METERED MEMORY SEARCH WITH CONCURRENT SHADOWING FOR LETTER PROPERTIES OR NAMES

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The question of whether or not man can perform two simple verbal tasks at the same time without loss of efficiency on either task is one that has received considerable theoretical and experimental attention in recent years. There are two highly distinctive views. Some psychologists (Broadbent, 1957) assume a single channel model of information processing. With a single channel model no simultaneous processing of two tasks is possible. Any appearance of simultaneity at the overt response level is due to a rapid underlying (central) switching between tasks. Other psychologists (Moray, 1967) support a flexible function model of information processing in which the human's processing capacity is available for a variety of uses, perceptual or conceptual. When the processing capacity is used for one function, there is less available for other functions. In this latter theory simultaneous processing of two independent tasks is theoretically possible and may improve with practice provided that both tasks do not exceed total processing capacity.

The purpose of the present study is to determine whether simultaneous processing occurs for two verbal tasks: shadowing and metered memory search. Also three different shadowing tasks were used involving different cognitive mechanisms. Differences in processing time and degree of simultaneous processing should tell us something about the nature of the verbal memory trace (Wickelgren, 1969). In the first experiment the shadowing task was performed alone to obtain some base line reaction time data for the shadowing task; in the second experiment the shadowing task was combined with the metered memory search task for a more comprehensive investigation of the data.

Review of the Literature

Shadowing

In the shadowing task introduced by Cherry (1953), the subject was presented with two different messages; his task was to shadow (repeat as accurately and as rapidly as possible) one and only one of the two messages. Separating the messages in the shadowing experiment is similar to the "cocktail party phenomenon" in which one tries to follow the speech of one person at a party amidst numerous loud voices and much noise. Cherry (1953) found that if the two messages were mixed together or binaural (two different spoken messages presented to the subject simultaneously using both ears) the subject had a great deal of difficulty shadowing one of the messages and was able to do so only after frequent playbacks of the recorded messages. If the mixed messages were strings of cliches connected by conjunctions, the subject could recognize whole cliches but was unable to shadow one complete message. This finding suggests that the transitional probabilities of the words themselves made shadowing of the cliches possible. If instead of binaural stimulation, one used a dichotic presentation (one message to the right ear and another message to the left ear); the shadowing task became much easier, and the subject was able to repeat the primary (shadowed) message without playbacks. Thus the subject was able to attend to one ear at a time.

Furthermore, according to Cherry (1954), the subject could actually switch his attention from ear to ear shadowing the primary message. The shadowing performance was not disrupted if the alternation between ears was very rapid (1/20 of a second) or very slow (1 per second). At intermediate rates, however, the shadowing performance was greatly disrupted, with the correct responses falling to zero at the switching rate of 1/6 to 1/7 of a second. Cherry (1954) reports that the attention switching time is 1/6 of a second. This interpretation has been questioned however (Neisser, 1967).

Interestingly enough the secondary message arriving at the unattended ear was hardly noticed by the subject (Cherry, 1953). Specifically, the language of the secondary message was unrecognized (Cherry, 1953). Even simple words repeated as many as thirty-five times in the secondary message could not be recalled later by the subject (Moray, 1959). If Moray gave the subject special instructions to remember numbers occurring in the secondary message, the subject was still unable to recall these numbers. Nevertheless, the subject was able to recall some characteristics of the secondary message (Cherry, 1953); for example, the subject reported that the message was normal human speech and that reversed human speech sounded queer. A change from a male to a female voice on the secondary message and also a change from human speech to a 400 c.p.s. tone was noted by the subject. If the two messages were identical, the subject noted that they were the same message only when the delay between the two messages was shortened to 2-6 seconds.

In addition to the above physical characteristics, Moray (1959) also reported that the subject recalls his own name when it is embedded in the secondary message. These results concerning the recognition of one's own name are similar to those of Howarth and Ellis (1961) concerning the lowered threshold during normal listening, and those of Oswald, Taylor and Treisman (1960) concerning recognition during sleep. The similarity of the three findings suggest that perhaps the same pattern analyzing mechanism is involved in all three situations (Howarth and Ellis, 1961).

Single Channel Mechanism

The shadowing experiments with the differences in binaural and dichotic presentations have led to numerous other studies investigating the pertinent factors involved and theories relating these factors to information processing. Broadbent (1954) reported that the dichotic effect could be simulated by means of loudspeaker placement and volume control; thus, the messages do not have to be presented to each ear alone as Cherry (1953) proposed. The fact that perceptual localization is an important variable in the intelligibility of the messages has also been substantiated by Hirsh (1950). Another factor that aids intelligibility is the tone quality; Spieth, Curtis and Webster (1954) reported that using an aural shaping filter which resulted in one of the messages having a different tone quality greatly aided intelligibility. In addition Poulton (1953) reported that density of communication and similarity of the primary and secondary messages are pertinent variables in the dichotic listening situation.

When the task becomes more complicated and the subject is required to listen and speak simultaneously, performance deteriorates in direct proportion to the amount of overlap of the two responses (Webster and Thompson, 1954; Broadbent, 1952). Furthermore, Mowbray (1964) reports that shadowing is almost totally disrupted precisely when a to-be-remembered single word occurs in the secondary message. Similar results are reported by Peterson and Kroener (1964) in which immediate recall of secondary target words while shadowing a primary message falls short of 100% correct. If the subject perceived the target word, he should be able to recall said word when the response is immediate because no memory decay has occurred. Thus the failure on this task must be in large part perceptual in nature.

The above results are consistent with a single channel mechanism similar to the filter theory proposed by Broadbent (1957) in which one particular message is allowed to pass through the filter on the basis of some predetermined characteristic while the other message is passively filtered out before it reaches the analysis level. Some further support for Broadbent's filter theory is provided by Treisman and Geffen (1967) in which they conclude that the main limit in simultaneous processing is perceptual. However, Treisman (1960) does take issue with the passive aspect of Broadbent's theory due to the amount of interference the secondary message affords. For example, the efficiency with which the shadowing task is performed is decreased if two irrelevant channels must be ignored rather than a single channel (Treisman, 1964a). Furthermore, context (Triesman, 1960), language differences and phonetic cues (Treisman, 1964b), and information load (Triesman, 1965) also greatly affect the shadowing performance. Thus, Triesman felt that Broadbent's filter merely attenuates the stimulus rather than blocking it entirely. Broadbent accepted Treisman's modification of his filter theory as a more accurate interpretation of the empirical data (Broadbent and Gregory, 1963).

Limited Capacity Processor

On the other hand we have findings which contradict Broadbent's notion of a fixed channel capacity. If we have a single channel with a finite capacity, then information can be filtered through this channel only at some maximum finite rate or at some slower rate. Thus, rate of presentation should affect information processing; however, Moray (1960) found contradictory results. Moray and Jordan (1966) also found that practice (repeating the task numerous times) and compatibility of stimulus and response increased performance which is likewise embarrassing for Broadbent's theory. Gray and Wedderburn (1960) found that words divided into syllables and presented at alternate ears were still recalled as words--thus requiring analysis at a meaningful level rather than a low level of blocking or attenuation. They likewise found the same results using sentences in which the words were alternately presented to each ear. Thus, the single channel idea is inadequate. Simultaneous processing was reported by Lawson (1966) when she found that the subject while shadowing could press a key to "pips" on a tape recorder without any interruption. This led her to assume separate pathways for physical stimuli and verbal stimuli.

In light of the above studies Moray (1967) proposed a model in which the human serves as a limited capacity processor. In this theory the total brain capacity is divided into different systems concerned with perception, encoding, storing, retrieving and responding. Attentional trade offs among systems provides for more information processing. As such it is not the amount of information, in the Shannon sense, carried by the stimulus but rather the discrimination difficulty of said stimulus that causes the shadowing performance to deteriorate (Mostofsky, 1970). Lindsay, Taylor and Forbes (1968) found compatible results by manipulating the number of dimensions requiring attention. Subsequent work by Lindsay and Norman (1969) and Norman (unpublished) point to a limitation of storing and retrieving information as task difficulty increases rather than a perceptual limit proposed by Broadbent and Treisman. Likewise, Deutsch and Deutsch (1963, 1957) say that the filter mechanism is inadequate and that the subject responds to the most important signal coming in at the time with a response limit rather than a perceptual limit.

Measuring Conceptual Space

So rather than being a problem of having a single channel by which to receive some stimuli while the others are filtered out, the problem seems to be one of a limited amount of conceptual space or attention. Brown and Poulton (1961) approached the concept of mental capacity and its measurement by means of car driving in busy (business) and slow (residential) areas while performing cognitive tasks involving memory. The problem of level of attention was approached by Peterson (1970) from the standpoint of task difficulty. He proposed a hierarchical classification of tasks requiring increasing attention. These task categories included emission (chanting a well known sequence like 1, 2, 3, 4, 5, 1,...), reproduction (repeating something exactly as it appears like shadowing), and transformation (using the stimulus to arrive at a different response--like mathematical problem solving). The difficulty with this classification is that in going from one level to another there is likely to be confounding of conditions due to different cognitive processes. What is needed is a way of holding stimulus-response factors constant while varying cognitive processing load. Thus, Weber, Cross and Carlton (1968) introduced transformations in terms of a circular sequence to be searched. The number and nature of the stimulus items and the response items were constant regardless of the size of the transformation to be made. For example, if the circular sequence consisted of the first five letters of the alphabet, the subject would search through a, b, c, d, e, a, b, c, ... in an endless fashion. In a given block of five stimulus items each letter appeared once and only once; the correct response to each stimulus item would likewise result in each letter appearing once and only once. For example, in the one-unit transformation in the metered memory search task, the stimulus item "a" would require the response "b" because "b" is the item one step away from "a" in the specified direction. Similarly a one-unit transformation would produce the following stimulus-response pairs: "b". . ."c", "c". . ."d", "d". . ."e", "e". . ."a". If instead of the transformation task required in the one-unit transformation, a simple reproduction task were needed a zero-unit transformation involving the same stimulus-response items could be employed. In the zero-unit transformation the following stimulus-response pairs would be appropriate: "a". . ."a", "b". . ."b", "c". . ."c", "d". . ."d", "e". . ."e". Weber, Cross and Carlton found that size of transformation, transformation direction, materials transformed, and the nature of the circular sequence (Weber and Castleman, 1969) were all significant variables. Because the subject had to perform transformations of different sizes, it is likely that a metered search of memory was required (Weber, Cross and Carlton, 1968). When this same metered memory search task was investigated with an emissive and transformational subsidiary task, Weber and King (1970) found that the emissive and transformation differences persist while performing the subsidiary task. Similarly the reproduction and transformation differences have been substantiated in concurrent processing by Blagowsky (1969) and Linden (1969).

Imagery

Recently the question of information processing has been viewed in terms of the maximum rates of speech and visual imagery for serial processing of letters. In the speech conditions the subject is required to repeat the alphabet aloud or silently; in the visual conditions, the subject must imagine the letters appearing singly on a screen with the eyes open or closed. Weber and Bach (1969) replicated Landauer's (1962) implicit and explicit speech conditions and compared the results with a visual imagery condition. They found that the implicit and explicit speech conditions were identical in processing rates (about 6.5 letters/second), and therefore, seem to involve the same central processes. The visual imagery rates, on the other hand, were found to be much slower (about 2.5 letters/second). The differences in speech and visual imagery processing time suggested different modalities for the two imageries (Weber and Castleman, 1970).

In related studies involving concurrent activities of a spatial and verbal nature, Brooks (1968a, 1968b) concluded also that spatial and verbal information are indeed handled in separate systems.

Statement of the Problem

The metered memory search task performed concurrently with different subsidiary tasks should tell us something about the mechanisms involved in the metered memory search task or memory in general. In the present study the metered memory search task is performed in conjunction with three different kinds of shadowing tasks. The first shadowing task is a reproductive task in which the subject merely repeats as rapidly as possible the letters appearing on a tape recording. The second shadowing task is a transformation task in which the subject dichotomously categorizes the letters according to their acoustic properties. The third shadowing task is also a transformation task but this time the subject dichotomously categorizes the letters in terms of their visually imagined properties. It is also the purpose of this study to determine the extent to which simultaneous processing in metered memory search and shadowing occurs when the shadowing tasks require that different letter properties be shadowed.

Before combining the shadowing tasks with the metered memory search task, Experiment I was performed to determine that the different shadowing tasks would result in different reaction times and also to obtain some base line scores for these reaction times. Then in Experiment II the shadowing tasks and the metered memory search task was studied in a more comprehensive fashion with the major purposes outlined above.

Hypotheses

There were eight hypotheses postulated: (the first one applying to Experiments I and II; the remainder applying to Experiment II only.)

1. For shadowing, the reaction time to shadowing for visual properties of letters will be greater than the reaction time for shadowing for the acoustic properties of letters which will in turn be greater than the reaction time to shadowing for letter names. The shadowing for letter names group is a reproductive task and should require very little processing. The shadowing for the acoustic properties of letters group, on the other hand, is a transformation task involving a "yes" or "no" verbal response to an acoustically presented letter according to an acoustic rule. But letter identification is not necessary in this group since the subject simply responds to the sound of the letter. Shadowing for the visual properties of letters group also requires a transformational task with the same verbal response as the acoustic group. In this group the subject presumably must first identify the letter, and then imagine what it would look like in lower case print, and only then can the subject respond.
2. There will be an effect due to transformation size with a one-unit transformation requiring more time than a zero-unit transformation. Since the one-unit transformation requires a search through memory and a transformation of the stimulus item, it will involve more processing time than the zero-unit transformation which is a simple reproductive task.
3. The concurrent performance of the metered memory search and shadowing will show greater reaction time for each of these tasks when compared with the reaction time for the two tasks done alone. Concurrent activities will result in loss of efficiency on both tasks due to the additional cognitive load.

4. The increase in reaction time from the zero-unit transformation to the one-unit transformation will be greatest for the shadowing for visual properties of letters group, less for the shadowing for acoustic properties of letters group and smallest for the shadowing for letter names group. This shadowing group by size of transformation interaction is hypothesized due to differences in task difficulties of the shadowing groups which will result in more cognitive load in the one-unit transformations for the more difficult rule-defined shadowing groups than for the reproductive shadowing group.
5. The increase in reaction time from the zero-unit transformation to the one-unit transformation will be greater for the concurrent performance than for the performance alone. Since the transformation tasks of metered memory search involve both reproduction and transformation, there will be more over-loading during the concurrent activities with the transformation task than with the reproductive task.
6. The increase in reaction time from the alone to the concurrent factor will be greatest for the shadowing for visual properties of letters group, less for the shadowing for acoustic properties of letters group and smallest for the shadowing for letter names group. This interaction is likewise hypothesized because of differences in task difficulties of the shadowing groups which will result in more cognitive loading in the concurrent condition than in the alone condition.
7. Some simultaneous processing will occur. This hypothesis is consistent with the limited capacity processor theory in which the

capacity is not yet at its upper limit.

8. Concurrent processing will improve with practice. This hypothesis is derived from the flexible function theory in which decreases in processing time as a result of practice are due to functional trade-offs within the information processing systems themselves (Moray and Jordan, 1966).

Results

The above hypotheses were analyzed by the analysis of variance appropriate to a repeated measures design with a factorial arrangement of treatments. Simultaneous processing was found to occur with all these shadowing groups. The different shadowing tasks did indeed differentially affect performance on the metered memory search tables. Size of transformation, shadowing groups, and concurrent factors were also found to be significant.

CHAPTER II

EXPERIMENT I

In the present experiment the shadowing task was performed alone in order to obtain some base line reaction times for the shadowing tasks.

Method

Conditions

In the shadowing for the acoustic property condition (S_a), the subject said "yes" as rapidly as possible, if the name of the letter had an "e" sound (g, p, v, z) and "no" if the name of the letter did not have an "e" sound (m, o, q, y). In the shadowing for the visual property condition (S_v), the subject said "yes" if the letter was long, that is, any part of the letter extending below the line of writing in lower case typed print (g, p, q, y) and "no" if the letter was not long (m, o, v, z). In the shadowing for letter names condition (S_n), the subject simply repeated as rapidly as possible the name of the letter previously presented auditorily.

Experimental Design

The experimental design was a repeated measures design with three within subjects conditions. The order of presentation of the three shadowing tasks (S_a, S_v, S_n) was counterbalanced over subjects to eliminate order effects. That is, there were six possible presentation orders: S_a, S_v, S_n; S_a, S_n, S_v; S_v, S_n, S_a; S_v, S_a, S_n; S_n, S_v, S_a; S_n, S_a, S_v. Two subjects were randomly assigned to each of the six possible orderings.

Subjects

Oklahoma State University undergraduates served as subjects. The twelve subjects were volunteers from a psychology class.

Procedure

The eight letters (g, m, o, p, q, v, y, z) to be shadowed were spoken in a normal voice by the experimenter. The letters were randomly presented. The experimenter spoke the letters into a start microphone of a voice relay with an attached clock--thus starting the clock with the spoken letter. The clock was subsequently stopped by the subject's verbal response by means of a throat microphone attached to the stop portion of the voice relay. The time between the spoken letter and the subject's response constituted the reaction time for the shadowing tasks.

The subject received instructions on the first shadowing condition he was to perform. He was then given 58 trials of that condition, with a 15 second rest between each trial while the experimenter recorded the time on a data sheet and reset the clock for the next trial. After all 58 trials had been completed on the first shadowing condition, the subject was given instructions explaining the second shadowing condition. He was likewise given 58 trials on the second condition and similarly for the third condition.

Results

Descriptive statistics for reaction time as a function of shadowing task are presented in Table I. Mean RTs were determined by averaging over number of trials (58) and number of subjects (12). The median RTs were determined by obtaining the median from the subject by trial matrix for each of the three conditions. An analysis of variance confirmed the differences in shadowing tasks, $F = 55$, which is significant ($p < .005$). With reduced degrees of freedom appropriate to the conservative test of the repeated measures design, the differences among shadowing conditions are still significant ($p < .025$). The Newman-Keuls' Test was used to determine which conditions were significantly different from each other. The results indicate that the visual and acoustic conditions are both significantly different from the name condition at the .01 level. However, the visual and acoustic conditions are not significantly different.

Figure 1 indicates that shadowing task proved to be a significant variable. RTs for the three shadowing conditions are shown as a function of blocks.

TABLE I

RT (SECS) DESCRIPTIVE STATISTICS AVERAGED OVER TRIALS AND SUBJECTS

Shadowing Condition	Visual	Acoustic	Name
Mean[a]	.761	.726	.483
S. E. M.	.138	.197	.107
Median	.740	.680	.460

[a]Means determined by averaging over number of subjects (12) and number of trials (58).

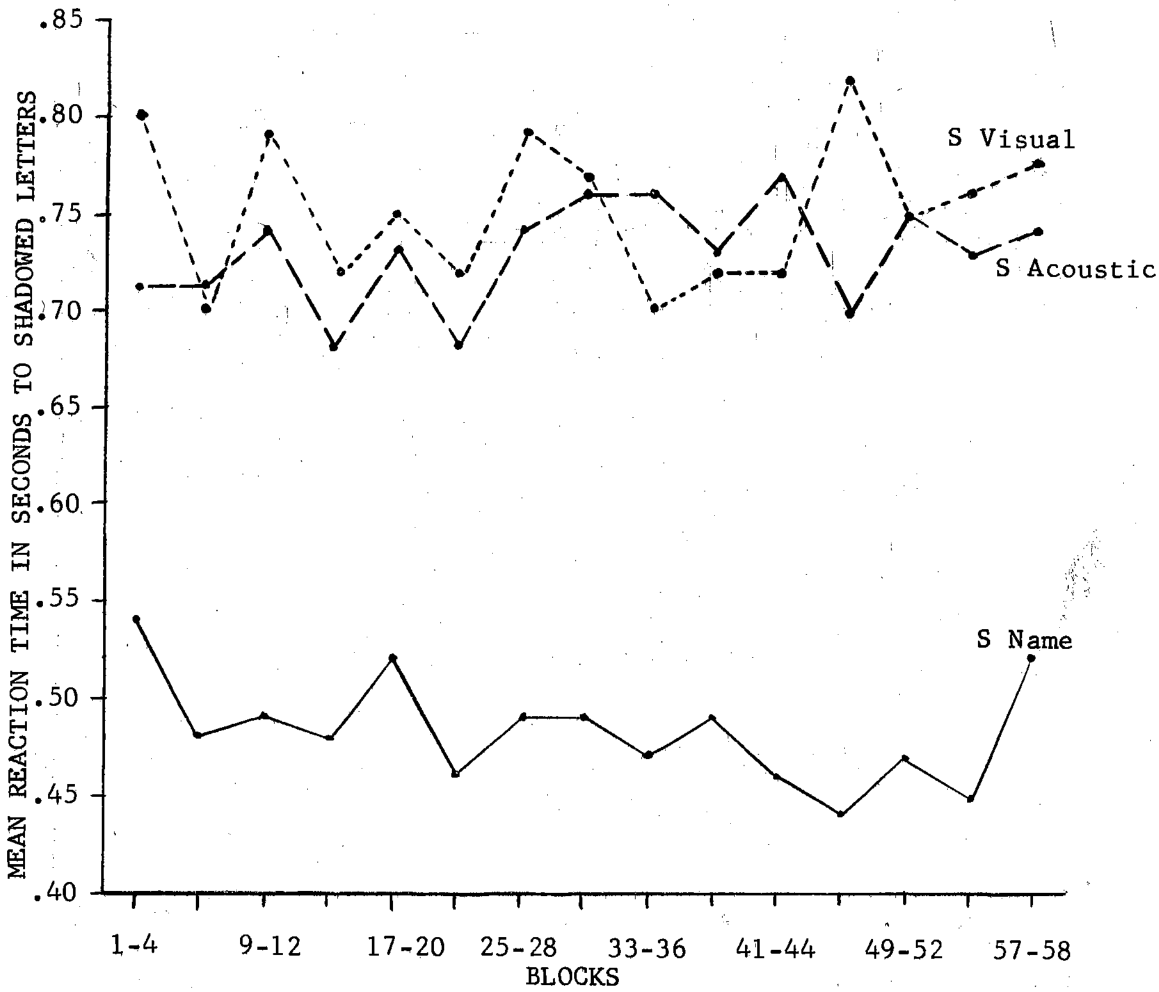


Figure 1. RT Shown As a Function of Blocks

CHAPTER III

EXPERIMENT II

In the present study the metered memory search task is performed in conjunction with three different kinds of shadowing tasks (Experiment I). The purpose of this study is to determine the extend to which simultaneous processing in metered memory search (searching the five number circular sequence) and shadowing occurs when the shadowing tasks require that different letter properties be shadowed.

Method

Experimental Design

The experimental design was a repeated measures design. The conditions were randomized according to a randomized block scheme with a factorial arrangement of treatments. Two kinds of data were collected: the total number of transformations made in nine seconds on the metered memory search task and the reaction time to the shadowed item presented on the tape recorder. Thus, the two designs are overlapping since two different kinds of data are obtained on the concurrent conditions.

In the metered memory search (MMS) data, there was a 3 X 2 X 2 factorial arrangement of treatments. The first factor was a between-subjects variable and had three levels: shadowing for the letter name (S_n), shadowing for the acoustic property of the letter (S_a), or shadowing for the visual property of the letter (S_v). The two within-subjects variables, each at two levels, include size of transformation (zero-unit transformation (T_0) and one-unit transformation (T_1)) and MMS alone (T_i) or MMS concurrent with the shadowing task ($T_i + S_j$). The major dependent variable was the number of transformations made in a 9 second period. To allow for comparison with past work, this information was converted to a time per transformation score.

To conceptualize the shadowing design, we may consider it as coming from a 3 X 3 design with 3 levels of shadowing (S_n, S_a, S_v) as a between-Ss variable and 3 within-Ss levels of cognitive processing (shadowing alone (S_j), shadowing with a zero-unit transformation ($T_0 + S_j$), and shadowing with a one-unit transformation ($T_1 + S_j$)). The major dependent variable was reaction time (RT) in shadowing; that is, the time from stimulus letter presentation to the onset of the shadowing response is RT.

It should be noted that the MMS and Shadowing tasks involve partially overlapping designs in which the same conditions sometimes occur, but in which different dependent variables are assessed.

Subjects

Oklahoma State University undergraduates served as subjects. The twenty-four subjects--eight for each between-subjects variable--were paid $1.00 for each hour of participation. All of the subjects were right-handed because left-handed subjects tend to cover the subsequent stimulus items as they write the response to the preceding item (Blagowsky, 1969). The subjects were randomly assigned to the three shadowing groups.

Conditions

All subjects searched the same five-digit circular sequence made up of the digits 4 through 8 as shown in Figure 2. The digits were chosen to minimize the acoustic interference (similarity) with the letters presented on the tape recorder. Thus the number sequence includes the digits 4 through 8 to eliminate the digit "3" which rhymes with the letter "g" appearing in the shadowed message. The 4-8 sequence is therefore highly comparable to the digit sequence used in Weber, Cross and Carlton (1968).

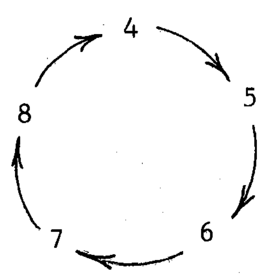


Figure 2. Circular Sequence

In the T_0 condition if "4" is the stimulus item, then "4" is the correct response because it represents a zero step in the circular sequence. Similarly, the other stimulus-response pairs would be "5"--"5", "6"--"6", "7"--"7", and "8"--"8". In short, the T_0 condition is a simple "reproductive task" to use the terminology of Peterson (1969).

In the T_1 condition if "4" is the stimulus item, then "5" is the correct response because it is one step from "4" in the circular sequence. The other stimulus-response pairs in the T_1 condition would be "5"--"6", "6"--"7", "7"--"8", and "8"--"4". The T_1 condition requires the "transformation" level of attention according to Peterson (1969).

In all MMS tasks the responses were written on specially prepared response sheets in a blank next to the stimulus digits which appeared in a randomized column of 30 typed double-spaced digits. The shadowing task required a verbal response of "yes" or "no" for the S_a and S_v groups. For S_n the response was simply to name or repeat the same letter presented on the tape recorder. The 8 shadowed letters (g, m, o, p, q, v, y, z) were chosen so that four letters would be "yes" and four letters would be "no" for both the S_a and S_v groups.

In the shadowing for the acoustic property group (S_a), the subject said "yes" if the letter had an "e" sound (g, p, v, z) and "no" if the letter did not have an "e" sound (m, o, q, y). In the shadowing for the visual property (S_v), the subject said "yes" if the letter was long, that is, any part of the letter extending below the line of writing in lower case typed print (g, p, q, y) and "no" if the letter was not long (m, o, v, z). In the shadowing for letter names group (S_n), the subject simply repeated as rapidly as possible the letter previously presented auditorily.

Task Alone or Concurrent (T_i Alone or S_j Alone; $T_i + S_j$ Concurrent) refers to whether the shadowing task or the transformation task discussed above was performed without the other task (alone) or whether the subjects were required to shadow while doing the MMS task (concurrent).

The conditions and their appropriate responses are illustrated in Table II. In the T_0 condition only the first and third columns of the top half of the table are necessary. In the $T_0 + S_n$ condition the first four columns of the top half of the table would be appropriate: the subject would write the responses in the third column while saying the responses in the fourth. Similarly, the fifth column refers to the shadowing for the acoustic properties of letters (S_a) group and the sixth column gives the appropriate responses for the shadowing for the

TABLE II

APPROPRIATE RESPONSES FOR THE VARIOUS CONDITIONS

	Stimulus	Correct Response			
MMS (T_0)	Shadowed letter on tape	MMS (Write)	Shadowing (Speak) (S_n)	(S_a)	(S_v)
6	g	6	g	yes	yes
5	p	5	p	yes	yes
7	o	7	o	no	no
4	v	4	v	yes	no
8	y	8	y	no	yes
7	z	7	z	yes	no
6	m	6	m	no	no
5	q	5	q	no	yes
MMS (T_1)					
6	g	7	g	yes	yes
5	p	6	p	yes	yes
7	o	8	o	no	no
4	v	5	v	yes	no
8	y	4	y	no	yes
7	z	8	z	yes	no
6	m	7	m	no	no
5	q	6	q	no	yes

visual properties of letters (S_v). The bottom half of the table refers to analogous conditions with a one-unit transformation in MMS.

Materials

The eight letters (g, m, o, p, q, v, y, z) to be shadowed were recorded on magnetic tape at the rate of one letter every two seconds. The letters were presented in randomized blocks of eight with no letter occurring twice in succession. All letters occurred an equal number of times.

The response sheet for the written response of the MMS task consisted of a 4¼ by 11 inch sheet of white paper with a column of 30 double-spaced typed digits (4, 5, 6, 7, 8) in internally randomized blocks of five, with no digit occurring twice in succession. To the right of each of the 30 digits was a line on which the subject was instructed to write the appropriate digit in his normal handwriting. Five of these response sheets with a cover sheet formed a blocklet to make data collection easier. There were four different randomizations used to determine the response sheets, and the order of the response sheets was also randomized within each booklet with subsequent pages being different.

Cue cards (4 x 6 inch white cards) containing the name of the condition (0, 1, SHADOW, 0 SHADOW, 1 SHADOW) and the circular sequence (4, 5, 6, 7, 8) in large block letters were used. The cue cards were placed by the experimenter on the table two feet in front of the subject. The appropriate condition card remained in view on the table during each trial; the circular sequence card remained in view only on instruction day (the first day) during the trials.

Two tape recorders were used. One monophonic recorder contained the letters to be shadowed while the stereophonic recorder was used to record the letters presented on the monophonic recorder on one channel while simultaneously recording the verbal responses of the subject on the other channel. The monophonic recorder was also hooked up to a speaker and to the triggering mechanism of an oscilloscope. Thus, the beam was triggered across the scope by the successive recorded letters to be shadowed.

Two microphones on an adjustable microphone stand were placed within six inches of the subject's mouth to record verbal responses. One of the microphones was plugged into the stereophonic recorder to record the subject's responses on one channel. The other microphone was plugged into the oscilloscope to record amplitude shifts in the beam when the subject responded.

Since the beam moved across the scope at a constant rate after being triggered by the to-be-shadowed letter, the point at which the amplitude shift occurred (due to the verbal response) represented the reaction time (RT) to the shadowed item. Furthermore, since the letters and responses were recorded on separate channels of the stereophonic recorder, the tape could be played back through the oscilloscope to check the reliability of the RT estimate.

A Hunter interval timer in circuit with a battery operated buzzer was used to determine the nine second interval. The timer was not used on the shadowing alone conditions. For the concurrent conditions the timer and monophonic recorder were started simultaneously. The recorder was turned off after four items had been presented to prevent the tape from being stopped in the middle of a letter. The timer was turned off a second or two after the buzzer had sounded to prevent foreshortening of the subsequent interval.

Procedure

On the first day the subject was randomly assigned to the shadowing group by order of arrival. The subject was told that the object of this experiment was to see how quickly he could process certain kinds of information. The subject was shown the card containing the circular sequence and his attention was called to the fact that the sequence was circular in the sense that every given digit was followed by another digit in the sequence. Then the one-unit transformation with the cue card was explained. The subject was instructed to go as fast as he could without making more than 2 or 3 errors. He was also instructed to write the digits in his normal handwriting and to stop immediately when he heard the buzzer. The subject was then given a practice trial lasting 9 seconds with the data obtained consisting of the number of transformations made in the 9 second interval. Similar instructions were then given concerning the zero-unit transformation with a practice trial following.

Next the shadowing card was shown and only the instructions pertaining to the subject's own group were given. The experimenter shadowed four items according to the appropriate rule and then the subject likewise shadowed four letters.

The subject was then told that there would also be some concurrent combinations of the transformation and the shadowing tasks. The instructions placed primary emphasis on the shadowing task requiring that the subject shadow each letter regardless of the number of transformations obtained. Then the card representing the concurrent condition zero-unit transformation with shadowing, was shown and the experimenter demonstrated a trial followed by the subject's trial. Since the shadowed items were spaced in two-second intervals, the final letter in a trial could conceivably occur as late as 8 seconds after the beginning of the trial. In the event that the last shadowed item occurred late in the interval and the subject had not had time to shadow the letter before the buzzer sounded, he was instructed to go ahead and shadow the letter after the buzzer had sounded but to stop writing immediately when he heard the buzzer. The subject was then shown the one-unit transformation while shadowing and given a demonstration by the experimenter. The subject then received one practice trial of said condition. For complete instructions see Appendix A.

After the instructions the subject was given three blocks of practice trials thus completing the first day's session. A block consisted of one trial for each of the five conditions.

On each of the next three days the subject was given minimal instructions with the cue cards to refresh his memory; he was also reminded not to make more than 2 or 3 errors. Then he was given ten blocks of trials. Between conditions within a block, there was a 15 second pause while the experimenter recorded the shadowing time on a prepared sheet and changed the cue cards. Between blocks there was an additional 30 second pause while the experimenter handed the subject a new booklet on which the subject subsequently recorded his name, group, and block. Following the fifth block the subject was given a 2 minute rest period. Each subject was given a total of 34 blocks over a four day period. Each daily period lasted approximately one hour.

Results

Since the present study is concerned with two separate measures, the metered memory search data and the shadowing times will be considered separately for the sake of clarity. Then the results will be used jointly to determine whether or not simultaneous processing has occurred.

Metered Memory Search

In order to make the current study more comparable to previous work with metered memory search (Weber, Cross and Carlton, 1968), the major dependent variable--the total number of transformations performed in nine seconds was converted to time per transformation by means of the reciprocal relationship. The resultant time per transformation data is presented in Table III. When the metered memory search task is performed alone, the T_0 and the T_1 conditions are the same for all shadowing groups. Only when the metered memory search task is performed in conjunction with the shadowing task do the conditions differ; that is, the $T_i + S_j$ conditions are different for all three groups. For example, the means for the T_0 condition are .47, .47 and .46 for the visual, acoustic and name groups respectively as would be expected since all three groups are performing identical tasks in the metered memory search alone. The differences between shadowing groups is not significant for all conditions except the one-unit concurrent condition where both the visual group and the acoustic group differ from the name group at the .01 significance level according to the Newman-Keuls procedure. Size of transformation was significant at the .01 level for all three groups. The alone vs concurrent factor was significant at

TABLE III

TIME (SECS) PER TRANSFORMATION DESCRIPTIVE STATISTICS AS A FUNCTION OF TRANSFORMATION SIZE AND SHADOWING TASK

Shadowing Group	T_0	$T_0 + S_j$	T_1	$T_1 + S_j$
	Transformation Condition			
Visual				
Mean[a]	.47	.63	.58	.84
S. E. M.	.06	.11	.06	.19
Median	.47	.60	.56	.82
Acoustic				
Mean	.47	.58	.61	.83
S. E. M.	.05	.13	.11	.24
Median	.50	.56	.64	.82
Name				
Mean	.46	.49	.54	.60
S. E. M.	.06	.09	.06	.09
Median	.47	.50	.56	.64

[a]Means determined by averaging over number of Ss (N = 8 for each group) and number of trials (30).

the .01 level for the visual and acoustic groups but for the name group the factor was significant at .05 for the one-unit transformations and was not significant for the zero-unit transformation.

Figures 3 - 5 indicate that size of transformation, and alone vs concurrent factors proved to be significant variables. Practice effects are clearly evident in Figures 3 - 5 due to the overall reduction in time per transformation across blocks for all conditions. All eight subjects in each group showed improvement when the mean of the first ten trials was compared with the mean of the last ten trials for the more complex transformation task (T_1 and $T_1 + S_j$). For the simple reproductive task however, practice effects were not so regular. Six of the name group showed improvement in the T_0 condition and seven in the $T_0 + T_n$ condition. Only 3 in the acoustic group showed improvement in the T_0 condition and seven in the $T_0 + S_a$ condition. In the visual group all eight subjects showed improvement in all conditions. Notice also from the figures that the conditions improved at different rates with the $T_1 + S_j$ condition showing the greatest amount of improvement.

Significance tests for the means of Table III were performed. An analysis of variance (Table IV) was performed with each subject's mean time per transformation at each condition as the cell entries. The main effects of shadowing group, size of transformation and alone vs concurrent factors were significant ($p < .05$). With reduced degrees of freedom appropriate to the conservative test of the repeated measures design, the significance levels remained the same.

It is also noted from the Figures 3 - 5 that the differences between conditions remain even after considerable trials, as Table V indicates. Table V is an analysis of variance on the last ten trials for

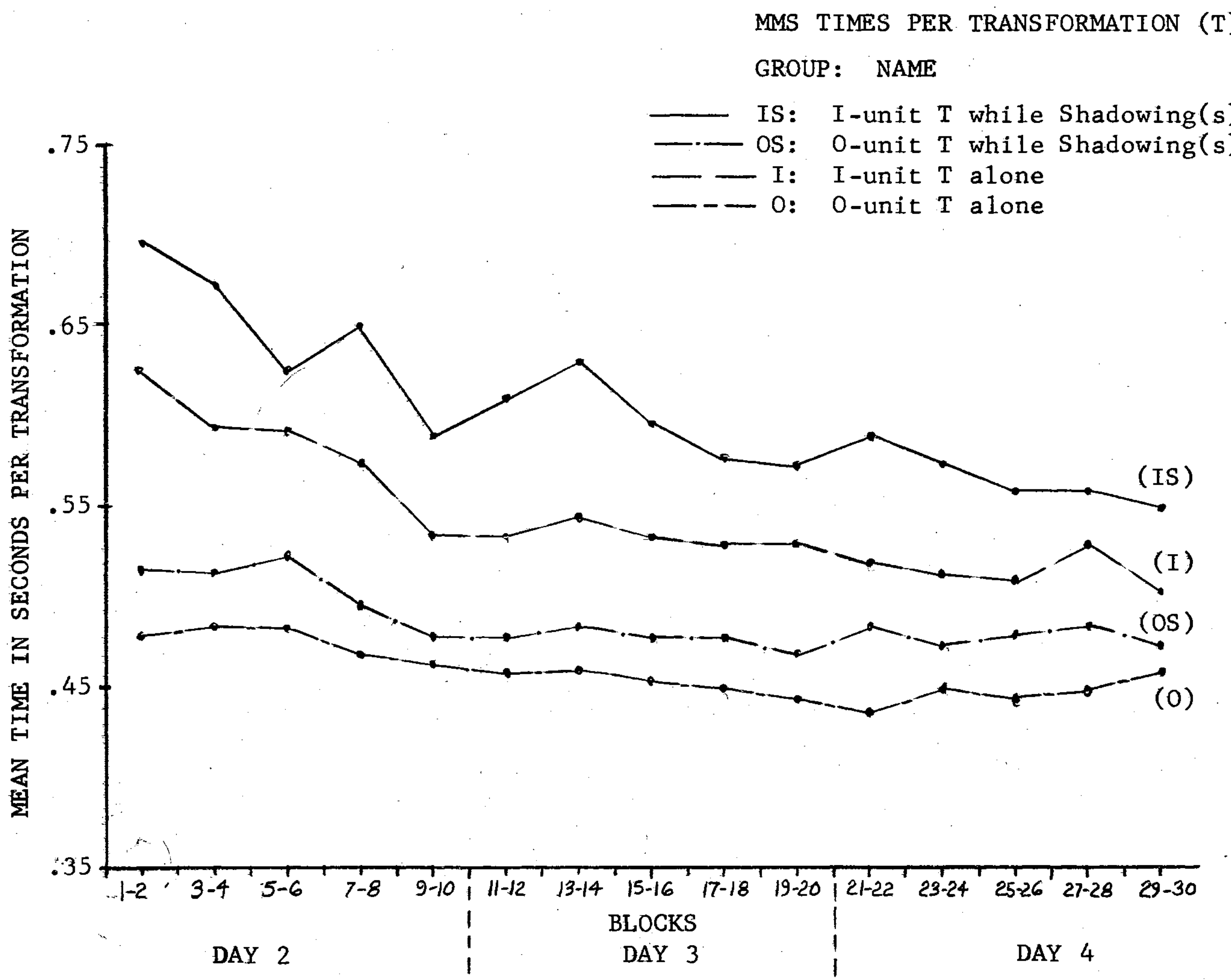


Figure 3. Time (Secs) per Transformation for the S_n Group Shown as a Function of Blocks

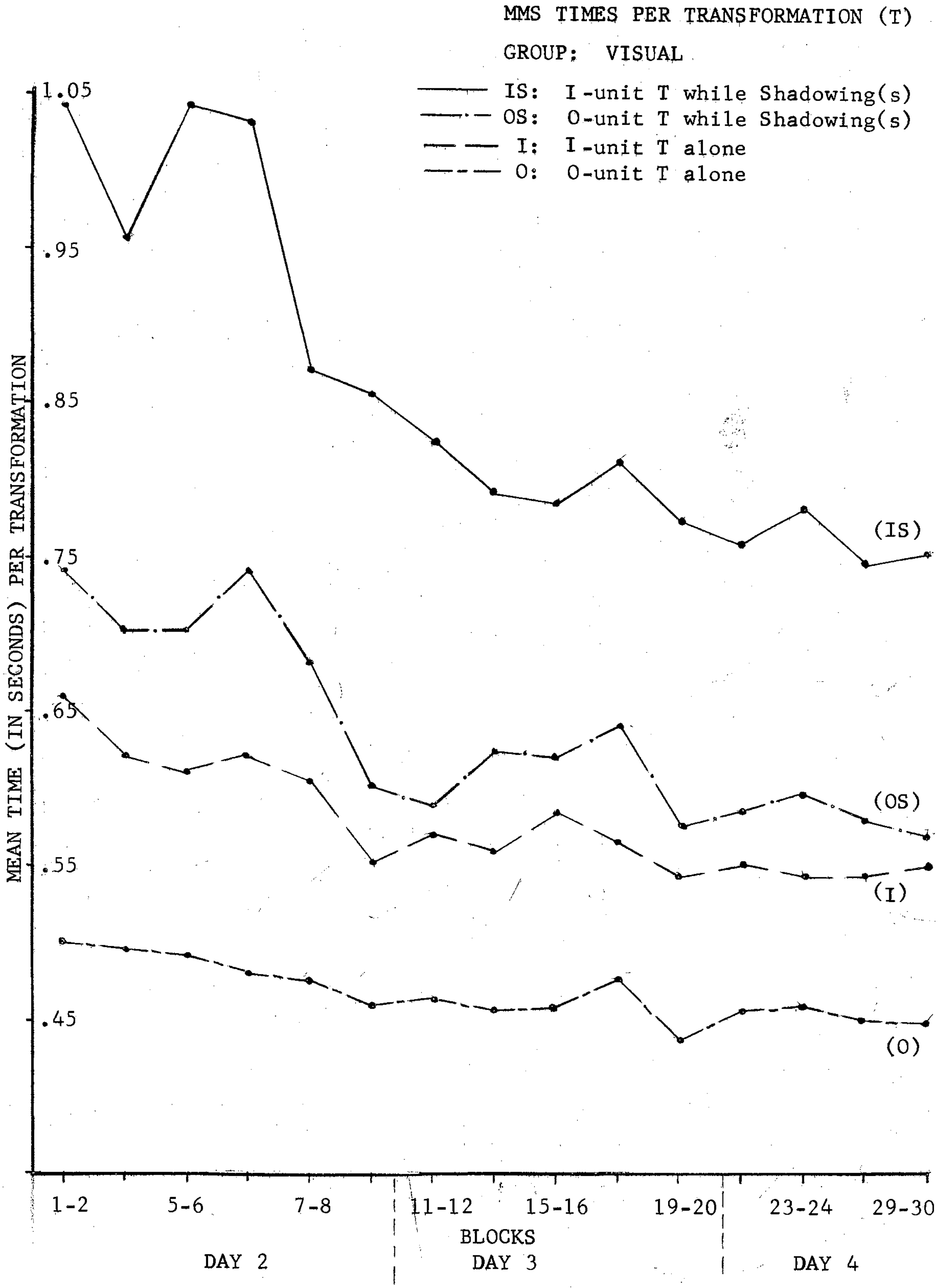


Figure 4. Time (Secs) per Transformation for the S_v Group Shown as a Function of Blocks

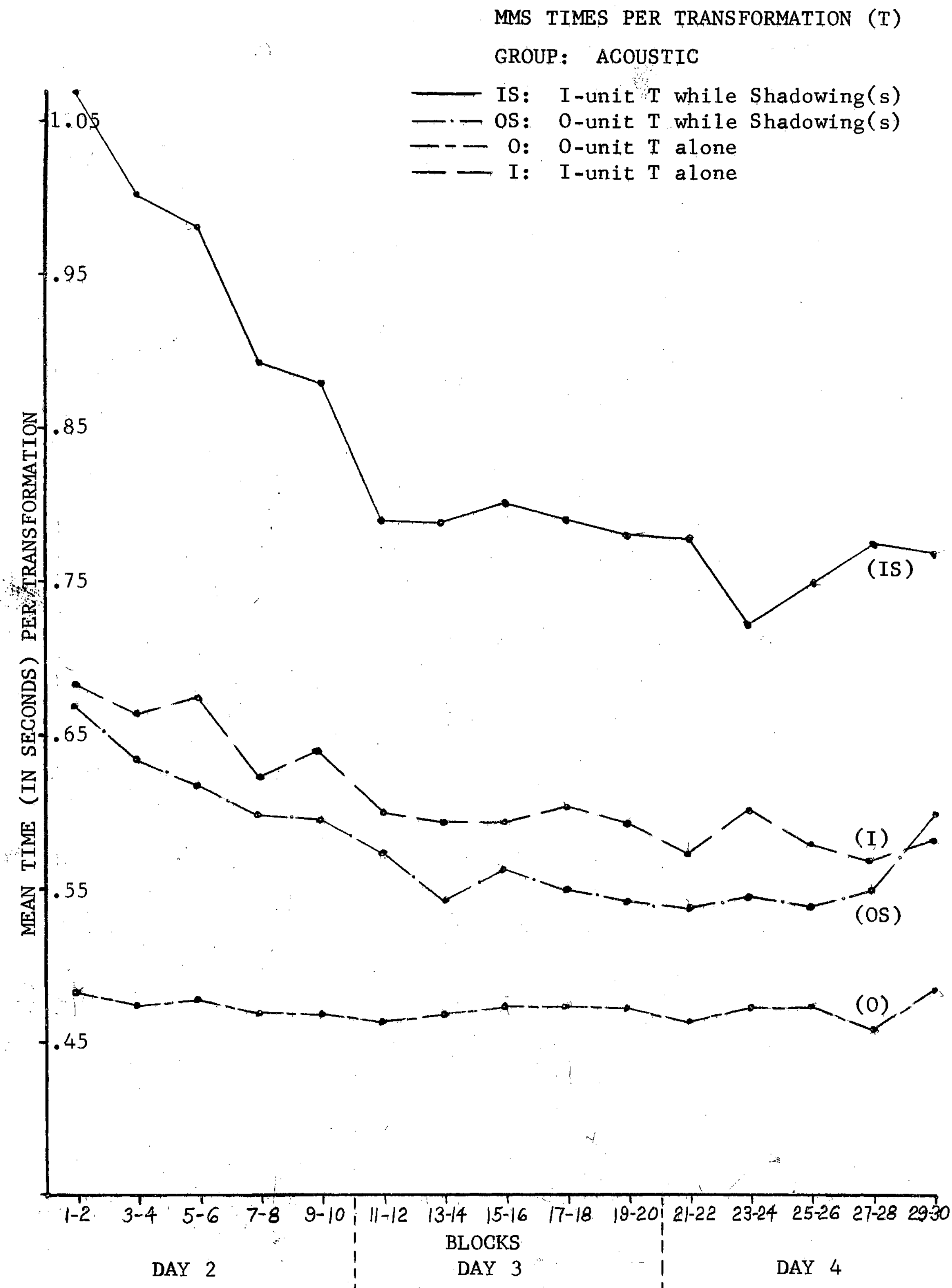


Figure 5. Time (Secs) per Transformation for the S_a Group Shown as a Function of Blocks

TABLE IV

ANALYSIS-OF-VARIANCE FOR TABLE III MEANS

Source of Variation	d.f.	SS	MS	F
Between Subjects	23	.97		
A (Name; Acous; Vis)	2	.27	.135	4.09($p <$ .05)
S's within GR	21	.70	.033	
Within Subjects	72	1.96		
B (Size of T)	1	.63	.63	63.00($p <$ .005)
AB	2	.06	.03	3.00($p <$ .10)
B x S in GR	21	.22	.010	
C (Alone vs. Conc)	1	.59	.59	59.0 ($p <$ .005)
AC	2	.15	.075	7.5 ($p <$ .005)
C x S in GR	21	.23	.010	
BC	1	.05	.05	52.63($p <$ .005)
ABC	2	.01	.005	5.26($p <$ .025)
BC x S in GR	21	.02	.00095	

TABLE V

ANALYSIS-OF-VARIANCE FOR BLOCKS 21 - 30

Source of Variation	d.f.	SS	MS	F
Between Subjects	23	.85		
A (Name; Acous; Vis)	2	.20	.10	3.33($p < .10$)
S's within GR	21	.65	.03	
Within Subjects	72	1.48		
B (Size of T)	1	.44	.44	44.00($p < .005$)
AB	2	.04	.02	2.00($p > .10$)
B x S in GR	21	.24	.01	
C (Alone vs. Conc)	1	.40	.40	44.44($p < .005$)
AC	2	.09	.045	5.00($p < .025$)
C x S in GR	21	.19	.009	
BC	1	.04	.04	44.44($p < .005$)
ABC	2	.02	.01	11.11($p < .005$)
BC x S in GR	21	.02	.0009	

each subject for each condition. Size of transformation and alone vs concurrent factors are still significant ($p < .005$), while the differences among shadowing tasks are no longer significant ($p < .10$).

Shadowing

In the shadowing analysis the dependent variable is the subject's reaction time (RT) from the onset of the stimulus letter until the subject's verbal response. The RTs are presented in Table VI. Notice that here too the RT increases for each group when the transformation task is changed from a simple reproductive task to the more complex transformation task. The Newman-Keuls Procedure indicated that the name group differed significantly from both the visual and acoustic groups for all three conditions at the .01 level of significance. Also the acoustic and visual groups were significantly different (.05) for the shadowing alone condition. This difference was not found in Experiment I. The alone vs. concurrent conditions were significant (.01) for all three groups. The size of transformation was only significant (.05) for the acoustic group.

An analysis of variance (Table VII) was performed on the mean RTs for each subject at each condition. The main effects of shadowing groups and alone vs concurrent condition were significant ($p < .005$). Size of transformation was not significant ($p < .10$). With reduced degrees of freedom appropriate to the conservative test of the repeated measures design, the significance levels remained the same.

Figures 6-8 indicate that shadowing group and alone vs concurrent factors proved to be important variables. Practice effects are evident with an overall reduction in RT across blocks for all conditions. When

TABLE VI

RT (SECS) DESCRIPTIVE STATISTICS AS A FUNCTION OF TRANSFORMATION SIZE AND SHADOWING TASK

Shadowing Group	Shadowing Task		
	S_j	$T_0 + S_j$	$T_1 + S_j$
Visual			
Mean[a]	.730	.836	.864
S. E. M.	.11	.08	.09
Median	.725	.875	.90
Acoustic			
Mean	.630	.820	.869
S. E. M.	.06	.05	.05
Median	.625	.825	.90
Name			
Mean	.373	.440	.455
S. E. M.	.10	.14	.15
Median	.375	.40	.425

[a]Means determined by averaging over number of Ss (N = 8 for each group) and number of trials (30).

TABLE VII

ANALYSIS-OF-VARIANCE FOR TABLE VI MEANS

Source of Variation	d.f.	SS	MS	F
Between Subjects	23	2.76		
A (Name; Acous; Vis)	2	2.19	1.095	40.56($p<.005$)
S's within GR	21	.57	.027	
Within Subjects	48	.42		
Treatments	2	.30	.15	57.69($p<.005$)
Alone vs. Concurrent	1	.296	.29	111.53($p<.005$)
Size of T (0 or 1)	1	.012	.01	3.85($p<.10$)
Residual	46	.12	.0026	

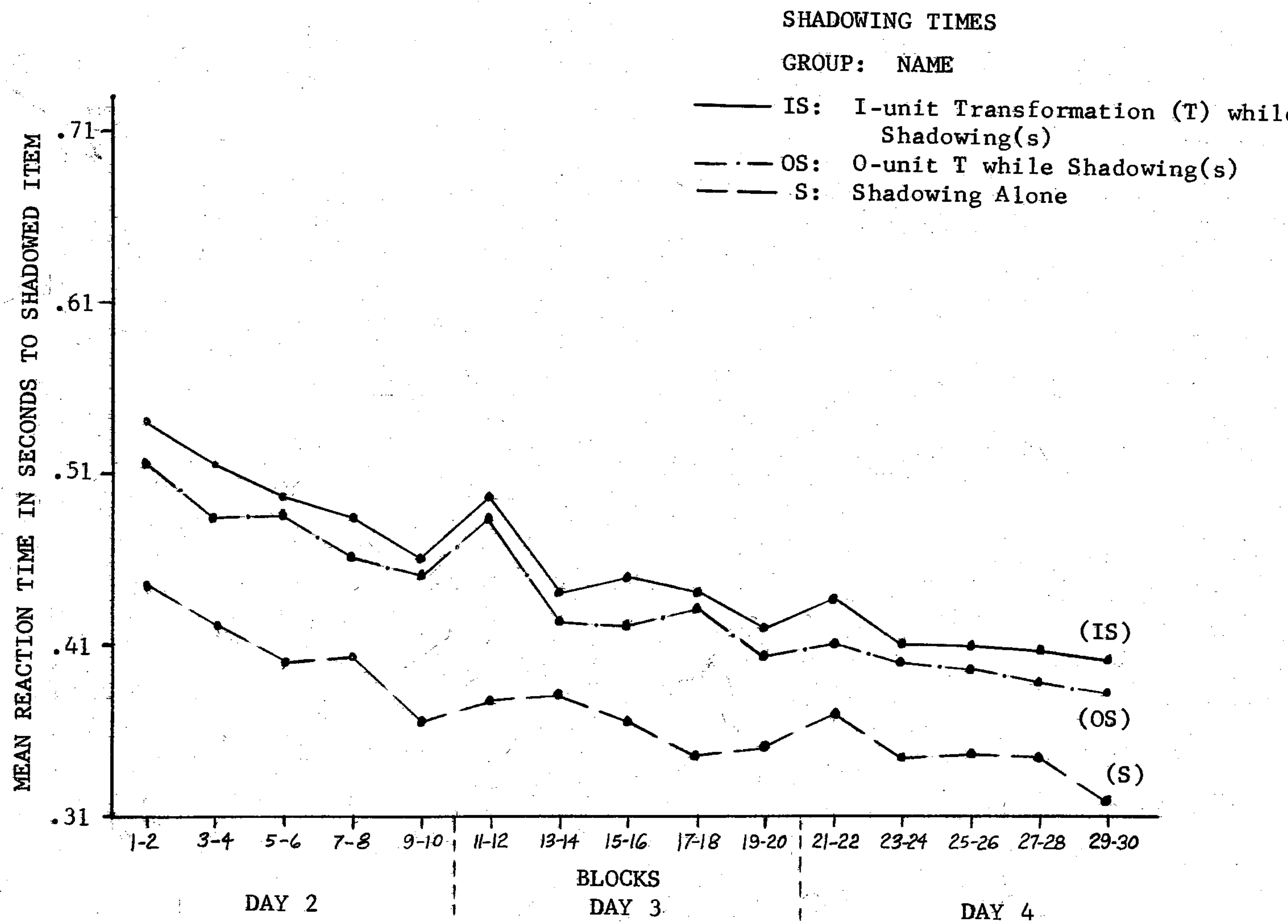


Figure 6. RT (Secs) for the S_n Group Shown as a Function of Transformation Size and Blocks

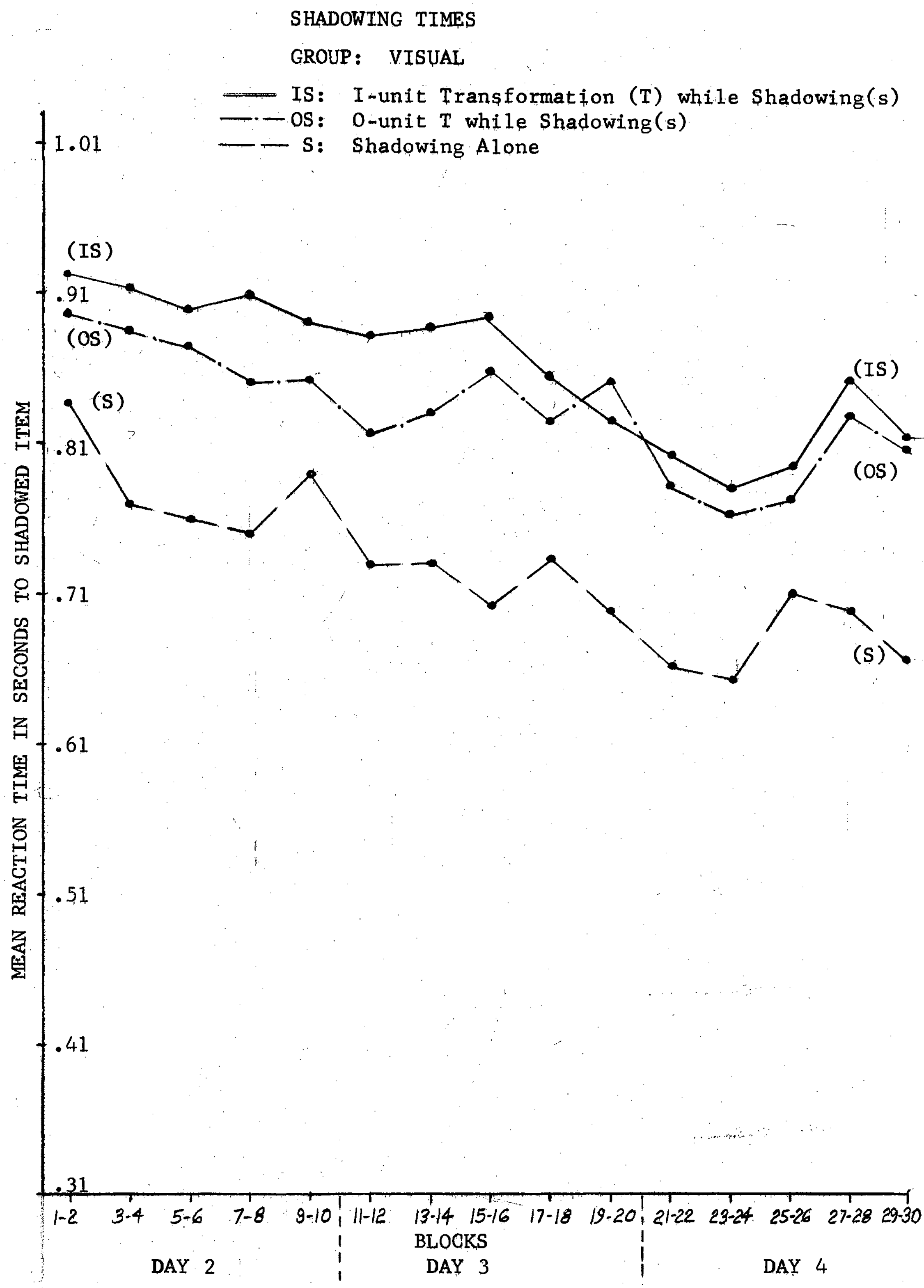


Figure 7. RT (Secs) for the S_V Group Shown as a Function of Transformation Size and Blocks

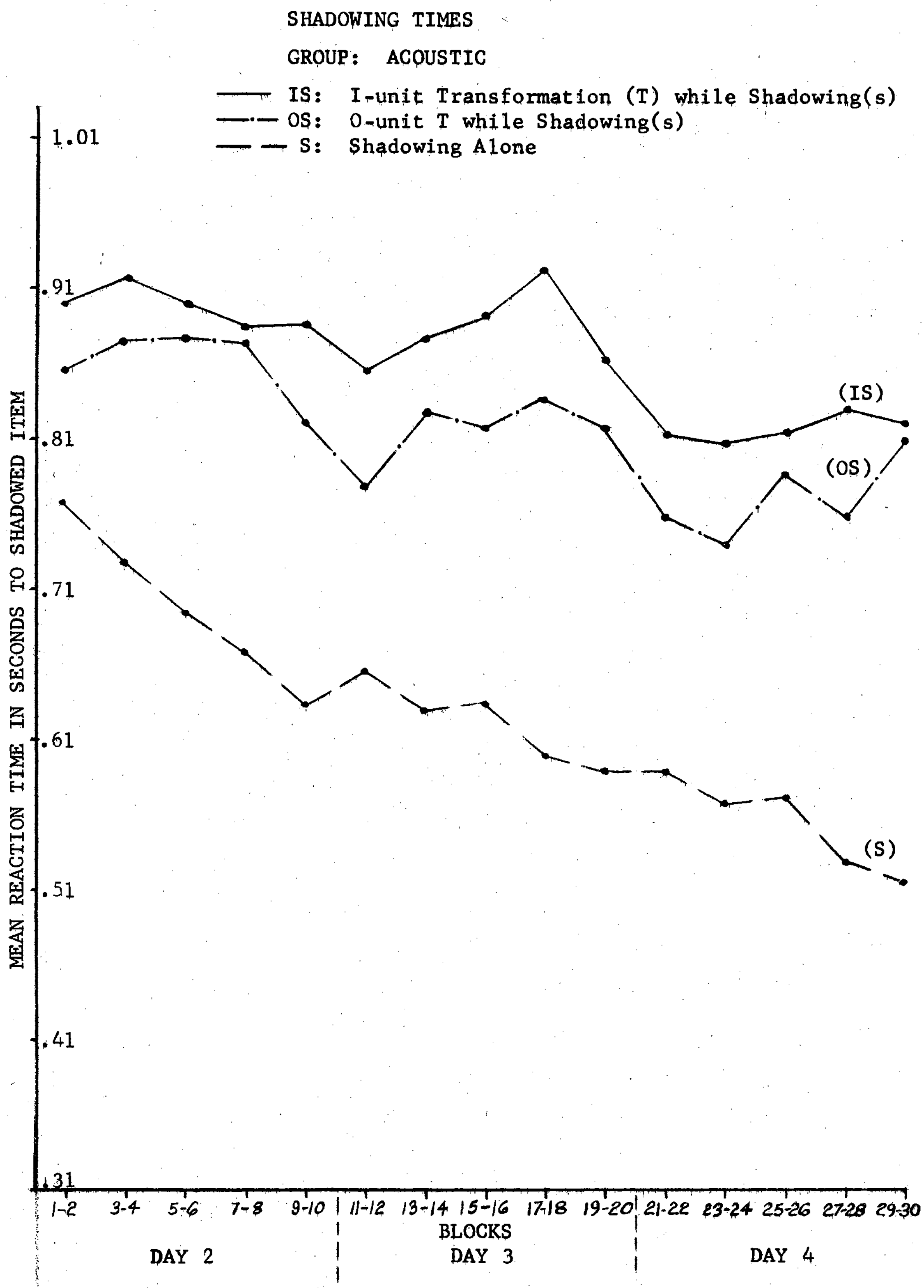


Figure 8. RT (Secs) for the S_a Group Shown as a Function of Transformation Size and Blocks

the mean of the first ten trials was compared with the mean of the last ten trials, seven of the eight subjects in the name group showed improvement in all three conditions. In the acoustic group seven subjects showed improvement in the S_a and $T_0 + S_a$ conditions but only six subjects showed improvement in the $T_1 + S_a$ condition. In the visual group five subjects showed improvement in the S_v condition, four in the $T_0 + S_v$ condition and seven in the $T_1 + S_a$ condition. Notice that here too the conditions improved at different rates as in the MMS data.

The differences in conditions remain even after considerable trials as Table VIII indicates, with the effects still being significant at the same level.

A reliability measure was performed on the shadowing RTs to insure that the RT measurements were reasonably accurate. The reliability was determined by measuring the RTs a second time using the tape recordings and the oscilloscope. The RTs for 24 randomly selected trials for each of the 9 conditions were chosen and remeasured by means of the oscilloscope. The original RTs were then correlated with the second RTs from the scope. All of the differences were within $\pm.05$ seconds. The following product-moment coefficients were obtained: $r = .98$ for the S_n group, $r = .99$ for both the S_v and the S_a groups. Thus, it is reasonable to assume that the RTs are reliable.

Simultaneous Processing

To determine whether or not simultaneous processing occurred, means for the different conditions were compared for each subject according to the following inequality: (N( ) refers to the number of transformations while t( ) refers to time per transformation)

TABLE VIII

ANALYSIS-OF-VARIANCE FOR BLOCKS 21 - 30

Source of Variation	d.f.	SS	MS	F
Between Subjects	23	2.79		
A (Name; Acous; Vis)	2	2.01	1.005	27.16($p < .005$)
S's within GR	21	.78	.037	
Within Subjects	48	.50		
Treatments	2	.33	.165	44.59($p < .005$)
Alone vs Concurrent	1	.32	.32	88.49($p < .005$)
Size of T (0 or 1)	1	.01	.01	2.70($p > .10$)
Residual	46	.17	.0037	

$$N(T_i) = \frac{9-4t(\overline{S}_j)}{t(T_i)} < N(T_i + S_j).$$

Simultaneous processing occurred if the inequality held. $N(T_i)$ is the maximum number of transformations that can occur, assuming that it is not possible to do both MMS and Shadowing at the same time. For example, comparisons were obtained by determining how many transformations could have been made at the maximum rate of MMS alone (assuming that maximum rate is MMS alone), during the concurrent conditions when the subject was not actually shadowing. That is, his mean shadowing time multiplied by four (since he shadowed four items) was subtracted from the total nine second interval to obtain the time he was not shadowing in the concurrent condition. The time remaining divided by the time per transformation for MMS alone gave the number of transformations possible at maximum rate. The resultant number of transformations was then compared to the actual number of transformations the subject performed: if the subject made more transformations than would have been possible between the shadowing items, he must have done some of them while shadowing, and thus he would have engaged in at least partial simultaneous processing.

The results are presented in Table IX. Specifically, Table IX indicates that subject 1 in the Visual group performed 5.21 more transformations than would have been possible for strictly serial processing in MMS and concurrent shadowing. All positive values indicate a savings or simultaneous processing while negative numbers indicate not only no savings but interference as well, i.e., a loss of over-all efficiency from doing the two tasks at once as compared to doing them separately.

TABLE IX

CONCURRENT PROCESSING ANALYSIS

Shadowing Group		Transformation Condition T_0	T_1
Visual			
Subject 1		5.21	3.25
2		- .76	- .70
3		3.73	1.69
4		2.30	1.65
5		3.69	2.23
6		4.04	1.21
7		.84	- .15
8		-1.53	- .65
	Mean	2.19	1.07
Acoustic			
Subject 1		4.03	2.30
2		5.13	3.48
3		4.40	1.65
4		3.07	.54
5		2.24	1.17
6		.24	.04
7		3.53	2.58
8		5.18	2.62
	Mean	3.48	1.80
Name			
Subject 1		.02	- .59
2		3.97	2.96
3		3.37	1.88
4		2.13	1.27
5		3.71	1.40
6		.38	1.06
7		4.03	3.19
8		2.60	2.43
	Mean	2.53	1.70

Notice that in each group there is less simultaneous processing in the one-unit condition when compared with the zero-unit condition. That is, compare column 1 by column 2 subject by subject.

Since the results in Table IX indicated simultaneous processing for most subjects, the same comparison was made for each block of the thirty trials for each subject to determine whether or not simultaneous processing increased with practice. The results are presented in Table X using the following inequality:

$$N(T_i) = \frac{9-t(\sum_{k=1}^{4} S_{jk})}{t(T_i)} < N(T_i + S_j).$$

Note that here the four shadowing times ($_k$) for each trial were summed rather than a mean for the shadowing time multiplied by four to obtain more accurate data.

Notice first of all that there was again more simultaneous processing in the T_0 condition when compared with the T_1 condition as seen by comparing the totals for each subject. For example, subject 1 in the visual group showed 29 cases of simultaneous processing in the T_0 condition but only 27 in the T_1 condition. These totals can be broken down day by day in blocks of 10 trials each. For example, subject 1 in the visual group showed 9, 10 and 10 cases of simultaneous processing for the first, second and third days respectively for the T_0 condition.

The practice effect of simultaneous processing can be seen most readily by comparing the figures in the last column which represents totals over all eight subjects. For example, in the visual group the T_0 condition increased from 53 to 67 for day 1 as compared with day 2.

Finally, the data can be interpreted as supporting the hypothesis of simultaneous processing.

TABLE X

FREQUENCY OF SIMULTANEOUS PROCESSING OVER SUBJECTS AND TRIALS

Shadowing Group		Subject 1	2	3	4	5	6	7	8	Total
Visual										
Blocks 1-10	T_0	9	1	10	6	10	10	7	0	53
	T_1	9	2	9	6	10	4	5	0	45
Blocks 11-20	T_0	10	7	10	10	10	10	9	1	67
	T_1	9	3	10	10	10	9	7	4	62
Blocks 21-30	T_0	10	4	10	10	10	10	6	7	67
	T_1	9	5	9	9	10	10	4	5	62
Totals	T_0	29	12	30	26	30	30	22	8	187
	T_1	27	10	28	26	30	23	16	9	169
Acoustic										
Blocks 1-10	T_0	9	10	10	9	7	4	9	10	68
	T_1	8	9	5	6	8	4	8	10	58
Blocks 11-20	T_0	9	10	10	10	9	8	10	10	76
	T_1	9	10	10	8	8	7	10	8	70
Blocks 21-30	T_0	10	10	10	9	10	6	9	10	74
	T_1	10	10	9	6	7	6	10	7	65
Totals	T_0	28	30	30	28	26	18	28	30	218
	T_1	27	29	24	20	23	17	28	25	193
Name										
Blocks 1-10	T_0	7	10	10	10	10	7	10	10	74
	T_1	3	10	9	9	9	8	10	10	68
Blocks 11-20	T_0	5	10	10	10	10	7	10	10	72
	T_1	3	10	10	7	6	8	10	10	64
Blocks 21-30	T_0	6	10	10	9	10	4	10	10	69
	T_1	4	10	10	8	7	8	9	10	66
Totals	T_0	18	30	30	29	30	18	30	30	215
	T_1	10	30	29	24	22	24	29	30	198

CHAPTER IV

DISCUSSION AND CONCLUSION

What conclusions can be made concerning the eight hypotheses postulated in Chapter I?

1. The first hypothesis stated that the shadowing reaction times would vary, with the shadowing for visual properties of letters being longest, shadowing for acoustic properties of letters next longest, and shadowing for letter names shortest. The analysis of variance for the shadowing reaction times showed that the differences in the shadowing groups was significant with a p value less than .005 for all thirty trials. This difference held after considerable practice as seen by the $p < .005$ for the last ten trials only. The differences between results obtained in Experiments I and II are probably due to design variables; that is, in Experiment I the shadowing conditions were within subjects while in Experiment II the shadowing task was a between subjects variable. The differences can again be explained in terms of task difficulty. The S_n group is a simple reproductive task requiring little processing of information other than identification. The shadowing for letter properties groups, however, required a transformation of the stimulus letter to a "yes" or "no" verbal response depending on the particular rule employed. In the S_a group the subject simply responds to an acoustic property of an acoustically presented stimulus letter;

actual identification of the letter is not actually necessary for the application of the rule. In the S_v group not only must the stimulus letter be identified but the letter must then be visualized in order to determine the physical property before the rule can be applied. Since more processing mechanisms are needed, the times are longest for this group.

Of course, it is possible that subjects simply learned arbitrary responses ("yes" or "no") in conjunction with particular letters, without any mediating images. After the subjects had completed all thirty trials, the experimenter asked if the subject had indeed visualized the letters. All subjects reported that they had visualized the letters before responding "yes" or "no".

The chance sequential dependencies interpretation although predicting the obtained results is inappropriate because of the two second delay between letters.

2. The second hypothesis postulated an effect due to transformation size with a one-unit transformation requiring more time than a zero-unit transformation. Since the significance level for this factor is less than .005, we conclude that size of transformation is indeed a significant variable. This difference can be explained in terms of increasing task difficulty as outlined by Peterson (1969). The zero-unit transformation requires only a simple reproduction of the stimulus item while the one-unit transformation requires that the stimulus item be transformed to the next item in the circular sequence.

3. The third hypothesis assumed that concurrent activities would significantly increase times for both the metered memory search and

shadowing. The metered memory search concurrent vs alone factor was significant at .005 level when all trials were considered; and even when only the last ten trials were considered the significance level remained the same. The shadowing data revealed identical significance levels for both the thirty trials and the well-practiced subjects including only the last ten trials. Since both times increased, the concurrent performance resulted in loss of efficiency on both tasks significantly. This is not surprising in terms of cognitive load; with the additional activity there is less conceptual space available for processing of the first activity.

4. The fourth hypothesis predicted an interaction between the three shadowing tasks and size of transformation of metered memory search. If the metered memory search task had a visual or acoustic component, then we would expect more interference as we move from a reproductive task in MMS to a transformation task involving memory during the concurrent conditions. However, the AB interaction was not significant ($p < .10$).

5. The fifth hypothesis proposed an interaction between concurrent vs alone factor and size of transformation in metered memory search. The resultant analysis produced a significance level of .005 for the BC effect for all thirty trials and also for the last ten trials. This effect is explained in terms of cognitive load: since the transformation tasks of metered memory search involve both reproduction (T_0) and transformation (T_1), there was more overloading and thus longer times during the concurrent activities with the one-unit transformation task than with the zero-unit reproductive task. This effect was long lasting as seen in the .005 level

for the last ten trials after the subject was well-practiced.

6. The sixth hypothesis assumed an interaction between shadowing groups and the concurrent vs alone factor. The analysis of variance resulted in a significant level of .005 for all thirty trials and .025 for the last ten trials alone for the AC interaction. Although the alpha level increased when viewing only the last ten trials, the level is still within the level of significance desired. This effect is again explained in terms of cognitive load: since the shadowing tasks involve different levels of attention, there were different over-loadings of processing functions during the concurrent activities.
7. The seventh hypothesis stated that some simultaneous processing would occur. As seen from the analysis of simultaneous processing, simultaneous processing probably did occur. The frequency of the simultaneous processing varied according to size of transformation and shadowing task difficulty, which was consistent with the cognitive load notion of the flexible function model of information processing.
8. The eighth hypothesis predicted an improvement in concurrent processing due to practice. Reference to the figures indicates a general improvement over days with the last trial requiring less time than the first trial for all conditions.

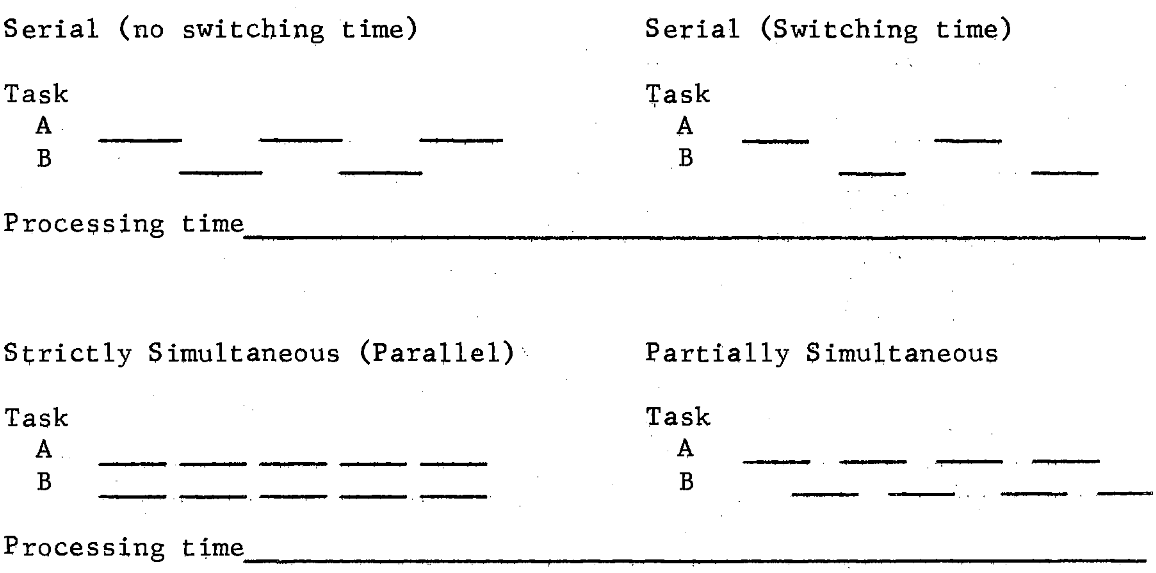
In Sternberg's (1969a, 1969b) recent work with the additive-factor method of processing stages he concluded that the possibility of getting temporal estimates of RT for separate stages of information processing by using subtractive procedures should be rejected. However, separate processes which operate additively can be studied by trying to find factors that will show various types of interaction with some hypothesized processing stages and not with others. For example, consider the concurrent processing models presented in Table XI. Here the time required for the processing of two tasks is considered. If one is receiving two kinds of information concurrently and if this information must be processed in a serial fashion, reference to the top half of the table is appropriate, the particular scheme depending on whether or not time is required to switch from task "A" to task "B" and vice versa. With the serial model the concurrent time would be equal to or greater than the sum of the two tasks when performed alone depending on switching time. In other words, concurrent processing should be an additive function of component times (no switching time) or an additive function with an additional constant (switching time).

If, however, it is possible to process the two tasks simultaneously, we obtain the schemes shown in the bottom half of the table with total overlapping or only partial overlapping of processing time. In these models the concurrent time would be less than the sum of the two tasks when performed alone because the processing occurred simultaneously. One exception to this would be if doing the two tasks concurrently increased the "dead time" between successive responses.

The serial models both seem to be inappropriate at the overt level because of savings scores and the fact that the subjects can respond with simultaneous written and spoken responses at the overt level (King and Weber, 1970). Thus at the overt level the strictly simultaneous model is appropriate. However, this model would not hold for information processing at a more central level unless the rate of doing two yoked tasks would be as rapid as the slower of the two tasks when done

TABLE XI

CONCURRENT PROCESSING MODELS



alone. This did not occur. The alone vs concurrent factor proved to be highly significant with concurrent processing taking longer than the slowest component alone. So what we must have at a more central level is, on first examination, partial simultaneous processing. However, with rapid enough scanning time either of the serial models might be appropriate (Sternberg, 1966). But the serial rates required would be far in excess of implicit or explicit speech rates (Weber and Bach, 1968).

In effect we cannot reject unequivocally any of the models at the central level. However, if either of the serial models holds, we are talking about a verbal trace system of an abstract form that is very different in rate of operation from implicit or explicit speech. Again if we consider either of the parallel models, we must be dealing with some kind of abstract trace system because we cannot "say" two things at the same time--there is a kinesthetic limitation, and secondly we cannot "hear" effectively two things at the same time, as shown by the shadowing literature. That is to say, the trace system cannot be in the form of acoustic images if they follow at all the same sorts of relations observed for dichotically presented acoustic stimuli.

In brief, all models lead eventually to an abstract trace system that is neither kinesthetic nor acoustic in nature. What then are the properties of the abstract trace?

1. From it characters can be "printed out" in written form or spoken form.
2. The written form is considerably slower than the verbal form.
3. Print out into verbal form occurs at about the same rate for implicit and explicit speech (Weber and Bach, 1968).

4. The print-outs to writings and speech are only partially independent as shown by the fact that a chant that is incompatible with the circular sequence slows processing down more than does a neutral compatible chant (Weber and Blagowsky, 1970).
5. More directly, any kind of chant slows down print-out as compared to no chant conditions as seen by the alone vs concurrent factor in the current experiment.

For the present study the abstract trace system seems to conform quite nicely to the results of the additivity analysis and is therefore given further support. Of greater significance however, is the fact that the visual and acoustic components of a verbal trace system were not supported as noted by the fifth hypothesis which postulated an AB interaction. If this interaction had been significant then the visual or acoustic trace system would have been supported rather than the current abstract trace system depending on whether the visual group or the acoustic group created the significant interference. The only way to obtain this particular finding would be to engage visual and acoustic components in conjunction with a memory task similar to the one in the present study.

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APPENDIX

INSTRUCTIONS

Numerical Sequences: The object of this experiment is to see how quickly you can process certain kinds of information.

TRANSFORMATIONS

Look at the sequence of numbers on this card. (Show) Please note that it is a circular sequence. This means that for any number "4" through "8", it should be possible for you to provide without hesitation the next number in the sequence. For example, if the number "6" is presented to you, then you should be able to write the number "7" because it is the number next to "6" in the sequence. If "8" is presented, write "4"; if "4" write "5"; if "5" write "6"; if "7" write "8".

ONE-UNIT TRANSFORMATIONS

Now here is a card explaining what you are to do. (Show) The "1" implies that you are to fill-in the blank beside each stimulus number with the number one step away in the sequence. For example, if the number "4" is given, then write "5"; if "5" write "6"; if "6" write "7"; if "7" write "8"; if "8" write "4". I want you to go as fast as you can and you should not make more than 2 or 3 errors. Please write the numbers in your normal handwriting and stop immediately when you hear the buzzer. Ready? Start...Please turn the page.

ZERO TRANSFORMATIONS

The meaning of this card is a zero shift. For example, if the number "4" is given, then write "4"; if "5" write "5"; if "6" write "6"; if "7" write "7"; if "8" write "8". I want you to go as fast as you can and you should not make more than 2 or 3 errors. Please write the numbers in your normal handwriting and stop immediately when you hear the buzzer. Ready? Start...Please turn the page.

SHADOW

This card represents a shadowing task; that is, we want you to respond as rapidly and as accurately as possible to the letters on the tape recorder.

NAME (ONLY)

The letters shown on this card will be randomly presented on the tape recorder. We want you to repeat said letter as rapidly and as accurately as possible. For example: (Turn on recorder and shadow 4 items then let subject shadow 4 items.)

VISUAL PROPERTY (ONLY)

Notice that some of the letters on this card extend below the line in lower case typed print (g p q y) while some of the letters do not extend below the line in lower case typed print (z v o m). (Show) These letters will be randomly presented on the tape recorder. We want you to say "yes" if the letter extends below the line and "no" if it does not extend below the line. Do this as rapidly and as accurately as possible. For example: (Turn on recorder and shadow 4 items then let subject shadow 4 items).

ACOUSTIC PROPERTY (ONLY)

Notice that some of the letters on this card have a long "e" sound (g p v z) and some of the letters do not have a long "e" sound (y q o m). (Show) These letters will be randomly presented on the tape recorder. We want you to say "yes" if the letter has a long "e" sound and "no" if it does not have a long "e" sound. Do this as rapidly and as accurately as possible. For example: (Turn on recorder and shadow 4 items then let subject shadow 4 items.)

CONCURRENT CONDITIONS

There will also be some combinations of the shifts and the shadowing task. When this is the case, pay particular attention to the shadowing task and do it as rapidly and as accurately as possible; also do the shifts at the same time, but place primary emphasis on the shadowing.

This card represents the shadowing with the zero shift. (Demonstrate) If the buzzer sounds before you have shadowed the last letter, go ahead and shadow the last letter after the buzzer has sounded but stop writing when the buzzer sounds. (Let S run 1 trial)

This card represents the shadowing with the one-unit shift. (Demonstrate and let S run 1 trial.)

REAL TRIAL

Now I am going to show you a card with one of the conditions we've talked about; begin making the required shifts or shadowing tasks as rapidly as you can without making more than 2 or 3 errors. Any questions?

VITA

Sandra Jean King

Candidate for the Degree of

Doctor of Philosophy

Thesis: METERED MEMORY SEARCH WITH CONCURRENT SHADOWING FOR LETTER PROPERTIES OR NAMES

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