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The role of interference and trace decay in the retention of a simple psychomotor task

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To J. and the Dream

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Abstract

The purpose of the present study was to try to distinguish between the interference theory and trace decay theory and to try to establish whether one or a combination of the two best accounts for the forgetting shown in motor short-term memory (STM). The experiment was a seven by three factorial design with repeated measures on the second factor. The first factor was number of prior responses which the S experienced on the linear slide apparatus, and the number of responses ranged from zero through six. The second factor, length of the retention interval between practice and recall, had values of 5 sec., 40 sec., and 75 sec. Neither main effect of retention interval nor number of prior responses were significant. The interaction of retention interval and number of prior responses was also non-significant. No definite conclusions could be drawn from the present study, but other studies were considered and Pepper and Herman's recent two-process theory of motor STM was discussed.

The role that interference plays in verbal retention has been established for some time, but its role in motor retention has not yet been confirmed. Although there have been many studies of short-term verbal learning (Conrad and Hille, 1958; Keppel and Underwood, 1962; Murdock, 1961; Peterson and Peterson, 1959), there have been relatively few studies on short-term retention of motor responses. It is not yet clear whether interference theory or trace decay theory best accounts for the forgetting shown in motor STM.

Adams and Dijkstra (1966) examined a linear motor response in which the basic variables were length of retention intervals and number of reinforcements or trials before recall. Absolute error was found to be positively related to length of retention interval, and consequently Adams and Dijkstra interpreted their results in terms of rapidly decaying memory trace which became increasingly stable with reinforcement. Adams and Dijkstra (1966) also reported negative algebraic error scores in their study which is consistant with the data of Posner (1967), and Williams, Beaver, Spence, and Rundell (1969). Adams and Dijkstra (1966) found that with increasing retention time algebraic error became increasingly negative and its variance increased.

Stelmach (1969), using a simple lever-positioning task, employed the three independent variables of magnitude of movement, retention interval, and number of prior positioning responses. Absolute error was found to be positively related to the number of prior positioning responses and to the length of the retention interval, but the magnitude of the movement was found to be non-significant. He considered the role of proactive interference in his results but seemed to favor the decay of the memory traces as the best explanation. Stelmach (1969) had a well designed study in which he had an opportunity to distinguish between these two theories, but after having found that number of prior positioning responses and length of retention interval were significant, and with more than two levels of each factor, he did not test the simple effects in order to find which levels within each of the significant main effects were significantly different from each other.

Pepper and Herman (1970) performed a series of five experiments measuring the retention of the magnitude of the force of a knob which was pushed or pulled through the vertical dimension in an attempt to establish whether decay, interference or a combination of the two was the cause of the forgetting shown in motor STM. Their results consistently showed an overshooting which is in contrast to Adams and Dijkstra (1966) Posner (1967), and Williams et al. (1969) who consistently showed undershooting. Pepper and Herman (1970) reported decreasing recall errors as retention intervals increased.

Pepper and Herman (1970), by the application of a second force response during the retention interval, showed that interference effects, traceable to the interpolated task, can be demonstrated for motor STM. Interpolated forces greater in magnitude than the criterion force produced significantly greater recall forces than did interpolated forces of smaller magnitude than the criterion force. The main effect of relative direction of the criterion and interpolated forces was not statistically significant thus showing that interference as a function of the directional similarity of the interpolated task to the criterion task was negligble . These results are in agreement with the results of Blick and Bilodeau (1963) who, using an arc-drawing task, found no significant differences as a function of whether the interpolated task was an arc drawn in the same or in the opposite direction to the original arc. Pepper and Herman (1970) also found that repetitions of the same force response resulted in poorer recall performance which is in contrast to Adams and Dijkstra (1966) who found repetitions yielded improved recall performance. In summary, Pepper and Herman (1970) suggested a two-process theory of motor STM incorporating both decay and interference effects.

Because of previous confounded designs and conflicting results, the role of trace decay and interference theory in the area of motor STM is nebulous. It was the purpose of the present experiment to establish precisely the role of trace decay theory and/or interference theory in motor STM.

METHOD

Subjects. 105 undergraduates from the University of Richmond participated in the experiment. Fifteen males and 20 females were in each of the three groups. All were drawn on a voluntary basis from four introductory psychology classes. The overall experimental design is presented in Table 1.

Insert Table 1 about here

Apparatus. The apparatus was a block of wood five cm. high, seven cm. wide, and 68 cm. long, with a groove two cm. wide cut down the length of the board in the center of the seven cm. side. A slide which measured 2.5 cm. long and slightly less than two cm. wide fit snugly in the groove and had a knob on the top which enabled the S to move the slide in the groove. Another slide, used as a stop by the E was put in the groove during the practice trials and removed during the recall trials.

Procedure. All Ss came into the experimental room and were seated across the table from the E. While looking at the apparatus, they were read the following instructions: "This is an experiment in memory. Your

Table 1

Overall Experimental Design

Number of Prior Responses	Retention Intervals: 5 sec.	40 sec.	75 sec.	
0				
1				
2				
3				
4				
5				
6				
	n = 35	n = 35	n = 35	N = 105

task will be to remember and duplicate as well as possible a series of movements along a straight line which you will make on this slide type of apparatus. This small block of wood slides in the groove. (The E demonstrated how the slide worked.) The metal knob on top of the slide is used to move it. You will be blindfolded throughout the entire experiment. The starting position will always be on your right just as it is now, and when I give the instruction 'move' grasp the knob and move the slide from right to left until you hit a stop. You will then hold the slide in that position for approximately three seconds until I give you the instruction 'return' at which time you will return the slide to the starting position."

At this point the retention interval of five seconds, 40 seconds, or 75 seconds began. In addition, the instructions differed for the three retention intervals. The five-second group was told the following: "You will leave your hand on the slide and when I give the instruction 'estimate', you will attempt to duplicate your previous response by returning the slide to the same position that you were guided to by the stop."

The 40-second and 75-second groups were given the following instructions: "You will leave your hand on the knob, but you may rest your arm on the desk. When I give the instruction 'estimate', you will then attempt to duplicate your previous response by returning the slide to the same position that you were guided to by the stop."

All groups were then given the latter part of the instructions: "Your response is to be one continuous movement. You are not allowed to move the slide back and forth. The speed that you move the slide is up to you. After you have attempted to duplicate your response, remove your hand from the slide. At this time there will be a rest. I will place the slide back at the starting position and you will be ready for another trial. There will be several different trials. Are there any questions at this time? If so please ask them because I do not want you to be uncertain about the procedure."

After the instructions had been read to the S and any questions answered, the S was blindfolded. He grasped the knob on top of the slide and on the instruction "move", he moved the slide until he hit a stop. The S's hand remained in this position for three seconds. On the instruction "return", he returned the slide to the starting position which was at the end of the groove at the S's right. A permanent stop was located there, to stop the slide when the S had moved it back to the starting position.

There were seven different lengths of movements which the Ss made. The lengths were 10 cm., 14 cm., 18 cm., 22 cm., 26 cm., 30 cm., and 34 cm. The lengths were presented in seven different randomized sequences with each length appearing in each position once in order to prevent any sequential effect from smaller to larger lengths or vice versa. The seven orders of the seven lengths are presented in the matrix in Table 2. In

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Insert Table 2 about here

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addition, the seven randomized sequences occurred equally often under each time interval with five Ss serving in each sequence.

After the S moved back to the starting position, the E started timing the retention interval of either five sec., 40 sec., or 75 sec. At the end of this period, the E gave the instruction "estimate", at which time the S attempted to duplicate his response. After the S had made the continuous movement, he removed his hand from the slide and the E started timing the intertrial interval of 20 sec. During the intertrial interval the E recorded the length of the S's response. After E recorded the response, he moved the slide back to the starting position and told the S to put his hand on the slide and prepare for another trial. The order of events within a single trial are presented in Table 3.

Insert Table 3 about here

During all of the response movements, the S held his arm off the desk and his hand touched only the slide.

Table 2

Order of Randomized Sequences

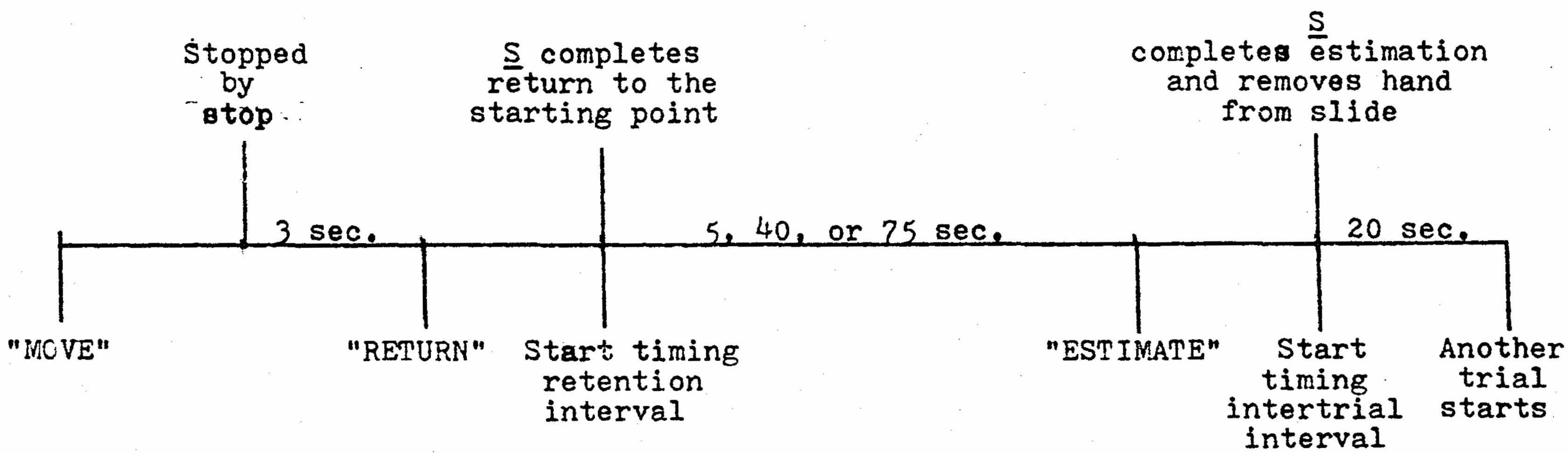
of the Seven Lengths of Lines (in cm.)

		Sequence Number						
		1	2	3	4	5	6	7
	0	10	22	18	30	14	26	34
	1	14	26	10	22	18	34	30
Prior	2	30	34	26	14	22	10	18
Responses	3	34	18	14	26	10	30	22
	4	18	30	22	10	34	14	26
	5	26	14	34	18	30	22	10
	6	22	10	30	34	26	18	14

Table 3

Schematic Presentation of Order of Events

Within a Single Trial



The Ss received no cues from sliding their hand along the block of wood or their arm on the desk. The only time that the Ss' arms were allowed to touch the desk were during the 40 sec. and 75 sec. retention intervals. The Ss positioned their chair in order that they were a comfortable distance from the apparatus.

RESULTS

Recall scores for each S were calculated as the absolute error in millimeters from perfect target reproduction. A plot of the mean absolute errors for each of the seven prior response conditions at the three retention intervals is shown in Fig. 1. Each point on the graph represents the mean error for 35 Ss.

Insert Figure 1 about here

The mean absolute error at recall for each of the retention intervals at each of the seven prior response conditions is shown in Fig. 2. Each point on the graph represents the mean error for 35 Ss.

Insert Figure 2 about here

The mean algebraic error, taking into account whether the S undershot or overshot the target, at recall for each of the retention intervals at each of the seven prior response conditions is shown in Fig. 3. Each point on the graph represents the mean error for 35 Ss.

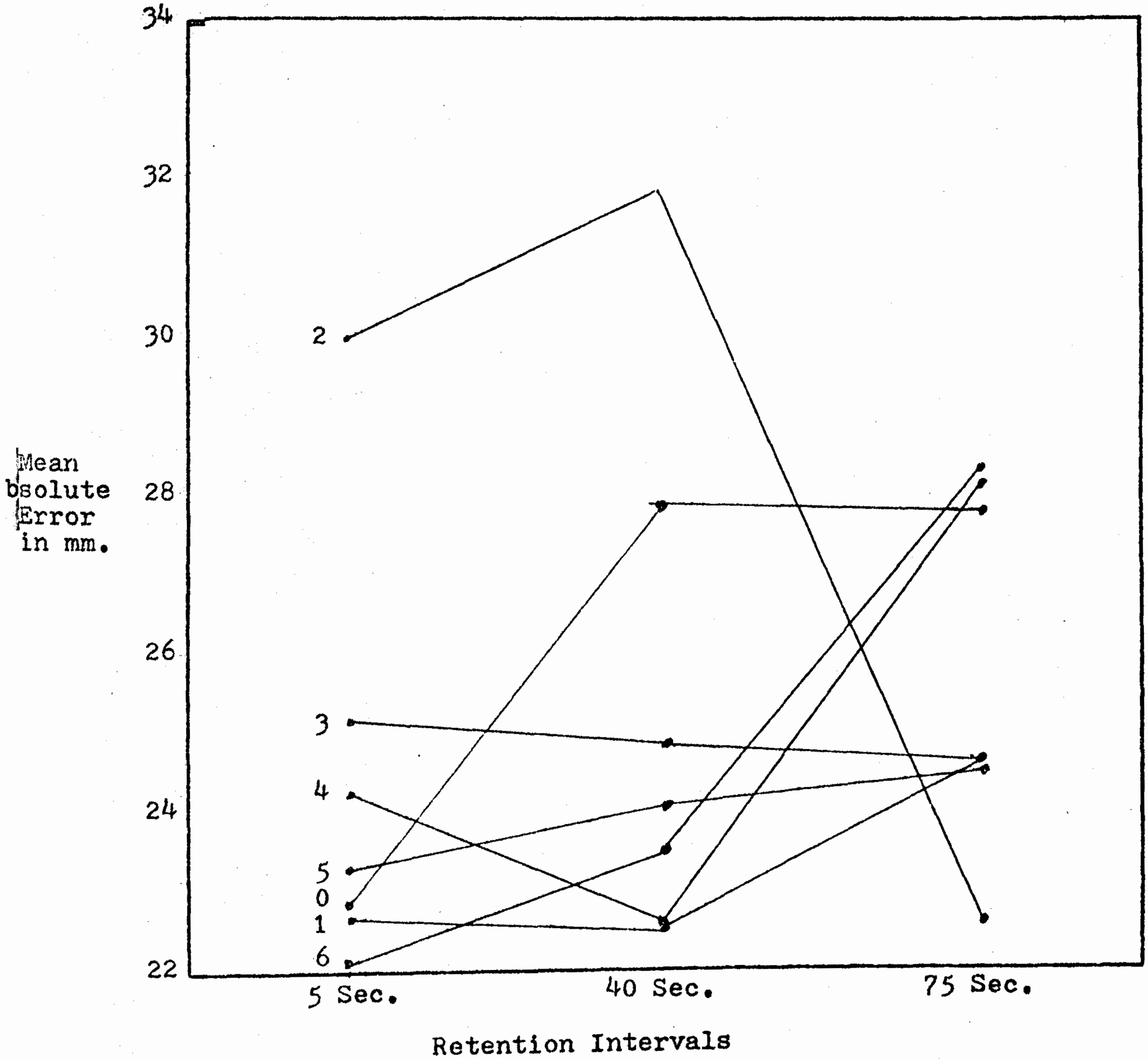


Fig. 1. Mean absolute error of the seven prior response conditions at the three retention intervals.

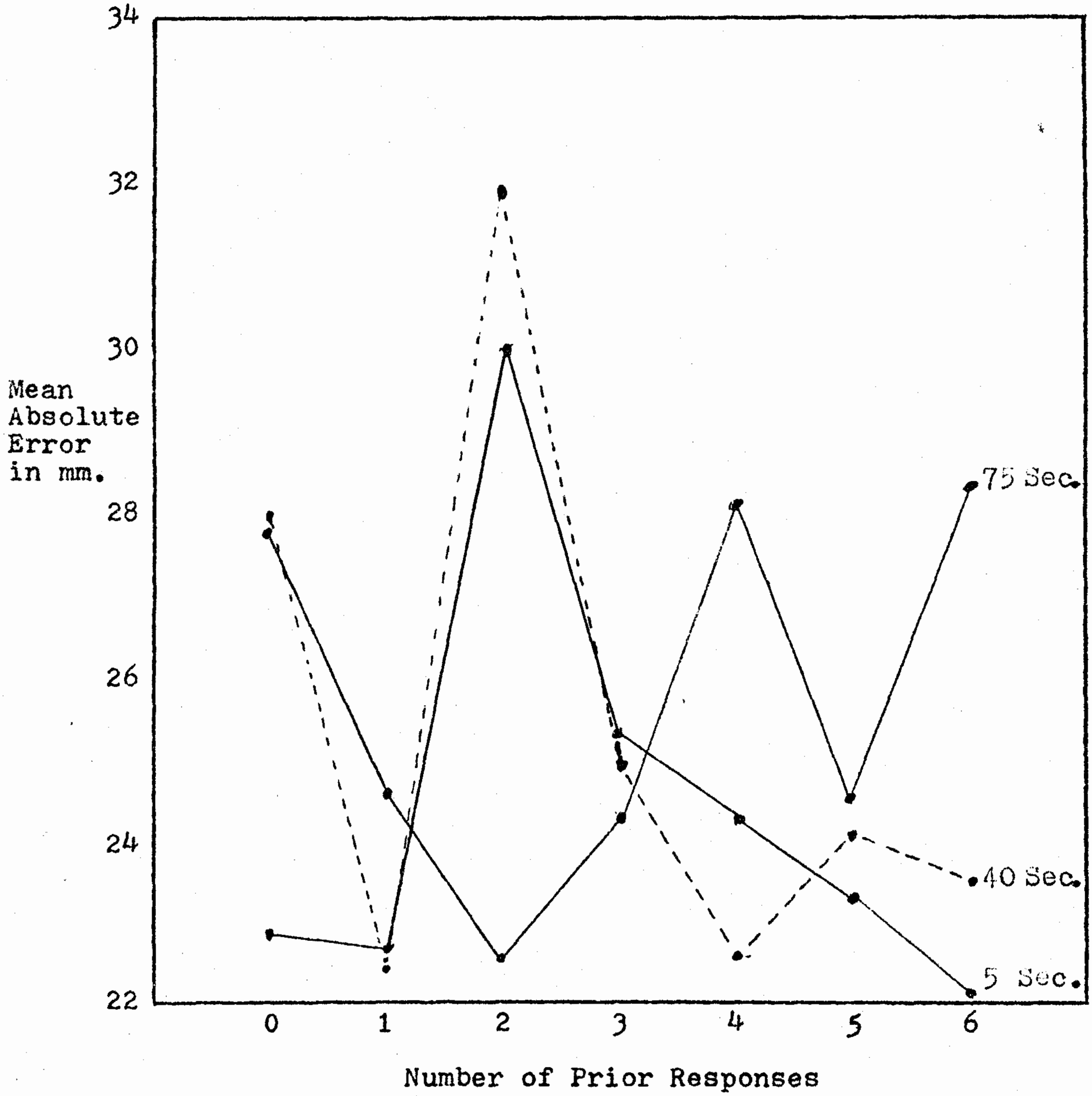


Fig. 2. Mean absolute error of the three retention intervals at the seven prior response conditions

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Insert Figure 3 about here

There do not seem to be any discernible trends in either of the figures according to visual inspection.

A two-factor analysis of variance with repeated measures on the second factor was performed on the data, and the analysis of variance summary table is presented in Table 4. Neither retention interval

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Insert Table 4 about here

$F(2,102) < 1$, nor number of previous responses $F(6,612) < 1$ were significant. The interaction of retention interval and number of previous responses was also non-significant $F(12,612) < 1$.

Pearson Product-Moment correlation coefficients were also computed between all recall responses within each retention interval for the 35 *S*s. The intercorrelational matrices are presented in Tables 5, 6, and 7. A value of

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Insert Tables 5, 6, and 7 about here

.32 is required for significance at the .05 level. Four correlations from a total of 63 were significant; however, it is possible that these significant correlations are the result of a Type I error due to the large number

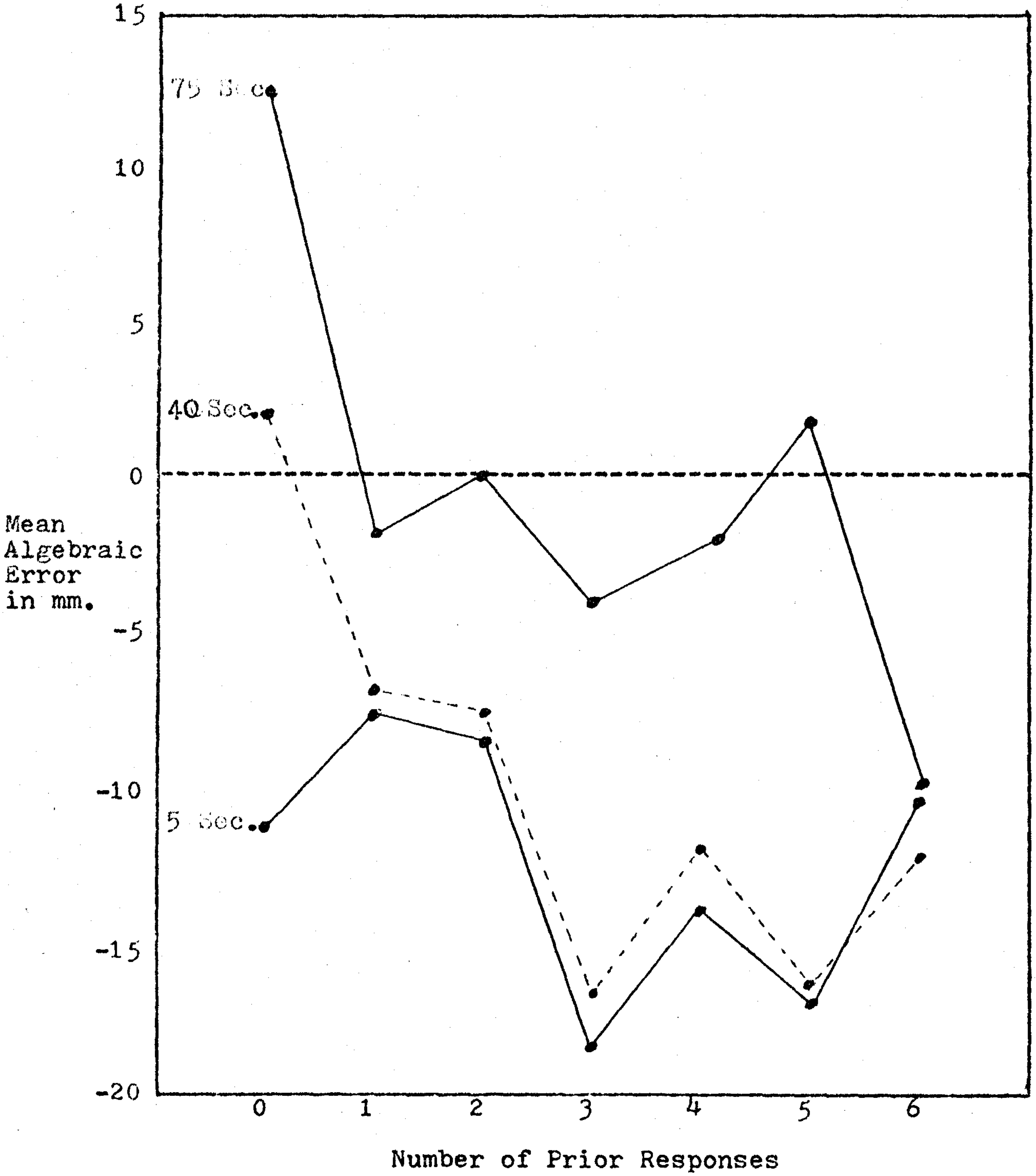

Fig. 3. Mean algebraic error of the three retention intervals at the seven prior response conditions

Table 4

Overall ANOV Summary Table

Source of Variation	df	MS	F
Between Subjects	104		
Retention Interval (I)	2	122.85	.24
Subj. w/in gps.,	102	521.21	
Within Subjects	630		
Number of Prior Responses (R)	6	273.08	.67
I X R	12	286.28	.70
R X Subj. w/in gps.	612	410.14	

Table 5

Pearson Product-Moment Intercorrelation Matrix of Mean Absolute Error for the Five-second Retention Interval

	Number of Prior Responses						
	0	1	2	3	4	5	6
0	X	.03	.16	.13	.07	.0005	.62*
1		X	.38*	.20	.06	.06	.27
2			X	.12	.25	.08	-.0027
3				X	.26	-.09	.41*
4					X	.16	.22
5						X	.21
6							X

$^{*}r_{.95} = .32$

Table 6

Pearson Product-Moment Intercorrelation Matrix of Mean Absolute Error for the 40-second Retention Interval

	Number of Prior Responses						
	0	1	2	3	4	5	6
0	X	.30	-.25	.12	.06	-.24	.04
1		X	-.08	.03	-.08	-.18	-.13
2			X	.09	.10	.34	.05
3				X	.0012	-.17	-.02
4					X	.57*	-.23
5						X	-.08
6							X

$*r_{.95} = .32$

Table 7

Pearson Product-Moment Intercorrelation Matrix of Mean Absolute Error for the 75-second Retention Interval

	Number of Prior Responses						
	0	1	2	3	4	5	6
0	X	.30	-.25	.12	.06	-.24	.04
1		X	-.08	.03	-.08	-.18	-.13
2			X	.09	.10	.34	.05
3				X	.0012	-.17	-.02
4					X	.57*	-.23
5						X	-.08
6							X

$^*r_{.95} = .32$

of correlations and to the relatively large alpha level (.05) chosen. There do not seem to be any discernible trends in either of the matrices according to visual inspection.

DISCUSSION

The idealized results are shown in Fig. 4. The

Insert Figure 4 about here

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unequivocal test of the trace decay theory is through analysis of the data received from the zero prior response condition. If the data from this group had shown no significant difference among any of the retention intervals and had given a line similar to case 1 in the figure, we could have then hypothesized that the data do not support the trace decay theory. Trace decay theory predicts that time along would cause forgetting, and if there were no more errors at the end of 70 sec. than at the end of five sec., it would have clearly demonstrated that time had no systematic effect on the number of errors. On the other hand, if there were some significant differences in the number of errors somewhere within the various retention intervals for the zero prior response condition, and if the plotted data had looked similar to case two, it would support the trace decay hypothesis. Time would have been the only cause of forgetting since there were no previous responses to produce interference. The only way to get results

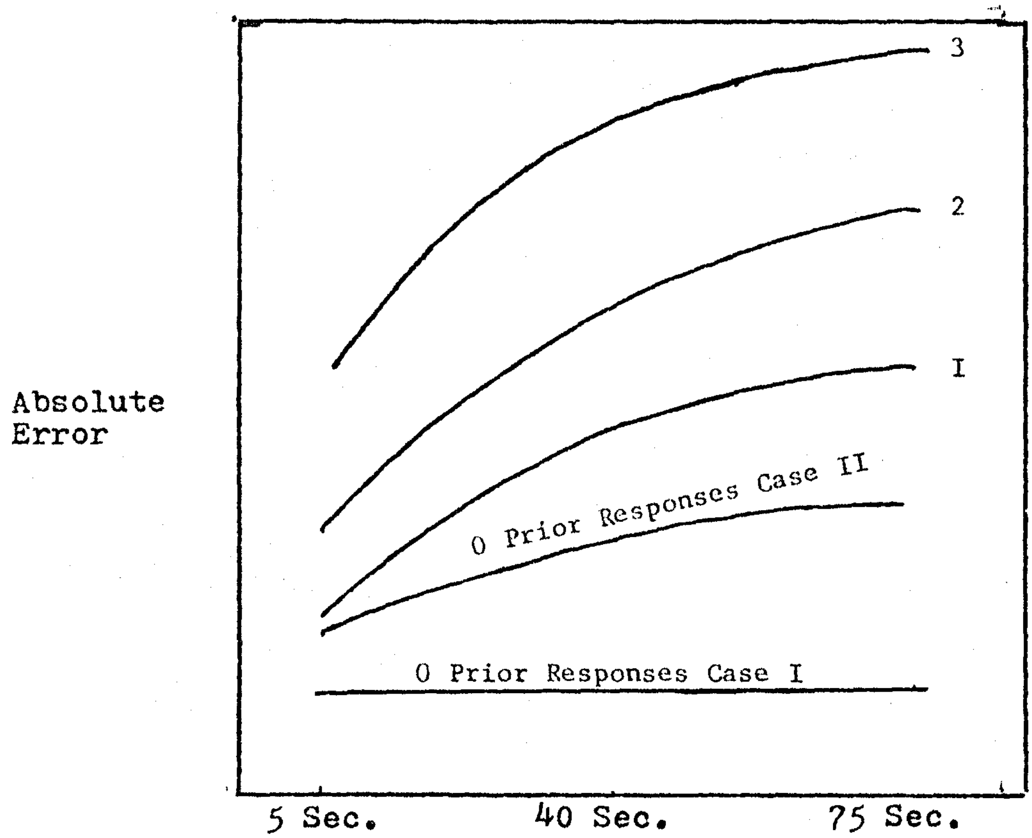

Fig. 4. Hypothetical data showing the expected relationship between retention interval and number of prior responses.

supporting the interference theory would be to have the lines of the various prior response conditions both horizontal and parallel. This would show that as you increase the number of prior responses, thus increasing interference, the absolute error would increase. Prior to the experiment it was predicted that the relationship between number of prior responses and retention interval would be similar to that shown in Fig. 4.

In Figs. 1 and 2 there do not appear to be any consistent results, because there is too much variation in both of the figures to draw any conclusions. However, Fig. 3 which displays algebraic error has one interesting phenomenon. The 75-sec. group, except for their first and last responses, flucturates closely around the point of zero algebraic error whereas the five and 40-sec. groups have a much greater negative algebraic error. The negative constant error is consistent with the data of Adams and Dijkstra (1966), Posner (1967), and Williams et al. (1969). These studies and the present one are in contrast to Pepper and Herman (1970) who found a consistent overshooting or positive algebraic error.

Brown, Knauft, and Rosenbaum (1948) point out that undershooting usually characterized movement distances exceeding approximately five centimeters, with distances smaller than this usually resulting in overshooting. Jenkins (1947), Bahrick and Nobel (1961), and Annett (1959) have studied force application tasks and found overshooting to characterize forces between approximately two and 20 pounds. Pepper and Herman (1970) used forces between two and ten pounds. Therefore, the observed overshooting of their Ss in the force application task and the undershooting of the Ss of Adams and Dijkstra (1966), Posner (1967), and Williams et al. (1969) in the positioning movement tasks is consistent with prior data.

The fact that in the present study the retention interval, which was a main factor, was not significant is also in contrast to the results of Pepper and Herman (1970). In their second experiment they not only found the main effect of the retention interval significant but that it was in the direction of decreasing errors as the retention interval lengthened.

Adams and Dijkstra (1966) found absolute error to be directly related to retention interval and consequently seemed to favor decay of the memory trace as the best explanation. Since Stelmach (1969) found length of retention interval and number of prior responses both significant he considered the role of both proactive interference and decay of the memory trace but favored decay of the memory trace. Since the results of both retention interval and number of prior responses in the present study were non-significant no conclusions can be drawn concerning the roles of proactive interference or decay of the memory trace on the basis of this study.

Pepper and Herman (1970) proposed on the basis of their results a two-process theory of motor STM which incorporated both decay and interference effects. In their theory, there is a weakening of the strength of the original trace due to the interference which occurs during the retention interval and also due to the passage of time.

The use of correlation coefficients in motor STM to find if there are any molar trends concerning repeated recalling is a new technique. Although this is not a practice task, one trend which Jones (1962) points out as a universal property of practice tasks is the superdiagonal form. The superdiagonal form is evidenced in a correlational matrix when the correlations in the superdiagonal are the highest and as one proceeds either up or to the right, the correlations decrease in magnitude. As with the other analyses in this paper, no conclusions can be drawn from the matrices of Pearson Product-Monent correlations. There do not appear to be any trends within either of the three matrices.

One reason why the results in the present study were non-significant could have been in the design of the apparatus. The variability in the recall scores for all of the various lengths were tremendous. Since Adams and Dijkstra (1966) used the same lengths and found retention interval significant, the design of the apparatus could have caused the variability.

Another reason could be the manner in which the previous responses were administered. Stelmach (1969) administered either two or four prior positioning responses immediately before the target position response. He then had the Ss recall the responses in reverse order of presentation but, unknown to the Ss he only recorded the target position response. The difference between Stelmach's study and the present one is that his prior positioning responses were not recalled until after the target position response whereas in the present study each response was recalled before another was administered. This could be the reason that interference was not shown in the present study. After a response was administered and recalled it could be dismissed by the Ss and he could concentrate on the next whereas in Stelmach's study the Ss had to retain either three or five responses at one time therefore this produced the interference that evidenced itself in his study.

Much more research is needed in the area of motor STM before any definite conclusions can be drawn. The proposal of the present E for future research is to attempt to produce interference in the same manner that Stelmach (1969) did in his study. By the use of Stelmach's method of producing interference and through the use of a well designed study, it is thought that some form of systematic forgetting will be evidenced.

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VITA

Stephen D. Southall, the author, was born October 30, 1945 in Richmond, Virginia. In 1949, he moved with his family to Deltaville, Virginia whereupon he completed his secondary education, graduating from Middlesex High School, Saluda, Virginia in 1964. In September of 1964 he entered the University of Richmond. While at the University of Richmond, the author accepted membership in Psi Chi Honorary Psychology Fraternity and Scabbard and Blade Honorary Military Fraternity. With a major in Psychology, he was awarded a B.A. degree in June 1968. The following September he was enrolled in the Graduate program at the University of Richmond where he was awarded an M.A. degree in June 1970. The author's future plans include earning his doctoral degree in experimental psychology and teaching at the college level.