CONCURRENT PROCESSING WITH METERED MEMORY SEARCH

By

Jim Dale Blagowsky

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Southwestern State College

Weatherford, Oklahoma

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PREFACE

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CHAPTER I

INTRODUCTION

The last two decades have shown a considerable amount of interest in the individual's capacity to engage in two different verbal activities at the same time. One assumption, held by many, has been that two verbal activities cannot be carried on simultaneously if either results in rapid verbal responses. The validity of this assumption has been questioned recently in an article by Peterson (1969). An implicit conclusion of the Peterson study is that concurrent processing of verbal activities is disrupted only if severe attentional demands are placed on the cognitive capacity by one or both of the activities.

The present investigation is designed to provide additional information on the capacity to engage in concurrent verbal activities whenever attentional demands of the verbal tasks are taken into consideration.

Review of the Literature

Much of the recent interest in concurrent processing of verbal materials stems from the so called shadowing experiments. The method of shadowing, originated by Cherry (1953) requires the individual to repeat a spoken message staying as "close behind" the passage as possible. In the initial experiments by Cherry (1953, 1954) the subject's task was to shadow a voice presented to one ear while another, unrelated message was presented to the other ear. Cherry found that the subjects could repeat back the primary (the shadowed message) passage, but could usually report nothing of the verbal content of the unattended ear. These results suggest that dichotic verbal stimuli cannot be processed simultaneously by the individual. Cherry felt that attention had to be switched from one ear to the other in order to process parts of both messages. He theorized that there is a circumscribed RT for attention and that during this interval no information can be processed. In the 1954 experiment, subjects were asked to shadow a message that was switched rapidly back and forth from one earphone to the other. This alternation did not interfere with shadowing if it was very rapid (20 times per second) or very slow (once every second), but it had a marked effect at intermediate rates.

Other investigators have replicated Cherry's procedure with minor variations (Moray, 1959; Treisman, 1960) and obtained substantially the same results. When two messages are presented, each from a different source, subjects can repeat one back very efficiently, but can usually report nothing about the verbal content of the other apart from a few highly important or relevant words. If the subject is specifically asked to recall single target words presented to one ear, his ability to repeat the words presented to the other ear is totally disrupted at the times when the target word occurs (Mowbray, 1964).

Broadbent (1954) conducted a study aimed at shedding further light on the results of the shadowing experiments. This experiment produced results which could not easily be reconciled with Cherry's interpretations. Contrary to that implied on the basis of Cherry's interpretation, selectivity is not based on the ear at which the message arrives, but on the perceived location of the sound source. The same critical rate of interruption appears even when a single ear is involved.

Broadbent (1958) proposed that there is a filter which selects a message on the basis of characteristics toward which it has been biased and allows this message alone to proceed to the central analyzing mechanisms. In this way, messages with other characteristics are excluded and the total amount of discrimination which has to be performed by the nervous system is greatly reduced. Thus, whole complex messages can be rejected on the sole basis of possessing some simple quality, and no further analysis of them would need occur.

However, there have been a number of studies which point out that often the selection of wanted from unwanted speech can be performed on the basis of highly complex characteristics. Peters (Deutsch and Deutsch, 1963) found that if an unwanted message is similar in content to the wanted one, it produces more interference in receiving the latter than if it is dissimilar to it. This seems to indicate that the content of the two messages is analyzed prior to the acceptance of one and rejection of the other. Gray and Wedderburn (1960) found that when speech was delivered to subjects in both ears simultaneously, so that a meaningful sequence could be formed by choosing syllables or words alternately from one ear, the subjects produced the meaningful sequence rather than simply the series of words or syllables presented to one ear or the other. In a study by Moray (1959), it was found that if a subject is listening selectively to one channel and ignoring the other, calling his name on the non-attended channel will on a certain number of instances cause him to switch his attention to this channel.

Deutsch and Deutsch (1963) have adopted a somewhat different view about where the limiting (serial) factor lies. They have suggested a model that places the limit in capacity for perceiving speech in the response side of the brain's central communication channel. They prefer the explanation that all stimulus inputs are fully analyzed and that selection is made only to determine responses and memory.

Treisman and Geffen (1967) conducted an experiment directed at resolving the controversy about where the limitation exists in selective attention. To test the extent to which attention is a feature of perception rather than of response, they compared the same response made to both the attended and the unattended message. In an attempt to establish the degree to which this limit lies on the response side, they investigated how much interference a second response to the same stimulus caused in the performance of a primary response. They combined these two problems in a single paradigm by presenting two messages and requiring two responses, one of each being given priority by the instructions. The primary message and response were chosen to occupy most of the limited capacity available to the subject. The primary response was made to the primary message only and the other response to both messages. Thus subjects were given two dichotic messages, one primary and one secondary, and had to make two different responses: the primary response was to shadow the primary message; the secondary response was to tap upon hearing certain target words in either message. The authors felt that since the secondary response was identical for the two messages, any difference in its efficiency between the two messages must be due to a failure in perception of the secondary message. Any interference between the primary and secondary responses (repeating and tapping) to target words in the primary message must be due to a limit in performing simultaneous responses, since if either was correctly performed the target word must have been perceived. The authors interpreted the results as clearly showing that the primary limit is perceptual.

A further, somewhat different approach toward the problem of parallel and sequential processing has been put forth by Moray (1967). His model suggests that the limitations on processing information by the human operator is not because he acts as a limited capacity channel with fixed capacity, but as a limited capacity processor. Moray states:

> The total capacity of the brain can be allocated to the separate aspects of the tasks, such as reception, recoding, emission, storing, etc. (Moray, 1967, p. 84.)

Simultaneous processing is possible where the total capacity is not exceeded, and where there is high compatibility. A model of this nature accounts very nicely for the results of another study (Moray and Jordon, 1966) performed to investigate a highly compatible two channel task.

The experiment was a variant on a study that Broadbent (1954) emphasized in establishing his model. Broadbent presented three pairs of digits to a subject. Each pair was presented simultaneously to the two ears. At presentation rates greater than one pair every 1-1/2 seconds, subjects could only recall the messages ear by ear, not alternating between the ears. As mentioned earlier in this section, Broadbent theorized that if parallel inputs arrived faster than the switch could operate, then one message must be held up, and the messages passed sequentially through the system. In their 1966 experiment, however, Moray and Jordan obtained different results by providing the subjects with a means of parallel output matching the parallel inputs. They presented three pairs of digits in the same way as Broadbent (1954), however, in this case subjects typed their responses on a keyboard in which two keys could be pressed simultaneously. Ten keys were provided so that the subjects could type out the left ear message with their left hands, and the right ear message with their right hands. The results indicated that subjects could engage in dual processing to a greater extent than when forced to use sequential modes of response.

In addition, there is other evidence that two verbal tasks can be processed at the same time. Paulhan, an early psychologist, reported that he could recite a poem and multiply at the same time (Woodworth and Schlosberg, 1954, p. 88). Further, there are the obvious instances of virtually simultaneous translation of one language into another (Treisman, 1965). It seems that the overall capacity of the processor is limited, but the brain can divide up this capacity and use it to best advantage according to the task or tasks at hand.

In a more recent article, Peterson (1969) adopts a similar conception couched in terms of the attentional demands that various verbal tasks require. He identifies three levels of tasks, each requiring differences in attention, and suggests that the capacity of an individual to engage in two independent verbal activities at the same time is a function of the attention required by the tasks. He also places a considerable emphasis on practice, implying that more attention is required for a newly organized activity than for an overtrained skill.

Peterson (1969) categorizes the simplest type of activity such as counting and the reciting of the alphabet as emissive activity. Such tasks are seen as requiring very little attention for the adult. A second level of attention is postulated for activities dependent on uncertain external events for which production is required. An example of this kind of activity might be the shadowing experiments in which direct correspondence between input and output is required. A third level of attention is suggested for activities which require some type of transformation of the input prior to the output, so that more than the simple reproduction of the second level is required. Examples of such activities are arithmetic computation, problem solving, etc.

Peterson investigated the subject's efficiency in performing two concurrent verbal activities with the above categories. In one case, the subject's task was to solve anagrams (a transformational task) while concurrently engaging in one of the following activities: counting (emissive), shadowing (reproductive), or addition (transformational). It was found that when an emissive activity was combined with anagram solution, both could be maintained with a minimal loss of efficiency indicating that actual simultaneous processing occurred. When reproductive or transformational activities were combined with anagram solution, however, performance as measured in terms of facility at anagram solution suffered in direct relation to position in the hierarchy. While Peterson's results from combining different tasks are probably generally correct, there are some problems of control. For example, changes in task level are confounded in many cases by simultaneous variation in stimulus and response complexity. The present experiment makes use of Peterson's categories but the metered memory search task used here holds constant stimulus-response complexity. Moreover the present study draws closely from Moray's (1967) conception of fixed cognitive capacity interchangeable for various kinds of cognitive functions.

Statement of the Problem

The purpose of this experiment was to investigate the extent to which subsidiary activities disrupt the performance of primary activities. It was thought that this could be best accomplished by adopting as the primary task a serial search procedure developed by Weber, Cross, and Carlton (1968). This task was originally developed as a procedure for measuring search time for a rule-specified target and thus has been labeled metered memory search. This procedure is perhaps best explained by summarizing the 1968 study by Weber et al. In this experiment, stimuli were presented and the target was rule-defined as a transformation a specified number of steps away from the stimulus. A transformation had the meaning of a change of the input prior to the output, so that more than simple reproduction of the stimuli was generally required. Transformation of various sizes were applied to the separate stimulus items of a circular sequency. The result of a transformation was a target or terminal response, also in the sequency, a given distance away from the starting state. The steps required in going from the starting stimulus to the terminal response were said to be searched through. By varying the size of the transformation it was possible to vary the amount of search required and assess the rate at which it took place.

In addition, a further study (Weber and Blagowsky, 1969) was conducted in order to gain a better understanding of these search processes. The primary purpose of the study was to compare the effects of implicit and explicit scanning on search time. Explicit scanning required overt verbalization while implicit scanning probably required implicit speech since the two scanning rates were approximately the same (Landover, 1962; Weber and Bach, 1969). It was therefore concluded that internal speech forms the basis for the search process. It was further concluded that the speech process apparently operates such that sequency items, starting with the stimulus, are generated one at a time until an appropriate meter reading is reached (corresponding to required size of transformation). At this time, the subject overtly responds with the last item generated. Thus, this would be a serial, self terminating, metered search process in which successive items are not just scanned from memory, but actually generated.

Hence, it would appear that if actual item generation is involved -- as in inner speech -- then the metered memory search tasks would be an almost completely objective method for the study of implicit speech processes. Therefore, it should provide an ideal tool for the study of concurrent verbal activity. It would allow the subject to perform overtly a verbal subsidiary activity and at the same time implicitly perform the transformations previously discussed. Both the procedure of present experiment and that utilized by Peterson (1969) involve an indirect measurement paradigm that has been delineated by Brown and Poulton (1961). That is, the relative cognitive load required to engage in a specific activity may be measured indirectly by assessing the decrement in performance on an auxilliary task performed concurrently with the above task relative to that of the auxilliary task performed alone.

The success of such a method, of course, depends both on the clearcut understanding of the cognitive operations involved in the task and a means of quantification. In the present study, the differing levels of the transformational task can be readily quantified based on the size of transformation, and corresponding response time. Therefore, it is possible to obtain a measurement of complexity. However, in the use of anagrams (Peterson, 1969) there is no simple way of knowing a priori just how task difficulty varies such that it could be readily quantified.

It was therefore believed to be advantageous to investigate the effects that a subsidiary emissive task (chanting) has on the performance of an easily quantified primary task (performance of transformations). A further question sought to determine if response modality (verbal or written) of the respective tasks influence performance. The chant and modality main effects and some of the interactions were expected to be of extreme interest. In particular, would the two chant sequences (letters and numbers) differ in their effects on the performance of transformation and would one or both of the chant sequences have differing effects on the performance of transformations at various sizes? It was also the intent of the study to note practice effects and to investigate the extent to which the chant effects increased the transformational RTs.

Six hypotheses were put forth: (1) The simultaneous performance of a subsidiary task (chanting) will decrease performance on the primary task (performing transformations). (2) Performance of letter chants will decrease performance on the primary task to a greater extent than the performance of number chants because of class similarity. (3) Chants will have a more marked effect when transformation sizes 1 and 2 are considered than at the _0_ level since less memory space is required at the _0_ level. (4) Concurrent processing of chants and transformations will improve with practice. (5) The RTs for the chant sequences and transformations will not be strictly additive whenever the two are performed simultaneously. (6) The modality, verbal or written, in which chants and transformations are performed will have little effect on their respective RTs.

CHAPTER II

METHOD

Subjects

The subjects were all right-handed and wives of graduate students at Oklahoma State University. They received $1.50 for each hour of participation. There were 8 Ss, 4 for each between-S condition. One additional S was discarded at an early stage of training because she was left-handed and it was difficult for her to write a response without covering the adjacent stimulus item.

Experimental Design

The design had one between-Ss factor at two levels (modality--write transformations and speak chants or speak transformation and write chants), and two within-Ss factors both at three levels (transformation size--0, 1, or 2 units) and (chant sequence--no chant, number chant, and letter chant). Four subjects were randomly assigned to each modality group.

Materials and Procedure

The same circular sequence of letters was used for all of the Ss in making their transformations. It consisted of the first five letters of the alphabet, (a, b, c, d, e; a, b, . . .). Besides the no chant (OC), Ss chanted either number (N) or letters (L). The N chant was the first five digits (1, 2, 3, 4, 5; 1, 2 . . .) and the L chant was the first five letters of the alphabet, but in reversed order (e, d, c, b, a; e, d . . .).

There were nine conditions for both the write transformations-speak chants (WT-SC) group and the speak transformations-write chants (ST-WC) group. The nine conditions and their appropriate responses are illustrated in Table I.

TABLE I

APPROPRIATE RESPONSES FOR THE VARIOUS CONDITIONS

	O Chant			N Chant			L Chant		
Stimuli	T Size			T Size			T Size		
	0	1	2	0	1	2	0	1	2
b	b	c	d	b1	c1	d1	be	ce	de
d	d	e	a	d2	e2	a2	dd	ed	ad
e	e	a	b	e3	a3	b3	ec	ac	bc
a	a	b	c	a4	b4	c4	ab	bb	cb
c	c	d	e	c5	d5	a5	ca	da	ea

In the case of the WT-SC group, the characters not underlined represent the written responses and those underlined represent the spoken responses. For the ST-WC group, the characters not underlined represent the spoken responses and those underlined represent the written responses.

In the case of where transformations (T) are performed with O chant only the terminal response corresponding to the required size of T was verbalized or written by the S. In the case where trials required both Ts and chants, the S was instructed to synchronize the chant response with the T response. For example, if he was in the ST-WC group, he would speak the terminal response and, at the same time, write the chant.

As an example, consider the top row to illustrate the Ss tasks for a 2-unit T. If he was in the ST-WC group then a 2-unit T with O chant would just involve S saying aloud "d". If the condition involved a 2-unit T and N chant, her response would be to speak "d" and simultaneously write "1". In the instance of a 2-unit T and L chant, the S would speak "d" and simultaneously write "e". The Ss in the WR-SC performed in the same manner except they were to write the Ts and speak the chants in all cases.

The experiment began with the presentation of a $4\frac{1}{2}$x11 inch sheet of paper with a column of fifteen typed, lower case letters. The letters a, b, c, d, and e occurred in internally randomized blocks of five. In a space beside each letter the S wrote in her normal script handwriting the appropriate T or chant character depending on which group she was in. The Ss either read or wrote their responses from the top to the bottom of the 15-letter page. She was instructed to go as rapidly as she could, but that she should not make more than two or three errors on the 15-line page. By allowing for a fairly high error rate it was hoped that Ss would emphasize speed and that the nature of the errors might reveal additional information on dual processing.

Each S was run over a six-day period. The first day consisted of instructions and three blocks of practice. On the first day, all Ss were told that the object of the experiment was to see how quickly they could process certain kinds of information. Each S was shown a 3 x 5 inch card with the letters a, b, . . . e shown in a circular sequence. They were told to note that it was a circular sequence, and that for any letter shown to them, it should be possible for them to provide without hesitation the next letter in the sequence. Examples were then given for each of the five letters. The circular sequence was then placed so that it could be viewed by the Ss for the entire experiment.

Next the S was presented 3 x 5 inch cards with either a 0, 1, or 2 on them, signifying size of transformation. Those Ss in the ST-WC group were instructed to speak the Ts, and those in the WT-SC group were told to write the Ts. Each S performed fifteen such Ts after each of these three cards was presented.

Three other 3 x 5 inch cards were also presented to all Ss. They contained the word "NONE" or the numbers 1, 2, 3, 4, 5 or the letters e, d, c, b, a on them. Ss were instructed to either speak or write the chants three times in rapid succession (corresponding to the fifteen lines of the column). Hence, the number of chant items and the number of items to be transformed were equal.

Then each S was presented the cards in combinations. The Ss were shown the chant cards and after about two seconds they were shown the card with the required T on it. The E demonstrated a 0 size T and N chant, and a 0 size T and L chant for each S, stressing that they were to synchronize their verbal and written responses. This was easily done by all Ss.

After presentation of instruction, each S received three blocks of trials for practice. These were given to insure that the S understood what each of the nine conditions required and to encourage the S to synchronize her responses. A block of trials consisted of a booklet of nine pages.

The experiment proper consisted of fifty blocks for each S over an additional five-day period. Ten blocks were presented each day for five consecutive days (with few exceptions). The nine conditions were randomized for each block so that each S had a different order than other Ss in each block. A restriction on randomization was that the same condition could not appear at both the end of one block and at the beginning of the next block. Each S also performed the chant sequences alone at the beginning and end of each day for the last five days. The S went through each chant sequence three times.

A trial of fifteen Ts started with the 3 x 5 card(s) depicting the condition, the E saying "start" and ended with the S saying "stop". The time interval between "start" and "stop" constituted the response time for a trial (RT). RT was recorded on a stopwatch, and verbal errors were recorded on a tape recorder. The entire session comprised about fifty or sixty minutes each session for the six sessions. Between each block of nine pages there was an approximate 30-second rest period. Between pages within a block there was a period of about 10 seconds while the E recorded RT on a prepared sheet.

CHAPTER III

RESULTS

Descriptive statistics for RT as a function of modality, transformation size, and chant sequence are presented in Table II. Mean RTs were determined by averaging over number of trials and number of Ss.

First, consider the RTs for the chant sequences performed alone. Reference to Figure 1 indicates that very little difference existed in the performance of the number chant alone as opposed to the letter chant alone. This was confirmed by statistical tests. The difference between mean RT for L chant and N chant were tested for both groups with the t-test. The t values were 1.00 and .61 for the WT-SC and ST-WC groups respectively. Neither of these values exceeded the required t value at the .05 level with three d.f.

Figure 1 and Table II indicate that modality, size of transformation, and chant sequence proved to be effective variables. Significance tests for the means of Table II confirmed this. The main analysis (Table III) was an analysis-of-variance performed on the mean RTs for each S at each condition. The main effects for modality, transformation size, and chant sequence were significant ($p < .005$). It is apparent from Table II that RTs differed substantially for the two modality groups. More striking is the effect that transformation size had on RT. It is clear that RT increased as transformation size increased. Table II also demonstrated that chant sequences had a very pronounced effect on RT with decreased performance as the chant condition changed from O chant to N chant, and to L chant.

TABLE II

RT DESCRIPTIVE STATISTICS AS A FUNCTION OF MODALITY, TRANSFORMATION SIZE, AND CHANT SEQUENCE AVERAGED OVER TRIALS AND SUBJECTS

WT-SC

Cond.	0	1	2	0N	1N	2N	0L	1L	2L	NC Alone	LC Alone
Mean[a]	7.26	9.72	11.94	7.75	10.48	12.63	7.94	11.52	13.20	2.59	2.51
S.E.M.	.76	.36	.51	.87	.81	.85	.88	.86	.74	.25	.18

ST-WC

Cond.	0	1	2	0N	1N	2N	0L	1L	2L	NC Alone	LC Alone
Mean	5.15	8.26	11.29	9.40	13.21	15.82	12.65	17.97	20.62	7.87	7.84
S.E.M.	.33	.34	.88	.76	.42	.94	.75	1.61	1.11	.35	.48

[a]Means determined by averaging over number of Ss (N = 4 for each group) and number of trials (50 trials).

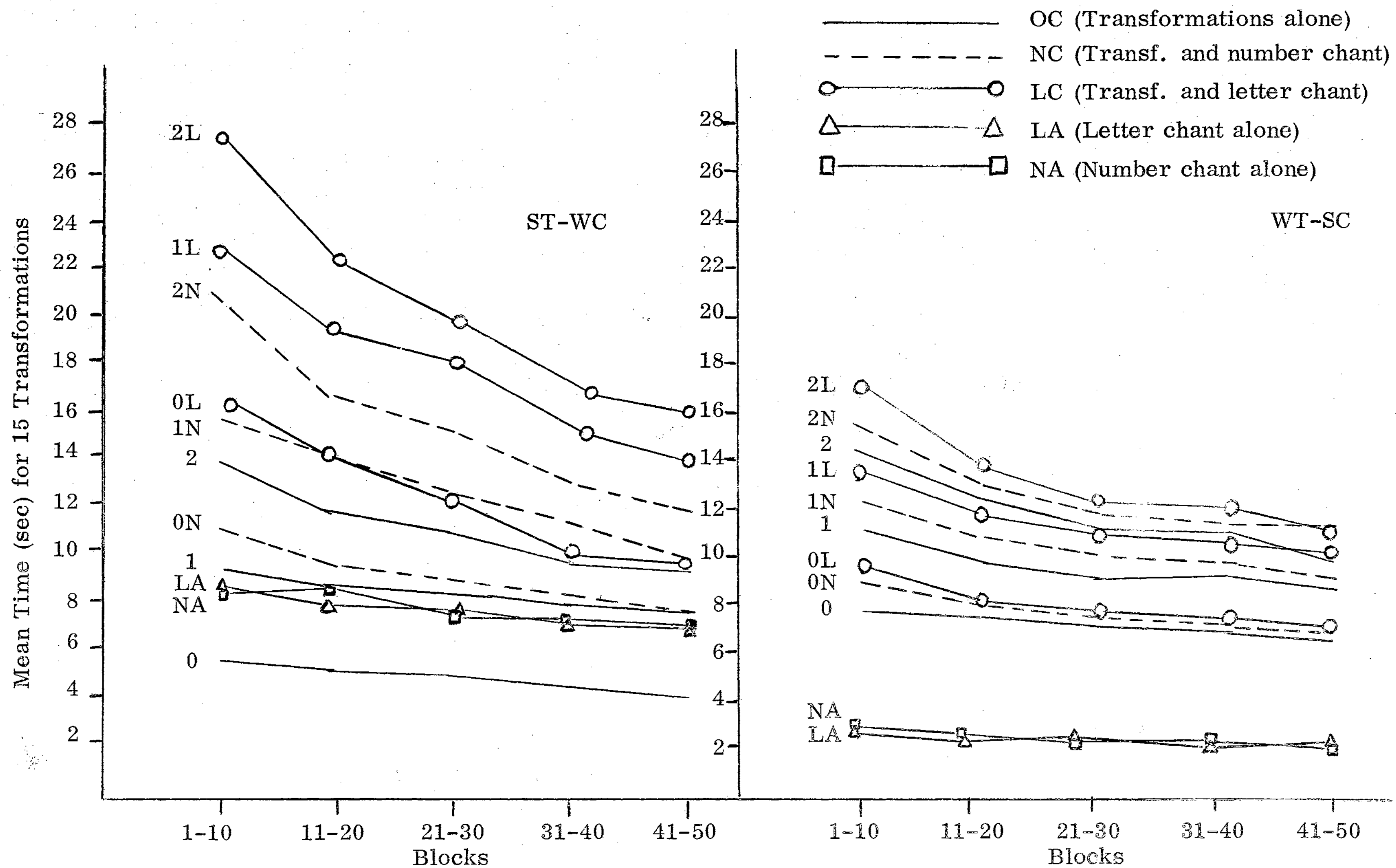

Figure 1. RT Shown as a Function of Modality, Transformation Size, Chant Sequence, and Trials

TABLE III

ANALYSIS-OF-VARIANCE FOR TABLE II MEANS

Source	df	SS	MS	F
Total	71	1065.38		
Between Ss	7	129.38		
Modality	1	110.33	110.33	34.75 ($p < .005$)
Ss w. group	6	19.05	3.17	
Within Ss	64	935.99		
Transformations	2	422.63	211.31	219.80 ($p < .005$)
M x T	2	11.33	5.66	5.89 ($p < .025$)
T x Ss w. group	12	11.53	.96	
Chant	2	298.30	149.15	116.30 ($p < .005$)
M x C	2	167.90	83.95	65.46 ($p < .005$)
C x Ss w. group	12	15.38	1.28	
T x C	4	5.53	1.38	14.01 ($p < .005$)
M x T x C	4	.99	.24	2.52
T x C x Ss w. group	24	22.36	.09	

Comparisons reported in Table IV were made among the subgroup means of transformation size and chant sequence by the Neuman-Kuels procedure (Winer, 1962). All comparisons on levels of transformation size and chant conditions were significantly different ($p < .01$).

Figure 2 is presented for two reasons. It clearly illustrates that RT increased monotonically as transformation size increased for both modality groups. Secondly, it helps clarify the simple interactions that were significant in Table III. As suggested by Figures 1 and 2, the modality by transformation interaction in Table III was significant ($p < .025$). RT as a function of transformation size differed for the two modalities in that RT increased more rapidly with transformation size in the ST-WC group. However, Figure 2 suggests that this differece decreased when transformation sizes 1- and 2-units are compared with transformation sizes 0- and 1-units.

In order to gain a better understanding of the Modality x Transformation interaction, two separate analyses-of-variance were performed on the data considering transformation size at 0- and 1-units in the first analysis and at 1- and 2-units in the second (Table V). The modality by transformation size interaction approached significance only in the first analysis ($p < .10$), indicating that modality had a somewhat small effect on transformation size, and then only if the indrease in transformation size of 0 to 1 unit was considered.

More important was the additional information provided by Table V concerning the significant Transformation x Chant interaction in Table III ($p < .005$). Figures 1 and 2 both suggest that the effects produced by chants were differential when transformation size is considered. This is confirmed in Table V. The Transformation x Chant interaction was significant ($p < .005$) only as transformation size increased from 0 to 1 units. Table VI demonstrates, however, that the effects of chant sequence on transformation size

TABLE IV

TESTS ON SIZE OF TRANSFORMATION AND CHANT SEQUENCE MAIN EFFECTS USING NEUMAN-KUELS PROCEDURE

	Size of Transformation		
	0	1	2
Means	8.357	11.920	14.249
8.357		3.562*	5.891*
11.921			2.328*
14.249			
	Chant Sequence		
	OC	NC	LC
Means	8.997	11.546	13.982
8.997		2.549*	4.985*
11.546			2.436*
13.982			

*Significant difference at p .01

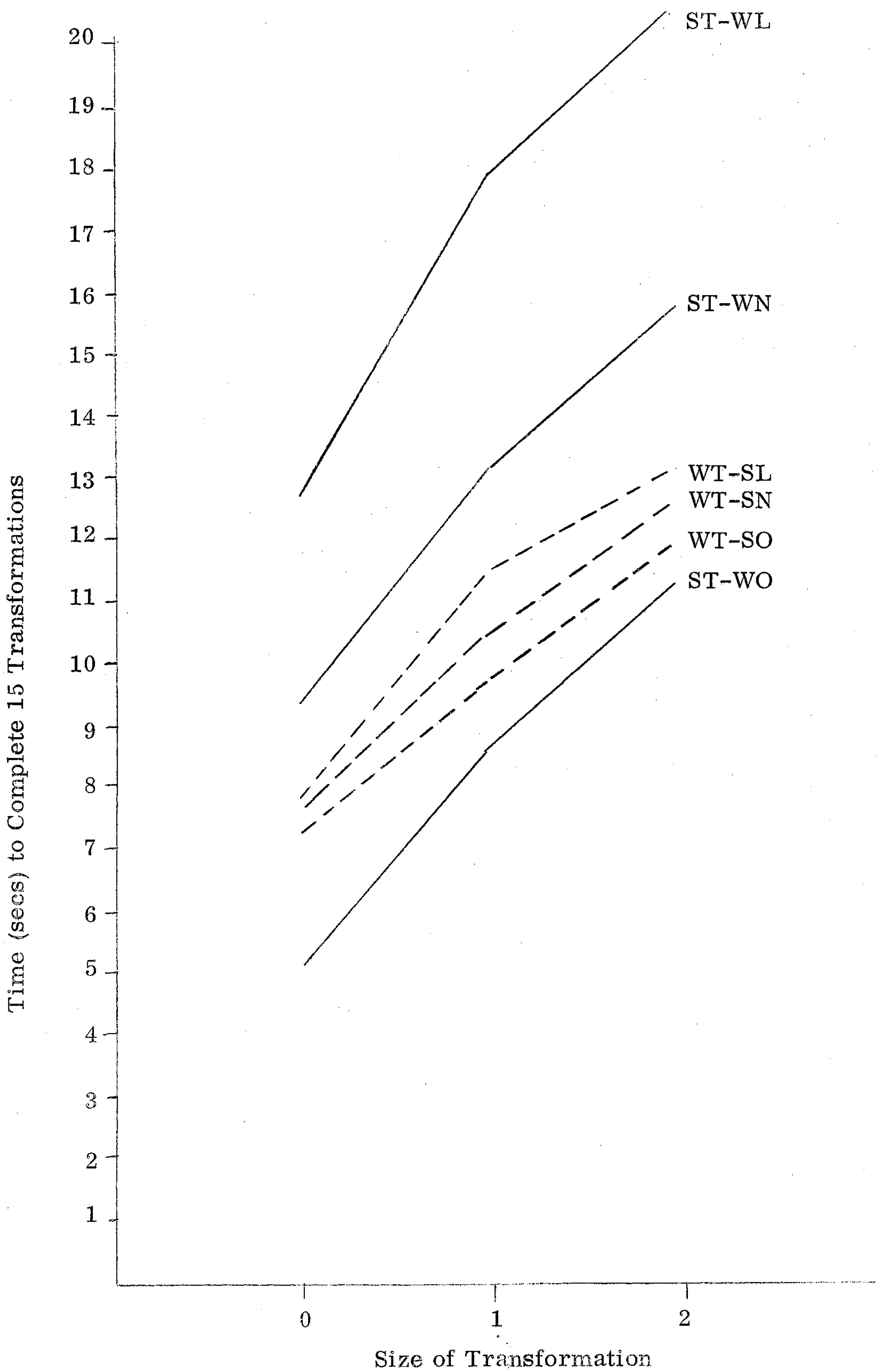

Figure 2. RT Related to Modality, Transformation Condition, and Chant Sequence

TABLE V

ANALYSIS-OF-VARIANCE ON DATA AT 0-1 UNIT TRANSFORMATIONS AND 1-2 UNIT TRANSFORMATIONS

		0-1 Unit Transformation			1-2 Unit Transformation		
Source	df	SS	MS	F	SS	MS	F
Total	47	533.49			568.95		
Between Ss	7	62.34			126.15		
M	1	50.52	50.52	25.64 (p .005)	108.51	108.51	36.89 (p .005)
Ss w. group	6	11.82	1.97		17.64	2.94	
Within Ss	40	471.14			442.79		
T	1	152.24	152.24	120.10 (p .005)	65.07	65.07	98.73 (p .005)
M x T	1	5.01	5.01	3.95 (p .10)	1.18	1.18	1.79
T x Ss w. group	6	7.60	1.26		3.95	.65	
C	2	186.89	93.44	118.98 (p .005)	236.15	118.07	104.64 (p .005)
M x C	2	103.41	51.70	65.83 (p .005)	122.00	61.00	54.06 (p .005)
C x Ss w. group	12	9.42	.78		13.54	1.12	
T x C	2	4.99	2.49	22.54 (p .005)	.17	.08	2.00
M x T x C	2	.23	.11	1.04	.17	.08	1.97
T x C x Ss w. group	12	1.32	.11		.52	.04	

were similar for both modality groups when transformation size was considered at all three levels. The Transformation x Chant interaction was significant for both the WT-SC group ($\underline{p} < .025$) and ST-WC group ($\underline{p} < .005$).

Figure 2 also illustrates the significant Modality x Chant interaction in Table III ($\underline{p} < .005$). Although performing transformations alone produced the best performance for both groups, and the L chant conditions produced the worst performance; it is obvious that the chant effects were more marked in the ST-WC group than for the WT-SC group. Table VI provided statistical evidence, however, that chant materials had a significant effect ($p < .01$) for the WR-SC group as well as for the ST-WC group when both transformation size and chant material were considered at all three levels. However, an analysis-of-variance for each level of transformation for both modality groups (Table VII) reveals that chant material had no effect if just the 0-unit transformation is considered for the WT-SC group. Chant sequences did have a significant effect ($\underline{p} < .01$) at the 1-unit and 2-unit transformation size for the WT-SC group. Chant sequence was significant, as Figure 2 suggests, at all levels of transformation size for the ST-WC group.

Even though chant material was significant at the 1- and 2-unit sizes of transformation, examination of Figure 2 results in the question of whether there was a significant difference in the L chant and N chant in the WT-SC group. Tests, reported in Table VIII, were made on the effects of chant sequence at each level of transformation size for both modality groups. As expected from Figures 1 and 2, all comparisons at each level of transformation were significantly different ($\underline{p} < .01$) for the ST-WC group. However, for the WT-SC group none of the comparisons were significantly different for the 0-unit transformation. At the 1-unit level the L chant was significantly different from the no-chant ($\underline{p}$ .05) and the L chant was also significantly

TABLE VI

ANALYSIS-OF-VARIANCE OF TRANSFORMATIONS AND CHANTING AT EACH LEVEL OF MODALITY

Source	df	SS	MS	F
WT-SC				
Total	35	178.78		
Ss w. group	3	11.93		
C	2	9.30	4.65	12.82 ($p < .01$)
C x Ss w. group	6	2.17	.36	
T	2	147.96	73.98	85.97 ($p < .005$)
T x Ss w. group	6	5.16	.86	
C x T	4	1.37	.34	4.78 ($p < .025$)
C x T x Ss w. group	12	.86	.07	
ST-WC				
Total	35	776.26		
Ss w. group	3	7.10		
C	2	456.90	228.45	103.74 ($p < .005$)
C x Ss w. group	6	13.21	2.20	
T	2	286.00	143.00	166.41 ($p < .005$)
T x Ss w. group	6	5.15	.85	
C x T	4	6.37	1.59	12.67 ($p < .005$)
C x T x Ss w. group	12	1.50	.12	

TABLE VII

ANALYSIS OF VARIANCE FOR EACH LEVEL OF TRANSFORMATION FOR BOTH MODALITY GROUPS

TRANSFORMATION SIZE		0			1			2		
Group					WT-SC					
Source	df	SS	MS	F	SS	MS	F	SS	MS	F
Total	11	9.09			12.45			9.27		
Ss w. group	3	7.46			4.29			5.35		
$\bar{C}$	2	.98	.49	4.53	6.55	3.27	12.14 (p<.01)	3.15	1.57	12.29 (p<.01)
C x Ss w. group	6	.65	.11		1.62	.27		.77	.13	
Group					ST-WC					
Total	11	117.79			186.37			186.09		
Ss w. group	3	1.51			6.17			5.80		
$\bar{C}$	2	113.23	56.66	11.36 (p<.005)	174.77	87.39	96.46 (p<.005)	174.06	87.03	83.69 (p<.005)
C x Ss w. group	6	3.05	.51		5.44	.91		6.24	1.04	

TABLE VIII

TESTS ON CHANT MAIN EFFECTS USING NEUMAN-KUELS PROCEDURE FOR BOTH MODALITY GROUPS

WT-SC

TRANSFORMATION		OC	NC	LC
SIZE 0	Means	7.2625	7.7475	7.9428
	7.2625		.4850	.6803
	7.7475			.1953
	7.9428			
TRANSFORMATION		OC	NC	LC
SIZE 1	Means	9.7175	10.4825	11.5200
	9.7175		.7650	1.8025*
	10.4825			1.0375*
	11.5200			
TRANSFORMATION		OC	NC	LC
SIZE 2	Means	11.9425	12.6300	13.1950
	11.9425		.6875	1.2525*
	12.6300			.5650
	13.1950			

*Significant difference at $p < .05$

ST-WC

TRANSFORMATION		OC	NC	LC
SIZE 0	Means	5.1475	9.3950	12.6500
	5.1475		4.2475*	7.5025*
	9.3950			3.2550*
	12.6500			
TRANSFORMATION		OC	NC	LC
SIZE 1	Means	8.6225	13.2100	17.9700
	8.6225		4.5875*	9.3475*
	13.2100			4.7600*
	17.9700			
TRANSFORMATION		OC	NC	LC
SIZE 2	Means	11.2925	15.8150	20.6200
	11.2925		4.5225*	9.3275*
	15.8150			4.8050*
	20.6200			

*Significant difference at $p < .01$

different from the N chant (.05). When the 2-unit transformation size was considered, only the L chant and no-chant comparison was significantly different (p .05).

Practice effects are clearly evident in Figure 1. There was an overall reduction in RT across blocks. It is also clear from Figure 1 that many of the conditions improved at different rates. However, the primary interest was the RTs for the various conditions after a fairly considerable amount of practice. Table IX contains an analysis-of-variance for the last ten trials. Inspection of the Table reveals that even after forty trials all three main effects were still significant (modality p .025 and transformation size and chant sequence p .005). However, reference to Figure 1 denotes the effects of chant material were very small for the WT-SC group when just trials 41-50 are considered. An analysis-of-variance for transformation size and chant material at each level of modality proved this to be the case (Table X). The chant material effect was no longer significant for the WT-SC group.

To examine the possibility of simultaneous verbal processing occurring in written and spoken modes Table XI was constructed. It represents a summary of derived scores calculated by means of a subtractive process. This was accomplished by taking the difference between the summed RTs for the chant sequences and transformations performed separately and when performed concurrently. For the purpose of economy only the trials 1-10, 20-30, and 40-50 were utilized. For instance, if comparisons desired are those of performing a L chant and a 0-unit transformation separately with the above tasks performed concurrently, the Table would be entered by reference to the summed column 0 + L and the concurrent column 0L respectively. Motivation for this indirect approach of viewing the data was provided by the several possible ways of performing the concurrent tasks. One way, time switching,

TABLE IX

ANALYSIS-OF-VARIANCE FOR TRIALS 41-50

Source	df	SS	MS	F
Total	71	564.26		
Between Ss	7	60.87		
M	1	40.06	40.06	11.54 ($p < .025$)
Ss w. group	6	20.80	3.46	
Within Ss	64	503.39		
T	2	243.00	121.50	167.45 ($p < .005$)
M x T	2	6.50	3.25	4.48 ($p < .05$)
T x Ss w. group	12	8.70	.72	
C	2	140.16	70.08	75.14 ($p < .005$)
M x C	2	83.94	41.97	45.00 ($p < .005$)
C x Ss w. group	12	11.19	.93	
T x C	4	2.92	.73	3.88 ($p < .025$)
M x T x C	4	2.43	.60	3.23 ($p < .05$)
T x C x Ss w. group	24	4.51	.18	

TABLE X

ANALYSIS-OF-VARIANCE FOR TRANSFORMATIONS AND CHANTS AT EACH LEVEL OF MODALITY FOR TRIALS 41-50

Source	df	SS	MS	F
WT-SC				
Total	35	110.66		
Ss w. group	3	6.97		
C	2	3.62	1.81	3.10
C x Ss w. group	6	3.23	.58	
T	2	85.29	42.64	35.86 ($p < .005$)
T x Ss w. group	6	7.13	1.18	
C x T	4	1.56	.39	1.65
C x T x Ss w. group	12	2.83	.23	
ST-WC				
Total	35	413.53		
Ss w. group	3	13.82		
C	2	220.48	110.24	83.09 ($p < .005$)
C x Ss w. group	6	7.96	1.32	
T	2	164.21	82.10	313.26 ($p < .005$)
T x Ss w. group	6	1.57	.26	
C x T	4	3.79	.94	6.77 ($p < 005$)
C x T x Ss w. group	12	1.68	.14	

TABLE XI

DIFFERENCES BETWEEN RTs FOR CHANTS AND TRANSFORMATIONS PERFORMED SIMULTANEOUSLY AND THE SUM FOR EACH PERFORMED SEPARATELY

Group	Condition											
WT-SC	0+N	0N	1+N	1N	2+N	2N	0+L	0L	1+L	1L	2+L	2L
Mean[a]	9.8	7.81	12.24	10.48	14.69	12.73	9.77	8.05	12.21	11.72	14.65	13.48
T+C<TC[b]	0+N>0N = 113		1+N>1N =107		2+N>2N =111		0+L>0L =112		1+L>1L =77		2+L>2L =85	
T+C-TC[c]	(0+N)-0N=1.99		(1+N)-1N=1.76		(2+N)-2N=1.96		(0+L)-0L=1.72		(1+L)-1L=.49		(2+L)-2L=1.17	
ST-WC												
Mean	13.23	9.55	16.74	13.30	19.60	16.28	13.09	12.97	16.60	18.24	19.46	21.22
T+C>TC	0+N>0N =118		1+N>1N =114		2+N>2N =107		0+L>0L =67		1+L>1L =48		2+L>2L =44	
T+C-TC	(0+N)-0N=3.68		(1+N)-1N=3.44		(2+N)-2N=3.32		(0+L)-0L=.12		(1+L)-1L=-1.64		(2+L)-2L=-1.76	

[a]Means determined by averaging over number of Ss (N 4 for each group) and 30 trials.

[b]Number of times out of possible 120 (4 Ss 30 trials) that RTs for transformations and chants performed separately but added together exceeded RTs for the same two tasks when performed concurrently.

[c]The mean difference between summed RTs for the transformations performed separately and performed concurrently.

would simply involve shifting back and forth between transformational and chanting activity. Another way, simultaneous processing, would suggest that two different verbal processes could go on at the same time.

Inspection of Table XI shows that summed RTs for transformations and chant sequences performed separately did exceed RTs for the two tasks performed concurrently. The summed RTs were greater than the concurrent RTs in 1103 of the 1440 possible comparisons. Similtaneity of different verbal processes is suggested. Two more specific findings were, first, that summed RTs exceeded concurrent RTs more in the case of N chants and transformations (670) than for L chants and transformations (433), and, second, that summed RTs exceeded concurrent RTs more frequently for the WT-SC group (605) than for the ST-WC group. In the case of the WT-SC group the summed RTs exceeded the concurrent RTs 331 times of a possible 360 when N chant was performed and 274 times when L chant was performed. For the ST-WC group, the corresponding frequencies were 339 and 159 respectively.

Mean differences for the summed RTs and concurrent RTs varied considerably with both modality and chant sequence. Subtraction of the concurrent RTs from the summed RTs yielded the largest mean differences in the case of the N chant for the ST-WC group. However, the summed RTs were actually less than the simultaneous RTs for the ST-WC group in the case of the L chant in conjunction with transformation sizes of 1- and 2-units. This large difference in the mean differences of the summed RTs and concurrent RTs between the N chant and the L chant was not found in the WT-SC group.

Error rates reported in Table XII for the various conditions were extremely low, even though the instructions were designed to encourage a moderate number of errors. The highest error rate was 2.86 per cent for the letter sequence performed concurrently with the 2-unit transformations

(WT-SC group), and the lowest error rate was 0.0 per cent for several of the conditions. As might be predicted, there were more errors for the transformations processed concurrently with the chant material than for the transformations performed alone. In addition, the error rates for the transformations and letter chant were higher than those for the transformations and number chant.

Since RTs for the various conditions were monitored with a stopwatch, a reliability measure was performed to insure that the RT measurements were reasonably accurate. The reliability was determined by measuring the RTs a second time through utilization of the tape recordings. The RTs for the first 60 trials of a randomly selected S for each group were chosen and remeasured from the tape with a stopwatch. The original RTs were then correlated with the second RTs from the tape. The following product-moment coefficients were obtained: $r = .99$ for the WT-SC group and $r = .98$ for the ST-WC group. It is reasonable to conclude that the method for measuring RTs in the experiment was satisfactory.

TABLE XII

PERCENTAGE OF INCORRECT RESPONSES AS A FUNCTION OF MODALITY, TRANSFORMATION SIZE AND CHART SEQUENCE

WT-SC

Cond.	0	1	2	0N	1N	2N	0L	1L	2L
Transf.[a]	0.00	0.20	0.73	0.06	0.33	0.86	0.20	0.60	1.08
Chant	0.00	0.00	0.00	0.20	0.06	0.00	0.33	1.40	2.86

ST-WC

Cond.	0	1	2	0N	1N	2N	0L	1L	2L
Transf.	0.26	0.66	1.06	0.00	0.26	1.26	0.13	1.13	2.20
Chant	0.00	0.00	0.00	0.26	0.46	0.26	0.00	0.73	0.40

[a]Percentage based on 3000 possible events (4 Ss x 50 trials x 15 items per trial for each group).

CHAPTER IV

DISCUSSION

The main effect of transformation size is not surprising (Weber, Cross, and Carlton, 1968). Neither is the decrement in performance on metered memory search produced by chanting in view of prior work with other concurrent tasks (Peterson, 1969; Broadbent, 1958; Deutsch and Deutsch, 1963). However, the significant differences between chant sequences, modes of responding, and the Chant x Modality and the Chant x Transformation interactions do deserve attention.

Although Peterson was aware of the possibility that differing tasks within one of his levels may differentially effect performance on another task, his experiment (1969) did not reveal any such differences that were due to what he termed class similarity (both tasks involving the same characters). The difference between the letter sequences and the number sequences in the present study do not necessarily represent differences attributable to class similarity, they do indicate that two tasks within the same category can have differential effects on the accompanying task. Even though both chants were of a predictable self-maintained nature, apparently chanting the letters backward required more attention or processing space than chanting the numbers forward. As a result, there is less evidence for simultaneous processing occurring with the letter chant, because total capacity was more nearly exceeded.

The differences between mode of responding is somewhat of a puzzle. As Figure 1 indicates, both chants were more disruptive on metered memory search for the ST-WC group than for the WT-SC group. Reference to the data for the chant sequences performed alone provides a possible explanation for this phenomenon. When written, completing the chant sequences took approximately seven seconds (Figure 1). On the other hand, speaking the chant sequences required only three seconds. If it can be assumed that when speaking the chants the Ss were operating at virtually asympototic performance level then it seems reasonable to conclude that generation of the chant item and response to it was virtually simultaneous. However, when the task involved a written response to items in the chant sequence, it seems feasible to assume that due to absolute restrictions on writing speed, the chant characters could conceivably have been implicitly generated at a rate greatly exceeding that of output. Hence, the resulting "dead-time" may have allowed the subject to anticipate items several steps forward in the sequence while producing a written response and then to commit them to short-term memory (STM). If this is so, the subject, when responding to a given chant item would simultaneously be holding a serial sequence of chant items in STM. Therefore, the conceptual operations involved in performing the chant and transformation within this condition may have been surprisingly similar. The explanation, therefore, would be a form of competition, at the implicit level, between two highly-similar search tasks. If the above suggestions are valid, then they can perhaps account for the otherwise inexplicable differences between response modalities.

Both chant sequences produce greater decrements in memory search rates for 1- and 2-unit transformations than for the 0-unit. This seems to suggest that transformational sizes of 1- and 2-units require more attention or cognitive capacity than a 0-unit does. If the task of metered memory search is viewed in terms of Peterson's suggested categories, the above result is perhaps not surprising. Performance of 0-unit transformations merely required "reproductive" activity. All that was necessary, therefore, was a direct correspondence between input and output. However, the higher level transformations did involve a change in the input, prior to the output, so more than simple reproduction was involved. As a result, these operations placed a greater demand on available capacity, therefore, less spare capacity was available for concurrent processing.

Practice effects were clearly evident for the tasks performed alone and when performed simultaneously. The improvement in metered memory search when performed alone provides an explanation for the finding that dual processing became more efficient as training increased. As performance on the memory search neared the asymptote of training, less cognitive space was needed for the various tasks, such as reception, recoding, mapping, storing, emission, etc. As a result, there was an increasing accumulation of spare capacity that could be utilized for dual processing. This was especially evident for the WT-SC group where after forty trials concurrent processing was, statistically, as efficient as performance on the metered memory search task performed alone.

The question remains as to whether time switching or simultaneous activity was involved. Perhaps the best evidence that concurrent processing of a simultaneous nature did occur, is obtained by means of the indirect subtractive process mentioned previously. It will be recalled that the summed RTs for chants and transformations performed separately, in general, exceeded the concurrent RTs. A sequential model would encounter some difficulty in explaining this result. A sequential interpretation would propose that indeed the two channels (corresponding to chanting and transformational activity) could be entered simultaneously, but processing itself would be sequentially performed at a later level (Broadbent, 1957). A sequential theorist would explain performance on concurrent tasks by assuming that a switching back and forth between tasks occurred. However, if this were the case, then chant RT plus transformation RT performed alone should have been smaller than the RT for these two tasks when performed concurrently. That is, RT for the two tasks performed together would then be a function of chant RT, transformation RT, and an additional switching time constant. The question then arises as to how results in the present study can be accounted for in a manner consistent with a serial model. A proponent of a serial model would perhaps point to the possibility that subjects were not forming at optimal asympototic level on each of the tasks performed alone. However, within the present experimental design, the subjects were so highly practiced on each task performed individually (six days of practice) that it seems reasonable to conclude that they were either operating at or so nearly close to true asympototic levels, at least for group WT-SC, that any discrepancy between observed performance and absolute asympotote would not be sufficient to justify such an interpretation.

On the other hand, such results do seem to fit very nicely into the conceptual schemas of Moray and Peterson. Moray's conception of a capacity processor leaves room for simultaneous processing if neither task occupies the full capacity of the individual. Furthermore, Peterson's model, which proposes that dual processing may occur if neither task demands complete attention is also consistent with the results of the present study.

Other systems for viewing concurrent processing, however, do exist. At least three ways have been suggested (Wickelgren, 1969) to account for how verbal trace systems are represented. Their representation may be acoustic, kinesthetic, or abstract. On the basis of both introspective and empirical grounds (Wickelgren, 1969), it is doubtful that either acoustic traces or kinesthetic traces can operate in a parallel fashion; but instead, would probably have to in a serial manner. For example, it is hard to imagine saying two different letters at the same time. In contrast, some verbal traces do seem to operate in parallel, e.g., the extemporaneous speaker who seems to be planning what he will say next while he is simultaneously speaking. To have such capability it seems necessary to posit an abstract verbal trace system in which two or more traces can operate at least semi-independently of one another.

In the present study, simultaneous verbal processing apparently did occur. Consequently, it seems likely that metered memory search with chanting draws on an abstract set of verbal traces, neither acoustic nor kinesthetic in nature. Moreover, the abstract traces operate in partial independence of one another and they can take several forms of output such as a spoken or written response.

CHAPTER V

SUMMARY AND CONCLUSIONS

In the present experiment the performance effects of three variables -- the size of transformation, self-generated chant sequences, and two response modes -- were evaluated in an attempt to assess the capacity for concurrent processing with a metered memory search task. Although performance for the memory task was decreased when subjects were required to concurrently chant either a letter chant or a number chant; an indirect, subtractive method for viewing the data yielded strong evidence that actual simultaneous processing did indeed occur in some of the conditions. In general, concurrent processing was more efficient when the number sequence was performed in conjunction with metered memory search. However, there was some evidence that concurrent processing of a simultaneous nature also occurred when metered memory search was performed with the letter chant. An additional finding indicated that simultaneous processing occurred to a greater extent when the chants were performed in conjunction with the 0-unit transformations rather than with the higher levels of transformational sizes. In all conditions, concurrent processing became more efficient with practice. These findings agree very nicely with the theoretical models that have been put forth by both Moray (1967) and Peterson (1969). Another explanation was also suggested to account for the results. Briefly, it was hypothesized that metered memory search with chanting draws on an abstract set of verbal traces that possibly may operate simultaneously. This seems plausible because if the chant sequence or metered memory search involves either acoustic or kinesthetic traces, then seemingly the two chants would have to have been performed sequentially and therefore in opposition to the experimental results.

Additionally, large differences were found between response modalities for the two tasks. Writing the transformations and speaking the chants were more efficient than when the modalities were reversed. An explanation was attempted that involved a form of implicit response competition.

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VITA

Jim Dale Blagowsky

Candidate for the Degree of

Master of Science

Thesis: CONCURRENT PROCESSING WITH METERED MEMORY SEARCH

Major Field: Psychology

Biographical:

Personal Data: Born in Weatherford, Oklahoma, December 3, 1943, the son of Jake A. and Bessie I. Blagowsky. Married to Linle Drue Lewis, April 5, 1962. Father of two sons, Brett and Barry.

Education: Graduated from Weatherford High School, Weatherford, Oklahoma, in 1962; received the Bachelor of Science degree with honors from Southwestern State College, with a major in psychology, in May, 1966; completed the requirements for the Master of Science degree, Oklahoma State University, in August, 1969.

Professional Experience: Became a member of Psi Chi in October, 1966; teaching assistant at Oklahoma State University, Fall, 1967, Spring, 1968; currently an N.D.E.A. Fellow.