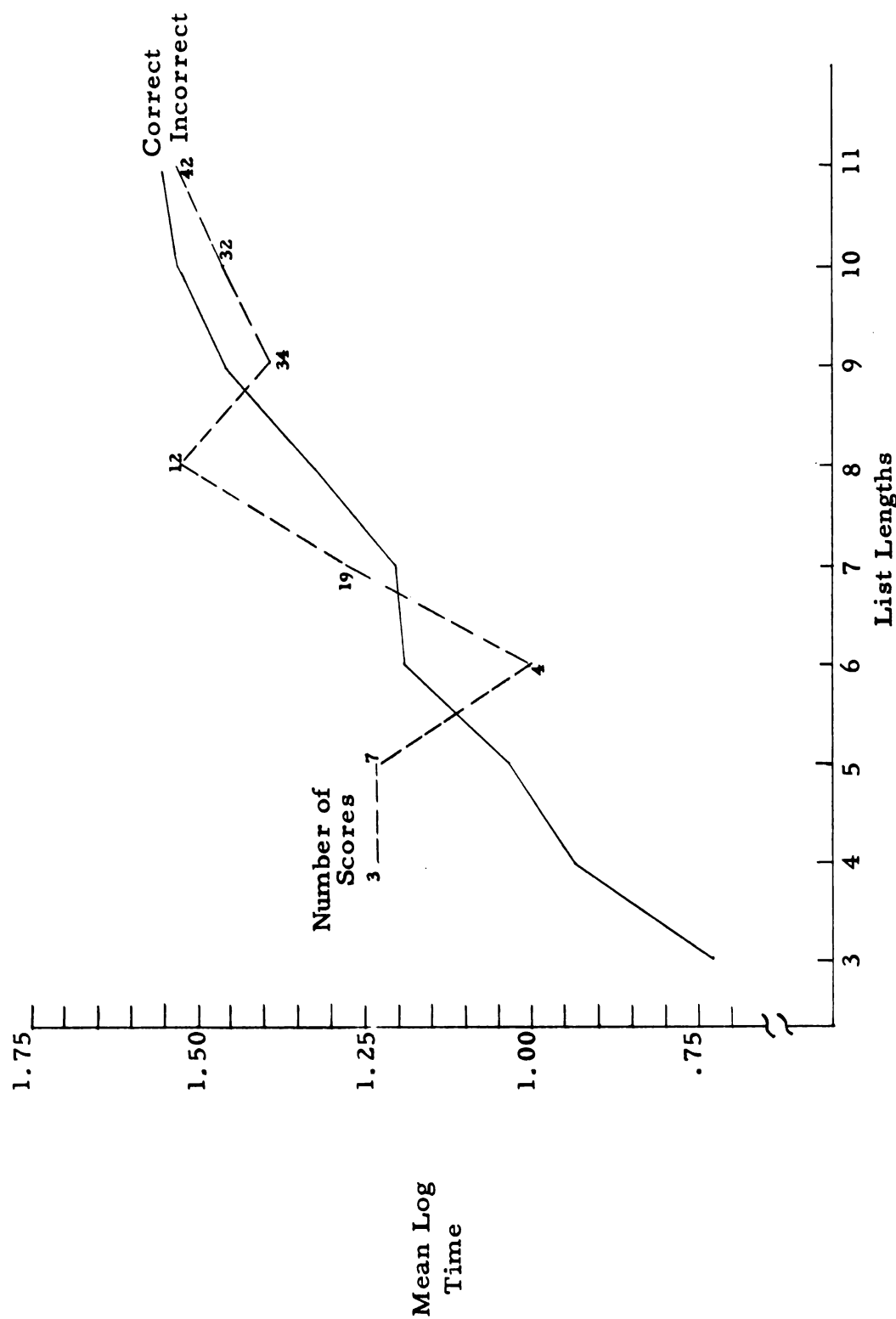


Figure 6. Mean solution time for correct and incorrect responses, No Switchback group.

This finding suggests that the accuracy of performance cannot be reliably determined by the length of the solution time phase.

Figure 7 presents the proportion of time spent in preparation to total time (preparation plus solution times) for correct and incorrect responses of the No Switchback group. Each data point was determined by dividing each preparation time score by the corresponding total time (both transformed to logs) at each of the 9 list lengths. The proportions on which correct responses were given were listed separately from those which were incorrect and a mean for each was taken. Since each of the 21 subjects was presented with 5 cards of each list length, the correct and incorrect scores sum to 105.

This plot of the fraction $\frac{\log \text{preparation time}}{\log (\log \text{prep. time} + \text{soln. time})}$ again points out the necessity of adequate preparation. In every case the mean proportion was higher for the correct responses. As is to be expected, the proportion of time spent in preparation gradually increases as the list lengths increase. Figure 7 indicates that the use of a proportion demonstrates the necessity of adequate preparation with more consistency and clarity than the use of preparation time alone.

Figures 8, 9 and 10 present the same data discussed above, for the Switchback group. The results are essentially the same. The proportion curve, Figure 10, yields the same relationship observed in the No Switchback group. The two irregularities are both based on only 3 scores, which does not invalidate the conclusion that a greater proportion of time spent in preparation results in superior performance in general.

Figure 11 presents the median log total time for each of the three groups. There is very little articulation in the curves until

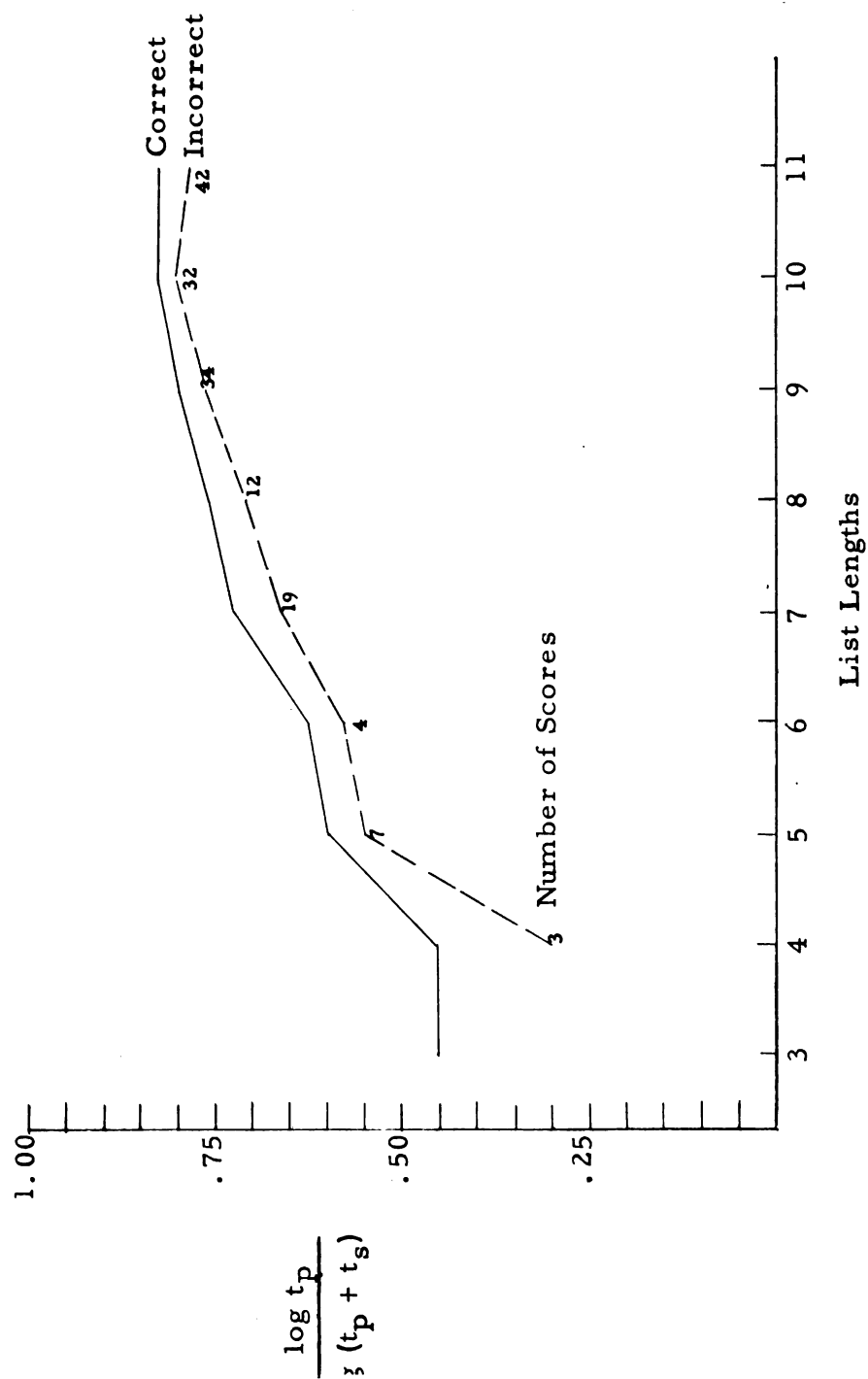


Figure 7. Mean proportion of time spent in preparation to total time for correct and incorrect responses, No Switchback group.

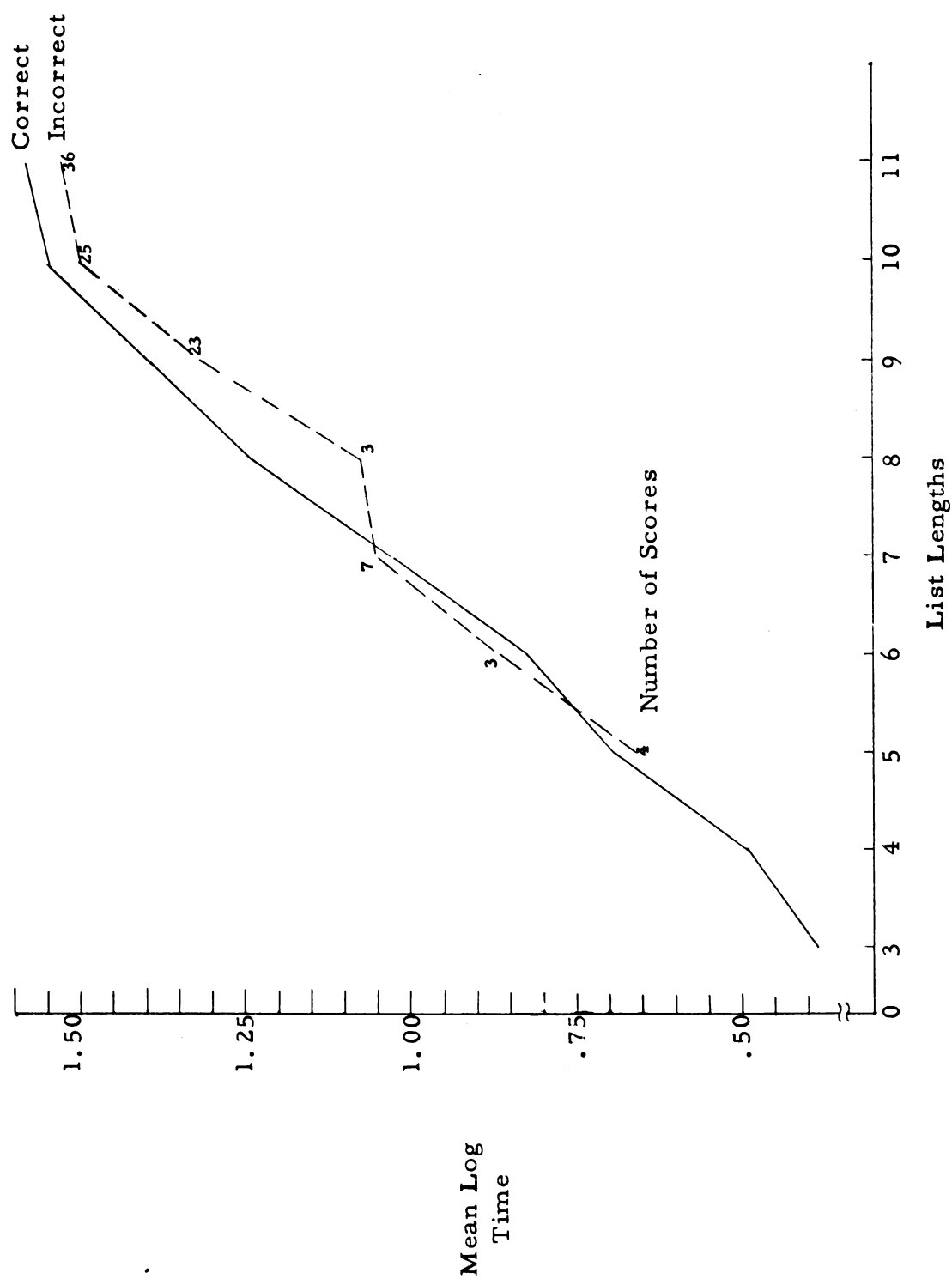


Figure 8. Mean preparation time for correct and incorrect responses, Switchback group.

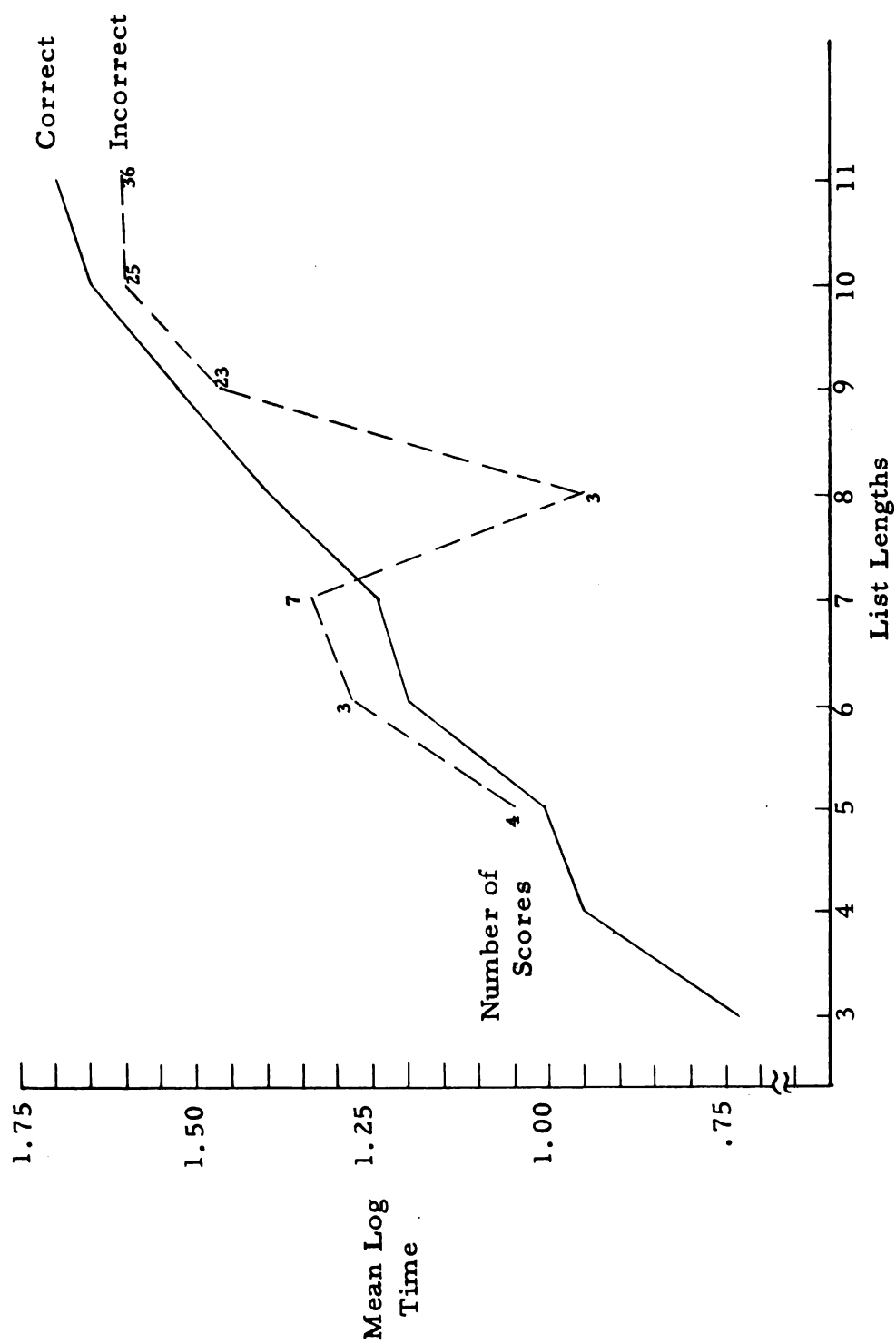


Figure 9. Mean solution time for correct and incorrect responses, Switchback group.

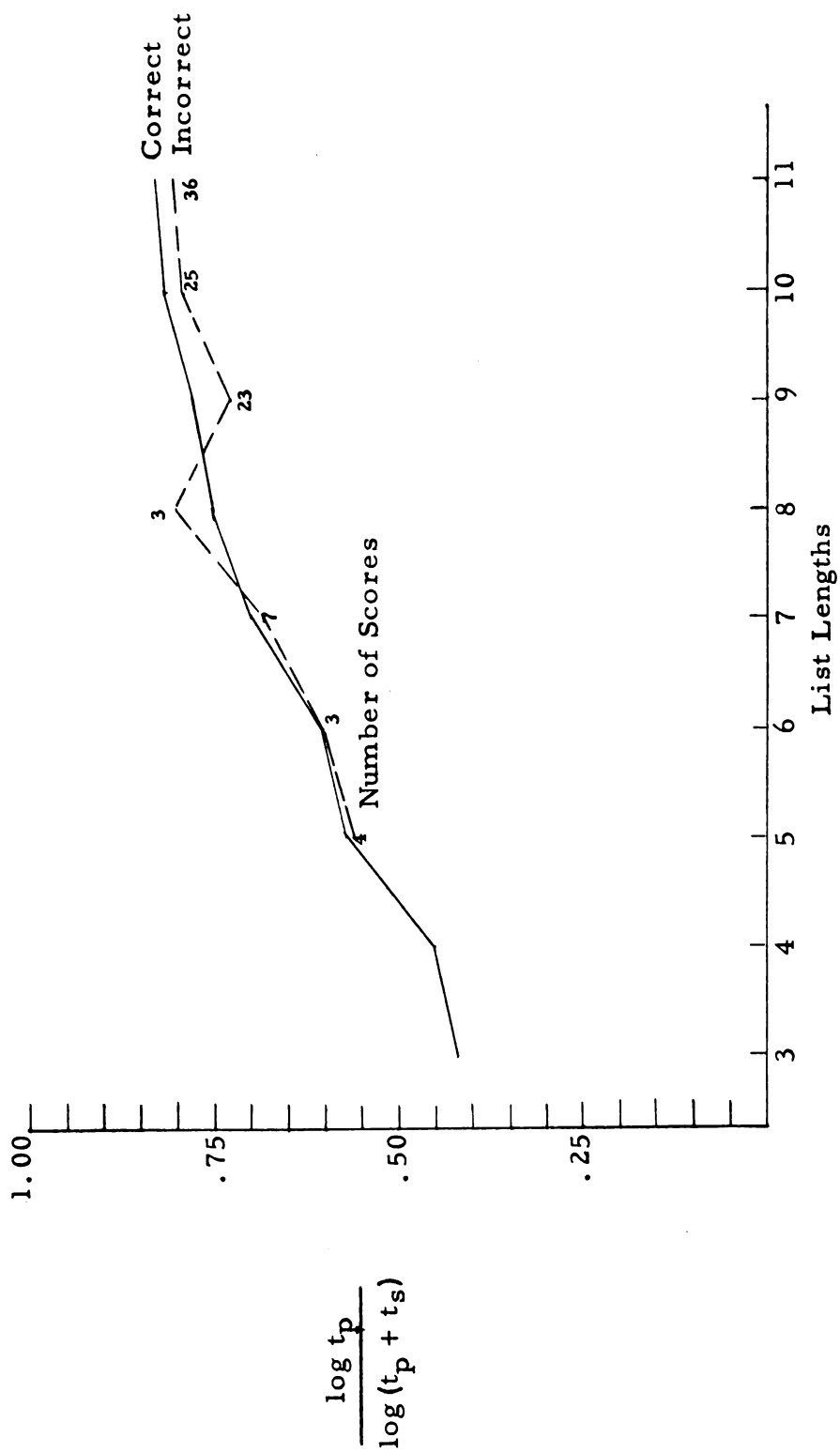


Figure 10. Mean proportion of time spent in preparation to total time for correct and incorrect responses, Switchback group.

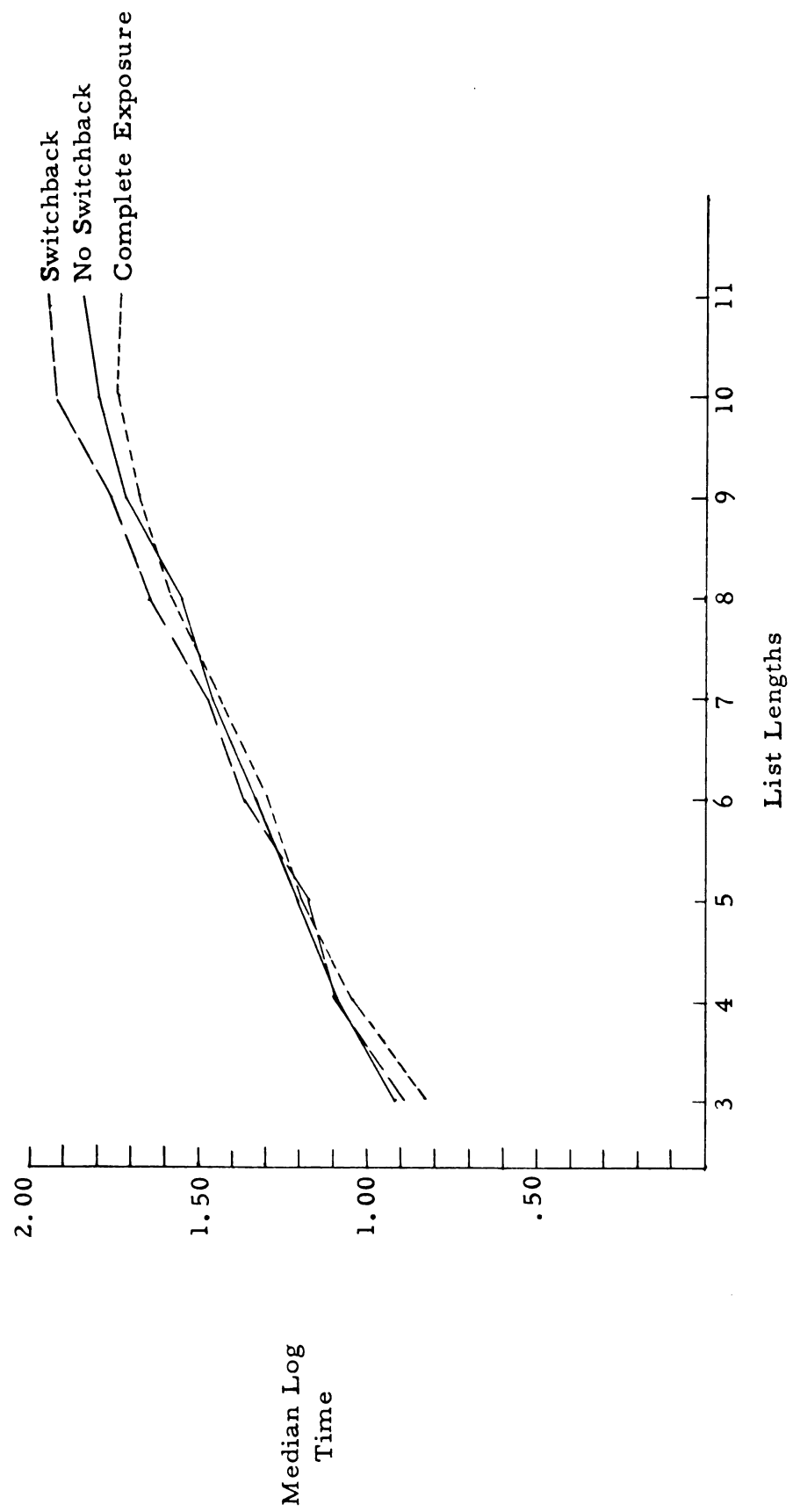


Figure 11. Median total time of Switchback, No Switchback and Complete Exposure groups.

the list length of 9 digits. After 9, the median total time for the Switchback group is greatest, followed by the No Switchback and Complete Exposure groups.

Figure 12 is a frequency plot of the total number of switchbacks made under that exposure condition. The slope of the curve increases gradually until about list length 8. The shape increase after this is consonant with the previously presented curves of time and errors. The dramatic drop in total switchbacks at list length 11 is quite unexpected but an attempt at explanation will be made in the following discussion section.

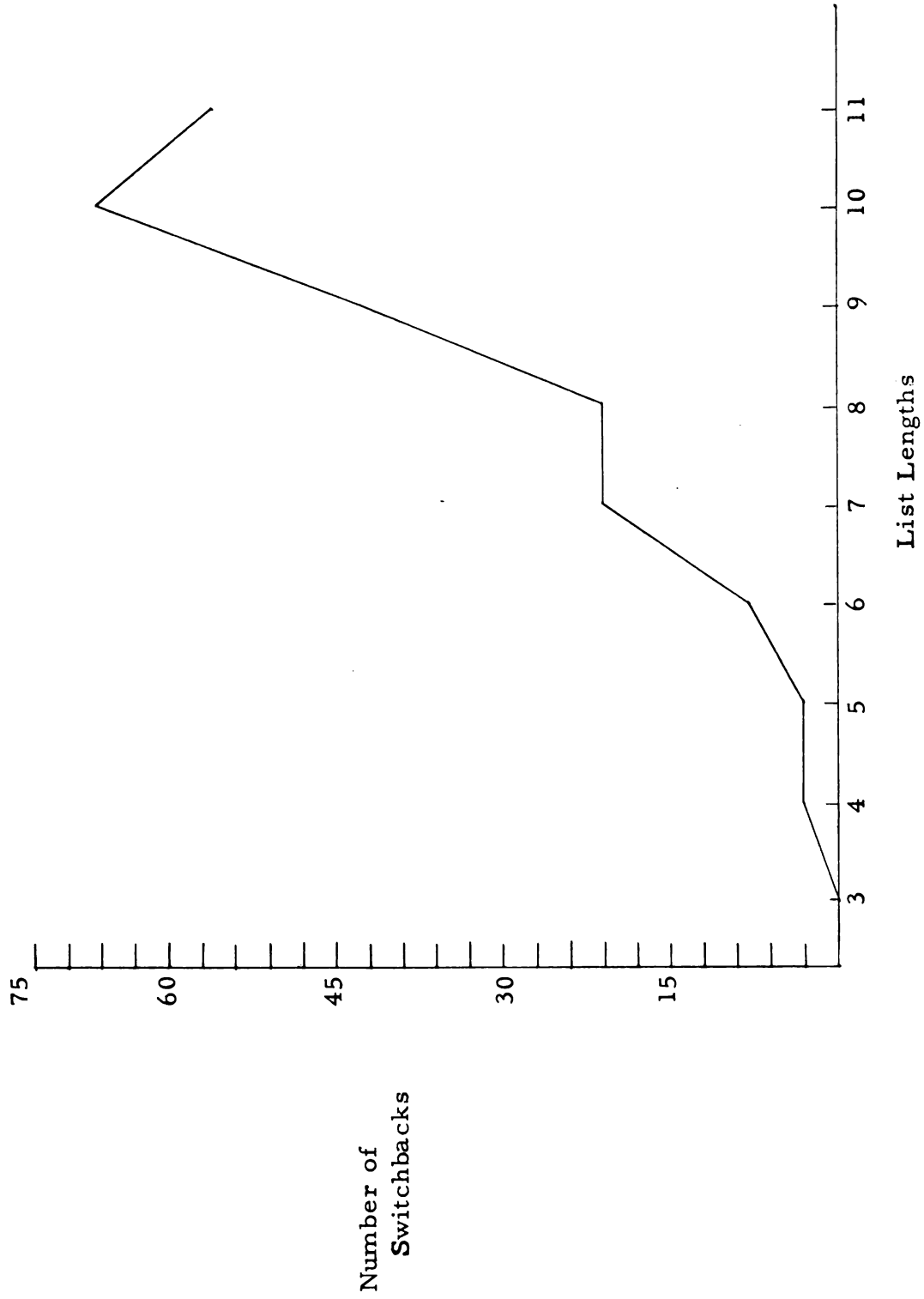


Figure 12. Total number of switchbacks of the Switchback group.

DISCUSSION

The purpose of this study, as stated in the introduction, was to determine in what manner the quantity of task material is related to the preparation period. Briefly, the method consisted of allowing the subject to view a list of numbers ranging in length from 3 to 11 digits. When he decided that his preparation to retain this list was adequate, he then viewed 10 similar lists only one of which contained all of the digits in the preparation list. His task was explained as picking the correct list from the multiple choices. On the basis of the memory span experiment of Gates and Taylor and the channel capacity study by Miller, it was expected that a decrement in the subject's performance would occur at about list length 8. The dependent variables of time, errors and switchbacks were chosen to reflect this sudden increase in difficulty when the limiting capacity of memory was exceeded. Three exposure conditions were used: (i) the subjects were permitted to switchback and review the preparation list, (ii) the subjects were allowed only one preparation period, i. e. no switchback, (iii) the subjects were presented with both preparation and solution lists exposed simultaneously, i. e. complete exposure.

It was stated in the introduction, that if preparation is as crucial a determinant of successful performance as is expected, subjects will spend greater time preparing for those list lengths they answer correctly than for those on which incorrect responses are given. This is based on the assumption that, when subjects take more time to organize and systematize the preparation material,

they will be better prepared; hence, the probability of a correct response will be higher than if a relatively short preparation period is taken. This expectation was borne out in every test that was considered. Figures 5 and 8, the mean preparation time for correct and incorrect responses of the No Switchback and Switchback groups, present data in support of this contention. Also, it was determined that solution time alone does not clearly differentiate between correct and incorrect responses. The data suggest that the best statistic to use in demonstrating the necessity of preparation is,

$$\frac{\log \text{preparation time}}{\log (\text{prep. time} + \text{soln. time})} \cdot$$

The analysis of variance that was applied to the preparation time data yielded a significant interaction between exposure conditions and list lengths. These data were presented graphically in Figure 2, and the observation was made that the Switchback group takes less time on shorter and more time on longer list lengths than the No Switchback group. This is thought to be due to the awareness of the Switchback group that if their preparation is inadequate they will be permitted to prepare further. For list lengths of 3 through 7 digits, one period of preparation is generally sufficient, as shown in Figure 12 by the relatively few switchbacks. The No Switchback group, on the other hand, when preparing for the shorter lists are aware that only one preparation period is allowed and consequently spend more time in preparing. For list lengths above 8, i. e. those exceeding the limiting capacity, the subjects find that a single preparation period is frequently inadequate and as a result, the frequency of switchbacks sharply increases. As a consequence of this increase in switchbacks, the mean preparation time of the

Switchback group is greater and the errors are fewer than the No Switchback group.

Several effects were noted in the graphs which require explanation. There is a general increase in the curves of Figure 4, total errors of all three groups, but there are many irregularities in their progressions. This is most likely caused by the list lengths not increasing in difficulty by equal increments. It had been assumed that by using 5 cards for each list length this irregularity could be eliminated, but apparently only through extensive pretesting of the task material will smooth error curves be obtained.

The finding that the Complete Exposure group made more errors than the other two groups was not anticipated. It was expected that the operation for this group would consist of a list by list comparison of the solution items with the preparation list. Since little retention is involved, the errors should be quite rare. A feasible explanation is that the task was approached differently by subjects in this group, i. e. the task was perceived as being of such a simple nature that concentrated effort was not necessary. The experimenter noticed that indications of anxiety were quite uncommon for this group. The median total time, Figure 11, was approximately the same as the No Switchback group but the Complete Exposure group were less accurate in their responses. Apparently the Switchback and No Switchback exposure conditions "force" the subject to adopt a strategy which results in superior performance. Casual reports of the subjects indicate that this strategy consists of an ordering or systematizing of the material.

It was anticipated that there would be a definite increase of preparation time, errors, and switchbacks at about list length 8.

Only the preparation time data, Figure 2, fail to support this hypothesis. The results indicate that this index is not as subject to the limiting capacity approach to memory as are the other two, but rather, preparation time increases uniformly as the amount of material is increased. It appears the curves are approaching an asymptote at list length 11 but the data offer no proof of this.

Figure 12, total number of switchbacks, indicates the occurrence of a rather sharp decrement in performance at about list length 8. The most salient feature of this curve is the dramatic decrease of switchbacks at list length 11. This event however, is consonant with the error score of Figure 4, i.e. the subjects switchback less and are correspondingly less accurate when compared with list length 10. A possible explanation of this is that a list of 11 digits appears almost insolvable and the subjects respond hastily in order to get to the easier cards. Also, there is a greater build-up of satiation on this long list. Only increasing the range of list lengths to 12 or 13 digits could substantiate this explanation.

A Mechanical Model

At this point it may prove useful to put forth an expository device to describe the recognition procedure employed by the subjects. Such a model will prove useful only in so far as it fits the data obtained in the experiment. The approach employed in this discussion is similar to the one postulated by D. E. Broadbent (1), i.e. the human perceptual system has a rather small limiting capacity and any operation of this system involves a selective grouping of inputs by the organism. Broadbent conceptualized this by describing a mechanical model of the human perceptual system. This model can be modified

to suit the present situation although it was originally postulated as a mnemonic for a formal theory of attention and immediate memory in terms of information theory.

The necessary components of the system are a Y-shaped tube mounted in an upright position, two return tubes leading back to the input branches, and a set of small balls. A diagram of the model is presented in Figure 13. Where the branches intersect the stem, there is a hinged flap which normally hangs in a downward position, but which may be forced to either side thereby closing off one of the branches. This pivoting may be done by a handle located outside of the tube which represents the attention of the individual. When the handle is left unattended, the flap moves freely, so that if a ball is dropped into one of the branches of the Y it hits the flap at the juncture, forcing it to one side, allowing the ball to drop into the stem.

Up to this point the model is exactly as presented by Broadbent; the adaptation consists of a different assigning of functions to the various components of the apparatus. He uses the branching arms to represent different sensory channels, whereas in the new model they are designated as the preparation and solution input systems. The balls represent groupings of digits or information units; for example, one 0, two 3's, one 4, three 7's, and so on. The bottom tip of the stem represents a response output, i.e. a choice of one of the ten solution lists. The purpose of the two return tubes leading back to the branches is to allow the balls to remain in circulation for a finite length of time. This feature introduces a necessary complication into the scheme. In order for the balls to remain in the system, they must maintain a critical speed which is determined

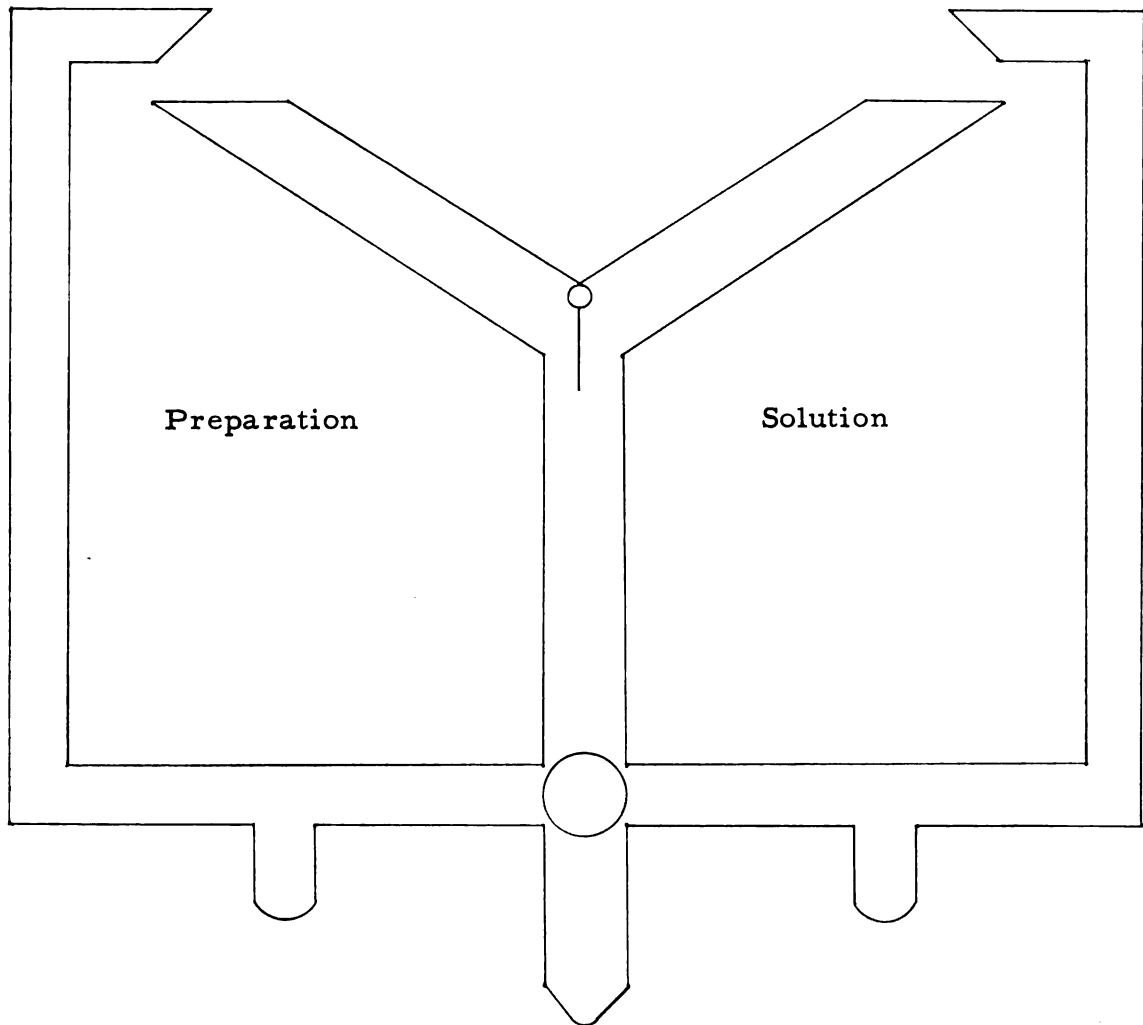


Figure 13. A mechanical model of the recognition procedure. At the top of the Y are the inputs to the system. The hinged flap representing the subject's attention is located where the branches intersect the stem. The vents through which the balls leave the system are located at the bottom of the apparatus.

by the force with which they enter, the length of time they have been circulating, and the interference encountered at the flap. After dropping below this critical speed, they are removed from the apparatus by means of the vents at the bottom of the return tubes. This feature is necessary to account for the forgetting factor in retention.

The mechanics of the model bear many similarities to the intellectual process under investigation. Before a detailed description of the operation is given, it is advisable to reiterate that the model is intended as nothing more than an expository device and, as Broadbent states, at no time is it implied that such a Y-shaped tube exists somewhere in the region of the thalamus. The model will be abandoned when it fails to coincide with the properties of the organism.

The system is initially set into motion when the subject starts to retain the preparation list. Verbal reports of the subjects indicate that they organize the digits into groupings as illustrated previously. A ball represents one of these groupings. The number of balls entering the preparation side of the Y is the number of groupings that have been formed. These enter the left branch and force the flap to the right side as they pass through the junction into the stem and are kept in circulation by passing through the left return tube. Their speed is thought of as increasing when the subject rehearses (recirculates) the rearranged preparation list. When the subject decides that he has prepared adequately, he then attends to the first of the ten solution lists. The digits in this list are similarly grouped and as each grouping is formed it is fed into the input on the solution side. This ball passes down the branch to the region of the flap at which time it is matched with the corresponding ball of the preparation side.

It would prove unduly complicated to describe a mechanical method by which this matching is accomplished. If the matching is successful, for example two 3's with two 3's, both balls are expelled from the system at the base of the stem. This procedure is then repeated with balls that are formed by the next grouping. If an unsuccessful matching is encountered, the subject then attends to the solution list that follows. When a solution list is found in which all of the balls on the solution side are matched successfully with those of the preparation side, the subject responds by specifying that list as the correct one. If no groupings are found to match those of the preparation list, the subject switches back if permitted, and the above procedure is performed again. If no switchback occurs, due either to subject preference or specified instructions, the subject will most likely respond with the list containing the most matched groups. The data support this contention since the Switchback group was highest in preparation time (Figure 2), solution time (Figure 3), and lowest in errors (Figure 4).

As each matching occurs, the balls that have not yet been matched on the preparation side must stop and somehow still maintain their kinetic potential. The longer they remain in this unmoving position, the more their potential is decreased. If this waiting period is too long, they drop out and forgetting is said to have occurred.

There is a finite number of balls which can be kept circulating in the system at or above the critical speed. This optimum channel capacity is some value less than 8 since each ball corresponds to one or more digits. When the system is overloaded, as is usually the case with list lengths 9, 10, and 11, the circulation speed is slowed

down with some balls dropping out thereby reducing the possibility of correct matching at the junction. The fewer the number of balls, the greater the speed that can be maintained and the shorter the waiting period for the balls in the system. This is posited as an explanation for the difficulty of the longer list lengths.

The properties of this model correspond closely in many respects to those of the organism. This mnemonic is only intended to serve as a means of conceptualizing the recognition procedure involved in this task.

SUMMARY AND CONCLUSIONS

There have been many attempts to separate the total thought process into its various phases. Wallas proposed an analysis consisting of four parts: preparation, incubation, illumination and verification. A study by Patrick offered a little supporting evidence for Wallas' fractionation. Johnson described problem solving in a general sense and placed particular emphasis on the preparation phase. These studies were successful in describing some of the factors which influence the nature of preparation but not all of the parameters of this process have been investigated. This study was an attempt to determine how the quantity of task material is related to the preparation period.

The method consisted of presenting the subject with lists of numbers. These list lengths varied from 3 to 11 digits. When the subject decided that his preparation to retain this list was adequate, he then viewed 10 similar lists only one of which contained all of the digits in the preparation list. This last phase is designated as the solution period. Both the preparation and solution periods were timed. Three methods of exposing the lists were employed: (i) the subjects were permitted to switchback and review the preparation list, (ii) the subjects were allowed only one preparation period, i. e. no switchback, (iii) the subjects were presented with both preparation and solution lists exposed simultaneously, i. e. complete exposure.

The following results were noted after an analysis of the data.

- (1) The time spent in preparation is a crucial determinant of successful performance,

- (2) All of the measures: preparation time, solution time, errors and switchbacks, increase as the list lengths increase.
- (3) There is a rather sharp increase of errors and switchbacks at about list length 8.
- (4) The Switchback group is superior in performance, followed by the No Switchback and Complete Exposure groups.
- (5) The Switchback group takes less time on shorter and more time on longer list lengths than the No Switchback group.

A mechanical model, based on an earlier model by Broadbent, was presented as a mnemonic of the recognition procedure employed by the subjects.

APPENDIX

The instructions that were given to each group are presented below.

Switchback Group

Preparation Side

On this side of the box you will see a group of numbers like the following example:

3
7
2

Examine the numbers as your task will be to pick out the same numbers (in a different group) on the other side of the card.

The numbers will not necessarily be in the same order as they are here. Do not attempt to find any order or sequence of arrangement in the numbers. The only requirement is that you pick a group which has the same numbers as the group on this side.

When you think that you are ready to recognize these numbers on the other side, turn the switch.

Solution Side

On this side of the box you are to pick one group from the ten that has in it all of the numbers from the other side.

For example:

A B C D E F G H I J

2	3	3	7	6	8	9	6	3	4
0	4	2	3	2	4	2	8	1	8
2	1	2	2	0	3	6	4	1	2

Only alternative "D" has the numbers 3, 7, 2 in it. So the correct response in this case is to press the button labeled "D" on the board in front of you.

Some problems will be easy and some will be hard, but you may switch back to the other side to look at those numbers whenever you wish, but return to this side to make your choice.

Although your times will be recorded, this is not a speed test. We are primarily interested in accuracy, so take as much time as you need to make a correct choice.

No Switchback Group

The instructions for preparation were the same as above.

The instructions for solution were the same as above with the exception of the next to the last paragraph, which was as follows:

Some problems will be hard and some will be easy. Once you switch to this side you may not switch back to the other side but must make your choice.

Complete Exposure

The instructions for preparation were the same as the other two groups except that the last paragraph was omitted.

The instructions for solution were the same as the other two groups except that the next to the last paragraph was as follows:

Some problems will be easy and some will be hard.

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