METERED MEMORY SEARCH AND CONCURRENT STIMULUS PROCESSING

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

BACKGROUND

Introduction

Research in the field of information processing has been much and varied. It has ranged from simple attention-reaction-time experiments to the complicated experiments of the past decade dealing with the processing of more than one piece of information and requiring more than one specific response, all to be carried out at the same time. The research involved in exploring man's capability in the realm of concurrent processing of various kinds of information (to which this study will address itself) has dealt mostly with auditory stimuli. Recently, however, the visual sense modality has come into use. It was Moray (1967) who framed the most pertinent question concerning concurrent processing capacity. That was, "Where is capacity limited?" He was, of course, speaking in terms of location but the same question might be asked not in terms of where, but rather in terms of how and to what degree capacity is limited.

Review of the Literature

Cherry (1953) presented _S_s with two mixed speeches one of which the _S_s were to repeat word by word or phrase by phrase. Only after a large number of playbacks were subjects able to do as they were required. However, if the messages consisted of cliches strung together by connecting words the Ss while able to pick out whole cliches were unable to separate them as to the messages in which they were contained. This was explained by the low transitional probabilities of cliches following each other. When speeches were separated and fed to separate ears Ss experienced little difficulty in shadowing the message of a previously designated appropriate ear. Generally, shadowing involves the continuous reproduction of a message with which an individual is presently being stimulated. A further finding revealed that messages in the unattended ear were almost completely unrecognized. However, some information did get through the unattended ear. Specifically, Ss could tell if the rejected message was spoken in normal human speech, were able to discriminate between a male and a female voice, could identify a 4000 CPS tone, and observed that reversed speech sounded queer. When identical messages were fed to both ears with the stipulation that the message to one ear start before the other and with the further stipulation that the time delay between them continue to decrease until they overlapped, Ss recognized the messages were the same when the delay was between 2 and 6 seconds.

When Cherry (1953) periodically switched one message between the two ears at various time intervals (i.e., 1 second, 1/20th to 1/50th of a second, 1/6th to 1/7th of a second) then the shadowing responses were 100%, 100% and 0% correct respectively: the point being that there was a switching period at which there was a minimum fraction of words repeated by the Ss. By introducing a silent period between switching scores fell below 20% correct while the silent period was no greater than 10 milliseconds.

In what virtually was a replication of some of Cherry's (1953) experiments, Moray (1959) had subjects shadow one message presented to one ear while another message was fed to the unattended ear. Results resubstantiated Cherry's finding that little of the unattended message is understood by the subject.

In a subsequent experiment, Moray (1959) presented some subjects with their name in the message which impinged on the unattended ear. Results showed that the affective value of a message is important if one is to determine whether or not it will break through the block in dichotic selective listening. The majority of those whose names were imbedded in the rejected message heard them. He also found that when neutral material (i.e., digits) was used instead of the subject's name it did not get through. This result led him to suggest that the "block in dichotic shadowing occurs at quite a high level, and that the block is central to some pattern-analyzing mechanism." His results were later confirmed by Oswald, Taylor and Treisman (1960) in an experiment dealing with the intelligibility of one's name during sleep and by Howarth and Ellis (1961).

In what appears to be a direct repudiation to Moray's (1959) results, Peterson and Kroener (1964) demonstrated in several experiments that if Ss were told they would be tested on material being presented to the ear opposite the one shadowed, then performance was fairly accurate. The first experiment consisted of shadowing digits on the first day, shadowing digits and recalling letters both being presented by the same male voice on the second day, and shadowing digits (presented by a female) and recalling letters (presented by a male) on the third day. The second experiment consisted of shadowing a voice of one sex while the voice of the opposite sex was presented to the non-shadowed ear. The male voice was shadowed worse than the female voice. Additionally, the female voice was recalled better than the male voice though not significantly. In the third experiment subjects were presented with words to be shadowed and digits to be recalled and vice versa. The words were spoken in a female voice while the digits were spoken by a male. Results showed shadowing to be better for words than for digits. Recall for both words and digits was also poorer than for the previous two experiments.

In an attempt to ascertain the effects of speaking and listening simultaneously, Broadbent (1952) had subjects respond to questions which were presented over a loudspeaker. The questions (which were phrased in a typical radio-telephone procedure) concerned pieces of paper on which were drawn abstract patterns. The Ss were to respond in the same manner as the questions (i.e., the same pattern). There were three conditions: 1) Questions which were presented after a specific interval of silence allowing for an answer to the preceding question; 2) Occasional overlapping of some answers by the next question; 3) Continuous overlapping. The results were general impairment of ". . . the interrupted response and the response to the interrupting question under the occasional overlapping condition" (Broadbent, 1952, page 272). However, the impairment was significantly increased when the overlapping was continuous. He supposes that there exists some interference between speaking and listening (Broadbent, 1952, page 272). Virtually the same empirical finding was obtained by Webster and Thompson (1954) using control tower operators. The more the overlap the less the accuracy of response.

Later experiments by Broadbent (1954), which were of a similar nature as those above but looking for the function of auditory localization in attention and memory span found by separating the sources of information in space, a relevant message, played simultaneously with an irrelevant one, was more likely to be understood. However, separation was not advantageous if rapid alternation between channels was required. This study was in confirmation of an earlier study by Poulton (1953) wherein he found that with no speaker separation errors increased and that similarity between the primary and secondary message resulted in more errors. Hirsh (1950), too, had found that "when two independent sound sources, one of speech and the other of noise, are changed in position relative to each other, the resulting changes in signal-to-noise ratio at the ear or ears of an observer will change the threshold of intelligibility of the speech." Furthermore, spatial separation and the resultant localizations are responsible for additional modifications in the threshold.

It was later found by Spieth, Curtis, and Webster (1954) that when two simultaneous messages were presented to operators their performance in responding to one of the two messages was greatly enhanced if the messages were spatially separated in an horizontal fashion. Too, if a filter was used which changed the tone quality in the several channels their performance again was aided. However, visual cues which indicated which message was about to come aided very little as did facilities which "pulled down" a message from its initial source into an earphone or loudspeaker near the operator's ear.

It was experiments such as these that led Broadbent to propose the idea of a filter which could be tuned to one of several input channels filtering out other impinging information which was not relevant. This, of course, means that limitations in processing capacity are due to fixed channel capacity.

Moray (1967) differed with Broadbent's notion that limitations in processing capacity are due to fixed channel capacity and proposed instead that capacity is fixed in terms of central processing capacity. In an experiment where subjects were provided with a means of reporting in parallel (pressing two keys simultaneously) thus matching parallel inputs it was found that simultaneous recall was more efficient than alternating recall when differing information was simultaneously presented to the left and right ears, respectively. The explanation put forth is that central processing capacity did not have to translate or transform parallel input into sequential output. This translation had been required in the Broadbent studies.

This finding by Moray (1967) confirmed virtually the same finding in an earlier experiment by Moray and Jordan (1966). This earlier study, however, demonstrated in addition, the effects of practice dramatically. In all cases Ss quickly improved with practice and reached a plateau equally as rapidly. In a reinterpretation of Broadbent's (1954) earlier experiment, Moray and Jordan (1966) stated that in unpracticed Ss if the rate of presentation is more than one pair/second with a two-channel message input of pairs of digits there is an overloaded portion of the system when there is only one output channel. However, this is not the case when parallel inputs do not have to be processed for sequential output and signal transmission rate is enhanced when compatible input/output channels are provided.

Broadbent (1954) had proposed that maximal performance in recalling pairs of digits presented simultaneously and dichotically occurred at a presentation rate of not more than one pair every 1.5 seconds. He interpreted this limit as being due to a rate effect. He had further postulated a switching rate and had estimated the time it takes to make a perception to be about 1/2 second. In an attempt to verify and extend Broadbent's notions, Moray (1960) used the same pair presentation patterns and recall patterns as had Broadbent. The results, however, did not verify Broadbent's results. They, in fact, contradicted them for the most part. For instance, Moray (1960) found a recall rate in excess of Broadbent's postulated one pair per 1.5 seconds. Subjects were making the least number of errors when binaurally presented with four digits per second under a free recall pattern. In contradistinction to Broadbent's notion of the limit on alternating recall of simultaneously presented digits being set by the rate, Moray proposed that the limit is set by interference. Where Broadbent had postulated perception to take about 1/2 second Moray experimentally demonstrated perfect recognition of digits (0-9) when only 1/3 to 1/8 of the digit was aurally presented which took considerably less time than 1/2 second. However, Moray was quick to assert that the question of perception is still unanswered and suggested that different sorts of signals may require different amounts of time to result in a perception.

Broadbent (1954) had further postulated there to be a STM on the peripheral side of the filter mechanism. Moray (1960) had shown results which indicated that some information presented later in a series apparently decayed before information presented early.

Specifically, paired digits presented midway through a series showed more errors than those presented first though the opposite is what would have been predicted under Broadbent's rubric. This led Moray to postulate an alternate model. Moray proposed that when signals overlap, rather than one set being held up while the other is dealt with, the two sets are passed through the filter together but are stored in separate stores according to the source from which they came. Then during recall the sets are recalled store by store. As further support for this model, Moray demonstrates that errors of transposition between ears occur though they could not have if Broadbent were correct.

Broadbent (1956 & 1958) had shown that grouping by ear-of-arrival was the predominant mode of recalling two lists of three digits presented simultaneously to separate ears at a speed of two digits per second on each ear. Gray and Wedderburn (1960) designed two experiments to find out if this was due to a built-in mechanism or demonstrated a method of attack.

The two experiments used: 1) three-syllable words broken up into syllables and presented to alternate ears, and 2) three-word phrases used in the same manner. The ear unoccupied with a word or syllable was presented with a digit.

Results of the first experiment using words showed that if instructions were such that the Ss knew broken words would be presented they were able to produce words under the experimental conditions. If, however, such a cue was not given then words were not made.

In the second experiment both groups were treated as in the first experiment but both used the grouping-by-meaning technique most often.

In the final analysis then, grouping by ear-of-arrival turned out to be a strategy not a biological proclivity. Further, grouping by ear-of-arrival may not even be the most efficient strategy.

Both authors echoed the same sentiments expressed by Moray (1960) concerning switching of attention. That was, that one cannot be sure switching was taking place.

In an attempt to answer the question concerning the origin of capacity limitation, that is, is the limitation at the perceptual or response level, Treisman and Geffen (1967) exposed subjects to two dichotic messages, one primary and one secondary. Ss were required to both shadow the primary message and make a tapping response upon hearing specific target words regardless of which of the two messages they came through. Their results clearly indicated the limitation to be at the perceptual level. The majority of tapping was relegated to the primary or shadowed message while very little tapping was done in response to target words imbedded in the secondary message.

Lawson (1966) used different stimuli, namely brief tones or pips, and came up with contradictory results. Instead of a large difference between responses to primary and secondary messages, almost no difference was noted.

Treisman and Geffen (1967) were able to show, however, that the secondary message in their experiment was not being perceived by noting the difference in apparant interference with the repeating response when tapping was done to target words in the secondary message as compared with tapping to target words in the primary message. Errors in the shadowing response increased to thirty percent when the tapping response was made to secondary message target words as compared to eleven percent for the primary message target words. This difference, say the authors, supports the idea of a perceptual rather than a response limitation.

The fact that any information from the secondary message was perceived at all was explained by the postulation of a lower threshold in the perceptual filter for significant information.

These results are questioned by Deutsch, Deutsch, and Lindsay (1967) and answered in the same article by Treisman and Geffen. Deutsch and Deutsch argue that the above results are not surprising in view of Treisman's and Geffen's instructions to tap and repeat one set of words and only to tap to another set of words. By so instructing Treisman and Geffen had given one set of stimuli a larger weighting of performance than the other so say Deutsch and Deutsch. In their theory, Deutsch and Deutsch (1963) proposed that incoming messages are perceived in relation to their order of importance and subsequently push up the "level" of attention so that messages of lesser importance are not attended to. Once an important message is accounted for the level of attention shrinks until it strikes the next most important incoming message. They also established that various states of the organism (e.g., alert or sleeping) had an effect on incoming messages so that sleeping individuals were likely not to perceive much of which would normally readily be perceived. Thus it was, that Deutsch and Deutsch concluded that Treisman's and Geffen's results support their theory as stated above. Deutsch and Deutsch also explained Lawson's results with the tones or pips in terms of their theory. That is, there was no differential weighting for the tones or pips.

Lindsay in the same article explains that the Deutsch and Deutsch theory was primarily concerned with the question of the point of origin of the single channel process. This was prompted by the empirical finding that information on the supposedly rejected channel did manage to get through and divert attention from a primary task. These findings would imply that the single channel process comes after all messages have been fully analyzed.

Where Treisman and Geffen report that memory played no role in their experimental tasks Lindsay argued that it did. Lindsay also argues that the lower response rate to the secondary message can be accounted for by the lack of emphasis placed on so responding resulting in infrequent monitoring of the secondary message.

Treisman in the same article countered with the explanation which stated that since the response to both the primary and secondary messages was the same, if there was a difference in the response rate (as there clearly was) between the two messages the implication would be that the limit would be at the perceptual level not the response level.

Treisman goes on to say that the relative weight of importance as stressed in her instructions to Ss was between shadowing and tapping not between tapping to target words in the two messages. Therefore, the number of responses should have been the same for both messages if the Deutsch and Deutsch theory of the processing limit being at the response level were correct. However, as indicated above the response difference was great between the two messages (i.e., 87% for the primary message and 8% for the secondary message).

Treisman acceded to the possibility of Lindsay's observation that her task incorporated a short-term memory, but she argues that the mean response lag for the primary and secondary targets is such that it could as well be due to losing track or perhaps a delay in perceiving the correct message.

As concerned Lawson's results, Treisman and Geffen had predicted the outcome based on Broadbent's theory as differences in the physical characteristics between stimuli are analyzed prior to the "filter" selecting the message to which to attend.

In an experiment which virtually resubstantiated Treisman's and Geffen's original findings (Treisman and Geffen, 1967) and accounts for the Deutsch and Deutsch and Lindsay criticisms, Treisman twice presented Ss with sixteen lists of sixteen pairs of digits which had a letter replace a digit at different positions in each list. Half the replacement letters were in a man's voice and half were in a woman's voice. The Ss were to shadow the digits on the right ear, but stop shadowing and tap if a letter was heard on either ear. Ss were even told which voice would speak the letter. Additionally, they were told what the letter would be. The results were: 71% correct for the primary message, same voice; 97% correct for the primary message, different voice; 28% correct for the secondary message, same voice; and 97% correct for the secondary message, different voice. Treisman and Geffen therefore concluded that the filter is at the perceptual level not the response level.

In an unpublished experiment involving Ss shadowing English words presented to one ear while two-digit numbers were presented to the unattended ear, Norman showed that they have no memory for the digits if shadowing continues for 20 seconds before being tested on their memory for the digits. They did remember some digits if tested immediately after their presentation thus demonstrating a short-term memory store which decays quickly over time. This study was in support of theories that postulate that all sensory inputs undergo analysis before filtering. If this were not so, then STM would not have been shown to exist under the conditions of this experiment.

As has been adequately demonstrated localization of two dichotically presented messages was important as a cue for selective attention (Broadbent, 1954). Too, if both ears were exposed to both messages separation of messages was difficult (Cherry,1953). Redundancy also plays a part in the ease or difficulty with which a message was shadowed (Moray and Taylor, 1958). Treisman (1960) wanted to see if transition probabilities between words upon which expectancy is based might be sufficiently strong to replace dichotic localization cues. Too, she wanted to know if words were merely highly probable rather than important would they be allowed free passage through the selective attention filter even though they came from the non-shadowed ear. To test these questions she used simple prose from a novel, a technical passage, and second and eighth order statistical approximations to English. These messages were randomized in pairs and dichotically presented to Ss. During their presentation the messages switched ears, however, Ss were initially instructed to shadow only one of the two ears. She found that remarkably few Ss switched ears when the messages switched. Those who did only did so for one or two words. In effect then Ss followed localization not contextual cues. It might be pointed out here though that Cherry (1953) had shown that Ss knew little of what they had shadowed which might relegate contextual cues to an almost irrelevant variable at least when shadowing. As support for this idea Treisman (1960) notes that only one S knew the switching of passages took place.

Treisman (1960) then presented some Ss with the same experimental situation only using male and female voices for the two messages. None of the Ss changed channels but all recognized that a switch had taken place.

As regards redundancy, Ss were more likely to switch channels if the message was simple prose rather than a statistical approximation to English, though no difference was found between the second and eighth order approximations.

Her experiment confirmed the finding that rejected messages do not for the most part effect Ss even though some of the rejected message seems to slip by the selective filter. She suggested that this slippage was due to a lower threshold for activation possessed by these words. This was in opposition to Moray's (1959) proposal of a pattern analysis prior to the filter.

In an experiment dealing with the binaural presentation of a variety of different messages (e.g., simple English prose, other English prose, Latin, French, Czech, etc.) where Ss were required to shadow the message which came on first, Treisman (1964) was able to demonstrate that if the sex of the voice transmitting the primary message was different from the one transmitting the irrelevant message then shadowing was efficient. A difference in language has the same effect but to a lesser degree. Phonetic cues aid in disregarding an unknown foreign language. Too, an individual's knowledge of a language can affect its interference capabilities. Additionally, she showed messages in the same language and voice make selection dependent upon transitional probabilities between words noting, of course, that selection efficiency depends upon contextual constraint too.

In an effort to ascertain whether or not sequential dependencies between words are used in alike fashion in shadowing both a native and foreign language, whether or not there is a difference between translating to or from a native language, and the effects of introducing syntactical prose, Treisman (1965) used first, second, fourth, sixth, and eighth order approximations to English and French as constructed by Moray and Taylor (1958) along with simple and syntactical prose for both the French and English languages. Her subjects were comprised of three groups; French, English, and bilinguals. All subjects were required to both shadow and translate English and French. Results showed that as information rate increased, efficiency decreased for both tasks. Further, translating was more difficult than shadowing. Additionally, the input language had a significant effect on both the English and French groups. Most interestingly, however, there was a larger regression coefficient in translation as opposed to shadowing (the regression being correct responses on information rate for the bilinguals and English groups). This was not the case, however, when subjects were asked to shadow in a foreign language rather than in their own native tongue. Strangely enough, both the French and English groups did best when translating from French into English rather than vice versa. This was expected of the English groups but not the French. However, it was suggested that this came as a result of the French subjects having to accomplish this task on a day to day basis since they were living in an English-speaking country. For syntactical prose, correct responses laid half-way between those with the normal prose and those with the first order passage. Grammatical redundancy aided shadowing more than translating in the syntactical prose passages. Finally, it was proposed the experiment showed that familiarity of the language, information load, and complexity of the transformation between stimulus and response were all important factors which dramatically affected the difficulty of an auditory-verbal speech transmission task.

In an earlier experiment Treisman (1962) using binaural presentation of various kinds of messages (e.g., English, French, reversed English, Czech nonsense) demonstrated that among other things the knowledge of a language affects the amount of interference it produces in correct shadowing of a differing message in the same language as the irrelevant message.

By holding the selected channel constant and varying the features of the irrelevant material Treisman (1964b) attempted to discern more about the nature of the selective filtering in auditory attention. The features of the irrelevant material which were varied were the number of input-channels, number of messages, and their informational content. Subjects shadowed their right ear. Irrelevant messages were given on one or more separate channels and differed from the primary message in apparent localization. In her first experiment she found that when presented over one channel, single irrelevant messages caused as much difficulty in accurate shadowing as two such messages. In addition, little information was recognized in the irrelevant messages. In a second series of experiments she found that interference or system overload was not a resultant of reducing the discriminability of two irrelevant channels. It turned out that it was not discrimination between rejected channels but the number of channels to be rejected which determined performance. She also found that two irrelevant messages caused more interference if they were easily discriminable than if not. When it came to the informational content of the rejected messages little effect on shadowing performance was noted when the irrelevant message had a high information content.

In an attempt to ". . . measure the mental concentration in driving by giving the driver a subsidiary task to perform . . ." and therefore measure the spare mental capacity of car drivers, Brown and Poulton (1961) required some seven average and eight advanced drivers to respond to an auditory task while driving over a particular track comprised of both shopping and residential areas. The results showed the subsidiary auditory task sensitive to changes in mental load. However, the subsidiary auditory task did not affect driving to any great degree.

In a later experiment dealing with fatigue Brown (1962) used the same technique but different subsidiary auditory tasks. One task required continuous attention but little memory while the other task required little attention but longer memory span. They found that spare mental capacity was greater after an eight-hour work day than before. Brown said there were some good reasons for this not the least of which was a large intersubject difference in hours of sleep and wakefulness. What he wanted to show and did show was the adequacy of the technique.

In an experiment concerned with the capacity of the humans to engage in two independent verbal activities, Peterson (in press, 1969) required Ss to solve a four letter anagram while performing one of three levels of tasks. The proposed hierarchical classification of tasks with reference to attention were as follows: emission (e.g., repeating an overlearned phrase); reproduction (e.g., shadowing); transformation (e.g., mathematical computation). For the emission activity Ss counted aloud. For the reproductive activity Ss repeated six digits between one and six which were presented over ear phones in an irregular order. For the transformational activity Ss were to add the same six digits presented under the reproductive activity. Results showed a corresponding drop in correct anagram solutions the higher the level of concurrent activity (i.e., emission, reproduction, transformation).

Peterson subsequently increased the rate of hierarchical activity to explore the limits of concurrent performance. Specifically Ss were required to solve either four-letter anagrams or add four digits while counting from 1 through 9 or reciting the alphabet over and over from A through I at high speed. Peterson felt that tasks involving the same class of characters might interfere with one another more than in the case in which the tasks used different classes of characters. This turned out not to be the case. Results further indicated that engaging the vocal mechanism did not prevent adding or problem solving at normal efficiency.

When a reproductive activity (reading) was combined with a transformational activity (adding) it was found that reproduction had no significant effect on performance of a transformational task.

Peterson went on to examine the possibility of rehearsal during concurrent rapid reproduction. The messages were CCC Trigrams. In the reading condition he tested retention after three to nine seconds of reading digits. In the second condition both reading and adding digits took place. In a third and final condition which dealt with switching the Ss were required to read alone for three seconds and subsequently read and add for three to nine seconds. As a control condition a zero second interval was used. All Ss were instructed to attempt rehearsal during a retention interval when reading aloud but not adding. Even though extensive forgetting occurred in all conditions much more occurred in the read and add condition. This, of course, suggested that there was more adequate control of rehearsal with two concurrent activities. As far as the switch condition was concerned it was intermediate between the other two.

Peterson proposed a model wherein Stage I consists of information from inputs of various sources being held briefly in storages associated with sense organs. In Stage II, incoming information is acted upon by a filter which attenuates all but one input at a given moment. In Stage III there is parallel processing since both short and long term memory stores cooperate to maintain processes of varying degrees of complexity. It is here that little attention is involved in coordination with emissive activity. Both reproductive and transformational activity take more time of attention. In Stage IV parallel responses engage in a variety of simultaneous behaviors (e.g., speaking and writing).

Using the reproductive and transformational classifications proposed by Peterson, but changing the reproduction classification to a zero transformation Weber, Cross, and Carlton (1968) explored a task which required internal search for a rule-specified target. They applied transformations of various sizes to items in a circular sequence. The transformations were -2, -1, 0, 1, 2, 3 steps away from the stimulus. By varying the size of the transformation they were able to vary the amount of the searching required. Results showed that reaction time was an increasing monotonic function of the size of transformation. They also found that reaction time was less for digits than for letters.

In a subsequent experiment Weber and Castleman (1968) using the same ideas as Weber, Cross, and Carlton (1968) but altering the kinds of sequences (i.e., they used arbitrary, ordered, and backward circular sequences) and using only 0, 1, 2 transformation sizes, they found a large effect which was attributable to transformation size. The functions were again substantially linear. They also resubstantiated the finding that reaction time was less for digits than for letters. Reaction time progressively increased for ordered, backward and arbitrary sequences. Both studies suggest an internal search process.

Summary

It was obvious that a great deal of work has gone into researching the area of concurrent information processing. However, except for the last two cited studies none has used a clear-cut manipulation of cognitive load. This study will extend the research into the area of processing simultaneously presented material while varying the cognitive load. The technique of measurement adopted by Weber, Cross, and Carlton (1968) and Weber and Castleman (1968) will be applied to this study.

CHAPTER II

THE PROBLEM

Statement of the Problem

The intent of this experiment was to study concurrent processing of several verbal stimuli. Dual visual stimulation occurred and transformational activity took place in two response modalities concurrently. The transformations are of the type used by Weber, et al. (1968). A comparison was made between concurrent processing (the experimental conditions) and control conditions where only one kind of processing took place.

The purpose of doing such a study was to ascertain the extent to which humans can carry on concurrent verbal activity and what effects various amounts of cognitive load and practice had on concurrent responding.

Hypotheses

There were five hypotheses, the first one being that no simultaneous processing of information would occur. The second hypothesis was that no difference would exist between response modalities. The third hypothesis was that no difference would exist between stimulus configurations. The fourth hypothesis was simply that time to complete the fifteen item list would lessen as a result of practice. Finally, the fifth hypothesis was that as the transformation, therefore cognitive load, increased so would the time to complete the fifteen item lists.

CHAPTER III

METHOD

Subjects

Twenty-four students from the Introductory Psychology classes were used. Ss were given extra credit points for one of the three hours in which they served as subjects as an inducement to participate in the experiment. In addition, they were paid one dollar per session for each of the last two.

Materials and Design

Stimuli consisted of three sets of fifteen pairs of letter/digit combinations of the form of letter first and digit second (L/D) or digit first and letter second (D/L). Separate lists of each stimulus configuration were produced (refer to Appendix A). Each set of fifteen was internally randomized in sub-blocks of five letters, a, b, c, d, e. The set of digits consisted of 1, 2, 3, 4, 5. The constraints were such that identical letters or digits did not follow one another at the junction point between each sub-block of five and that within any one set of fifteen L/D or D/L combinations no two combinations were alike. These pairs of items then received zero- or one-unit transformations. For example, a zero-unit transformation involved reproducing the stimuli as seen whereas a one-unit transformation involved giving the stimulus letter or digit one step away from the stimulus as shown. Thus for stimuli b, d, e, c, a the respective responses would be c, e, a, d, b.

Circular sequence cards for letters and digits were designed with a two and a half inch radius to insure adequate viewing. The circles were divided into five equal parts and in each position either one inch letters or the same sized numbers were placed with an arrow between each letter or digit pointing in a clockwise direction.

For the instruction cards all numbers were two inches high and a quarter-inch thick. Single numbers for the control conditions were placed on either the extreme left or right side of the card thereby indicating whether to attend to the letter or digit depending on the stimulus material being used. When the numbers were in pairs they were placed in the center of the card separated by one and a quarter inches in the middle of which was placed a comma.

Fourteen random lists of the three sets of letter/digit combinations were produced. Ten of these lists were put into six random combinations from which pairs were chosen at random and assigned to each subject. Each pair signified the particular combination of ransom lists presented during each of the two experimental sessions. There were ten blocks of eight conditions for each experimental session. The other four random lists were randomly combined and presented to each subject during the instructional phase.

The stimuli were presented in either L/D or D/L configuration and the Ss either wrote (W) the letter transformation and verbalized (V) the digit transformation or vice-versa for either of the two configurations.

Graphically speaking the four between-subject conditions (hereinafter referred to as stimulus/response states) were displayed in Table I.

In addition, there were eight within-subject conditions, four concurrent tasks (experimental) and four single tasks (control). They are illustrated in Table II.

Under the LD/WV or DL/VW stimulus/response states all letters were written and all digits spoken out loud. The 0s and 1s represent the degree of transformations involved (e.g., a 0 under the LW indicates the S copied the letter presented. A 1 under DV indicates the S said the next digit in the digital circular sequence). It was noted here that a zero transformation was what Peterson (1969) referred to as reproduction. Similarly, under the LD/VW or DL/WV conditions all letters were spoken out loud and all digits written.

Ten random lists of the eight conditions were produced and placed into six random combinations from which pairs were chosen at random and assigned to each subject. This then became the particular random order in which the eight conditions were presented to the subjects for each of the ten trial blocks for each of the two experimental sessions. Similar randomization was accomplished for the instructional phase.

There were three one-hour sessions for each subject. The first session was devoted to instruction and familiarization with the experiment and the last two one-hour sessions were the primary experimental sessions. There were separate instructions for each stimulus/response state. That is, one set for the LD/WV, one set for DL/VW, one set for LD/VW, and one set for DL/WV stimulus/response states. These instructions were used during the first session as instructional material to familiarize Ss with the required tasks. In subsequent sessions Ss were

TABLE I

BETWEEN-SUBJECT'S CONDITIONS

Response Modality				
		VW	WV	
Stimulus	LD	LD/VW	LD/WV	Six subjects
Configuration	DL	DL/VW	DL/WV	occupied each cell

TABLE II

WITHIN-SUBJECT'S CONDITIONS

Stimulus Configuration/Response Modality				
	LD/WV or DL/VW		LD/VW or DL/WV	
	Control Conditions		Control Conditions	
	LW	DV	LV	DW
1)	0		0	
2)	1		1	
3)		0		0
4)		1		1
	Experimental Conditions		Experimental Conditions	
	LW	DV	LV	DW
5)	0	0	0	0
6)	0	1	0	1
7)	1	0	1	0
8)	1	1	1	1

briefly refamiliarized with the instruction cards to insure adequate understanding prior to the actual testing. Because all four sets of instructions were virtually alike except as the conditions varied, only one set is included (Appendix B).

In the control situation Ss worked with only one set of materials at a time. Corresponding to the LD/WV or DL/VW stimulus/response states subjects were required to make either written zero- or one-unit transformations for letters ignoring digits; or make zero- or one-unit verbal transformations of digits ignoring the letters. Corresponding to the LD/VW or DL/WV conditions the situation was reversed in that Ss were required to make a zero- or one-unit verbal transformation of letters ignoring the digital stimuli; or make a zero- or one-unit written transformation of digits ignoring letters.

In the experimental situation under the LD/WV or DL/VW stimulus/response states when there was a zero-unit written letter transformation there was either a zero- or one-unit verbal digit transformation. The same held true for a one-unit written letter transformation. Under the LD/VW or DL/WV conditions when there was a zero-unit verbal letter transformation, there was either a zero- or one-unit written digit transformation. Again, the same conditions prevailed for digits when there was a one-unit verbal letter transformation.

The Ss were signaled to start by the experimenter and were stopped when they had completed each fifteen item list. Response time, as measured by a hand-held stop watch was the elapsed time between start and completion of each separate list.

CHAPTER IV

RESULTS AND DISCUSSION

Principal results are summarized in Table III. Mean times in seconds are shown for the conditions singly and in combination for each of the four stimulus/response states. The experimenter's measurements of individual response times were accurate within plus or minus .2 of a second with a reliability of 95%.

Figures 1-4 represent changes in the response time over a total of twenty trials. Each graph represents the eight conditions for each separate stimulus/response state. Each point is the result of averaging over six Ss and two trials. This was accomplished in order that a better idea could be had of what was actually happening as the Ss progressed.

There were four AOV's performed on the data and all AOV's will be presented in table form and then discussed. Cell entries consisted of each S's score for a given condition(s) summed over twenty trials.

The first, and most general, AOV performed was a 2X2X2 factorial. The first factor represents the stimulus configurations (LD or DL). The second factor represents the response modality (WV or VW). These two factors are the same for all the AOV's discussed. The last factor represents a comparison between the response times combined for the control conditions (the first four conditions of the eight in which only one task at a time was performed) and the response times combined

TABLE III

OVERALL MEANS AND STANDARD DEVIATIONS IN SECONDS ACROSS 20 TRIALS FOR INDIVIDUAL STIMULUS/ RESPONSE STATES AND CONDITIONS

Stimulus/ Response State	Conditions			Mean	SD
		LW	DV		
1	1	0		9.09	.37
	2	1		12.66	.92
LD/WV	3		0	4.41	.22
	4		1	9.11	.53
	5	0	0	12.08	.58
	6	0	1	20.97	2.69
	7	1	0	21.69	1.92
	8	1	1	22.23	1.66
		LV	DW		
2	1	0		4.26	.30
	2	1		8.63	.49
LD/VW	3		0	6.72	.23
	4		1	8.45	.34
	5	0	0	10.05	.65
	6	0	1	17.48	2.61
	7	1	0	18.91	2.12
	8	1	1	18.70	1.50
		DW	LV		
3	1		0	3.90	.17
	2		1	9.14	.58
DL/WV	3	0		7.28	.15
	4	1		9.13	.46
	5	0	0	10.86	.85
	6	0	1	18.73	1.90
	7	1	0	15.97	1.52
	8	1	1	19.20	1.72
		DV	LW		
4	1		0	8.32	.39
	2		1	12.05	1.14
DL/VW	3	0		4.40	.21
	4	1		8.52	.78
	5	0	0	12.42	1.06
	6	0	1	22.20	2.22
	7	1	0	20.22	2.40
	8	1	1	22.77	1.95

Legend: L = Letters; D = Digits; W = Written; V = Verbal.

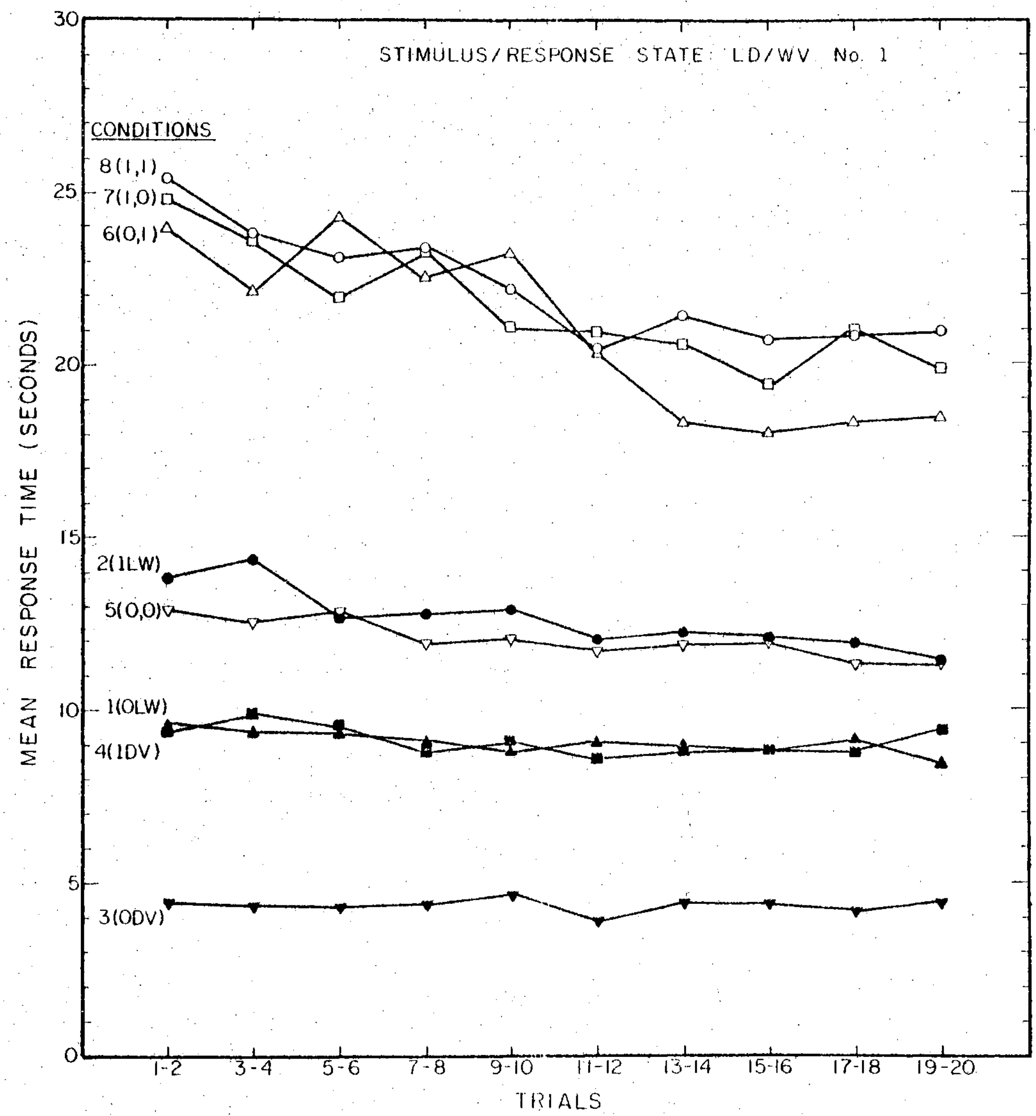

Figure 1. Stimulus/response State LD/WV with Response Time as a Function of Condition and Practice

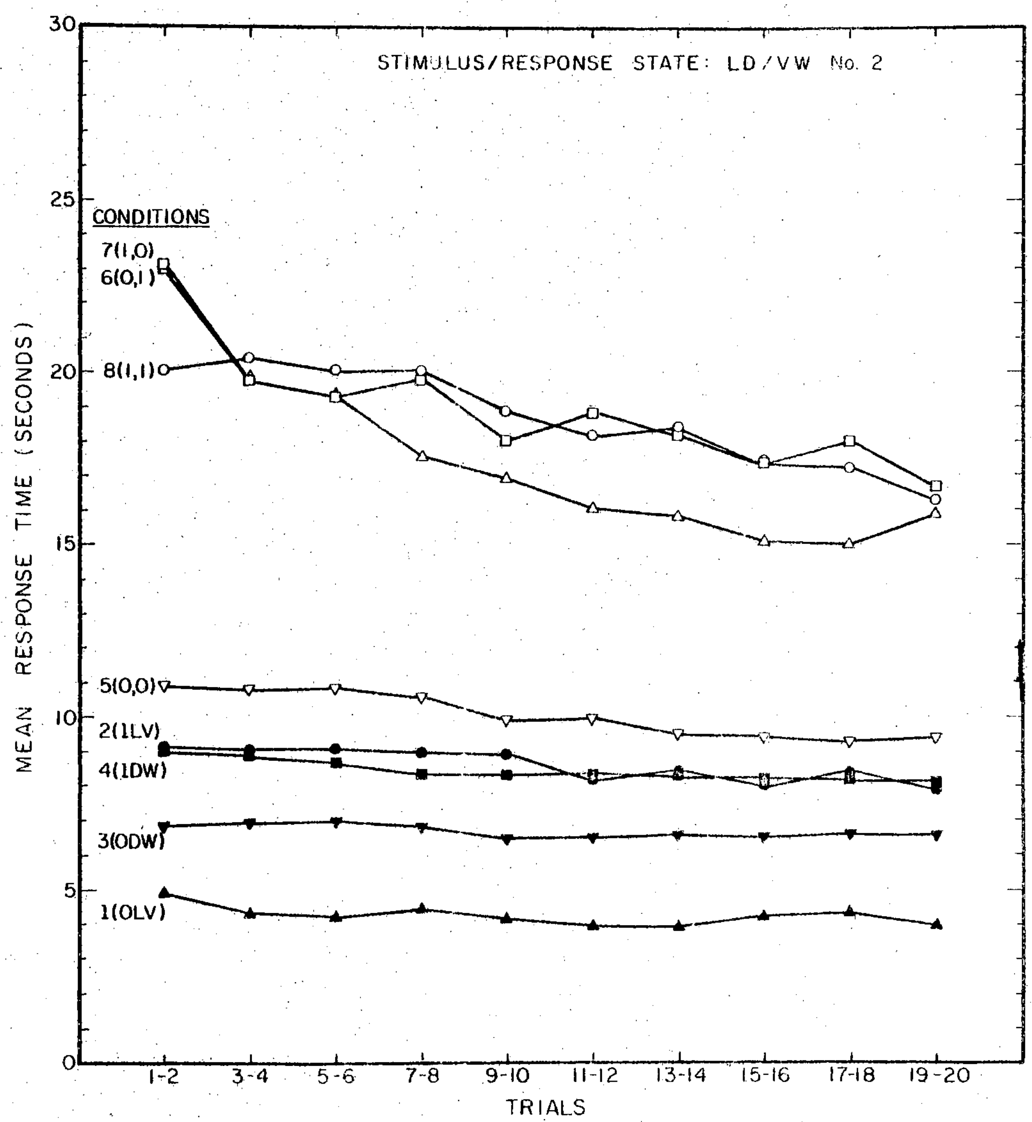

Figure 2. Stimulus/response State LD/VW with Response Time as a Function of Condition and Practice

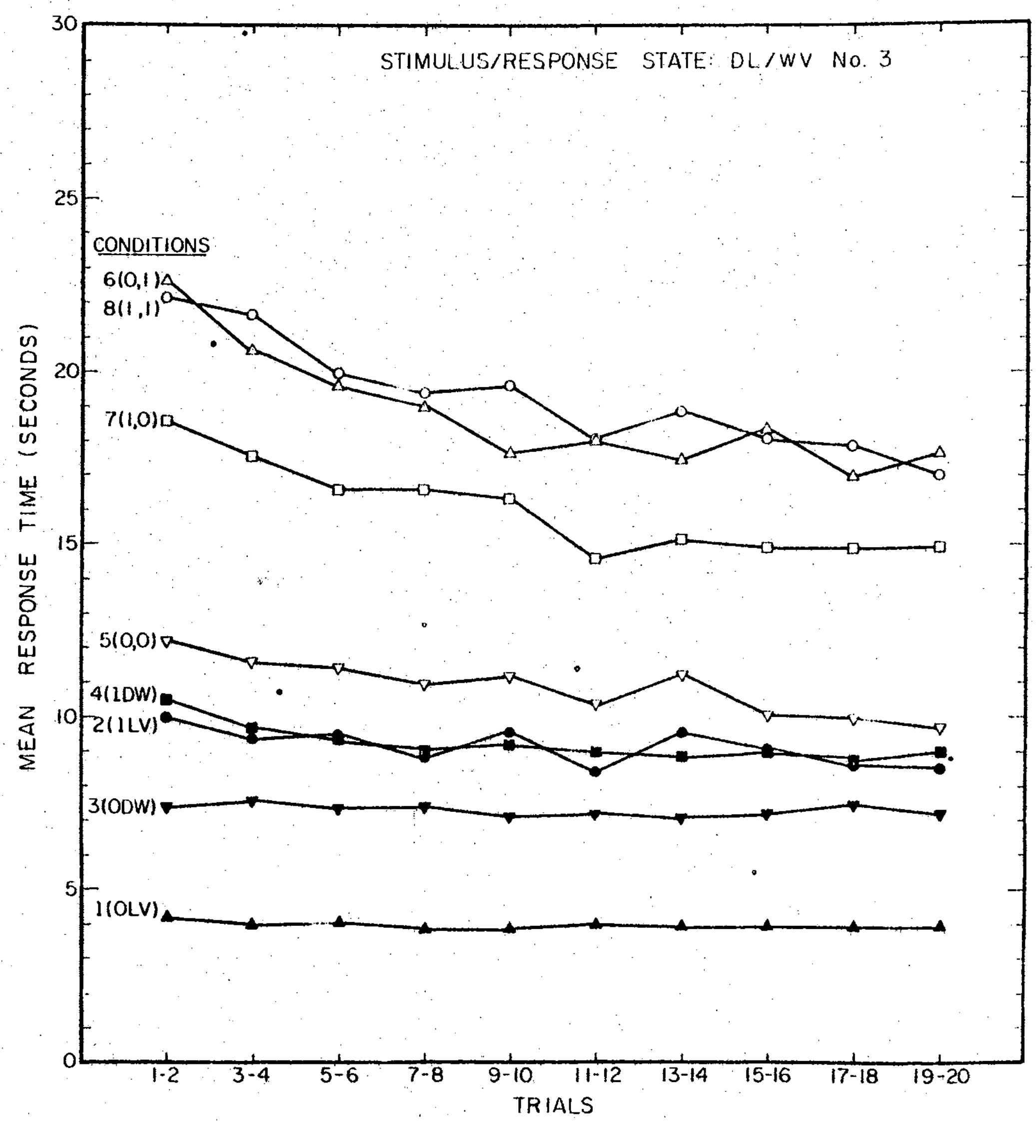

Figure 3. Stimulus/response State DL/WV with Response Time as a Function of Condition and Practice

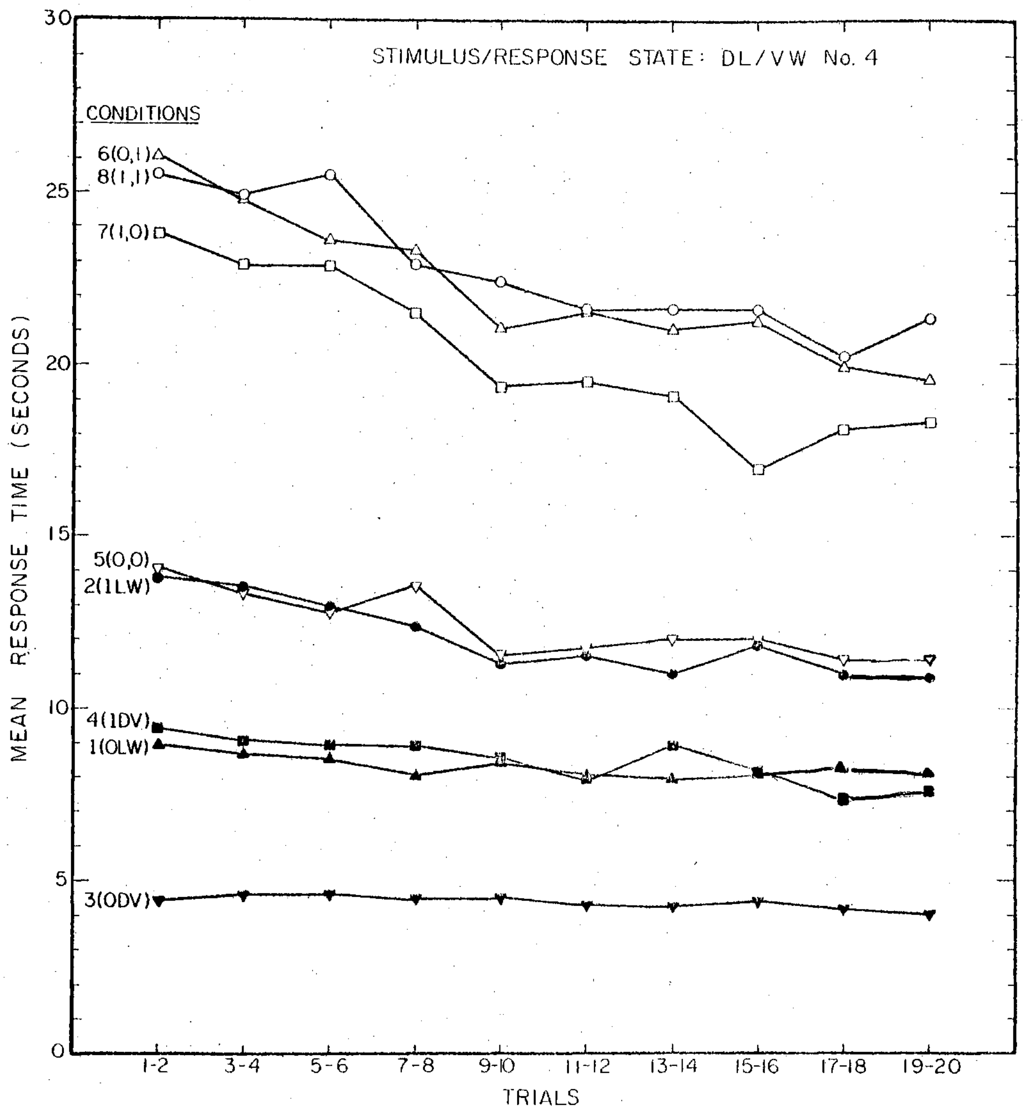

Figure 4. Stimulus/response State DL/VW with Response Time as a Function of Condition and Practice

TABLE IV

SUMMARY OF 2X2X2 AOV

Source of Variation	SS	df	MS	F
TOTAL	8852338.00	47	188347.62	
Between Subjects		23		
1 (Stimulus Configuration)	55.25	1	55.25	.00
2 (Response Modality)	1804.43	1	1804.43	.05
12	381401.42	1	381401.42	9.99*
Subject with. Groups (Error Between)	762867.39	20	38143.37	
Within Subjects		24		
3 (Conditions: Experimental and Control)	7520242.00	1	7520242.00	1202.92*
13	204.33	1	204.33	.03
23	5548.67	1	5548.67	.89
123	55186.83	1	55186.83	8.83*
3 X Subject with. Groups (Error Within)	125032.63	20	6251.63	

*$p < .01$

for the experimental conditions (the last four conditions of the eight in which there were dual tasks). (Refer to Table II.)

Only the effects of conditions (experimental and control), the interaction between stimulus configuration and response modality, and the interaction between all three factors were significant (Table IV).

In all stimulus/response states the means for the control conditions were less than the means for the experimental conditions LD/WV: 8.81 vs 19.27; LD/VW: 7.02 vs 16.28; DL/WV: 7.36 vs 16.19; DL/VW: 8.32 vs 19.41. (Refer to Figs 1-4.) The reason for this was obvious; the experimental conditions involved accomplishing dual tasks while the control conditions involved singular tasks.

Rather than a narrative description of the interaction between stimulus configuration and response modality a graphic representation was chosen. Figure 5 illustrates the interaction pattern.

As regards the interaction effect for all variables suffice it to say that their interactions were found to be significant at the .01 level.

The next AOV performed as a 2X2X4 factorial to assess differences among control (single) conditions only. The first two factors refer to stimulus configuration and response mode respectively. The last factor refers to the first four conditions, namely the control conditions where writing and speaking were done separately (refer to Table II).

Once again, only the effect of conditions (single task), the interaction between stimulus configuration and response modality, and the interaction between all three factors were significant (Table V).

Even though not significant, comparisons for the response mode (written or verbal) were made between the means for the four control

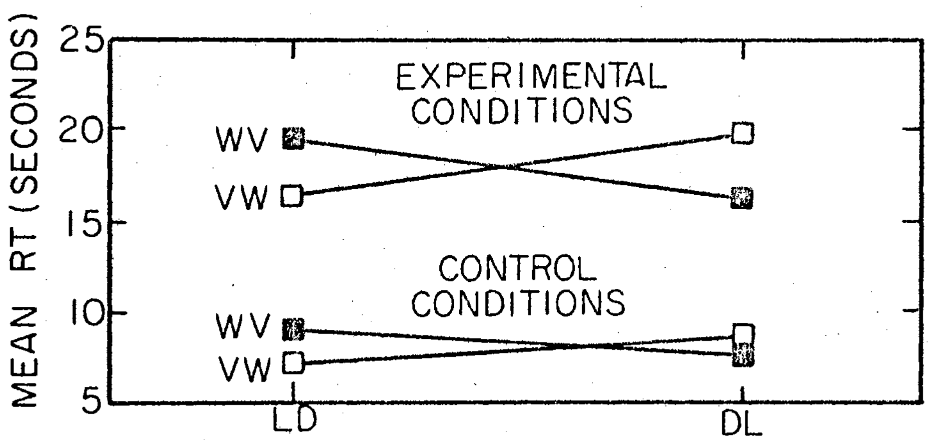

Figure 5. Interaction Between Stimulus Configuration and Response Mode

TABLE V

SUMMARY OF 2X2X4 AOV--FIRST FOUR CONDITIONS (SINGLE)

Source of Variation	SS	df	MS	F
TOTAL	314638.19	95	3311.98	
Between Subjects		23		
1 (Stimulus Configuration)	53.84	1	53.84	.02
2 (Response Modality)	1705.99	1	1705.99	.72
12	18301.46	1	18301.46	7.73**
Subject with Groups (Error Between)	47322.18	20	2366.11	
Within Subjects		72		
3 (Conditions: 1-4)	147213.73	3	49071.24	142.81*
13	913.21	3	304.40	.89
23	317.09	3	105.69	.31
123	78193.78	3	26064.59	75.85*
3 X Subject with Groups (Error Within)	20617.13	60	343.62	

*p $<$ .01

**p $<$ .05

conditions. It was found that:

a. In the LD configuration written responses contributed to higher mean response times than verbal responses for comparable transformations except for the one-unit transformations in the LD/VW state which were slightly reversed. (Refer to Table III, stimulus states 1 and 2 and Figs 1 and 2, conditions 1-4.)

b. In the DL configuration written responses contributed to higher mean response times than verbal responses for comparable transformations except for the one-unit transformations in the DL/WV state which were very close to equal. (Refer to Table III, stimulus states 3 and 4 and Figs 3 and 4, conditions 1-4.)

The four conditions were compared and it was found that:

a. In all the stimulus/response states the first and third conditions' mean response times were lower than the second and fourth mean response times (refer to Figs 1-4, conditions 1-4 and Table III).

b. While in the LD/WV and DL/VW states the mean response time for the third condition was less than the first and the fourth less than the second, the opposite was true for the first and third conditions of the LD/VW and DL/WV states (refer to Figs 1-4, conditions 1-4 and Table III).

c. In the case of the second and fourth conditions of the LD/VW state, the fourth was less than the second but they were about equal in t the DL/WV state. (Refer to Table III and Figs 2 and 3, conditions 2 and 4.)

d. From the least to the most mean response time for each condition the four states fell as follows: (Refer to Table III and Figs 1-4.)

1. Condition 1: DL/WV, LD/VW, DL/VW, LD/WV.
2. Condition 2: LD/VW, DL/WV, DL/VW, LD/WV.
3. Condition 3: DL/VW, LD/WV, LD/VW, DL/WV.
4. Condition 4: LD/VW, DL/VW, LD/WV, DL/WV.

e. It is noted that condition 2 in the LD/WV and DL/VW states produced similar mean response times and both were the highest of all mean response times for the four conditions. It is also noted that these two states are similar with respect to how the stimuli (L & D) are treated (i.e., LW and DV). (Refer to Table III and Figs 1 and 3.)

f. In the LD/WV and DL/VW states (wherein the written responses are made to letters and verbal responses to digits) it was noted that in the LD/WV state the mean response times for the four conditions were all higher than in the DL/VW state for comparable transformations and stimuli. Except for condition 1 the opposite held for the comparison between LD/VW and DL/WV states. (Refer to Table III and Figs 1-4.)

The foregoing results pointed out that digits were manipulated more rapidly than letters. This was probably due not only to the fact that letters are more highly structured than digits, which would account for the difference when the written response mode was involved, but also that digits are the stimulus items most usually manipulated and changed. Therefore, manipulation of digits was a highly over-learned response where letter manipulation was not.

The interaction effects between the stimulus configuration and response mode for each of the four conditions are shown in Figure 6a, b, c, d.

Once again, suffice it to say that the interaction between all three variables was significant at the .01 level.

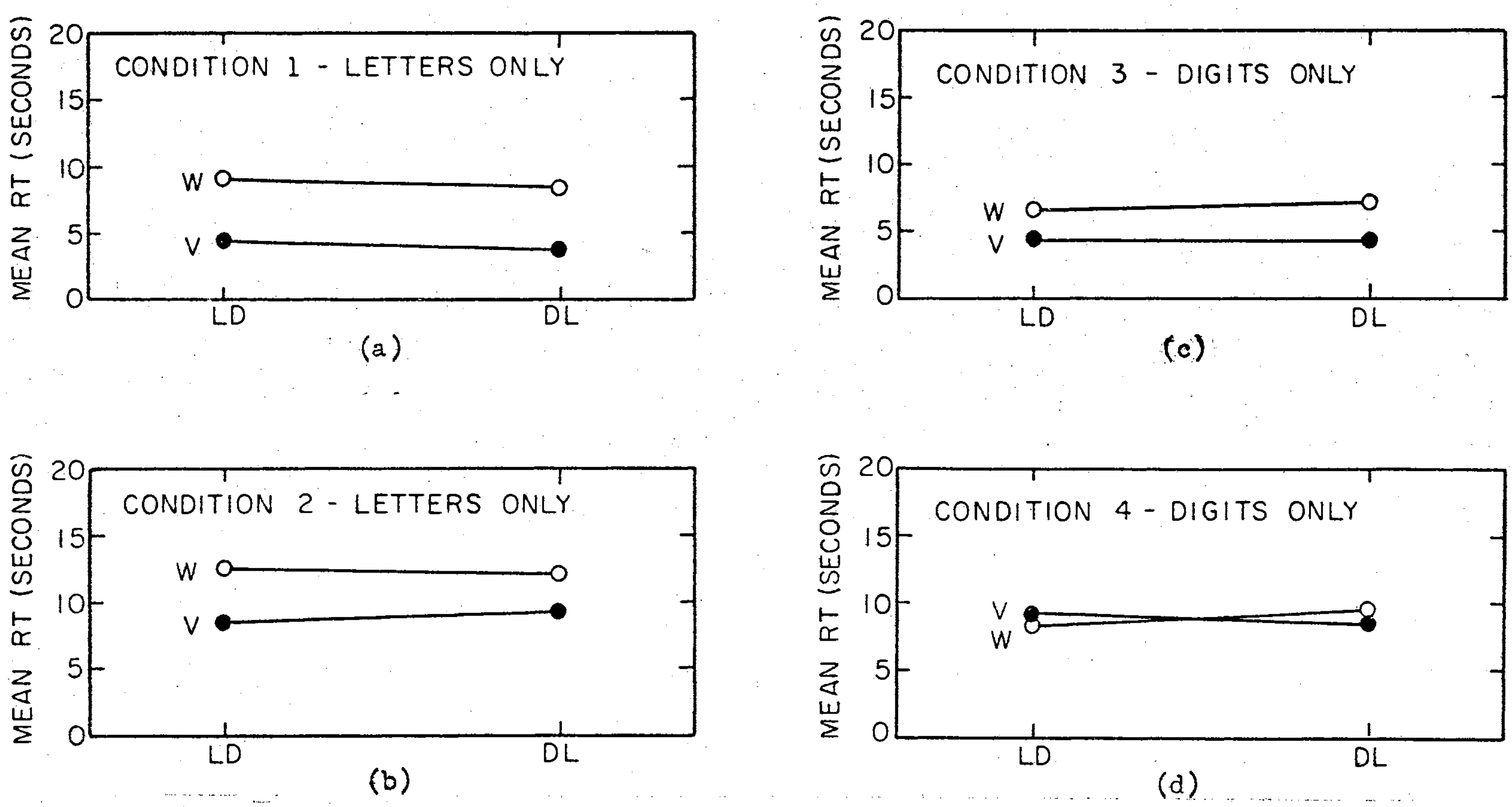

Figure 6. Interaction Between Stimulus Configuration and Response Mode for the First Four Conditions (Single)

The next AOV performed was also a 2X2X4 factorial employed to assess differences among the experimental (dual) conditions. The last factor refers here to the last four conditions where two operations (writing and speaking) were carried on simultaneously. (Refer to Table II, conditions 5-8.)

The effect of conditions (the last four), the interaction between stimulus configuration and response mode, and the interaction between stimulus configuration and conditions were significant (Table VI).

When the four experimental conditions were compared the following was found: (Refer to Table III.)

a. In the LD/WV and LD/VW states the mean response times for the fifth and sixth conditions were less than the seventh and eighth (refer to Figs 1 and 2). However, in the DL/WV and DL/VW states the fifth and seventh conditions showed a lower mean response time than the sixth and eighth conditions (refer to Figs 3 and 4).

b. In all stimulus/response states the fifth condition showed the lowest mean response time by far. (Refer to Table III and Figs 1-4.)

c. From the least to the most mean response time for each condition the four states fell as follows: (Refer to Table III and Figs 1-4.)

1. Condition 5: LD/VW, DL/WV, DL/VW, LD/WV.
2. Condition 6: LD/WV, LD/VW, DL/WV, DL/VW.
3. Condition 7: DL/WV, LD/VW, DL/VW, LD/WV.
4. Condition 8: LD/VW, DL/WV, LD/WV, DL/VW.

d. When the LD/WV and DL/VW states (wherein the written responses are made to letters and verbal responses to digits) are compared it is noted that all conditions in the LD/WV state except condition 7

TABLE VI

SUMMARY OF 2X2X4 AOV--LAST FOUR CONDITIONS (DUAL)

Source of Variation	SS	df	MS	F
TOTAL	940746.50	95	9902.59	
Between Subjects		23		
1 (Stimulus Configuration)	4.33	1	4.33	.00
2 (Response Modality)	126.96	1	126.96	.01
12	90847.56	1	90847.56	10.40*
Subject with. Groups (Error Between)	174657.25	20	8732.86	
Within Subjects		72		
3 (Conditions: 5-8)	542683.97	3	180894.63	99.75*
13	16683.62	3	5561.21	3.07**
23	1337.49	3	445.83	.25
123	5598.45	3	1866.15	1.03
3 X Subject with. Groups (Error Between)	108807.18	60	1813.45	

*$p < .01$

**$p < .05$

produced lower mean response times than in the DL/VW state. (Refer to Table III and Figs 1 and 4.) The same holds for the comparison between the LD/VW and DL/WV states. (Refer to Table III and Figs 2 and 3.)

The interaction effect between stimulus configuration and response mode is illustrated in Figure 7a, b, c, d. The interaction was explained once again by the structural difference between letters and digits and overlearning of digital manipulation as opposed to letter manipulation in daily life.

The interaction effect between stimulus configuration and conditions is shown in Figure 8. The specific interaction for conditions 6 and 7 between stimulus configurations pointed once again to the ease of manipulating digits as opposed to letters. Condition 6 in the LD configuration was a zero-unit letter transformation and one-unit digit transformation while it was opposite under the DL configuration. Had the two stimuli been equally manipulable the response times would have been comparable.

It was noted that the interaction between all three variables was non-significant in this instance.

The last AOV performed was a 2X2X8 factorial in which the last factor refers to all eight within-subjects conditions. Examination of Table VII shows that several of the effects were significant at the .01 level. Specifically, the effect of conditions (1-8), the interaction between stimulus configuration and response modality, and the interaction between all three conditions were significant.

Virtually all that needed to be brought out concerning these effects has been brought out in either the narrative or graphical descriptions of both 2X2X4 AOV's and the 2X2X2 AOV.

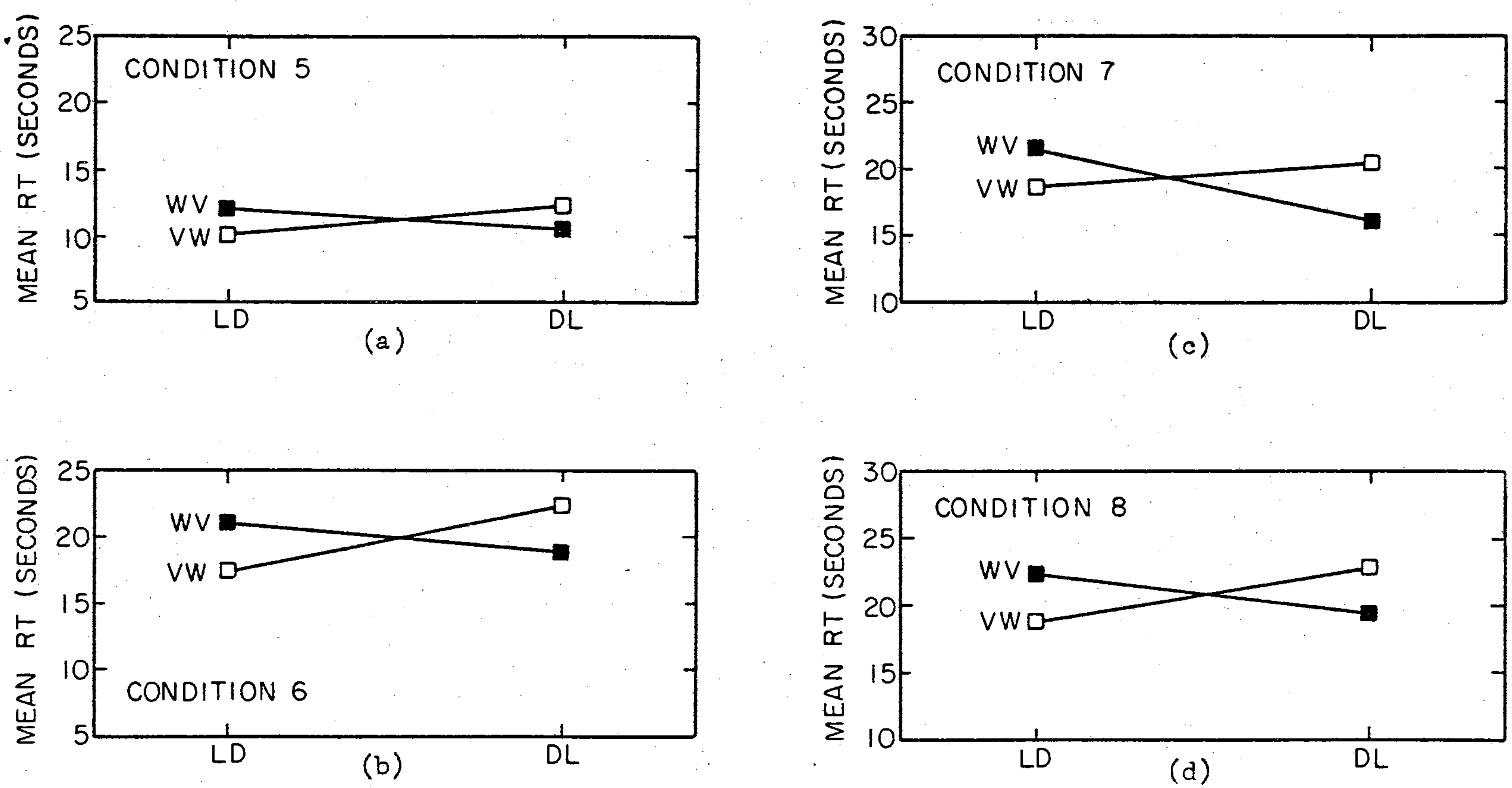

Figure 7. Interaction Between Stimulus Configuration and Response Mode for the Last Four Conditions (Dual)

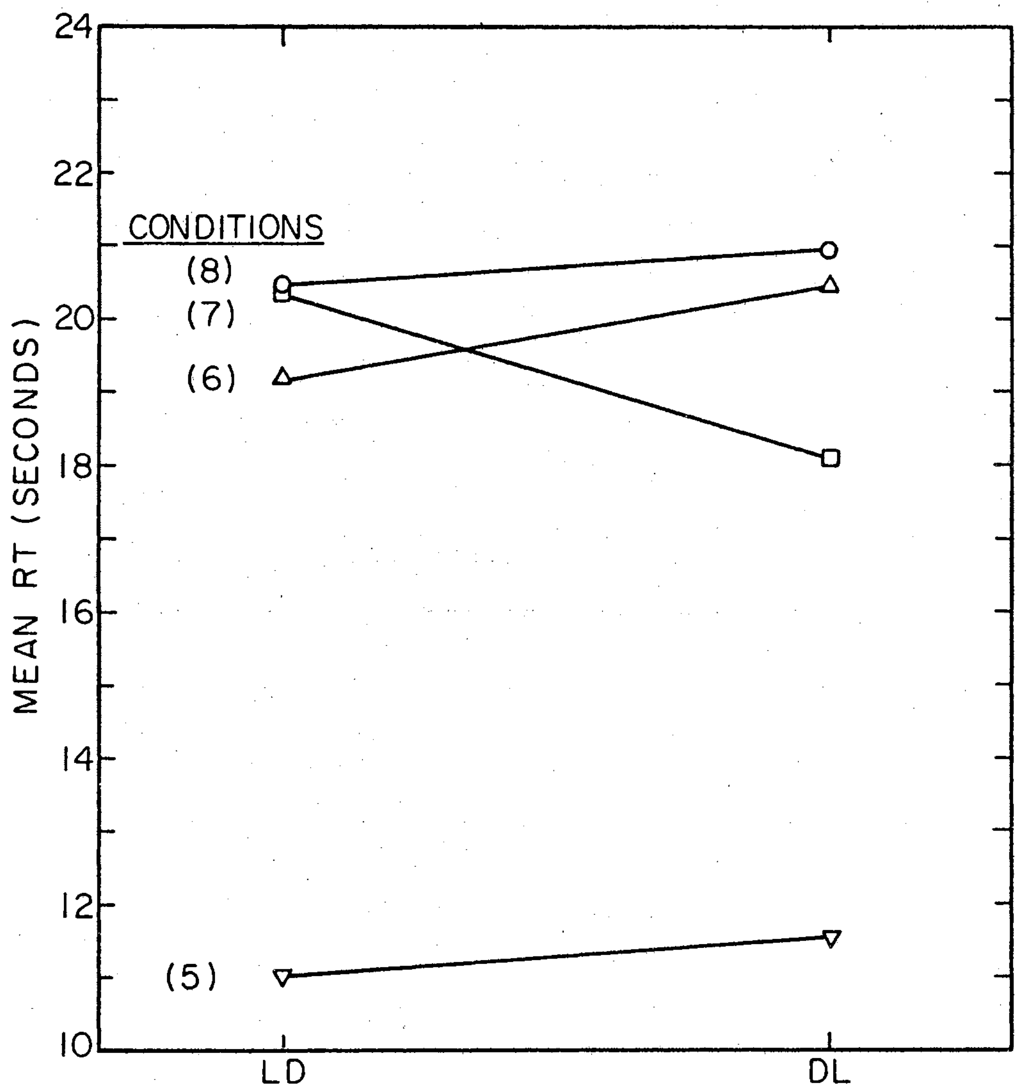

Figure 8. Interaction Between Stimulus Configuration and Conditions 5 through 8

TABLE VII

SUMMARY OF 2X2X8 AOV

Source of Variation	SS	df	MS	F
TOTAL	3135384.00	191	16415.62	
Between Subjects		23		
1 (Stimulus Configuration)	13.81	1	13.81	.00
2 (Response Modality)	451.08	1	451.08	.05
12	95349.98	1	95349.98	9.99*
Subject with. Groups (Error Bet)	190716.69	20	9535.83	
Within Subjects		168		
3 (Conditions: 1-8)	2569965.58	7	367137.94	320.00*
13	17641.45	7	2520.21	2.19
23	3036.82	7	433.83	.38
123	97592.75	7	13941.82	12.15*
3 X Subject with. Groups (Error Within)	160622.34	140	1147.30	

*$p < .01$

Error data was also of interest. Each subject was graded for accuracy of response over six blocks of trials. Therefore, there was a total of 12,960 possible written and 12,960 possible verbal errors over all stimulus/response states. For each specific state there was a total of 3,240 possible written errors and the same number of possible verbal errors.

Verbal responses were recorded on tape and subsequently graded with the written responses. Table VIII depicts the percentage of written and verbal errors for each state and their overall error rate.

All Ss in the LD/VW state made consistently fewer verbal errors than written errors. The opposite was true for the DL/VW state, the one reversal. The difference between the verbal and written errors in the DL/WV state was attributed to one subject who made many more written than verbal errors. Errors in the LD/WV state were subject specific. Specifically, subjects in this state that made more written than verbal errors to begin with were usually consistent throughout. About half of the six subjects in this state made more written than verbal errors. The other half reversed this trend.

Table IX depicts the percentage of digit and letter errors for each state and their overall error rate. All Ss in the LD/VW and DL/VW states made consistently fewer letter errors than digit errors. The difference between the letter and digit errors in the DL/WV state was attributed to one subject who made many more digit than letter errors. Again, errors in the LD/WV state were subject specific. In other words, subjects in this state that made more letter than digit errors to begin with were usually consistent throughout. Half of the Ss made more letter than digit errors, the other half reversing this trend.

TABLE VIII

PERCENTAGE OF WRITTEN AND VERBAL ERRORS

	LD/WV	LD/VW	DL/WV	DL/VW	Total
Written	3.58	4.63	2.35	1.76	3.08
Verbal	3.54	2.25	1.85	2.31	2.49

TABLE IX

PERCENTAGE OF LETTER AND DIGIT ERRORS

	LD/WV	LD/VW	DL/WV	DL/VW	Total
Letter	3.58	2.25	1.85	1.76	2.36
Digit	3.54	4.63	2.35	2.31	3.21

Practice effects are shown in Figs 1-4. With regards to practice effects the following was observed:

a. Across all conditions practice had the least effect for a zero verbal transformation regardless of whether it was letters or digits. (Refer to Figs 1-4, bottom lines.)

b. For the LD/WV and DL/VW states some practice effects were noted for conditions 1 and 4 and to a greater extent 2 and 5. However, practice had its greatest effect on dual conditions 6, 7, and 8. (Refer to Figs 1 and 4.)

c. For the LD/VW and DL/WV states condition 3 was virtually unaffected by practice. Conditions 2 and 4 showed some effects of practice while condition 5 showed this effect even more. Again, conditions 6, 7, and 8 showed the effects of practice to the greatest extent. (Refer to Figs 2 and 3.)

Summarizing for all four stimulus/response states, practice had little or no effect on the first four conditions, showed some on the fifth condition and showed the greatest effect on conditions 6, 7, and 8.

In order to investigate the possibility of parallel processing in the dual processing conditions, the response times of various pairs of singular conditions were added together and then had subtracted from the comparable simultaneous condition, e.g., for conditions 1 and 3 (OL + OD)--condition 5 (0, 0): cond. 1 + cond. 3 - cond. 5. It was felt that if the response times of the separate conditions, when summed, were always greater than the times required to do the two tasks simultaneously there would be presumptive evidence for parallel processing. If, however, they were equal it might be concluded that there was a time sharing mechanism with efficiency equal to that of doing the tasks separately. If the simultaneous conditions for the most part took longer than the sum of two appropriate single conditions it would imply that attention switching was relatively slow and added time to the total process.

Tables X - XIII confirmed that dual tasks usually took longer than two similar singular tasks added together. Specifically, with the possible exception of the 1 + 3 - 5 (zero's) combination, response time differences increased as cognitive load (via a change in transformation size) increased. Perhaps it was easier to perform a dual zero transformation because it was an easy set to assume.

It was felt that perhaps some of these differences might be accounted for by virtue of the fact that Ss actually viewed four columns in the accomplishment of two single tasks but only two columns when performing the simultaneous tasks. In order to test this hypothesis four previous subjects were recalled and asked to accomplish single transformations (again, either 0 or 1 unit) in both the written and verbal mode for both single and double column stimulus sheets. The four subjects represented three of the four stimulus/response states used in the main experiment. Means were derived across subjects for all conditions and it was found that the largest difference between single and double columns was .03 seconds which effectively dispelled the hypothesis.

It was felt, therefore, that the data pointed towards the acceptance of a switching mechanism that slows down as cognitive load increases.

TABLE X

DIFFERENCE SCORES FOR STIMULUS/RESPONSE STATE: LD/WV

	Conditions 1 + 3 - 5					Conditions 2 + 4 - 8			
	Trials			Total		Trials			Total
S	1	10	20	20 tr	S	1	10	20	20 tr
1	4.2	4.0	2.4	52.2	1	-2.4	5.2	-3.2	4.2
3	- .6	.2	- .6	-3.8	3	-1.0	3.6	- .6	2.2
5	-1.0	.8	2.8	45.8	5	-1.4	-4.8	-2.0	-27.4
7	- .8	.8	.4	3.2	7	-2.4	-1.4	-2.6	-31.2
9	4.2	2.6	3.0	49.2	9	-3.4	-2.8	3.8	36.4
11	0	1.2	1.8	23.8	11	-3.6	1.8	-2.2	-39.8

	Conditions 1 + 4 - 6					Conditions 2 + 3 - 7			
	Trials			Total		Trials			Total
S	1	10	20	20 tr	S	1	10	20	20 tr
1	4.0	4.4	13.8	77.2	1	-8.6	-3.0	-13.8	-105.2
3	-4.0	-10.0	-4.2	-122.0	3	-11.4	-1.4	-7.6	-107.8
5	-11.0	-13.4	-1.0	-75.6	5	-1.2	-6.2	-5.2	-58.0
7	- .6	-7.8	-3.0	-66.0	7	-16.0	-3.2	-8.4	-105.0
9	4.4	-4.4	-1.2	-104.0	9	-11.2	-5.0	-6.0	-129.2
11	-9.2	- .2	.6	-41.8	11	-3.0	-1.2	-1.6	-50.0

TABLE XI

DIFFERENCE SCORES FOR STIMULUS/RESPONSE STATE: LD/VW

Conditions 1 + 3 - 5					Conditions 2 + 4 - 8				
	Trials			Total		Trials			Total
S	1	10	20	20 tr	S	1	10	20	20 tr
13	2.8	3.2	2.6	55.8	13	2.2	0	-1.6	-33.8
15	- .8	0	- .2	-20.2	15	-2.4	- .8	- .2	-16.6
17	.6	-1.8	.8	- .4	17	-4.6	-4.4	-2.6	-64.6
19	- .2	- .6	.6	13.0	19	-1.2	-1.6	2.6	-27.6
21	-1.6	.4	1.4	9.2	21	-1.8	-3.0	-2.0	-50.6
23	3.0	3.0	3.0	54.0	23	0	- .4	2.6	- 1.0

Conditions 1 + 4 - 6					Conditions 2 + 3 - 7				
	Trials			Total		Trials			Total
S	1	10	20	20 tr	S	1	10	20	20 tr
13	-3.0	0	.8	- 11.6	13	- 5.2	1.0	-2.6	-27.6
15	-12.0	-7.6	-9.2	-214.6	15	- 7.6	.6	-5.6	-90.0
17	-12.2	-9.6	-5.0	-130.4	17	- 5.8	-2.4	0	-51.4
19	- 7.4	-3.0	-6.0	-114.4	19	-28.2	-2.4	-1.8	-162.2
21	- 4.6	-3.2	.2	- 40.4	21	- 1.0	-8.8	-4.0	- 39.4
23	-16.8	.2	-3.8	- 60.2	23	- 8.4	-4.0	-1.6	- 56.0

TABLE XII

DIFFERENCE SCORES FOR STIMULUS/RESPONSE STATE: DL/WV

Conditions 3 + 1 - 5					Conditions 4 + 2 - 8				
	Trials			Total		Trials			Total
S	1	10	20	20 tr	S	1	10	20	20 tr
2	0	.2	1.2	- 1.0	2	-3.0	.8	-1.8	- 4.2
4	-1.4	.2	.6	- 3.8	4	-7.8	-2.6	-3.8	-86.2
6	- .8	.2	3.2	27.2	6	-1.8	3.0	3.2	12.8
8	.4	- .4	1.6	22.8	8	0	-2.6	1.6	-20.7
10	-1.6	-1.0	.8	- 8.4	10	-2.6	-2.6	4.2	-10.6
12	- .6	1.2	.8	1.7	12	- .2	2.8	-1.0	- 3.0
Conditions 4 + 1 - 7					**Conditions 3 + 2 - 6**				
	Trials			Total		Trials			Total
S	1	10	20	20 tr	S	1	10	20	20 tr
2	- 1.0	-9.2	-3.4	-63.8	2	-5.6	-1.0	.6	3.4
4	- 1.6	- .8	-2.0	-37.4	4	-6.0	-1.2	-3.4	- 64.8
6	-10.6	- .2	-4.0	-52.6	6	-8.2	-1.2	- .6	- 36.4
8	- 4.8	-2.6	2.6	-35.3	8	.6	1.6	0	- 1.8
10	-5.4	-2.0	.4	-40.6	10	-6.8	-2.0	-4.0	-103.4
12	-5.4	-8.8	-8.0	-122.9	12	-6.6	1.4	-5.6	- 74.0

TABLE XIII

DIFFERENCE SCORES FOR STIMULUS/RESPONSE STATE: DL/VW

Conditions 3 + 1 - 5					Conditions 4 + 2 - 8				
	Trials			Total		Trials			Total
S	1	10	20	20 tr	S	1	10	20	20 tr
14	-5.0	.4	2.2	- .8	14	.6	0	-5.8	- 6.6
16	.8	.8	- .4	-10.8	16	-1.4	1.2	-3.2	-36.6
18	-1.6	- .2	1.8	-13.0	18	-3.2	- .2	-3.8	-79.6
20	3.0	2.8	- .2	57.6	20	-3.8	-11.0	-2.4	-84.8
22	- .2	0	2.2	18.2	22	-3.4	- 3.8	.4	-33.4
24	.4	0	-1.8	-15.0	24	- .4	.2	1.0	-22.8

Conditions 4 + 1 - 7					Conditions 3 + 2 - 6				
	Trials			Total		Trials			Total
S	1	10	20	20 tr	S	1	10	20	20 tr
14	-16.6	- 5.8	-2.6	-103.4	14	- 4.6	-8.2	-7.8	-153.2
16	- 5.6	- 1.6	-3.6	- 85.4	16	- 3.2	-4.0	-7.0	- 85.0
18	- 2.0	1.0	.2	- 33.4	18	- 8.0	-5.2	-4.8	-115.2
20	.2	-20.0	-2.0	.2	20	- 4.4	0	-3.0	- 60.8
22	- 9.4	- 4.2	-2.0	- 93.4	22	-12.4	-7.6	-2.0	-125.8
24	- 1.6	- 4.4	.2	- 90.4	24	- 8.6	-1.0	-5.0	-150.6

CHAPTER V

CONCLUSIONS

By way of summary the data supported the following statements:

<u>Single Conditions</u>

1. There was a consistent effect due to transformation size. That is, response time was less for a zero-unit transformation than a one-unit transformation.

2. While not significant there was a consistent effect due to response mode. Speaking was always faster than writing for comparable transformations and stimuli.

3. Though not significant, there was a consistent effect due to stimulus configuration. When letters were written and digits spoken (LD/WV, DL/VW) then the LD configuration produced higher mean response times than the DL configuration. The opposite was true when the letters were spoken and digits written (LD/VW, DL/WV) for all but the first condition.

4. There was little or no effect due to practice.

<u>Dual Conditions</u>

1. Response time for condition 5 (0, 0) was considerably less than all other dual conditions.

2. Dual conditions usually took longer than appropriate single conditions added together with the possible exception of the 0, 0 dual

transformation thus implying an attention switching mechanism.

3. Though not significant, when letters were written and digits spoken (LD/WV, DL/VW) the LD configuration produced lower mean response times than the DL configuration for all conditions except 7. The opposite was true when letters were spoken and digits written (LD/VW, DL/WV).

4. Practice effects were in evidence for all dual conditions.

5. As transformation size was increased, response times were increased.

Based on the foregoing statements the first hypothesis that no simultaneous processing would exist is accepted under the proviso that the 0, 0 transformation was an anomaly.

The second hypothesis that no difference would exist between response modalities was accepted for all conditions even though as stated in single condition 2 above there was a consistent effect due to the particular response modality employed with some qualifications due to interaction effects.

The third hypothesis that no difference would exist between stimulus configurations was accepted for both the experimental and control conditions again with some qualification due to interaction.

The fourth hypothesis that practice would lessen reaction times for completion of the fifteen item lists was rejected for the control conditions but accepted for the experimental conditions.

The fifth and final hypothesis, that as the transformation size increased so would response times, was accepted for both the control and experimental conditions.

CHAPTER VI

SUMMARY

This study investigated the phenomena of concurrent processing of several verbal stimuli. The intent was to discover whether or not humans can carry on concurrent verbal activity and what effects alterations in cognitive load and practice had on concurrent responding.

Twenty-four students enrolled in Introductory Psychology classes at Oklahoma State University were used as subjects. Each subject was presented with a series of fifteen combinations of letter/digit or digit/letter stimuli to which they were to respond by performing either single or dual transformations.

It was hypothesized that no simultaneous processing of information would exist. The data supported this hypothesis except when zero-unit transformations were applied to both stimuli.

It was also hypothesized that no difference would exist between response modalities. However, a consistent (though non-significant) difference for response mode was found for the single tasks as would be expected under the parameters of this experiment. Generally, written responses took longer than verbal responses regardless of the stimulus.

Further, it was hypothesized that no difference would exist between stimulus configurations. The data confirmed this hypothesis with some qualification due to interaction effects.

It was also hypothesized that practice would result in a lessening of response time. Practice did have this effect in all conditions except the zero verbal transformation of letters or digits. The effects increased as cognitive load (via an increase in transformation size) increased.

Finally, it was hypothesized that as the transformation size increased so would the time to complete the fifteen item list. This was the case for all conditions in all stimulus/response states except for condition 5 (0, 0) in the LD/WV state where this task took less time than condition 2 (1L).

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APPENDIXES

APPENDIX A

Two examples of the stimulus configuration discussed in Chapter III.

DL list	LD list
3c ___	c2 ___
1d ___	d5 ___
5b ___	a1 ___
2a ___	b4 ___
4e ___	e3 ___
3a ___	b2 ___
2c ___	e1 ___
4d ___	c3 ___
5e ___	a5 ___
1b ___	d4 ___
4a ___	c1 ___
2e ___	a4 ___
1c ___	d3 ___
5d ___	b5 ___
3b ___	e2 ___

APPENDIX B

INSTRUCTIONS FOR SUBJECTS IN THE LD/WV CELL

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

Look at the sequences of letters on this card (show letter circular sequence card). Please note that it is a circular sequence. This means that for any letter I give you, it should be possible for you to provide the next letter in the sequence without hesitation. That is, if I show you the letter "e" then you should be able to give me "a" because it is the letter next to "e" in the direction of the arrows. Similarly, if an "a" is shown you should respond with "b" and so on.

Now look at the sequence of digits on this card (show circular sequence card). Note that it also is a circular sequence. This means that for any digit I give you, it should be possible for you to provide the next digit in the sequence without hesitation. That is, if I show you the digit "5" then you should be able to give me "1" because it is the digit next to the "5" in the direction of the arrows. Similarly, if a "1" is shown you should respond with "2" and so on.

Now look at this sheet (show LD sample stimulus sheet). You will notice that it is comprised of a list of letter first and digit second combinations with a lined space to the right of the digit. The lined space will be used to write in when you are instructed to do so.

In a moment you will be presented with your first sheet along with an instruction card which will tell you the distance to go in the circular sequence in order to make a correct response. That is, if the card displays a "0" you will respond by either copying the letter in the blank space or repeating out loud the digit presented depending on my instructions. If a "1" is presented you will respond by either writing the next letter in the alphabetical circular sequence or saying out loud the next digit in the digital circular sequence from the one presented. Are there any questions?

In the two lists to follow you are to attend only to the letters. You are to write the proper response in the space provided. When you are finished with the first sheet do not turn the page until instructed to do so. Are there any questions?

Zero Transformation - L/W

Now here is an instruction card explaining what you are to do (present the "0" card). The zero tells you that you are to fill in the blank by copying the letter presented. That is, if a "d" is shown to you, then write "d" in the blank. I want you to go as fast as you can and you should not make more than 3 or 4 errors. After you have finished do not turn the page until instructed to do so. Ready? Please turn the page. Begin.

One Transformation - L/W

This card represents a one shift (show the "1" card). The "one" tells you to fill in the blank with the letter one step away in the alphabetical circular sequence. That is, if the letter "e" is shown to you, then write "a" in the blank space. I want you to go as fast as you can and you should not make more than 3 or 4 errors. After you have finished do not turn the page until instructed to do so. Ready? Please turn the page. Begin.

For the next two sheets I want you to attend only to the digits. The proper response is to be spoken out loud only. When you are finished with the first sheet do not turn the page until you are instructed to do so. Are there any questions?

Zero Transformation - D/V

Here is your instruction card telling you what kind of a shift to make (present the "0" card). Remembering that the response is to be verbal, I want you to go as fast as you can and you should make no more than 3 or 4 errors. Ready? Please turn the page. Begin.

One Transformation - D/V

Here is your instruction card telling you what kind of a shift to make (present the "1" card). Again, I want you to go as fast as you can and you should not make more than 3 or 4 errors. Ready? Please turn the page. Begin.

During the rest of the experimental situation you will be presented with several different instruction cards which will have two numbers on them separated by a comma (present one of the two-number cards). The first number tells you what kind of shift you are to make with reference to the letter stimuli. In all cases this letter shift will be written in the space provided. The second number will tell you what kind of shift you are to make with reference to the digital stimuli. In all cases the digital shift will be spoken out loud. Both shifts will be made at the same time. That is, if the instruction card displays a 0, 0 you will copy the stimulus letters onto the blanks and repeat the digital stimuli out loud at the same time. Any questions?

0,0 Transformation

This instruction card represents a 0,0 shift (show the 0,0 card) as mentioned above. Remember, both the written response and the verbal response is to occur at the same time. E.g., if the combination is "al" you will write "a" and say "l". I want you to go as fast as you can and you should not make more than 3 or 4 errors. Ready? Please turn the page. Begin.

0,1 Transformation

This card represents a 0,1 shift (show the 0,1 card). You respond by copying the letter and saying the next digit in the digital circular sequence, both at the same time. E.g., if the combination is "al" you will write "a" and say "2". I want you to go as fast as you can and you should not make more than 3 or 4 errors. Ready? Please turn the page. Begin.

1,0 Transformation

This card represents a 1,0 shift (show the 1,0 card). You are to respond by writing the next letter in the alphabetical circular sequence and repeating out loud the digit presented, both at the same time. E.g., if the combination is "al" you will write "b" and say "l".

I want you to go as fast as you can and you should not make more than 3 or 4 errors. Ready? Please turn the page. Begin.

1,1 Transformation

This card represents a 1,1 shift (show the 1,1 card). You are to respond by writing the next letter in the alphabetical circular sequence and saying the next digit in the digital circular sequence, both at the same time. E.g., if the combination is "a1" you will write "b" and say "2". I want you to go as fast as you can and you should not make more than 3 or 4 errors. Ready? Please turn the page. Begin.

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