THE PUPILLARY RESPONSE TO INSTRUCTIONAL SET

By

DONALD BRUCE HEADLEY

Bachelor of Science

University of Massachusetts

Amherst, Massachusetts

1968

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
May, 1971

THE PUPILLARY RESPONSE TO INSTRUCTIONAL SET

Thesis Approved:

Thesis Adviser

Dean of the Graduate College

ACKNOWLEDGEMENTS

Work on this thesis began in the Fall of 1969. Since that time, certain people have been instrumental in the transition of a research idea from the "blackboard" stage to the laboratory, and finally to this manuscript. Special thanks are extended to Dr. Robert F. Stanners, who served as the thesis adviser, and who gave generously of thoughtful advice throughout all stages of the thesis. Appreciation is also given for the use of his research facilities.

The author also wishes to thank the other members of his committee, Dr. Robert J. Weber, and Dr. Larry L. Brown. A special note of thanks should go to Dr. William R. Clark; his experience with the technique of pupillometry made him a much sought after individual, and the help he gave is appreciated.

Finally, this thesis is dedicated to human subjects everywhere.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

THE PROBLEM

Purpose of the Study

Three decades ago, Dashiell (1940) listed four main classes of determinants of human behavior: stimulus-response, habits, genetic factors, and set. He complained that set was a neglected area of investigation, and argued that it was an important phenomenon for psychological research to describe. The problem was that the term "set" was used so loosely that it held different connotations for many psychologists. Gibson (1941) noted that the following terms had been used to define whatever was meant by set: mental set, motor set, preparatory set, situation-set, expectation, attitude, directing tendency, and determining tendency. This ambiguity led him to state at that time that "The concept of set or attitude is a nearly universal one in psychological thinking despite the fact that the underlying meaning is indefinite, the terminology chaotic, and the usage by psychologists highly individualistic" (p. 781). The situation is somewhat the same today in that the concept plays a part in most areas of psychology. As stated by McGee (1967), a set has become a well-used hypothetical construct, and

> the very fact that it has been used so extensively by so many different individuals under so many different synonyms indicates a need for a unifying system of theoretical postulates and empirical studies related to a _psychology of set_ (p. 14).

Generally speaking, set seems to be described as a disposition, a state of mind, and the effect of set is that of selection or guidance of the mental processes. This thesis was concerned with an investigation of experimentally induced set, and sought a more direct approach to an empirical description of it than has been provided so far. As will be shown, most studies have utilized response data from the S-O-R paradigm to infer set and its actions. However, the logical and desirable point at which an investigation of set should take place is at the "O" variable. That is, the state and its influence should be studied as it occurs. Such an approach was offered through the technique of pupillometry, to be described later.

The History of "Set"

The concept of set is as old as the first experimental studies of the mental processes. G. E. Müller, in redoing Ebbinghaus' work on memory, extended his own findings to include the concept of "preparatory set" (Anlage). That is, the memory processes were not as mechanical as Ebbinghaus may have thought; rather, subjects seemed to be engaged actively in their tasks, indicating that learning was not a completely automatic process (Watson, 1963).

This idea carried on with the work of Külpe, who had studied with Müller, and the "Würzburg School". Basically, the task (Aufgabe) was responsible for inducing an unconscious set (Einstellung), such that the type of activity which was influenced by this set took place with little awareness during a trial - one was not aware of the "determining tendency" guiding his strategy or behavior in the task (Watson, 1963).

Over the years, set has been used in one context or another by most areas of psychology (Boring, 1950; McGee, 1967). The terms developed and employed by the Würzburg School (task, determining tendency, etc.) have taken on a motivational context in today's usage. That is, set is a variable that influences the mental processes. "Attitude" is used as a replacement for Einstellung in social psychology. In the area of perception, an attentive set enables a subject to perceive more readily certain aspects of visually presented stimuli as compared to his performance when he is given no advanced information on what to look for. Two main hypotheses have been proposed to explain this effect of set on visual perception (Haber, 1966). One is a perceptual tuning hypothesis: set enhances the perceptual processes by causing a focusing of attention on particular attributes of the stimulus. This interpretation places the effect of set during the stimulus presentation. The other hypothesis is a non-perceptual approach, and it argues that set does not affect the percept but does influence the memory trace; Haber feels that set induces different coding strategies (speed of encoding, order of encoding) which reorganize the memory such that the more relevant aspects of the stimuli will be reported accurately.

Different types of perceptual set experiments have been conducted in Russia by D. N. Uznadze (1966). Set in his experiments is a manifestation of the testing situation itself and is not induced by instructions (advanced information) in the manner mentioned above. For example, two balls of different volume (size) are placed in the _S_'s hands, and he judges the size of the two objects. After a series of such procedures (called the "fixing" or "setting" experiment), the _S_ is given two balls of equal volume. The response is invariably that one of the objects is larger. Uznadze argues that when a task ("need") and a situation for its completion is presented, "a specific state develops in the subject which may be described as a tendency, an inclination, or a state of preparation for the performance of the act capable of satisfying this need" (p. 203). Set is an internal state which is directive on the dynamics of the mind, and is reflected by preparation for a definite activity.

In the area of learning, "expectation" is commonly used to describe a guiding factor of the mental processes. Mowrer (1940) used this term in an experiment involving reaction times to measure the influence of set. Subjects were instructed to release a button when a tone came on; the occurrence of this tone was generally at twelve second intervals except for test trials where the tone occurred before or after twelve seconds. Mowrer obtained a "curve of expectancy" in which reaction times were longer on either side of the twelve second mark. He postulated a decline in readiness or expectation on the S's part after each trial until the perceived point in time when the tone would occur again.

In personality assessment, set has generally been used to describe any response bias or preconceptions a subject brings into the laboratory with him. Its effect is the various response styles a subject uses in taking a personality test.

A distinction was made between set induced experimentally, as that created by instructions in perceptual experiments, and set which is a manifestation of the testing situation itself (Uznadze's experiments). Any attempt to isolate the influence of set on the mental processes should stem from a study of experimentally induced set. Experiments which induce set as a guiding factor in the handling of specific task requirements offer well defined situations in which to isolate the influence of set. Studies illustrating such an approach are given next.

A Survey of Induced Set Studies

One factor that can influence memorization of materials is the knowledge or anticipation of future task demands placed on a subject. In a study by Pollack, Johnson, and Knaff (1959), the auditory presentation of digit lists of known length, or of unknown length in a backward memory task produced differences in recall performance. For message lengths of fifteen items or more, the digit spans for the "known" conditions were consistently greater than the "running digit spans" (number of items correctly recalled in the "running memory task" - the task with unknown digit length). The results were attributed to differences in behavioral (rehearsal) strategy of the material in an attempt to find a suitable method of retention for each task.

A study by Kay and Poulton (1951) also obtained results suggesting differences in memorization techniques. The S's task was to memorize eight display items (positions of directional arrows). In condition A, the first four items were to be learned and recalled, then the next four. Another condition (C) required the S to learn all eight, then recall them in serial order. In both cases, S knew the task that was to be performed. Two other conditions were such that S did not know during the learning of the items what the recall procedure would be; all eight items had to be learned, but in condition B_2 items 5-8 were to be recalled first, then 1-4, while in condition B_1 serial order was required.

A typical result is seen in comparison of conditions B_1 and C. Here, the tasks were exactly the same, each condition differing only to the extent that in C the S knew the recall task, whereas in B_1 the task was made known after the presentation of the items had already taken place. The percentage of correctly recalled display items for each serial position in condition C followed a typical U-shaped curve with performance gradually diminishing over positions except for a sharp increase at item 8. The dominant rise in the performance curve for B_1 was at item 5, which was followed by a steady decline through item 8. Due to these differences in the serial position curves, the authors reasoned that memorization techniques differed in response to the knowledge or anticipation of when and how recall was to take place; that is, a "preparatory set" had been established directing the memory processes. "The end determines the manner of memorization...Anticipation of how the learned material will be utilized is one of the variables affecting the mental set of the subject" (Kay and Poulton, 1951, p. 38).

Hinrichs (1968) tested the effect of pre- and post-stimulus cuing on recall performance for two different types of tasks (either recalling in the same order as presentation, or recalling in backward order). Randomly arranged sequences of the digits 1-9 were presented by tape recorder to Ss who received either the word "forward" or "backward" just before or after stimulus presentation. It was argued that differences which might be found in serial position curves between the pre- and post-cuing conditions would reflect different strategies undertaken in order to meet the demands of the specific task situation.

It was found that when the subject was cued before presentation of the digits, better recall occurred for the forward order task than for the backward demands. However, when the subject did not know until after stimuli presentation what the required order would be, significantly different performance did not result between the forward and backward tasks. Because of the failure to obtain forward order superiority in the post-conditions, the strategies which took place to deal with the digits under the pre-stimulus condition might not have been the same as those for the post-stimulus condition.

The three studies cited above indicate that differences in performance result from differences in knowledge of task requirements. However, in order to determine more precisely the influence of set on the behavioral strategy of dealing with stimuli, a useful methodological approach would be one which allows measurement <u>while the preparatory set is guiding the learning</u>, thus allowing for a more immediate and direct data source. This idea of dealing with the "O" instead of the "R" in a S-O-R paradigm was suggested earlier by Mowrer (1940). He argued that the reaction time index, as well as other measures, has the defect of not providing "a means whereby the course of this phenomenon [expectation] can be continuously followed in a single, individual subject" (p. 28). The technique of pupillometry was used to observe whether different encoding strategies would result from different sets induced experimentally.

The Technique

A study by Hess and Polt (1964) was responsible for creating interest in the pupil as a possible index of cognitive processing. These investigators presented multiplication problems of varying difficulty to their subjects. It was reasoned that the more difficult problems would result in greater mental activity, and interest was centered on whether pupil size would reflect such differences. For all problems, the pupil increased slowly in size after presentation, and reached a peak just before the answer was given. Greater dilation was observed to the more difficult problems (16 X 23, as compared to 8 X 13, for example), and hence the authors felt that there is a close correlation between pupillary changes and problem difficulty. They concluded that "the pupil response will prove to be a valuable tool in the study of problem-solving and other mental processes, which have to date been largely a matter of subjective responses on the part of the subject" (pp. 1191-1192).

Kahneman and Beatty (1966) further substantiated the fact that pupil diameter varies with the cognitive load on a subject at any given moment. Pupil dilation increased during the presentation of a list of words or digits to be memorized (loading phase). It was also found that the pupil dilation for words was greater than that for digits. Recall of the words or digits resulted in a constriction of the pupil (unloading phase), which was interpreted as a decrease in rehearsal load.

Furthermore, the pupillometric index is a very sensitive measure of mental processing, as shown in a study by Simpson and Hale (1969). Their tasks apparently required little in the way of cognitive effort, yet the measure distinguished cognitive activity during the foreperiod to a motor reaction task which involved a simple decision, from cognitive activity in the foreperiod to a similar task which required no decision. This sensitivity was also demonstrated by Paivio and Simpson (1966) who found that Ss who were required to form mental images to both abstract and concrete words gave more dilation to the abstract words. Presumably, the attempt to create an image for a word such as sadness required more "attention" by the S than a word such as candy, and this increased cognitive effort resulted in greater dilation. Finally, Beatty and Kahneman (1966) found greater dilation to a long-term memory task in which Ss were to respond with a previously memorized telephone number upon cue presentation, than to a short-term memory task in which a telephone number of similar length was presented to the S for immediate recall.

Bradshaw (1968) found that subjects responded with different levels of dilation to tasks which varied in manipulated difficulty. Sequences of three items (digits or letters) were presented via earphones to Ss who were engaged in a continuous processing task. Task difficulty was manipulated by varying the rate of stimulus presentation (80 items/minute, or 40 items/minute), and the number of decisions required in the task: the "easy" task involved digits and required a button-pressing response if the first and third digits in the sequence were the same, or if the second digit was an odd number; the "hard" task involved letters and required a button-pressing response (right hand) if the first letter was greater alphabetically than the third letter, or if the second letter was a vowel; a pressing of a button in the left hand was required if the second letter was greater alphabetically than the third. Each S received all four tasks. The results indicated that in terms of average pupil diameter for each condition (that is, one mean value for each condition), both the faster presentation rate and the greater processing load ("hard") were significant contributors to increased pupil size. Thus, manipulated task difficulty was reflected by differential dilation.

It seems that the type of activity that is monitored by the pupil during mental activity is activation of the sympathetic nervous system.

A study by Kahneman, Tursky, Shapiro, and Crider (1969) showed that pupillary, heart rate, and skin resistance measures effectively indicated differential increases in activity due to loading and processing of stimuli during tasks of varying difficulty. "Although the energy requirements which mental activity imposes on the organism are minimal, large and precisely modulated autonomic changes are associated with such activity" (p. 166).

The neurophysiological basis for pupil size is innervation of the iris by the autonomic nervous system (Adler, 1959; Loewenfeld, 1966). The sphincter pupillae muscle of the iris is innervated by the parasympathetic third cranial nerve. Parasympathetic stimulation causes constriction of this muscle, and results in a smaller pupillary aperture. On the other hand, the dilator pupillae of the iris is supplied by sympathetic fibers. Stimulation of these fibers causes contraction of the dilator pupillae, and also causes muscle tone inhibition of the sphincter as well. Such inhibition may result from postulated sympathetic inhibitory fibers which also innervate the sphincter (Adler, 1959), or from inhibitory influences on the Edinger-Westphal (oculomotor) nucleus, which is the controlling site for parasympathetic fibers of the third cranial nerve (Loewenfeld, 1966). The inhibition would "quiet" activity in the efferent parasympathetic connections from this nucleus to the sphincter. The result of sympathetic influence is dilation of the pupil. To be noted is that the efferent sympathetic pathway to the dilator muscle of the iris is believed to be under the control of cortico-thalamic-hypothalamic mechanisms (Loewenfeld, 1966).

Task-Set and Pupillometry

The above studies indicate that the pupillometric index is a sensitive indicator of mental activity. If set does influence cognitive processing, differences in autonomic activity should be monitored by the pupil. In order to demonstrate empirically set and its influence, this thesis employed an experimentally induced set situation which would allow the inducement of different sets within a given subject by varying certain aspects of a task situation. The pupillometric technique should be able to measure the effect of set by tracking the mental activity associated with the processing of stimuli as they are presented under the various conditions.

A pupillometric study by Kahneman, Onuska, and Wolman (1968) suggested the task-situations to be used in this thesis. The investigators predicted that rehearsal of a nine-digit string would vary according to the form of presentation of these strings; and that the pupillometric index would be able to distinquish effectively the mode of rehearsal. They found that presentation of the digits in an equally spaced, ungrouped manner caused a linear type increase in dilation with each digit heard, and reflected a "cumulative and repetitive" type of rehearsal. A presentation of the digits in three sets of three caused no major increases in pupil size while the digits were presented; however, a significant rise in diameter occurred after presentation of the ninth digit, suggesting a pulling-together splurge of activity - rehearsal here was "intermittent and non-repetitive," occurring at the pauses between groups and confining itself to the group last heard.

This study thus showed the pupillometric response to be a useful indicator of rehearsal mode as a function of the type of stimulus presentation. A procedure which might also cause differential methods of encoding and rehearsal of stimuli during their presentation would be one in which the subject knew before the presentation what the task requirements would be - the instructions would induce a task-set, a special form of preparedness to handle the stimuli, and the effect of set should be represented by differential pupillometric responses based on different strategies of encoding.

Such a procedure is well suited for pupillometry if different task-sets are represented by various degrees of sympathetic arousal. There are various lines of evidence indicating that instructions do create autonomic arousal, and that such activity can be measured via the pupillometric index. Johnson and Campos (1967), using tasks involving arithmetic problems, informed the S before stimulus presentation whether or not he would have to verbalize how he solved the problem upon completion of it. Acceleration effects of both heart rate and skin conductance measures were noted in those trials requiring verbalization. The results were summarized in the following manner:

> ...all physiological measurements were taken before the Ss actually reported their experiences. Despite this, the instructional variation has in every case accounted for a very large and highly reliable proportion of the variation in the physiological measures. It becomes quite clear that rather simple instructional or set variables can influence these responses and clearly override other factors such as the modality, affective tone and complexity of the stimulus, and direction of attention. This finding clearly indicates that such instructional effects are extremely strong and should be carefully dealt with in all psychophysiological research (p. 149).

In digit transformation tasks utilized by Kahneman, Peavler, and Onuska (1968, Experiment II), Ss were required to add either 1 or 0 to each of four digits and respond with the appropriate values after the digits had been presented. One of two levels of incentive in the form of a small monetary reward was used with each transformation task. Instructions indicating the task and amount of incentive began each trial. During the latter part of a pause interval which followed the instructions, and during the period when the digits were presented, the pupillary response to the more difficult task (add-1) was greater than that to the add-0 task. These results were independent of amount of incentive (the higher level of incentive did produce, however, a slightly greater response to the add-0 during presentation). Thus, anticipated task difficulty distinquished itself shortly after the instructions.

Finally, a study by Clark (1970) showed that the pupillary response to short-term memory tasks does effectively indicate changes in cognitive processing which are caused by instructional variations concerning task requirements. Ss were presented auditorially a list of digits, followed a few seconds later by a probe digit. A cue just before the probe instructed the S whether or not he would have to decide if the digit was a member of the preceding sequence. A between-S variable was the added task of recall; half the Ss were informed that they would have to recall on every trial, while the other half was not given this memory requirement. It was found that significantly greater dilation occurred during digit presentation by those subjects who had to recall, than by those who did not. Also, when Ss were instructed that a probe decision was required, greater dilation occurred following the cue as compared to the trials when Ss were informed that no probe decision was necessary. This pupil dilation to the task requiring a "search" by the S through the previously heard list of digits resulted even when no recall was demanded. Presumably, a search requirement caused a rapid rehearsal of the digit string.

Such influences of task-instructions on sympathetic arousal and preparation were used in this thesis to study set and its effects on reception and processing of simple sets of stimuli.

Statement of Hypotheses

The major question being investigated in this study was whether knowledge of future task requirements would change the manner in which one processes a digit string while it is being presented. The basic task involved attending to a string of five digits, and reacting to a probe item shortly thereafter. Different tasks were created by varying the requirement of an interpolated task and/or a recall task in addition to this basic search task. It was hypothesized that instructions at the beginning of a trial would induce distinct sets which would selectively guide the strategy used to deal with the digits. Specifically, it was felt that the differential difficulty imposed by the various task-situations would result in differential cognitive effort during presentation, which in turn would be reflected in the size of the pupil. The main distinctions imposed by the tasks were the amount of opportunity for rehearsal of the digits, and whether recall was required. One basis for different mental activity in the tasks may be linked to rehearsal (see the Kahneman, Onuska, and Wolman, 1968, study discussed in the previous section). In the condition requiring both the interpolated task and recall (IT-Recall), and in the interpolated task-no recall situation (IT-No Recall), rehearsal would be prevented during the period following presentation of the digits (see Peterson and Peterson, 1959); encoding and storage would have to take place during the presentation of the digits, as there would be no time for rehearsal afterwords.

The no interpolated task-recall (No IT-Recall), and no interpolated task-no recall (No IT-No Recall) conditions were expected to show lesser dilations because no activity was required after presentation, and this time before the probe could be used for rehearsal.

It was also expected that (IT-Recall) demands would impose greater cognitive effort on the S than would the (IT-No Recall) requirements, and that larger pupillary dilations would therefore occur during stimuli presentation under the former condition.

The recall demands of the (No IT-Recall) situation likewise were expected to cause more processing during stimuli presentation than would the (No IT-No Recall) task. These two situations offered a further comparison, in that they allowed for the possibility of distinquishing between "recall memory" and "recognition memory" on the basis of how the S handles material during its presentation.

One other interval in which differential dilations were expected was a pause period which occurred between the instructions and the first digit. It is here that the different instructions should first produce differential "mental preparations". It was hypothesized that differences occurring in this period would selectively reflect the proposed difficulty associated with the instructions for each task.

Another feature of the proposed experiment would be to see whether Ss change their cognitive strategies on a second-to-second basis. Toward this end the present experiment employed a completely within-S design.

CHAPTER II

METHODOLOGY

Subjects

Thirteen subjects (Ss) were obtained from undergraduate psychology classes during a summer session at Oklahoma State University. Ten Ss were given a few extra points toward their final course grade as an inducement for participation; three additional Ss were run to replace three of the original ten when it was discovered that an error in use of the photographic equipment resulted in film unfit for data collection; these three Ss received two dollars each for participation. The pupillometric data, then, were based on ten Ss, five males and five females.

The following restrictions were required of the Ss: that they (1) be right-handed, (2) have at least 20/30 vision without the aid of glasses or contact lenses, and (3) possess eyes that are light in color (e.g. blue, etc.). Restriction (2) was to ensure that the S would be able to fixate properly and comfortably on a distant fixation point, and restriction (3) was for photographic purposes - light irises provide a more distinct pupil to iris contrast on film, and thereby allow a more accurate measurement of pupil diameter.

Apparatus

The basic equipment used to obtain the pupillometric records consisted of a pupillometer and a 16 mm. motion picture camera. The pupillometer was a rectangular wooden box with dimensions of 22 1/2" x 22 1/2" x 48 1/2". The front end was equipped with chin rest and stationary eyepiece. The back end consisted of a rear projection screen (polyethylene covering), and a fixation-cross (3/4" high; 1/4" arms) positioned in the center. The inside was painted flat black.

A Beaulieu R16 movie camera was mounted on the right side of the pupillometer; the camera was equipped with a Vemar 135 mm. f/2.8 telephoto lens, a Vemar "C" mount adapter, and 30 mm. of extension tube. Camera speed was calibrated to 2 frames/second, and to ensure constant speed throughout the experiment, the camera's separate power supply was connected to a voltage stabilizer (Raytheon VR6114)-powerstat (Superior Electric Co., Type 116). The film was Kodak Double-X Negative, Type 7222.

A half-silvered mirror was situated inside the pupillometer at a 45 degree angle from the S's line of vision to the camera. The positioning allowed S a view of the rear of the box, and also allowed a reflected image of the right eye to strike the lens system.

The experiment took place in a large, air-conditioned room with a normal level of lighting (ambient level of 100 ft-c at S's eye level when seated; windows were covered with aluminum foil in order to control for changes in external light levels). Illumination inside the pupillometer was provided by a projector fitted with a zoom lens and a blank slide; a 30 cm. x 30 cm. area was projected onto the rear projection screen. Illumination at S's eye was approximately 13 ft-c.

Materials were presented over a tape recorder (Uher Royal de Luxe) equipped with headphones for the S. Also connected with the tape recorder was a sound-operated relay (Grason-Stadler, Model E7300A-1, modified with a latching relay). This relay (normally open) was in circuit with a Hunter Klockounter (Model 120A). A two-way toggle switch (normally closed) located at the lower right-hand side of the pupillometer was also in connection with the Klockounter. Camera operation was controlled by the sound-operated relay on the tape recorder. A cue was placed on one channel of the tape, and a connection to the camera allowed for remote control start and stop functioning via this cue.

Stimulus Material

From a table of random digits, forty, five-digit sequences were selected with the restrictions that (1) no digit was to appear more than once in a sequence, (2) that the forty sequences were to be different from one another, and (3) that ordered patterns such as 1-3-5-7-9, 8-7-6-5-4, etc. were to be excluded. Zero was not used as a digit.

These digit sequences were then randomly assigned to one of the four task conditions, such that ten occurred in each. Further, five of each of the ten sequences were randomly selected for use on a positive probe trial (the probe digit being one of the preceding five); the probe consisted of a digit from one of the five serial positions such that each position was represented with equal frequency. For the other five trials of each condition, a negative probe digit (a digit that was not one of the preceding five) was randomly selected for use.

Then, an order of presentation for the forty trials was randomly determined with the restriction that no condition occur twice in a row.

Such a procedure was adopted in order to determine whether Ss would change their cognitive strategies on a second-to-second basis. A different random order was used for each half of the S pool.

Twenty of the trials required the IT task, and one letter from a pool of twenty was randomly assigned to these trials (W was excluded because it is not monosyllable, and B, D, E, I, and P were excluded in order to prevent acoustic confusability).

The trials were tape recorded. The timing of stimulus events during recording was accomplished by keeping pace with the dial of a Hunter Klockounter set at a one second interval. Precautions were taken to account for variations in timing that may have occurred in the taping of the various trials; these procedures are described in the last section of this chapter. A tape of sixteen practice trials was composed, which consisted of a random arrangement of four trials of each condition; none of these five-digit sequences appeared in the experimental trials.

Experimental Design

In order to determine whether different induced sets would be represented by differential degrees of cognitive processing, as indexed by the pupillary response, a within-subjects design was employed which consisted of the four tasks of varying difficulty. Set was induced by informing the S of task demands before presentation of the stimuli, and degree of difficulty was manipulated by the interpolated task and/or recall task combinations.

Two between-S variables were manipulated in this experiment - order (two different orders of the forty trials), and toggle switch movement.

A predetermined random arrangement placed five Ss with one tape, and five with the other; also, half of the Ss were instructed to indicate the presence of a positive probe by throwing the switch to the right, while the other half were instructed to move the lever to the left to indicate a positive probe. A card indicating the proper directional movements was taped above the toggle switch to remind the S of the pattern.

Procedure

Ss were first checked for uncorrected vision of at least 20/30 as determined by the Snellen Eye Test. They were then seated before the pupillometer, and instructions (see Appendix A) were played to them over headphones. During this time, the Ss were free to look inside the pupillometer and become familiar with it.

Next followed the series of sixteen practice trials to acquaint the Ss with the four different tasks. No filming occurred during these trials.

Before the forty experimental trials were presented, a small ID card with the proper S number was photographed on the leading frames of a given S's film. Trials were separated by the exposing of two blank frames at the end of each trial.

The order of events during a trial was as follows: S first heard the word READY, which indicated that he was to position his head properly in the apparatus; three seconds later, the word START was heard, and was followed by a five second period of filming; then brief verbal instructions were given which informed the S of the task demands for that given trial. If both IT and Recall were required, S heard the words

"Letter, Recall" at this time; likewise, "Letter, No Recall", "No Letter, Recall", or "No Letter, No Recall" were placed on the appropriate trials. The instructions took two seconds, and were followed by a four second pause period. Then the five digits were presented at a one second interval. If the IT task were to take place, a randomly selected letter of the alphabet occurred one second after the last digit. The task required the S to recite the alphabet as rapidly as possible beginning with this letter. This activity was to continue until the probe digit was heard five seconds later. S was to indicate whether this digit was one of the preceding five by throwing a toggle switch in the proper direction as soon as he made his decision. The onset of the probe tripped the voice-relay (sensitivity of the relay was at E's control), and started the Hunter Klockounter. S's throwing of the toggle switch stopped the Klockounter. If recall was to occur, it took place immediately after the probe decision. This task required the S to report verbally to the E the five digits previously heard; free recall was allowed. The E wrote down S's recall, copied the RT to the probe, reset the Klockounter, exposed two frames, and then presented the next trial.

Filming began with the word START and continued through the last digit. An accurate correlation of stimulus events with filming was made possible by the camera-to-tape recorder connection. Cues which controlled camera operation were placed appropriately on one channel of the tape. The five second baseline period took place on every trial, because as Woodmansee (1966) has pointed out, basal levels do not necessarily remain at the same values throughout an experiment; an "arousal decrement effect" due to boredom, random thoughts, etc. can change this level. To control for such changes, pupil measurements for analysis were in the form of deviations from the mean baseline value for that given trial.

Scoring of Film

The processed film was projected onto a screen such that the image was ten times its actual size. Pupil diameter was then measured frame by frame with a millimeter ruler to the nearest millimeter. Some frames were not measurable because of eye blinks or eye movement. Such frames accounted for approximately 11% of the 12,800 frames scored (this percentage was the same for each of the four conditions).

In order to ensure an accurate correlation of each stimulus event on the tape with its proper frames, a Digital Clock (Marietta Apparatus Co.) controlled by the sound-operated relay on the tape recorder was used to time each event on each trial. The correct frames were determined by multiplying time by camera speed. In this manner, ten frames were assigned to the baseline period, four to the instructions, eight to the pause interval, and two frames to each digit, for a total of thirty-two per trial.

CHAPTER III

RESULTS

Pupillometric Data

The pupil dilations during the Instruction, Pause, and Digit segments are displayed in Figure 1 for each of the four conditions. Each point on the graph represents the average deviation from baseline for the ten subjects. The actual values are given in Appendix B. The values used for each subject in the analyses of variance discussed below were the average deviations of the ten trials for each condition. In all statistical analyses, the .05 level was adopted as the minimum for an effect to be considered significant.

Instructions Segment (Frames 11-14)

The results of the AOV are presented in Table I. In this analysis, and in the analyses discussed in the following two subsections, the variables of interest were Frames (number of levels varied), Recall (2 levels), and Interpolated Task (2 levels), as well as the various interactions. During this two-second interval, the only significant effect turned out to be that due to Frames (F; $p < .01$), and is reflected by the upward trend in Figure 1. The other variables of Recall (R), Interpolated Task (IT), and the interactions did not approach significance.

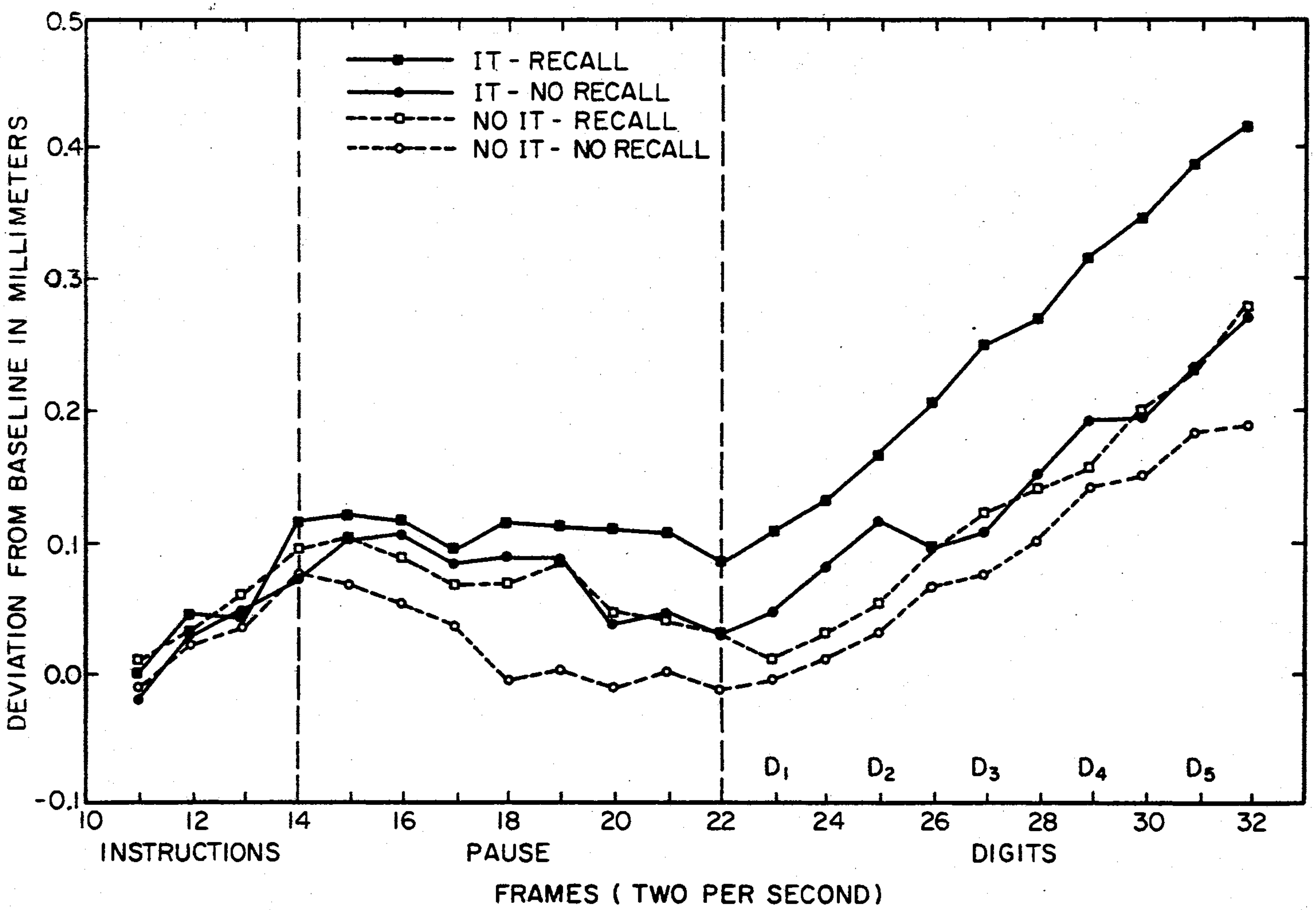

Figure 1. Pupil Response to the Instructions, Pause, and Digit Segments. Each value is based on the mean of ten Ss. Following the last digit were the (No) IT, probe, and (No) recall phases of the trial.

TABLE I

AOV OF AVERAGE PUPIL RESPONSE TO INSTRUCTIONS

Source	df	SS	MS	F[1]
Total	159	0.68983		
Subjects (S)	9	0.12517	0.01391	
Frames (F)	3	0.18385	0.06128	19.896***
SF	27	0.08306	0.00308	
Recall (R)	1	0.01395	0.01395	3.614
SR	9	0.03474	0.00386	
Int. Task (I)	1	0.00001	0.00001	0.003
SI	9	0.03220	0.00358	
FR	3	0.00249	0.00083	0.428
SFR	27	0.05234	0.00194	
FI	3	0.00289	0.00096	0.706
SFI	27	0.03674	0.00136	
RI	1	0.00001	0.00001	0.001
SRI	9	0.08134	0.00904	
FRI	3	0.00263	0.00088	0.620
SFRI	27	0.03841	0.00142	

[1]Individual error terms (indented) were used in each F-ratio. For the Newman-Keuls tests (see text), all error terms except SF were pooled together. Significance levels for all tables are represented by the following: *** = $p < .01$; ** = $p < .025$; * = $p < .05$.

Pause Segment (Frames 15-22)

Frames was a significant variable ($p < .01$) during this four second period, as were the main effects of R and IT, $p < .025$ in both cases. No interactions were significant. Table II contains the analysis.

In order to determine the distinctiveness of each of the four curves, a Newman-Keuls multiple comparison test (with p level set at .01) was performed on the overall mean of the eight frames for each subcondition. The results indicate that the average dilation for the (IT-R) condition was significantly greater than the other three, and that both the (IT-No R) and (No IT-R) conditions were not different from one another, but were greater than the (No IT-No R) condition.

Digit Phase (Frames 23-32)

The AOV for the Digit segment is presented in Table III. The variables of F, R, and IT were significant during this five second period (all $p < .01$). Also, the Frames X Recall interaction was significant ($p < .01$) and is sketched in Figure 2. The rate of increase in the pupillary response is greater for recall than for no recall. The Recall X IT interaction approached significance ($F = 4.575$; 1,9 df; 5.12 needed for $p < .05$).

Again, the Newman-Keuls tests (p level set at .01) were carried out on the data for the Digit phase, and the overall means of the ten frames for each condition were tested against each other. The same trend found for the Pause phase held here: IT-R greater than the others, and IT-No R and No IT-R each greater than No IT-No R but not different from each other.

TABLE II

AOV OF AVERAGE PUPIL RESPONSE TO PAUSE

Source	df	SS	MS	F
Total	319	2.63850		
Subjects (S)	9	1.00648	0.11183	
Frames (F)	7	0.14732	0.02105	7.234***
SF	63	0.18311	0.00291	
Recall (R)	1	0.14770	0.14770	9.225**
SR	9	0.14412	0.01601	
Int. Task (I)	1	0.19086	0.19086	9.808**
SI	9	0.17514	0.01946	
FR	7	0.02208	0.00315	1.575
SFR	63	0.12628	0.00200	
FI	7	0.01205	0.00172	0.748
SFI	63	0.14513	0.00230	
RI	1	0.00534	0.00534	0.261
SRI	9	0.18411	0.02046	
FRI	7	0.01341	0.00192	0.893
SFRI	63	0.13536	0.00215	

TABLE III

AOV OF AVERAGE PUPIL RESPONSE TO DIGITS

Source	df	SS	MS	F
Total	399	7.82135		
Subjects (S)	9	1.74543	0.19394	
Frames (F)	9	2.46584	0.27398	42.151***
SF	81	0.52651	0.00650	
Recall (R)	1	0.57501	0.57501	31.629***
SR	9	0.16360	0.01818	
Int. Task (I)	1	0.79977	0.79977	11.231***
SI	9	0.64092	0.07121	
FR	9	0.07991	0.00888	4.879***
SFR	81	0.14724	0.00182	
FI	9	0.01711	0.00190	1.218
SFI	81	0.12666	0.00156	
RI	1	0.13660	0.13660	4.575
SRI	9	0.26871	0.02986	
FRI	9	0.02282	0.00254	1.954
SFRI	81	0.10521	0.00130	

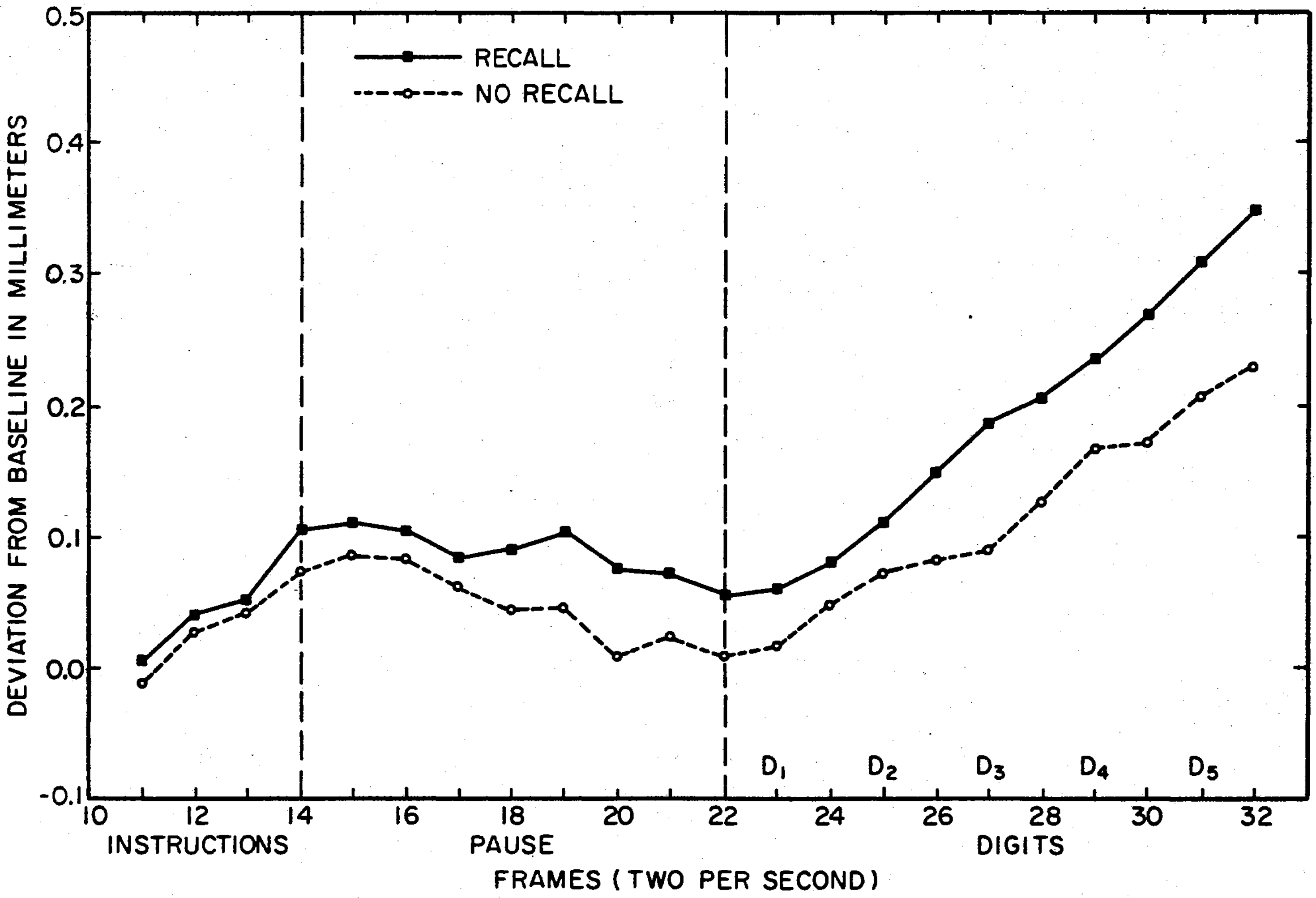

Figure 2. The Frames by Recall Interaction. The two conditions requiring recall of the digits were averaged together, as were the two conditions which required no recall of the digits. The interaction is significant during the digit phase.

Baseline Averages

Table IV contains the average baseline values of the ten trials in each condition for each subject. The data indicates that a given *S*'s basal level remained fairly constant from one condition to the next. An AOV (Table V) shows that neither the main effects of IT and R, nor the IT X R interaction were significant.

Secondary Response Measurements

Results of data discussed here are summarized in Table VI.

Reaction Times

The means of the RTs to the probe (P) digit are given in Table VI for each condition. An analysis of variance (Table VII) found the effect of IT significant ($p < .025$), as well as the P X R X IT interaction ($p < .01$), which is shown in Figure 3.

Decision Errors

Table VI shows that incorrect movements of the toggle switch occurred only in the two conditions requiring the Interpolated Task.

Recall Performance

Two conditions required verbal recall of the five digits. Free recall was allowed, and each correct digit in *S*'s response was scored for the proper serial position. Since errors occurred only in the IT-R situation, there was some additional evidence that greater task difficulty was produced by the Interpolated Task requirements.

TABLE IV

MEAN VALUE OF BASELINE PERIOD FOR EACH CONDITION

Subject	IT-Recall	IT-No Recall	No IT-Recall	No IT-No R
1	2.9949	3.0162	2.9750	3.0421
2	4.0804	4.0419	4.0811	4.0695
3	3.0198	3.0623	3.0133	3.0016
4	2.9389	2.9154	2.9798	2.9734
5	2.9873	3.0398	3.0428	3.0009
6	3.8636	3.9264	3.9638	3.8862
7	3.0218	3.0575	3.0264	3.0754
8	3.0024	2.9821	2.9835	3.0306
9	3.8600	3.8292	3.8458	3.8481
10	2.9835	3.1412	2.9860	3.0131

TABLE V

AOV OF BASELINE DATA

Source	df	SS	MS	F
Total	39	7.43477		
Subjects (S)	9	7.39750	0.82194	
Recall (R)	1	0.00229	0.00229	1.789
SR	9	0.01155	0.00128	
Int. Task (I)	1	0.00014	0.00014	0.141
SI	9	0.00891	0.00099	
RI	1	0.00117	0.00117	0.796
SRI	9	0.01322	0.00147	

TABLE VI

SUMMARY OF SECONDARY DATA: RT TO PROBE, DECISION ERRORS TO PROBE, AND RECALL PERFORMANCE OF THE DIGITS

	IT-Recall	It-No Recall	No IT-Recall	No IT-No Recall
Mean RT to Probe (Msec)				
Positive	1343	1087	1020	1113
Std. Err.$_M$	121	59	105	120
Negative	1270	1388	1021	985
Std. Err.$_M$	120	100	88	101
Decision Errors to Probe (out of 100 decisions/condition)	12	22	0	0
Recall Performance of the Digits: Mean # correct at each serial position (out of 10 possible)	1 8.6 2 8.6 3 8.1 4 7.3 5 7.8	Not Applicable	1 10.0 2 10.0 3 10.0 4 10.0 5 10.0	Not Applicable

TABLE VII

AOV OF REACTION TIME TO PROBE

Source	df	SS	MS	F
Total	79	8.71488		
Subjects (S)	9	3.55247	0.39472	
Probe (P)	1	0.01253	0.01253	0.285
SP	9	0.39544	0.04394	
Recall (R)	1	0.00822	0.00822	0.146
SR	9	0.50548	0.05616	
Int. Task (I)	1	1.12741	1.12741	8.722**
SI	9	1.16330	0.12926	
PR	1	0.07595	0.07595	3.895
SPR	9	0.17551	0.01950	
PI	1	0.15673	0.15673	3.558
SPI	9	0.39642	0.04405	
RI	1	0.04770	0.04770	0.764
SRI	9	0.55331	0.06148	
PRI	1	0.31563	0.31563	12.378***
SPRI	9	0.22950	0.02550	

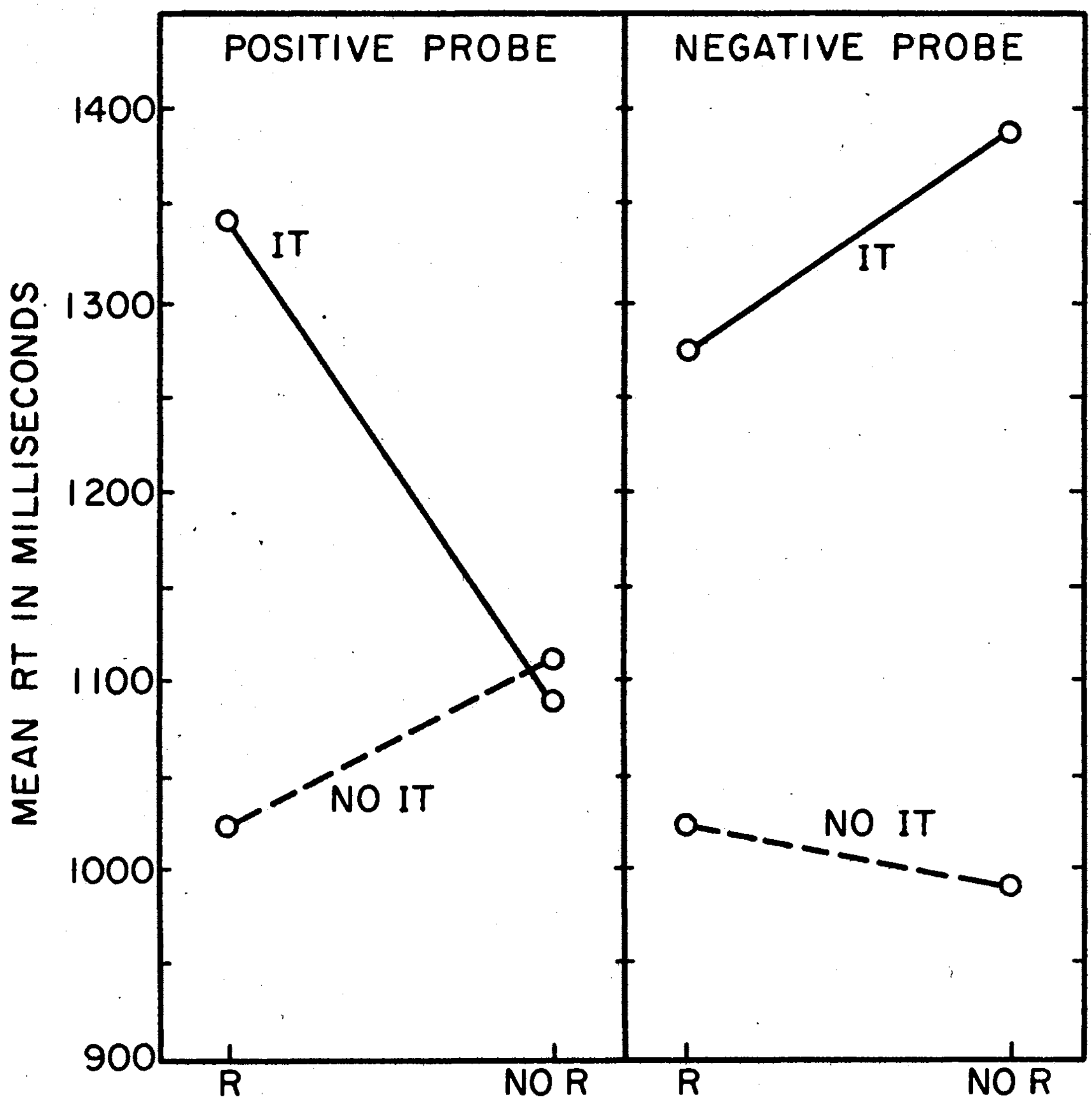

Figure 3. The P by R by IT Interaction: Mean RT to Probe Decision as a Function of Recall and Interpolated Task

CHAPTER IV

DISCUSSION

Set and Processing of Stimuli

The hypotheses stated earlier (see Introduction) were concerned with the effect which previous knowledge of task requirements would have on the processing of common sets of stimuli during their presentation. It was reasoned that different task requirements would cause varying degrees of "preparedness" to receive the stimuli, and that time commitments on opportunity for rehearsal would invoke different strategies for dealing with the material.

As is evident from Figure 1, the changes in pupil size during digit presentation separated into three, overall different levels. According to the Beatty and Kahneman (1966) interpretation of pupil diameter during mental tasks, the index here was sensitive to these different levels of momentary cognitive load on the subjects. Clearly, the greatest effort was exerted on those trials requiring both the interpolated task and recall of the digits. Least effort occurred in the condition requiring only a decision to a probe item.

The (It-No Recall) and (No IT-Recall) conditions showed the same overall degree of dilation. This lack of separation is not in line with the original hypotheses which predicted relatively greater effort in the (IT-No Recall) condition because of the lesser amount of opportunity for encoding of the digits (there was no time available for rehearsal after the last digit in this condition). However, the separation of (IT-Recall) from all the other conditions, and of (IT-No Recall) and (No IT-Recall) from the (No IT-No Recall) condition is in line with the original expectations. In these cases, the common stimuli (five digits) were treated differently during the presentation period.

A notable aspect of the data shown in Figure 1 was the separation during the Pause segment. There was a gradual dilation during the Instruction segment for all conditions. By the first frame of Pause (#15), the curves began to diverge. The (IT-Recall) condition maintained its high level over this four second period. The (IT-No Recall) and (No IT-Recall) conditions showed very similar patterns with a slight decrease over time. A return toward baseline occurred in the (No IT-No Recall) condition over this period. There is a definite correspondence between these levels of preparedness and the amount of cognitive effort exerted during the Digit phase. The instructions apparently were responsible for inducing these levels of preparation and subsequent processing of the digits.

The separation of conditions that occurred during the Pause and Digit periods are intriguing for several reasons. It will be recalled that the design was within-Ss, and that the conditions were arranged randomly such that no condition appeared twice in a row. Rather than adopting an all-out maximal strategy, the Ss were shifting their strategies during presentation of the stimuli to meet the requirements on a given trial; cognitive effort to the common stimuli was simply "enough to get the job done" in each case.

Digit Processing and Memory

To summarize this far, evidence was presented which indicates that knowledge of future task requirements can influence the way in which common stimuli are handled during their presentation. However, the nature of the processing is not known. The pupil responses to the four conditions could reflect different strategies, or different levels of a given strategy. One possibility is that different types of rehearsal occurred. The Kahneman, Onusak, and Wolman (1968) investigation (see Introduction) found that rehearsal mode was effectively distinguished by the pupillary index. The differences in dilation were discussed in terms of the greater cognitive effort that a cumulative and repetitive type of rehearsal necessitates as compared to an intermittent and non-repetitive type of rehearsal. Similarly, different rehearsal modes could have been responsible for the differences in the pupil responses during the Digit Phase.

Although the form of cognitive processing can not be interpreted from the data, it seems that the Ss' treatment of the digits was different when they were required to recall, as compared to when no recall was required. In both the (No IT-Recall) and (No IT-No Recall) tasks, opportunity was available for rehearsal after the last digit. Yet the pupillary response to the former condition was greater during the Pause, and more importantly, the Digit segment. However, accessibility to the digits by the time the probe was presented was equal in both cases, as indicated by the similar reaction times to the probe, and lack of errors in the decisions (see Table VI). The distinction that occurred during the presentation of the digits may have been a result of the nature of the task situations - (No IT-No Recall) did not require a rote knowledge of the digits, whereas (No IT-Recall) demanded memorization. Thus, the Ss seemed to have treated differently the five digits for a Recall task as compared to the treatment for a Recognition task.

The differences in pupil response to the (No IT-Recall) and (No IT-No Recall) conditions offer some implications for recall memory and recognition memory. Recognition and recall have generally been regarded as two aspects of the same memory state. This view is called the threshold theory, and states that the higher level of performance generally found with recognition is due to the lower threshold of associative strength needed for a correct response. However, several authors (Adams, 1967; Kintsch, 1970, e.g.) have presented the view that recognition and recall follow different mechanisms and serve different functions. Adams argues that recall, "the capability for repeating a response" (p. 10), is characterized by a memory trace. Recognition, which requires an identifying response, is based on another kind of trace:

> the stimulus trace of an environmental stimulus lays down a perceptual trace, called S perceptual trace, and subsequent appearance of the stimulus on the retention test activates the perceptual trace and results in identification of the stimulus (p. 286).

Kintsch mentions several variables which affect recognition and recall differentially in memory tasks. For example, low-frequency words are recognized more easily, whereas high-frequency words are recalled better. Also, intentional learning aids recall performance, but recognition is the same under intentional or incidental learning conditions. These differences can not be readily explained by a threshold theory.

On the basis of such findings, Kintsch feels that qualitative differences exist between recognition and recall. In the case of recognition, "the item is sensorily present and it is a simple matter to retrieve its corresponding representation in memory" (p. 337). On the other hand, recall involves a retrieval process, and those variables affecting interitem relationships should influence performance. Kintsch presents evidence that the organization of the material to be learned (high structure of materials, e.g.) has important consequences for recall, but not recognition, performance. Kintsch is thus arguing that "recognition is independent of the subject's intention to learn and hence of particular methods of rehearsal, while appropriate rehearsal greatly increases recall" (p. 338).

The differences in pupil response to the (No IT-Recall) and (No IT-No Recall) conditions support the Adams and Kintsch contention that recognition and recall are separate memory states governed by different variables. The pupillary data suggests that the distinguishing features may well begin with the mechanisms for extraction of information during presentation of the stimuli, and that these mechanisms may first exert their influence in the form of preparatory activity.

CHAPTER V

SUMMARY

The purpose of this study was to investigate the effect of instructional set on the pupillary response during the presentation of common stimuli. Five female and five male Ss were auditorially presented with a series of 40 experimental trials. Instructions at the beginning of each trial informed the S of the task requirements. Task difficulty was varied by requiring different combinations of an interpolated task and/or a recall task. Four seconds after the end of the instructions, five digits were presented at a one second rate. If the interpolated task (reciting the alphabet rapidly) was required, a starting letter was presented one second after the last digit. Five seconds later, a probe digit was presented, and S was to indicate via lever movement whether the digit was (positive probe) or was not (negative probe) one of the preceding five digits. If recall was required, it took place after the probe decision.

Response measurements were (1) filmed records of the pupil during each trial (filming ended with the last digit), (2) reaction times and decision errors to the probe digit, and (3) recall performance.

The main findings were as follows: The level of the pupillary response indicated that knowledge of future task requirements selectively prepared the Ss for differential processing of the digits. Differences in pupil responses indicated that the greatest amount of mental activity occurred during stimuli presentation under the (IT-Recall) condition. Although dilation during the Digit phase of the (IT-No Recall) and (No IT-Recall) conditions were similar, each was greater than that to the (No IT-No Recall) situation. These same relative trends occurred during the Pause interval as well.

Because one of the main distinctions of the tasks was the opportunity for rehearsal of the digits, the results for the Digit phase were interpreted as possibly reflecting differences in rehearsal strategies during stimuli presentation. Also of interest were the differences in dilation to the (No IT-Recall) and (No IT-No Recall) tasks. The former task necessitated memorization of the digits, whereas the latter did not, and the pupil responses to these tasks were interpreted as reflecting the strategy of encoding for recall memory as opposed to recognition memory.

Results of the RTs and decision errors to the probe, and of recall performance of the digits, offered supporting evidence that the tasks did indeed vary in difficulty.

In conclusion, the pupillometric index proved to be a reliable and sensitive measure of both preparation for, and encoding of, common stimuli presented under task situations of varying difficulty.

A SELECTED BIBLIOGRAPHY

Pupillometric and STM Studies

Adams, J. A. Human Memory. New York: McGraw-Hill, 1967.

Adler, F. H. Physiology of the Eye. (3rd Ed.) St. Louis: Mosby, 1959, pp. 167-210.

Beatty, J., & D. Kahneman. Pupillary changes in two memory tasks. Psychonomic Science, 1966, 5, 371-372.

Bradshaw, J. Load and pupillary changes in continuous processing tasks. British Journal of Psychology, 1968, 59, 265-271.

Clark, W. R. A pupillographic study of short-term memory search. Unpublished doctoral dissertation, Oklahoma State University, 1970.

Hess, E. H., & J. M. Polt. Pupil size in relation to mental activity during simple problem-solving. Science, 1964, 143, 1190-1192.

Kahneman, D., & J. Beatty. Pupil diameter and load on memory. Science, 1966, 154, 1583-1585.

Kahneman, D., L. Onuska, & R. Wolman. Effects of grouping on the pupillary response in a short-term memory task. Quarterly Journal of Experimental Psychology, 1968, 20, 309-311.

Kahneman, D., W. S. Peavler, & L. Onuska. Effects of verbalization and incentive on the pupil response to mental activity. Canadian Journal of Psychology, 1968, 22, 186-196.

Kahneman, D., B. Tursky, D. Shapiro, & A. Crider. Pupillary, heart rate, and skin resistance changes during a mental task. Journal of Experimental Psychology, 1969, 79, 164-167.

Kintsch, W. Models for free recall and recognition. In: D. A. Norman (Ed.), Models of Human Memory, New York: Academic Press, 1970, pp. 331-373.

Loewenfeld, I. E. Pupillary movements associated with light and near vision: An experimental review of the literature. In: M. A. Whitcomb (Ed.), Recent Developments in Vision Research. Washington: National Academy of Sciences, 1966, pp. 17-105.

Paivio, A., & H. Simpson. The effect of word abstractness and pleasantness on pupil size during an imagery task. Psychonomic Science, 1966, 5, 55-56.

Peterson, L. R., & M. J. Peterson. Short-term retention of individual verbal items. Journal of Experimental Psychology, 1959, 58, 193-198.

Simpson, H. M., & S. M. Hale. Pupillary changes during a decision-making task. Perceptual & Motor Skills, 1969, 29, 495-498.

Woodmansee, J. J. Methodological problems in pupillographic experiments. Proceedings of the 74th Annual Convention of the American Psychological Association, 1966, 1, 133-134.

Set Literature

Boring, E. G. A History of Experimental Psychology. New York: Appleton-Century-Crofts, 1950.

Dashiell, J. F. A neglected fourth dimension to psychological research. Psychological Review, 1940, 47, 289-305.

Gibson, J. J. A critical review of the concept of set in contemporary experimental psychology. Psychological Bulletin, 1941, 38, 781-817.

Haber, R. N. Nature of the effect of set on perception. Psychological Review, 1966, 73, 335-351.

Hinrichs, J. V. Prestimulus and poststimulus cuing of recall order in the memory span. Psychonomic Science, 1968, 12, 261-262.

Johnson, H. J., & J. J. Campos. The effect of cognitive tasks and verbalization instructions on heart rate and skin conductance. Psychophysiology, 1967, 4, 143-150.

Kay, H., & E. C. Poulton. Anticipation in memorizing. British Journal of Psychology, 1951, 42, 34-41.

McGee, R. K. Response set in relation to personality: an orientation. In: I. A. Berg (Ed.), Response Set in Personality Assessment, Chicago: Aldine, 1967, pp. 1-31.

Mowrer, O. H. Preparatory set (expectancy) - some methods of measurements. Psychological Monographs, 1940, 52, no. 233.

Pollack, I., L. B. Johnson, & P. R. Knaff. Running memory span. Journal of Experimental Psychology, 1959, 57, 137-146.

Uznadze, D. N. *The Psychology of Set.* New York: Consultants Bureau, 1966. Trans. by Basil Haigh.

Watson, R. I. *The Great Psychologists.* Philadelphia: Lippincott, 1963.

APPENDIX A

INSTRUCTIONS TO SUBJECTS

The following instructions were tape recorded and played to all <u>Ss</u>.

This is an experiment dealing with memory. Your eyes will be photographed while you do some simple memory tasks. These tasks you will perform are not an intelligence test of any kind and should not be interpreted as such. Although the task may seem to be a very simple one, our research indicates that it can provide important information concerning the memory processes. Therefore your very close cooperation is absolutely necessary for the success of the experiment. If for any reason during the course of the experiment you feel you can not fully cooperate, please let me know. You will still get full credit for participation.

When you look into the apparatus, you will see a small black cross in the center of an illuminated field. Since we are interested in the exact center of your eye, it is imperative that you maintain a steady gaze at the center of the screen. The small black cross will be your fixation point.

The tasks you will perform deal with digits. In each trial, you will hear a series of five digits. A little bit after the last digit, another digit will be spoken. You are to decide as quickly as possible whether this digit was one of the five digits you heard a few seconds ago. If it is, you indicate so by moving this lever in the YES direction, as indicated by the experimenter. If it is not one of the digits, you will signify so by moving the lever the other way (<u>E</u> indicates), to the NO position. Again, if the digit you hear was one of the five, move the lever to the YES position; if it was not one of them, move it to the NO position. This decision task will occur on every trial. However, there will also be some extra tasks for you to do on some trials. These tasks depend on some very brief instructions which you will hear a few seconds before the first of the five digits begins.

If you hear the word LETTER, this means that right after the fifth digit, you will hear one letter of the alphabet; you are to begin at this letter and immediately proceed through the alphabet as fast as you can, in a low voice; if you come to z, go right to a, etc. This alphabet procedure occurs before the decision task and lasts for a few seconds, until the digit on which you must make a decision comes up. Be sure to recite the alphabet in a low voice so that you will be able to hear the digit. If the instruction you hear before the digits begin is NO LETTER, you will not have this alphabet task to do.

Another brief instruction you may hear before the digits come on is the word RECALL. This means that as soon as you move the lever, indicating your decision, you are to recite verbally to the experimenter the digits you heard. Recite them in any order you wish. If you are somewhat unsure of a number, you may give the digit you thought you heard. After you repeat the digits, move the lever back to the middle position. If the instruction is NO RECALL, then you will not have to recall the digits. Therefore, after you make a decision by moving the lever, the trial ends at this point, and you may move the lever back to the middle position.

You will have a few seconds between trials, and you may remove your face from the apparatus and rest during this time. When you hear the word READY, this means that a new trial will start in a few seconds. You should fixate your eyes on the small black cross again and maintain a steady gaze on it. Also, you should be holding the lever from this time on.

Now let me quickly review the procedures. You will hear the word READY, and are to look at the cross. Shortly thereafter, you will hear the word START, meaning that the trial is now in progress. It is imperative at this time that you are fixating upon the cross. A few seconds later, you will hear the instructions which tell you what task or tasks you will perform. If you hear both the words LETTER and RECALL, you are to perform both tasks. If the instructions say NO LETTER, RECALL, this means that you are only to recall the digits. You will not do the alphabet task. If you hear LETTER, NO RECALL, you are to perform the alphabet task only, and you will not recall. Sometimes you will near NO LETTER, NO RECALL, indicating that neither of these tasks will be performed. In another few seconds you will hear the first digit. After the last digit, a letter will be spoken if the alphabet task is to occur. Then you will hear a digit and you are to make a decision by moving the lever. If you are to recall the digits, do so after you have moved the lever. Then put the lever back in the middle position. In a few seconds the next trial will begin.

If you hear a faint background tone during a trial, disregard it. It is simply for apparatus control.

We will start with a few practice trials to get you acquainted with the tasks. You may ask questions at any time during these trials.

APPENDIX B

MEAN PUPILLOMETRIC VALUES FOR EACH TASK[1]

Segment	Frame #	IT-Recall	IT-No Recall	No IT-Recall	No IT-No Recall
	11	.000	-.020	.012	-.012
INSTRUCTIONS	12	.045	.033	.034	.023
(11-14)	13	.044	.045	.060	.038
	14	.114	.073	.096	.077
	15	.120	.105	.101	.068
	16	.117	.107	.087	.056
	17	.097	.083	.068	.038
PAUSE	18	.116	.088	.069	-.004
(15-22)	19	.114	.087	.091	.001
	20	.110	.039	.046	-.014
	21	.106	.044	.041	.000
	22	.082	.032	.034	-.016
seg. avg.		.10782	.07302	.06715	.01628
	23	.108	.044	.013	-.006
		.020	.026	.026	.023
	24	.134	.080	.034	.012
		.029	.025	.030	.024
	25	.165	.116	.056	.032
		.028	.030	.027	.022
	26	.205	.092	.095	.070
		.025	.037	.026	.026
DIGITS[2]	27	.252	.104	.121	.076
(23-32)		.033	.035	.040	.028
	28	.272	.149	.140	.100
		.035	.036	.036	.034
	29	.317	.189	.157	.142
		.035	.037	.038	.035
	30	.342	.192	.200	.148
		.037	.041	.039	.030
	31	.384	.233	.236	.180
		.046	.041	.039	.032
	32	.415	.268	.279	.186
		.051	.045	.040	.037
seg. avg.		.26306	.14769	.13309	.09422

[1]Values are frame averages over 10 <u>S</u>s, and represent deviations from baseline in millimeters.

[2]Indented values represent standard error of the mean.

VITA

Donald Bruce Headley

Candidate for the Degree of

Master of Science

Thesis: THE PUPILLARY RESPONSE TO INSTRUCTIONAL SET

Major Field: Psychology

Biographical:

Personal Data: Born in Pittsfield, Massachusetts, August, 1946, the son of Mr. and Mrs. Francis B. Headley.

Education: Graduated from Agawam High School, Agawam, Massachusetts, in June, 1964; received the Bachelor of Science degree from the University of Massachusetts in 1968 with a major in Psychology.

Professional Experience: Served as a Graduate Research Assistant, College of Arts and Science, Oklahoma State University, 1968-1970; was a N.S.F. Summer Reserach Assitant, 1969-1970; N.S.F. Fellow, 1970-1971.