70-24,468

GREENBERG, Stanley, 1940-
ELICITED OPTOKINETIC NYSTAGMUS DURING PROBLEM SOLVING AND DAYDREAMING.

The City University of New York, Ph.D., 1970
Psychology, experimental

University Microfilms, A XEROX Company, Ann Arbor, Michigan

ELICITED OPTOKINETIC NYSTAGMUS DURING PROBLEM SOLVING AND DAYDREAMING

by

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A dissertation submitted to the Graduate Faculty in Psychology in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York.

1970

This manuscript has been read and accepted for the Graduate Faculty in Psychology in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

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PREFACE

I am greatly indebted to a large number of people without whose help and cooperation this complex study would not have been possible. Special gratitude must go to my primary sponsors, Dr. Jerome L. Singer and Dr. John S. Antrobus, who were invaluable in every phase of my work. Whether in providing conceptual and technical aid or patient support and encouragement, they fostered a true spirit of scientific endeavor. While modeling and demanding the highest caliber of work they consistently communicated an attitude of respect for me as a peer and colleague, thereby creating an atmosphere of trust and creativity which has aided my growth immensely.

Dr. William Itelson was invaluable in helping to clarify many of the knotty conceptual and technical problems in the planning stages of the study. Also of aid at that time were Dr. R. Gardner and Dr. Pedro Pasik.

The nature of the present study required the design and manufacture of a unique and complex projection apparatus. Dr. Stanley Policht, an engineer with Berkey Photo Laboratories, did just that. He most generously gave of his time and creativity and was invaluable in the execution of this study. Also important in providing technical assistance were Messrs. William and Conrad Isecke whose day to day availability was a godsend.

Dr. Earl Wittenberg of the New York Optometric Center provided immense aid and creative expertise with regard to those aspects of the study relating to visual accommodation. He also helped compose the optometric questionnaire, efficiently performed all the visual examinations on the subjects and provided the specifications for the corrective lenses used in the study.

Especial thanks must be given to Mr. Ralph Renta and Miss Sharon Altman who had the tedious job of scoring the untold reams of eyemovement data. Also to the many students working in Drs. Antrobus' and Singer's laboratory at City College who chipped in so often when aid was needed. And of course to my subjects, who,although they were paid, were most cooperative and patient during the many laborious and sometimes uncomfortable procedures they had to endure.

Finally, I must express my debt to two institutions without whose support this study would not have been possible. First, to the City College Psychology Department and its chairman, Dr. Joseph Barmack, and then to the National Institute of Mental Health which provided me with a generous pre-doctoral research fellowship (1F1 MH-34, 175-01 PS) so as to enable me to carry out my work.

One last note of gratitude--to my wife, for her patience, support and love.

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CHAPTER 1

INTRODUCTION

A. FOCUS OF THE PRESENT STUDY

The importance of the limited span and selective nature of "attention" for the organization of cognitive experience in higher organisms is widely recognized and supported by a large body of empirical evidence. Miller (1956), for example, has collected substantial evidence to show that humans are only capable of adequately attending to about seven "sychological units" of information at one time. More recently, while investigating some parameters of internally produced spontaneous cognitive processes, Antrobus and Singer (1964) have found that attention to internally produced information (continuous free association) "interferes" with performance on a concurrent visual signal detection task. On the basis of some further studies (Antrobus, Singer & Greenberg, 1966; Antrobus, 1968) they suggest that cognitive events resulting from either sensory inputs (perceptions) or memory inputs ("spontaneous" or "detection task-irrelevant" cognitive events) are produced by a common, limited-capacity cognitive system, but that within this framework there exists a reciprocal relationship whereby an increase in the rate of operating on either an internal or external channel leads to a reduction in the rate of operating on the other (albeit not in direct proportion). When the information rate is high enough, we apparently cannot efficiently "pay attention" to both channels at once.

Much effort has been devoted to emphasizing the functional usefulness of these limitations in terms of enabling us to cope with the complexity of our environment, but few empirical studies have been specifically designed to investigate the various task and behavioral parameters involved, and/or the nature of the physiological mechanisms utilized by the organism in effecting the necessary attentional shifts required to accomplish these functional ends. The focus of the present investigation lies in this direction. More specifically, this study examines the consequences for perceptual response when an observer shifts attention from the external environment to ongoing internally produced cognitive processes such as daydreaming and/or more directed thought sequences such as arithmetic problem solving.

B. VISUAL RESPONSES ASSOCIATED WITH THOUGHT

Pioneer work in the neurophysiological substrates of attention has been carried out in an extensive series of experiments by Hernandez-Peon and his colleagues. Hernandez-Peon, Scherrer and Jouvet (1956) demonstrated that when a series of previously attended-to acoustic clicks(as measured by evoked potentials at the dorsal cochlear nucleus) are made "irrelevant" through the introduction of newly attended-to visual or olfactory stimuli, the neural pulses from a cat's ear almost completely disappear. More importantly, in later work with human subjects (Hernandez-Peon & Donoso, 1959), it was demonstrated that attending to such "internal channel" activities as solving arithmetic problems or remembering a particular past experience served to significantly reduce potentials evoked by flashes of light (external channel activities). On the basis of this and other evidence the authors suggest that during inattention to a signal, the transmission of information concerning this signal is "blocked" at the level of the first sensory synapse by means of "reticulofugal descending inhibiting influences."

Within the visual system there may be alternative means of diminishing the perception of external stimuli so as to prevent excessive sensory bombardment of the brain and to maintain selective attention. Evidence accumulating from various other sources seems to suggest that the changes in sub-cortical evoked potentials reported by Hernandez-Peon, while probably originating in and being controlled by a central perceptual selecting unit such as the reticular formation, may effectively result from the activity of more peripheral factors than he and others have suggested. Rather than indicating a transmission blockage at the first sensory synapse, they may represent a decrease in the effective intensity of "irrelevant" stimuli because of alterations at the receptor itself.

Naquet, Regis, Fischer-Williams, & Fernandez-Guardiola (1960), for example, found that if the size of the pupil of unanesthetized cats were fixed by local application of atropin, the evoked potential recorded from placements below the cortex demonstrated a consistent amplitude during distraction. Their findings would suggest that the "peripheral" factor of variation in pupillary diameter seems to be the independent variable responsible for the potential changes. In line with this finding, Kahnemann & Beatty (1966) have found that pupillary diameter increases as a direct function of increasing difficulty of short term memory tasks and, significantly, they note that their subjects report that subjectively the visual field becomes blurred during those stages of the tasks where pupillary diameter is at its maximum. In a subsequent study involving signal detection tasks they further report that subjects engaged in concurrent mental activity were "...to some degree functionally blind when they were engaged in thought." (Kahnemann, Beatty & Pollack, 1967, p. 219). It should be noted that though they did indeed observe a similar time course for failures to detect and for changes of pupil size (with these variations paralleling changes in task loads), they do not explain the detection failures by the pupillary changes.

Some of the findings of recent research in ocular motility would also seem to apply here and possibly may further clarify what apparently is occurring in the visual system during these selective attention situations. High ocular motility such as might be found in rapid environment scanning and visual looking has been associated with avoiding threatening thoughts or stimuli, i.e. in cases of what might be called "autodistraction" (Luborsky, et al, 1963; Antrobus & Singer, 1964). In situations such as these, visual attention is captured by the external environment so that there is apparently a rapid and continuous influx of new visual stimuli. On the other hand, a shift of attention to internal channels such as occurs in daydreaming or deep thought is accompanied by a reduction in ocular motility (Singer & Antrobus, 1965), and is often observed to be accompanied by a "blank stare" and/or blurred awareness of the external field.

What seems to be indicated by both of these lines of evidence is that when attention is being directed to internal channel activities such as daydreaming or problem solving (particularly those involving memory demands), a large portion of potentially competing external stimuli is "kept out" of the visual system by the eyes in some way going out of focus with the "irrelevant" or competing environment.

The "reflexive" process of accommodation with its effective blurring and sharpening of visual stimuli as projected on the retina is a logical possibility for implication in such situations. Vision depends upon the sensitivity of the retina to light. Light rays deflected from objects pass through the cornea and then through the lens, by which they are bent and then brought to a focus on the retina. The shape of the lens can be changed by the action of the ciliary muscles so that clear images of objects at different distances and of moving objects are formed on the retina. This ability is known as "accommodation." There is some evidence accumulated by Pheiffer (1955a, b) suggesting that, in fact, accommodation varies as a function of interest value and difficulty of reading material and television programming. Using retinoscopic techniques he found that when material is read or viewed with interest or there is a search for meaning, the amount of accommodation in use increases, whereas when material is so difficult that meaning is obscured (or if the material is readily comprehended but not interesting) it decreases (i.e. accommodation is maintained beyond the plane of regard). In line with this evidence it would seem plausible to hypothesize that where attention is directed toward internal channel cognitive activity the individual may "gate-out" part or all extraneous visual stimulation by focusing his eyes at visual infinity. One of the major purposes of this study was to attempt to experimentally control and observe the relationship between such accommodative activity and the type and direction of ongoing cognitive activity.

C. THE OPTOKINETIC NYSTAGMUS OCULAR REFLEX

One disturbing and persistent problem in many psychological studies of sensitivity or threshold changes in visual perception has been the necessity for investigators to rely upon subjective responses as the dependent measure of any such changes. In the domain of perception and attention of concern here such a measure would seem to be even more inappropriate given the need for measurements at the same time that subjects are engaged in an ongoing activity of experimental interest. It becomes imperative then to find and utilize an "objective" measure for such study.

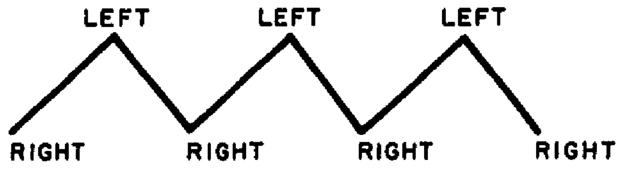
For many years the medical profession has utilized the ocular reflex optokinetic nystagmus (hereafter to be referred to as OKN) as a clinical tool for diagnosing certain types of cortical lesions (see Smith, 1963). OKN refers to the "involuntary," rhythmic, to and fro oscillation (tracking movement) of the eyes elicited in "normal" organisms in response to a series of discriminable moving visual targets. More recently, OKN has been successfully used by several investigators for the objective determination of visual acuity with a close correlation between OKN acuity and the Snellen equivalent being reported (Nicholai, 1954;

Weigelin, et al, 1955; Gunther, et al, 1957; Reinicke & Cogan, 1958; Reinicke, 1961.)

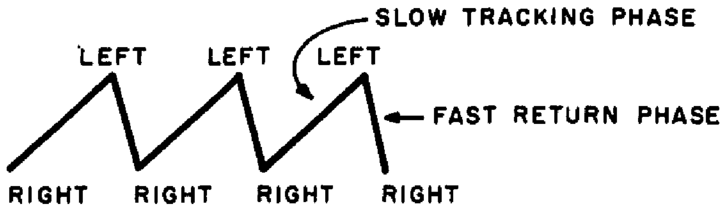
The procedure used to assess visual acuity rests on the fact that OKN is elicited only when a person can spatially discriminate between two moving targets (often stripes), i.e., as long as the separate images can be resolved by his eyes. This attribute of the OKN method has even been used to prove that infants can see at a surprisingly young age (Gorman, et al, 1957; Dayton, et al, 1964), and to detect simulations of total blindness in adults (Ohm, 1952).

Observation of OKN eye movements may be made either visually by direct observation of the oscillating eyes of a subject or through means of electro-oculogram recordings. In order to familiarize the reader with the reading of electro-oculogram recordings, Figure 1 presents four simulated illustrations of different types of eye movements as they would be recorded by D.C. electro-oculograms. Figure 1a illustrates a simulated recording of the eyes tracking some moving visual target(s) (typically stripes) which move in only one horizontal direction, in this case from right to left. Such stimulation elicits what we have referred to as the optokinetic nystagmus reflex (OKN). OKN produces a characteristic "sawtooth" EOG deflection pattern. As can be observed in Figure 1b each nystagmus "beat" is composed of a slow tracking phase and a fast return phase.

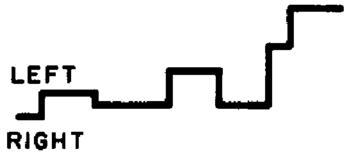
1a. EYES TRACKING A STIMULUS FROM RIGHT TO LEFT AND THEN BACK AGAIN:



1b. ELICITED OPTOKINETIC NYSTAGMUS (OKN):



1c. RANDOM "LOOKING" EYE MOVEMENTS IN LIGHT ILLUMINATION WITH FIXATIONS AT STATIONARY OBJECTS:



1d. RANDOM EYE MOVEMENTS WITHOUT FIXATING ON STATIONARY OBJECTS:

FIGURE 1
SIMULATED EXAMPLES OF HORIZONTAL (D.C.) ELECTRO-OCULOGRAM RECORDINGS OF FOUR TYPES OF EYE MOVEMENTS

What occurs in such a situation is that the eyes are captured by a target as it moves across the visual field with the eyes moving in a tracking fashion following the stimulus. When the target disappears from view (or sometimes before this) the eyes quickly return to the opposite side of the field of vision and are recaptured by another moving target with the slow phase tracking process again being repeated. A comparison of Figure 1b with Figures 1c and 1d illustrates how OKN can be distinguished from other forms of random "looking" eye movements.

Most clinical investigators will take any evidence of "1b" as evidence of the presence of OKN. It is possible, however, to quantify the presence and/or absence of OKN in several ways. The simplest and most direct way is to measure the rate of OKN by making a simple frequency count of the numbers of OKN beats in any given time segment. In addition to mere presence and absence, this method allows for quantification of increments and decrements in the rate of OKN. Another method of scoring has been used by Collins (1962). This method entails a quantification of the amplitude (in degrees of visual angle excursed) of the slow tracking phase eye movements. This amplitude scoring method is somewhat more tedious because of the necessity of first scoring the pen deflections in centimeters and then transforming these metric scores into degrees of eyemovement. Furthermore because of individual differences in corneoretinal potential each subject's eyes must be separately calibrated to a standard so that an individualized conversion factor can be obtained.

These two scoring methods (frequency and amplitude of OKN) may provide differential information. It is conceivable, for example, that under different conditions variations in target tracking in any given time segment may occur (or there may even be stylistic differences among subjects). A subject might in some situation track the targets for shorter horizontal distances and thereby produce a higher rate of elicited OKN for that time segment. In such situations the amplitude measure would not be affected since it is a mesure of total eye movement distances traversed (in terms of degrees of visual angle) summed over the given time regardless of rate. In any event, there has not been sufficient experimentation involving the use of these scoring methods to prefer or exclude one over the other and in the present study both scoring methods are employed. In subsequent discussion, however, the term "elicited OKN" will refer to the presence of elicited OKN at any frequency or amplitude. Distinctions between rate and amplitude will only be made as warranted by subsequent data.

In addition to being a well standardized measure of visual acuity, some remarks in the clinical literature suggest that OKN appears to be especially suited for the purposes of study in this area for another reason. Whereas under "normal" conditions it is claimed to be an involuntary reflex response to moving targets, Schumann notes that it is differentiated "...from the true unconscious reflexes through the cooperation of the attention and a longer latent stage." (1961, p. 646.) Smith (1963) informs us: "The importance of encouragement and exhortation by the examiner (for eliciting OKN) must be stressed." The above considerations suggest the possibility that attention to relevant external visual stimuli is required to elicit OKN and when attention is not so directed (e.g. is directed to internal channels), a reduced optokinetic response may be evidenced. Anecodotal evidence such as this provides additional justification for the necessity of systematically studying the relation between visual functioning and attention as outlined above, and suggests that OKN should be a sensitive indicator of such a relationship. Findings from a study investigating the relationship of OKN to sleeping and waking indicating that OKN drops out after sleep onset and diminishes when subjects were instructed to fix beyond the stripes, lends further support to the latter proposition (Gardner & Weitzman, 1967). On the other hand, it should be noted that in this same study there was a reported failure to obtain OKN disappearance in one or more 30-second time segments during varying waking activities or when a +20 diopter lens was interposed. Citing the latter, the experimenters ruled out refractive change in the eye as an explanation for subjects' lack of OKN response during sleep. However, the gross scoring criteria (e.g., they failed to adequately quantify decrements in OKN) and the lack of a balanced and controlled presentation and grading of the tasks would seem to greatly limit the generality of these waking findings and seemed not to obviate the utility of OKN for the purposes of our study.

To summarize, there seemed to be several key advantages for using elicited OKN in the present study as a way of deepening our understanding of the consequences for perceptual responses of shifts of attention from "external" to "internal" cognitive operations. OKN is an ocular reflex which has been reliably used as a measure of visual acuity. It is "objectively" observable and measurable through electro-oculogram recordings. Furthermore, it allows control of the stimulus parameters of the "external" visual environment by limiting the latter to the moving stripes necessary to elicit it. Finally, the evidence suggests that it is measure sensitive to alterations in attention and arousal.

D. CLASSES OF MENTATION UNDER STUDY

Although it has been hinted at earlier, we must now explicitly confront the complexity of the previously mentioned "internal channel." Within the internal channel two distinct classes of mentation may be delineated: (1) well ordered thought sequences or problem-solving operations such as solving a geometry problem; and (2) daydreaming-thought sequences such as imagining relaxing on a tropical beach with one's favorite girlfriend. The contents, and degree of structure in terms of articulated goal-directedness, frequently differ; in fact, there is often direct competition amongst the two (e.g. as when a daydreaming thought interrupts problem solving). On the other hand, problem solving and daydreaming seem to exhibit some functional similarity. In the case of a model of a limited (information) capacity cognitive system, as the motivation or payoff increases for operating on either problem solving or daydreaming, irrelevant (external or internal) information or stimuli may be suppressed or "gated-out."

The present study will focus on the suppression of "irrelevant" external rather than internal information. The disappearance of the OKN reflex in the presence of continuous moving visual (stripe) stimuli would seem to constitute an appropriate measure of the suppression of irrelevant stimuli in the external mode. OKN should be gated-out both by problem solving and non-directed or daydreaming-type cognitive states.

In the present study each of the two classes of mentation, "ARITHMETIC PROBLEM SOLVING" and "NON-DIRECTED COGNITIVE STATES" were varied over three conditions:

1. <u>ARITHMETIC PROBLEM SOLVING</u>. Three continuous tasks were used. The three tasks varied as to the number of items to be stored and retrieved from short-term memory. (A variant of the tasks used by Kahnemann & Beatty, 1966.)

2. <u>NON-DIRECTED COGNITIVE STATES</u>. It is somewhat more difficult to vary <u>quantitatively</u> the degree of attention devoted to less-directed long term memory operations such as daydreaming. Three conditions were used which required a variation in long term memory processing as delineated by the instructions:

    a. "Mind Blank": active suppression of any persistent daydreaming or other thought. This condition excludes internal channel cognitive processing.

    b. "Cognitive Flexibility": analog of Collins (1962) "reverie" condition. Mind free to wander without specific direction or restriction. This condition has more internal channel cognitive processing than "a," but less than "c."

    c. "Instructed Daydream": active engagement in analog of daydreaming thought. This condition demands more internal channel cognitive processing than either the "Mind Blank" or the "Cognitive Flexibility" conditions.

E. ALERTNESS AND OKN

The fact that OKN will disappear when the eyes are not focusing on the moving visual stimuli suggests that it should be an excellent measure of the suppression or gating-out of visual input by a different class of cognitive activity. There is, however, some experimental evidence that a difficult non-perceptual cognitive task can increase rather than decrease certain ocular nystagmus. It is a well-known fact that rotating a subject on a platform surrounded by stationary visual stripes will elicit the same nystagmoid movements as are elicited when a moving train of stripes are paraded past a stationary subject. If the rotation takes place under complete darkness similar nystagmoid movements are observed even though the subject cannot see the stripes. This form of eye movement is called vestibular nystagmus in that it is elicited by the movement detectors of the vestibular canal system. If the rotation in darkness is sustained for a sufficient period the vestibular nystagmus movement eventually disappears (habituates). Collins (1962) found that vestibular nystagmus could be sustained for a considerable period of time if the subjects engaged in active cognitive tasks such as mental arithmetic. The rate of habituation was actually increased if the subjects were asked to relax or engage in reverie. Similarly in the Gardner & Weitzman (1967) study cited above they argue for their obtained variability in OKN to be a function of the sleeping-waking continuum. The present study attempted to evaluate such notions by incorporating differences in alertness in the experimental design.

F. GATING AND ALERTNESS MODELS AND STATEMENT OF HYPOTHESES.

Both the "GATING and ALERTNESS" models are concerned with the single non-perceptual, cognitive variable which has been referred to as "internal channel cognitive processing." By this we mean those various cognitive operations such as storing and retrieving items from short or long term memory and making various transformations on these items. The present study therefore compares two conflicting models of the relationship between internal cognitive processing and OKN. The "GATING" model says that as the amount of internal channel cognitive processing increases, elicited OKN should decrease. The Gating model therefore predicts:

1. HYPOTHESIS ONE: That elicited OKN will decrease as a function of the number of items to be stored and retrieved from short term memory in the Arithmetic Problem Solving tasks.

2. HYPOTHESIS TWO: That in the Non-Directed Cognitive State Condition, elicited OKN will be lowest in the "Instructed Daydreaming" condition, intermediate in the "Cognitive Flexibility" condition, and highest in the "Mind Blank" condition.

The "ALERTNESS" model says that as task difficulty and

and effort expended increases, then elicited OKN increases. The Alertness model therefore predicts:

3. HYPOTHESIS THREE: That elicited OKN will increase as a function of the number of items to be stored and retrieved from short term memory in the Arithmetic Problem Solving tasks.

4. HYPOTHESIS FOUR: That in the Non-Directed Cognitive States conditions OKN will be elicited in the following order: "Mind Blank" ≥ "Instructed Daydreaming > " Cognitive Flexibility.

If either Hypothesis One or Two are supported we may further inquire concerning the mechanism by which this gating process is accomplished. To test the notion that the visual mechanism employed to suppress or gate-out the irrelevant OKN stripe stimulation is focusing at visual infinity("Accommodative Alteration"), subjects were tested with both normal and corrected lenses within each condition. The corrected lens condition caused the eyes to be focused at the plane of regard thereby *preventing* focusing at visual infinity.

The notion that the suppression of the irrelevant OKN stripe stimulation is focusing at visual infinity predicts:

5. HYPOTHESIS FIVE: No difference in elicited OKN among the three conditions in both classes of instructed mentation when subjects were wearing the

"corrected"lenses. Alternatively, no difference between the two lens ("uncorrected" vs. "corrected") conditions would tend to rule out refractive change in the eye as a controlling factor, i.e. if the same patterns of elicited OKN are found with as without the corrected lenses it would seem safe to assume that focusing at visual infinity cannot be implicated in explaining the observed differences.

An additional test of the gating model and the accommodative alteration mechanism was made. Ratings on a 1-5 scale of the direction of subjects' attention with regard to an "inner" ("5") vs. "outer" ("1") directed continuum were taken after each trial to provide an additional measure of the extent to which elicited OKN varies as a function of the direction of attention in terms of subjective report regardless of instructions. The gating model predicts:

6. HYPOTHESIS SIX: That ratings of inner directed attention will correlate negatively with elicited OKN under the uncorrected lens conditions, but that no correlation will obtain in the corrected lens condition if indeed accommodative alteration proves to be implicated. More concretely, if subjects manage to gate-out processing of external stimuli by focusing at infinity (accommodative alteration) they will manifest lower OKN when attending to inner stimuli during use of uncorrected

lenses. When focusing at infinity is precluded by wearing of corrected lenses, the report of internal-directed attention will not be correlated with reduced OKN.

CHAPTER II

METHOD

A. SUBJECTS

Twelve C.C.N.Y. undergraduates (7 females, 5 males) were paid $2.00 per hour for their participation in the experiment. Three criteria were used in subject selection: (a) no history of visual impairment or cortical involvement. All prospective subjects were carefully screened and tested by an optometrist to assure that this requirement was met. (See Appendix for copy of information questionnaire used.) (b) no previous experience in nystagmus experimentation; and (c) ability to immediately recall a string of six verbally presented digits.

B. DESIGN

The experiment consisted of two 2 x 3 Randomized Blocks analysis of variance designs (one each for each class of instructed mentation: ARITHMETIC PROBLEM SOLVING AND NON-DIRECTED COGNITIVE STATES.) This design allows ready analysis of variations in instructed mentation as well as the effect of the two lens conditions. In a study where the same subject undergoes each treatment condition, it is necessary to assure that no significant carryover effects of preceding conditions exist. To control for such residual effects both within and between the two classes of instructed cognitive activity as well as both lens conditions, the design was further elaborated into two 12 x 12 balanced Latin squares in which each treatment follows every other treatment the same number of times (After Williams (1949), in Cochran & Cox (1957)). Use of the balanced Latin square design provides for an estimate of both the direct treatment effects and the residual effects of the immediately preceding treatment. Subjects were therefore randomly assigned to two balanced sequences of 12 trials each, effectively then going through each of the six combinations in each 2 x 3 randomized blocks design twice.

C. INDEPENDENT VARIABLE TASKS

1. ARITHMETIC PROBLEM SOLVING:

(a) Simple counting: n, n+1, n+2... (minimum short term memory load):

> In this trial you asked to engage in some continuous counting. Immediately after the initial click has been sounded you will be presented with a whole number. Starting with this number you are asked to count continuously for the duration of the trial. For example, if you are given the number "25" you would say out loud, "25, 26, 27, 28," etc. No matter how boring this may become, we ask you to please cooperate and continue the out loud counting for the duration of the trial as bounded by the two clicks. Please remeber to keep your eyes open.

(b) Transformation of digits: n+1...n+10 (medium memory load):

In this trial you are asked to engage in an arithmetic task of some difficulty. To clarify the exact procedure you are to follow, we will begin with an example. At the sound of the click you will be presented with a number. Let us assume that the number is 10. You are to add 1 to this number and report "11." Then add 2 to this new number and report 13. Next, add 3 to 13, report 16; add 4 to 16, report 20; add 5, report 25; add 6, report 31; add 7, report 38; add 8, report 46; add 9, report 55; add 10, report 65. Now listen closely, when you reach this point of adding 10, you are to start the addition series all over again by adding one to the last sum, in this case, 65. This will give you 66; then add 2 to 66, report 68; add 3, report 71, and so on. You are to continue this procedure until the final click is sounded, with each time you have reached 10 returning to 1, and beginning the addition series once again. Please work carefully. Should you make an error please return to the last number of which you are sure--if necessary to the original starting number. Again, no matter how boring or difficult it may become for you to continue, we ask you to please do so until the final click is sounded. Please remember to keep your eyes open.

(c) Transformation of digits: n+1, -1...n+10, -1 (high memory load):

In this trial you are asked to engage in a very difficult arithmetic task. To clarify the exact procedure you will follow, we will begin with an example. At the sound of the click you will be presented with a number. Let us assume that the number is 10. You are to add 1 to this number and report out loud "11." From 11 you subtract 1 and report "10." Then you are to add 2 to 10 and report "12." Now subtract 1 from 12 and report "11." Then add 3 to 11 and report "14." Subtract 1 from 14 and report "13." Then add 4 and report "17." Subtract 1, report 16; add 5, report 21; subtract 20; add 6, report 26. Continue this procedure of subtracting 1 and adding the number of the next magnitude until you get to the point where you are adding 10. Now listen closely. When you reach this point of adding 10, you are to start the addition/subtraction series all over again by adding 1 to the last sum, in this case, 56. Thus, you would say aloud "55, 56; 55, 57; 56, 59; 58, 62; 61, 66..." and so on. Please work carefully. Should you make an error please return to the last number of which you are sure--if necessary to the original starting number. Again, no matter how boring or difficult it may become for you to continue we ask you to please do so until the final click is sounded. Please remember to keep your eyes open and your mouth on the bite plate.

2. <u>NON-DIRECTED COGNITIVE STATES</u>:

(a) Mind Blank (Active suppression):

In this trial, after you hear the click, you are asked to keep your mind blank. Many people find the experience of sitting in the booth to be a rather boring and unstimulating one and find themselves thinking about this unpleasant fact, others find their minds wandering to other things of concern to them. After you hear the click we ask you to consciously keep your mind free of any thought or images whatsoever for the duration of the trial. We know that this may be difficult, but again you are asked to please cooperate and keep your mind blank until the final click is sounded. Please begin after you hear the click and remember to keep your eyes open.

(b) Cognitive Flexibility:

In this trial you will be given no particular instructions as to what, if any, kind of mental activity you may wish to engage in. From after you hear the initial click, until after the final click is sounded, you are permitted to do as you wish. Of course, you are still asked to remain in the same bodily position, to keep your eyes open, and to keep your mouth on the bite-piece. And, as usual, you will be asked to rate the trial after it is completed. Please begin after the initial click is sounded.

(c) Instructed daydream:

> In this trial you will be asked to engage in some unstructured thinking. We ask you to refrain from carrying out the instructions until the click is sounded. Many of us at one time or another find our minds drifting in the direction of future plans, hopes, events, experiences with people, etc. After you hear the initial click you are asked to direct your attention in this direction, with the specific content of the thoughts left open to your discretion. For example, you may wish to review your plans for the upcoming weekend or how you will spend tonight or even what you intend to do next year. The specific content of your thoughts will remain private. All that is asked of you is that you continue to direct your attention in this direction until the final click is sounded. Please begin at the sound of the click."

D. APPARATUS AND SCORING TECHNIQUES

The OKN stimulating equipment, situated in a light proof, sound attenuated booth, consisted of a rear-screen projection system capable of projecting moving stripes upon a 4' x 4' flexible lenscreen which was mounted 17-18 inches from the head of the seated subject. This system, which was designed to maximally encompass the subject's visual field so as to prevent him from focusing on a static external environment, allows variability of the width, speed and light intensity of the stripes. The subject's distance from the screen was fixed through the employment of a bite plate apparatus attached to the experimental chair. (The latter was a used barber chair which remained stationary at a fixed distance from the screen.)

In order to facilitate detection of subtle changes in elicited OKN, the width, and intensity of the stripes must be at a minimum so as to provide minimal retinal stimulation. A pilot study was conducted to empirically determine that width, speed and intensity of stripe which would yield a reliable probability of eliciting OKN of approximately .70 under "normal" viewing conditions (i.e. subject attending to stripe stimuli under "simple counting" task conditions wearing the uncorrected lenses). Establishing the probability well below 1.00 in this manner, increased the desired sensitivity of the tasks to small decrements as well as increments in OKN, yet did not yield so small a stripe that no OKN at all might be elicited for some subjects. In the final study one-eighth inch light (20 ft. - L) stripes passed over the darkened 4' x 4' screen at an angular velocity of 15.7 ± 2 degrees/sec. in a right to left horizontal direction.

Three sets of eyeglasses were used. One pair (taped for easy identification in the dark) consisted of two uncorrected (plain glass) lenses, whereas the other two contained lenses so corrected as to prevent the eyes from focusing beyond the moving stripes at visual infinity. The latter two were ground slightly differently (+2.25, 3.00d.) under suggestion of the optometrist to allow for the slight observed differences between subjects' eyes (this in spite of all being certified to be in the normal range of vision). Direct current bipolar horizontal and vertical, as well as

AC horizontal monopolar electro-oculograms (EOG's) were recorded with standard electrode placements. For the horizontal recordings, two electrodes were placed as close as possible to the outer canthus of each eye, while the verticals required placing one directly above the supraorbital margin and the other below the infraorbital rdige. The record from the latter enabled us to monitor for blinks and/or closing of the eyes. Ground electrodes were placed on the earlobes (for monopolars) and in the middle of the forehead (indifferent ground). For all placements Beckman (brand) electrodes were used. The recording was done on an eight-channel Offner, Type R Dynograph. Resistance checks were made on all pairs of electrodes.

As explained in the introduction, OKN produces a characteristic "sawtooth" EOG deflection pattern and "blind" analysis of the results was made on these recordings by two trained college undergraduate judges (reliability coefficient = 0.98). The recordings were analyzed for two types of data in each of the 24 ninety-second trials; frequency and amplitude (degrees of slow phase eyemovement) of OKN beats. The amplitude output was scored by a modification of the method used by Collins (1962) where the measurements made represent the vertical distances from the peak of each nystagmic beat to the slow-phase baseline of that beat, summed for the 90-second trial length period. In cases of ambiguity, the judgment as to when a deflection was to be scored as a separate nystagmus beat was made by requiring that both fast and slow phase components of the deflection must measure to an excursion criterion of at least 0.5 centimeter. In addition the fast component must be manifest (i.e. sweep in less than 0.25 second). All metric scores were transformed into degrees of eyemovement by means of the conversion factors. (For example of actual recordings, see Appendix A.)

E. PROCEDURE

After electrodes were applied and S was comfortably seated in the experimental chair, taped introductory instructions outlining the nature of the experimental and instructions for post-trial rating of ability to carry out instructions and attention direction were presented through the earphones:

> In this experiment you will be presented with a series of instructions requesting you to engage in various types of mental activity. On the screen in front of you will be projected a series of moving black and white stripes. Before going into any further details I want to emphasize that I am not, I repeat I am not, interested in measuring your intellectual ability nor am I interested in assessing your personality. This is a study concerned with what happens physiologically when people engage in different types of mental activity. What becomes important, then, is that you cooperate in carrying out the instructions as best as you can. Your faithfulness in conforming to what is requested of you will enable us to be sure that the Physiological measures that we obtain truly represent what happens during the kind of mental activity tapped by any particular set of instructions.
>
> The experiment will consist of a series of separate trials. Prior to the onset of any particular

trial you will receive a set of detailed instructions asking you to engage in a particular type of mental activity and instructions as to what glasses to put on. The beginning and the conclusion of each trial will be signaled by the presentation of a click which sounds like this: "CLICK." Because it is important that each subject engage in the same type of mental activity for each set of instructions you are asked to please cooperate in carrying out the instructions as requested of you for the duration of the trial as bounded by the clicks. It is also important to remember that you should not attempt to begin to carry out the instructions until the initial click is sounded. Should you have any questions during the instructions you are asked to please hold them until the conclusion of the trial--in other words, please carry out the instructions as you understand them to the best of your ability. Since some of the trials will be repeated more than once, you may be familiar with the particular set of instructions for that trial. Although the repetition may be somewhat boring, we beg your indulgence in this regard.

In order to properly calibrate our recording instruments for each trial, after you are given the instructions for that trial but before hearing the click, you will hear the word: "calibrate." When you hear this word just be sure that your eyes are open, your mouth is on the bitepiece, and you are looking straight ahead at the cross which will be projected on the screen.

At the conclusion of each trial you will be asked to make two ratings, each on a one to five scale: first, you will be asked to rate the degree to which you were able to carry out the instructions, and second, <u>where</u> your attention was concentrated or directed with respect to a distinction in direction between your inner world or to the external world. In general, attention to one's inner world may be understood as concentration on what is going on in that which is commonly called the "mind."

Let me attempt to explain further. For example with regard to the first dimension, the degree to which you were able to carry out the instructions: a rating of "one" would signify that you were unable to carry out the instructions at all, while a rating of "five" would indicate that you were completely able to carry out the instructions. With regard to

> this rating please remember that it does not refer to whether you liked or disliked what you were asked to do (and don't begin to fret, we will ask you to do nothing which might be embarrassing), nor does it refer to whether you felt you carried out the instructions at a level of accuracy lower than what you think we might expect if you understood the instructions and proceeded to carry them out for the duration of the trial, then you would give a rating of "five."
>
> Now for the second rating, the direction of your attention with regard to an inner vs. outer directed continuum. This will only be a relatively gross approximation on your part with a rating of "1" indicating that your attention was completely directed towards the external environment, while a rating of "5" would indicate that you were completely or almost completely oblivious of the external environment and that your attention could be said to have been directed towards events taking place in your "mind's eye." In deciding, you are asked to generalize over the whole trial: if you were only sometimes aware of the external environment but the overwhelming majority of the time were not, then you would still rate that trial with a "5." On the other hand, if all of the time your attention was directed to the world around you--the external world of the booth environment--then you would rate it a "one." Of course with both of these ratings you don't have to use the extremes--you can use any number along the continuum from one to five.
>
> Finally, although it may require some discipline on your part, during each trial you are asked not to remove your mouth from the bitepiece nor to close your eyes other than when you must blink. Also, please do not engage in any unnecessary body movements, and in no case bring your hands within your line of vision.
>
> This concludes our introductory instructions. In order that we may be sure that you understand the rating procedures, please describe the two sets of ratings that you will be asked to make and also feel free to ask any questions that you may have up to this point.

Stationary stripes were on during this presentation so as to allow subjects to dark adapt to the darkened booth. The introductory period was designed to last approximately fifteen minutes to allow for adequate dark adaptation and general habituation to the experimental booth situation.

Each subject was then tested on all experimental conditions in four blocks of six ninety-second trials. A rest period of ten minutes was given between each block of trials. Prior to the third block of trials 50° eye movement calibrations were obtained from each subject and used as conversion factors for the later data measurements.

As noted in the introductory instructions, after each trial subjects were asked to rate the trial on two dimensions. The purpose of these ratings was to obtain an independent check on the validity of the instructions--i.e., the extent to which the cognitive activity and attention direction were indeed engaged in, and to serve as an additional motivating device to encourage subjects to carry out the instructions as presented. Furthermore, as noted earlier the second rating was designed to provide an additional measure of the degree to which elicited OKN varies as a function of attention direction regardless of instructed mentation.

CHAPTER III

RESULTS

A. OVERALL BALANCED LATIN SQUARE ANALYSIS

Overall analysis (across all conditions) by means of the balanced Latin Square analysis of variance (See Table 1) yielded a significant F for the adjusted direct (treatment) effects ($p. < .005$), whereas no significant adjusted residual (carryover) effects were obtained. The latter result indicated that within the limits of the test utilized, the effect of having all subjects go through each condition did not significantly bias the obtained treatment effects, and enabled us with confidence to analyze separately the results for the two classes of instructed mentation.*

B. ARITHMETIC PROBLEM SOLVING

For this class of instructed mentation, the model suggesting that "irrelevant" external stimulation is "gated-out" in order to allow "internal" problem solving predicted that elicited OKN would decrease as a function of an

---

*All elicited OKN measurements reported hereafter represent an arithmetic average of the two replications per subject per condition. Nine (of 144) scattered trials represent only one replication. In these cases the second replication was not usable because the subjects reported themselves not being able to adequately carry out the instructions.

TABLE 1

SUMMARY OF (2) 12 x 12 BALANCED LATIN SQUARES
ANOVA ACROSS ALL TRIALS
AND SUBJECTS

Source		MS	F
Adjusted Direct Effects	11	6789.68	4.6*
Adjusted Residual Effects	11	1631.60	N.S.
Error	220	1653.57	

* p.$<$.005

increase in the number of items to be stored and retrieved from short-term memory. The "mental effort/alertness" model alternatively predicted an <u>increase</u> in elicited OKN as a function of an increase in task difficulty and effort expended.

The evidence for the Arithmetic Problem Solving conditions seems to fit well the predictions of the "mental effort/alertness" model. Table 3 shows that there is a significant positive linear effect. As we can see by inspection in Figure 2, the direction of the trend was such that elicited OKN increased as a function of an increase in task difficulty and effort expended.

Further support for the arousal notion is provided by the finding that the overall level of elicited OKN was greater for the combined "Arithmetic Problem Solving" conditions than the combined "Non-Directed Cognitive States" conditions (See Figures 2 and 3, Table 2).

C. NON-DIRECTED COGNITIVE STATES

The model suggesting the "gating-out" of "irrelevant" stimulation and information during daydreaming-type mentation predicted that elicited OKN would be significantly lower in the "Instructed Daydream" condition than in the "Mind Blank" condition with "Cognitive Flexibility" being intermediate. The "mental effort/alertness" model alternatively predicted the following direction as a function of task difficulty and mental effort expended: "Mind Blank"$\geq$ "Instructed Daydream"$>$

TABLE 2

MEAN FREQUENCY AND AMPLITUDE ELICITED OKN FOR EACH OF THE THREE ARITHMETIC PROBLEM SOLVING AND THREE NON-DIRECTED COGNITIVE STATES CONDITIONS*

LENSES	ARITHMETIC PROBLEM SOLVING			NON-DIRECTED COGNITIVE STATES		
	Low	Medium	High	Mind Blank	Cogn. Flex.	Inst. Day.
Uncorrected:						
Frequency (Beats)	81	94	101	88	70	53
Amplitude (Degrees)	1616	1864	2011	1634	1331	1074
Corrected:						
Frequency (Beats)	92	113	116	106	100	86
Amplitude (Degrees)	1904	2405	2444	2091	2068	1573

*See Appendix C for table of raw data.

TABLE 3

SUMMARY OF 2 x 3 RANDOMIZED BLOCKS ANOVA OF ELICITED OKN IN "ARITHMETIC PROBLEM SOLVING" CLASS OF INSTRUCTED COGNITIVE ACTIVITY

Source	SS		df	MS		F	
	Amplitude	Frequency		Amplitude	Frequency	Ampl.	Freq.
Lenses	3,187,812.51	3,930.86	1	3,187,812.51	3,930.86	5.69*	3.85*
Arithmetic:							
Linear	2,620.338.02	5,525.52	1	2,620,338.02	5,525.52	4.67*	5.41*
Non-Linear other	315,334.18	580.00	1	315,334.18	580.00	n.s.	n.s.
Lenses x Arithmetic							
Linear	21,821.46	12.10	1	21,821.46	12.10	n.s.	n.s.
Non-Linear other	170,857.77	170.63	1	170,857.77	170.63	n.s.	n.s.
Blocks (Subjects)	77,728,837.41	92,836.94	11	7,066,221.58	8,530.63		
Error	30,819,347.10	56,143.89	55	560,353.58	1,020.80		
Total	114,864,348.45	160,199.94	71				

*p. $<$ .025

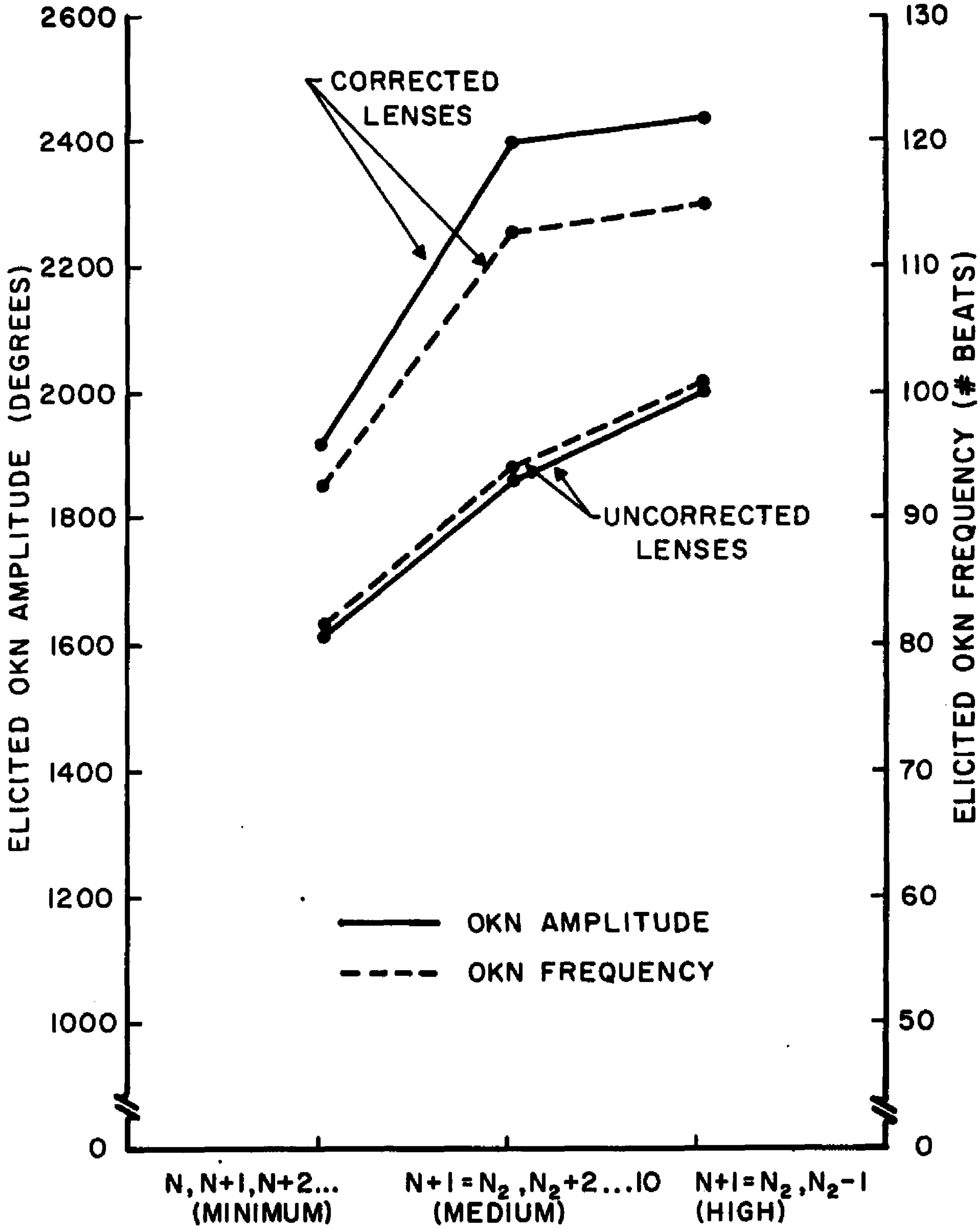


FIGURE 2

MEAN AMPLITUDE AND FREQUENCY OF ELICITED OKN FOR EACH OF THE THREE INSTRUCTED "PROBLEM SOLVING" AND TWO "LENS" CONDITIONS

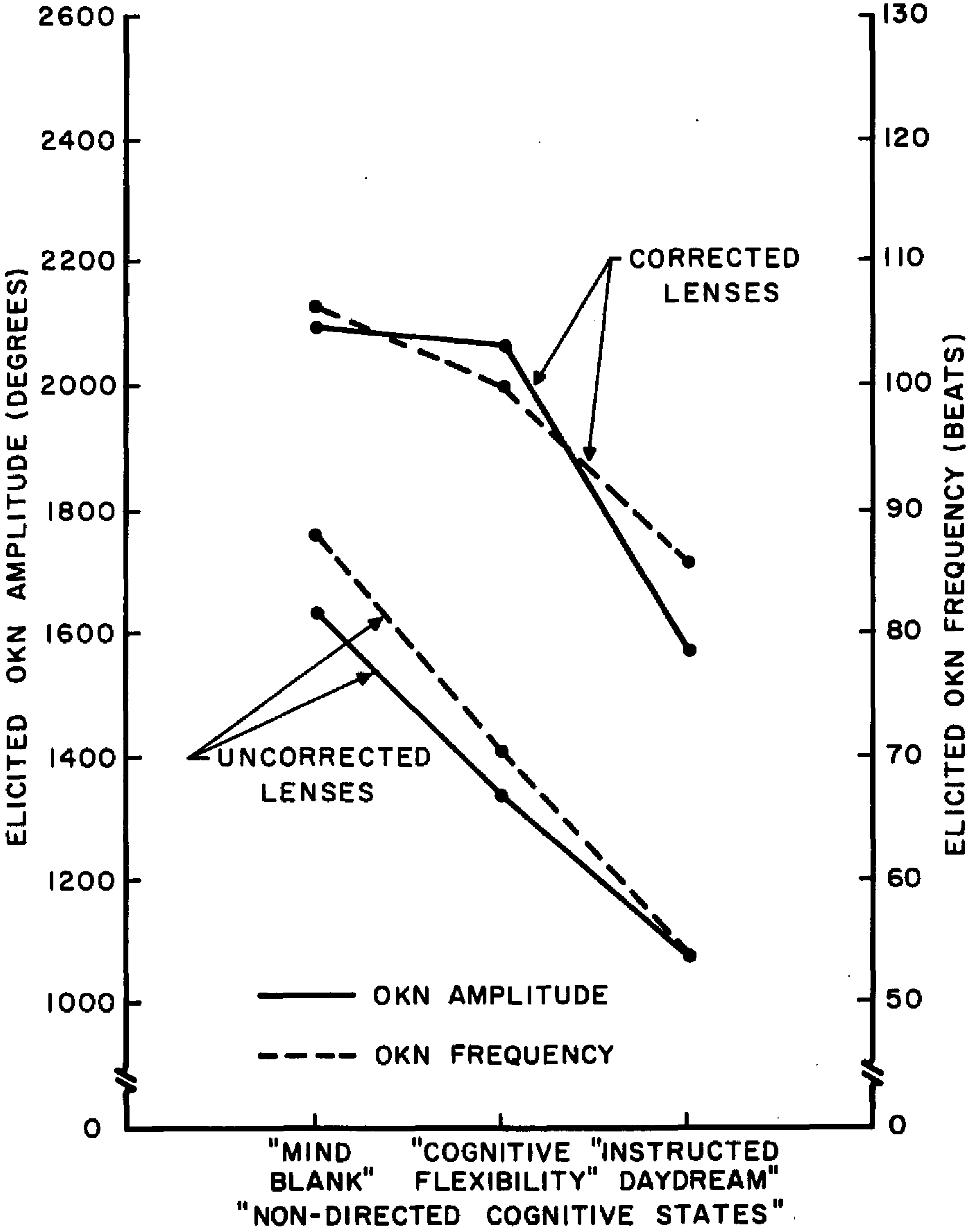


FIGURE 3
MEAN AMPLITUDE AND FREQUENCY OF ELICITED OKN FOR EACH OF THE THREE INSTRUCTED "NON-DIRECTED COGNITIVE STATES" AND TWO "LENS" CONDITIONS

"Cognitive Flexibility."

The frequency and amplitude of elicited OKN differed significantly for the three "Non-Directed Cognitive States" (averaged over lenses) conditions ($p. < .05$, See Table 4). The direction of the differences among the three conditions are tested by Sheffe's comparisons yielded a significant difference ($p. < .05$) between the "mind blank" and the "instructed daydream" conditions with lenses uncorrected, while paired comparisons between each of these conditions with "cognitive flexibility" did not reach significance. In spite of the latter insignificant result, inspection of the direction of the means as plotted in Figure 3 along with the significant difference obtained between the "Instructed Daydream" and "Mind Blank" conditions fits well with the predictions of the "gating-out" model.

(For examples of actual recordings for all six cognitive task conditions see Appendix A.)

D. LENSES

All subjects underwent all conditions with both normal and corrected lenses (the latter involuntarily preventing focusing of the eyes beyond the plane of regard at "visual infinity") in order to test the fifth hypothesis that focussing at visual infinity is the primary mechanism in enforcing a "gating-out" of the "irrelevant" OKN stripe stimulation.

TABLE 4

SUMMARY OF 2 x 3 RANDOMIZED BLOCKS ANOVA OF ELICITED OKN IN "NON-DIRECTED COGNITIVE STATES" CLASS OF INSTRUCTED COGNITIVE ACTIVITY

Source	SS		df	MS		F	
	Amplitude	Frequency		Amplitude	Frequency	Ampl.	Freq.
Lenses	5,727,463.11	12,987.35	1	5,727,463.11	12,987.35	10.5*	9.75*
Non-Directed Cognitive St.	3,669,516.78	9,130.36	2	1,834,758.39	4,565.18	3.36**	3.43**
Lenses x Non-Dir. Cogn. St.	276,263.21	834.36	2	138,131.61	417.18	n.s.	n.s.
Blocks (Subjects)	58,344,035.55	61,214.49	11	5,304,003.23	5,564.95		
Error	30,009,433.30	73,282.10	55	545,026.06	1,332.40		
Total	98,026,711.95	157,448.66	71				

*p. $<$.005
**p. $<$.05

This notion predicted no difference in elicited OKN between the three conditions in both classes of instructed mentation when subjects were wearing the "corrected" lenses. Alternatively, no difference in trend between the two "lens" conditions would tend to rule out refractive change in the eye (accommodative alteration) as a controlling factor, i.e., if the same patterns of elicited OKN are found with or without the corrected lenses it would seem safe to assume that focusing at visual infinity cannot be implicated in the explaining the observed differences.

In the "Non-Directed Cognitive States" class of instructed mentation no statistical trend analysis was possible, but by inspection no differences in trend between the two lens conditions seemed evident (See Figure 3). In the "Arithmetic Problem Solving" class where a statistical trend analysis was possible due to the nature of the tasks, the lack of significance for the linear component of the Lens x Arithmetic interaction sum of squares indicated that there was no significant difference between the (linear component of the) trends of the means of the two lens conditions (See Table 3).

The above findings suggest that in neither the "Arithmetic Problem Solving" nor the "Non-Directed Cognitive States" classes of instructed cognitive activity can any observed differences in elicited OKN be explained by accommodative alteration (focusing at visual infinity). The same trend of differences in elicited OKN was evidenced in both classes whether subjects were wearing the corrected or normal lenses.

In spite of the absence of differences in trend it must be noted that across both classes of cognitive activity significantly more OKN was elicited when the subjects' eyes were prevented from being focused beyond the stripes by the corrected lenses. The differences between the two lens conditions were highly significant (See Tables 3 and 4, Figures 2 and 3). This finding supports the notion that elicited OKN in sensitive to changes in visual focus, i.e. that elicited OKN does indeed vary as a function of accommodative alteration, but does not contribute towards an understanding of whether accommodative alteration is produced by variations in instructed cognitive activity or is a mechanism needed to "gate-out" irrelevant visual stimulation. Some further light may be shed on the latter question when findings with regard to attention rating correlations and sex differences in trends are discussed below.

E. SUBJECTS' ATTENTION RATINGS

Ratings on a 1-5 scale of the direction of subjects' attention with regard to an "inner" (5) vs. "outer" (1) directed continuum were taken after each trial to provide an additional (gross) measure of the degree to which elicited OKN varied as a function of attention direction in terms of subjective report regardless of instructed mentation. It was predicted that such ratings would negatively correlate with elicited OKN across the uncorrected lens conditions, whereas no significant correlation was expected in the corrected lens conditions if indeed accommodative alteration proved to be implicated.

In order to facilitate analysis correlations were computed separately for each class of mentation (See Table 5). No significant correlations were obtained for the "Arithmetic Problem Solving" conditions where we saw that elicited OKN increased as a function of an increase in task difficulty and effort expended.

For the "Non-Directed Cognitive States" class of instructed mentation where previous results supported the "gating-out" hypothesis, the subjective attention direction ratings correlate in the predicted direction for the uncorrected lens condition lending further support to the above hypothesis. In the corrected lens condition, although the correlations are also significant, there are significant ($p < .05$) reductions in the magnitude of the correlations. The direction of this finding gives some pause in generalizing too far the inference made in the previous section to the effect that accommodative alteration in no way accounts for any of the observed differences in elicited OKN. On the basis of the finding of no difference in the trend of elicited OKN between the two lens conditions for each of the three instructions in this class of

TABLE 5

PEARSON'S PRODUCT MOMENT "r" CORRELATIONS BETWEEN SUBJECTS' ATTENTION-DIRECTION RATINGS AND ELICITED OKN FOR EACH CLASS OF INSTRUCTED MENTATION

	Frequency	Amplitude
ARITHMETIC PROBLEM SOLVING		
Uncorrected Lenses	- .12	- .14
Corrected Lenses	- .19	- .11
NON-DIRECTED COGNITIVE STATES		
Uncorrected Lenses	- .64*	- .60*
Corrected Lenses	- .28**	- .31*

[1] (1 = outer; 5 = inner oriented)

Critical Values

*p. < .01 r = .303

**p. < .05 r = .232

70 dfs, 2-tailed

mentation what might be the explanation of the sizeable reduction in correlation between the two lens conditions? Perhaps the sex differences uncovered in the post hoc analysis below may provide some clues.

F. MISCELLANEOUS FINDINGS (POST HOC ANALYSIS)

It appeared worthwhile, given the unique demand aspects of the moving stripes to investigate possible sex differences in the observed effects considering the evidence accumulated by Witkin and his associates (1962) with regard to sex differences in field dependence/independence. The results of such an analysis displayed graphically in Figures 4 and 5 do indeed seem to be instructive.

In the uncorrected lens conditions we find substantially greater elicited OKN for females vs. males in the most "difficult" tasks ("mind blank" and the two arithmetic transformation tasks), whereas there is little observed sex difference for the other tasks. In the "corrected" lens condition the above differences reflect themselves in a substantially lower "lens effect" for females vs. males, especially (but not exclusively) within the problem solving class of instructed mentation. These findings suggest that the female subjects in this study were less able to resist the demand of the stripe stimulus, lending support to the Witkin findings that females are more "field dependent" than males. Furthermore, and most important to the present study, possible implications for a differential sex use of

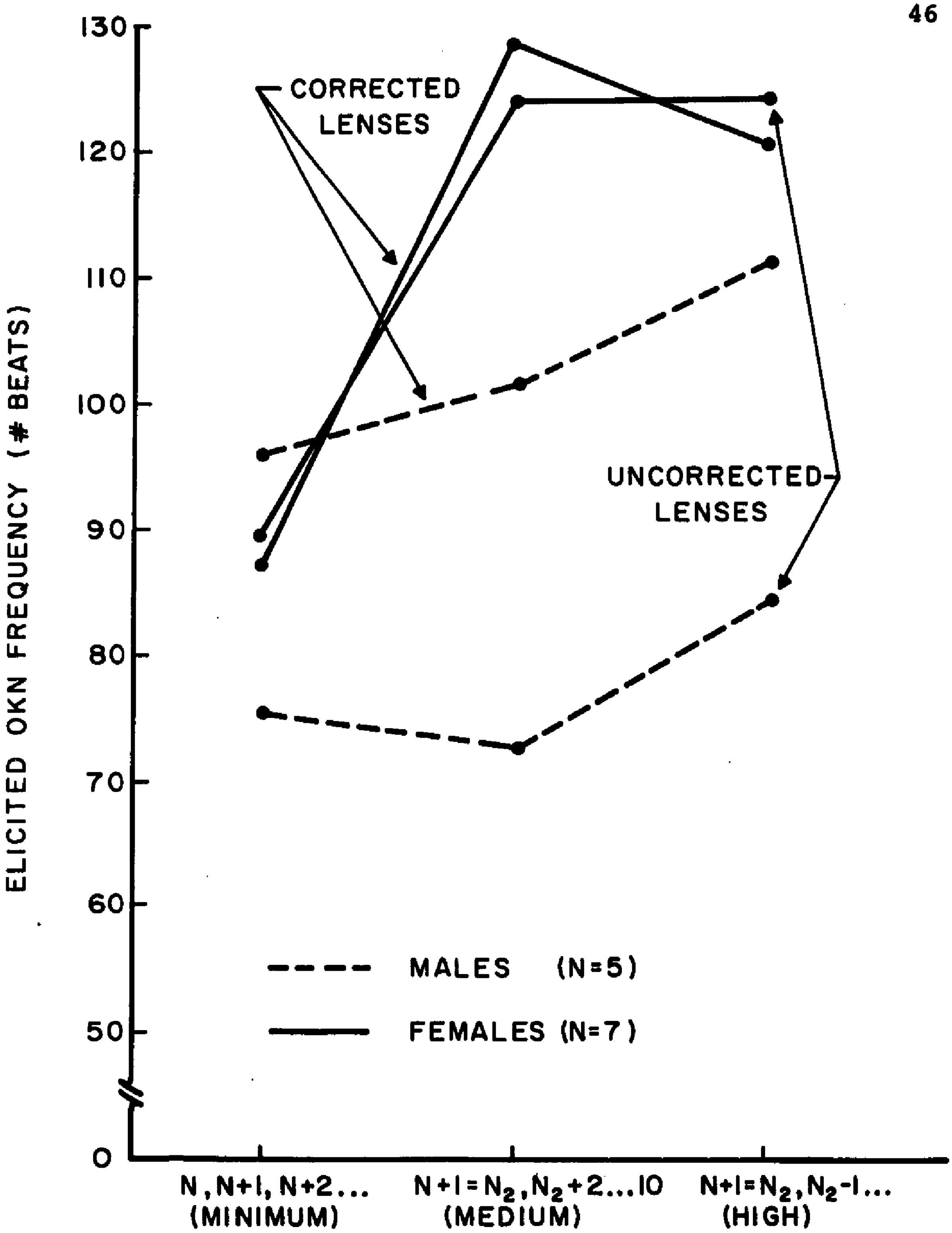


FIGURE 4

MEAN FREQUENCY ELICITED OKN BY SEX FOR EACH OF THE THREE "ARITHMETIC PROBLEM SOLVING" AND TWO "LENS" CONDITIONS

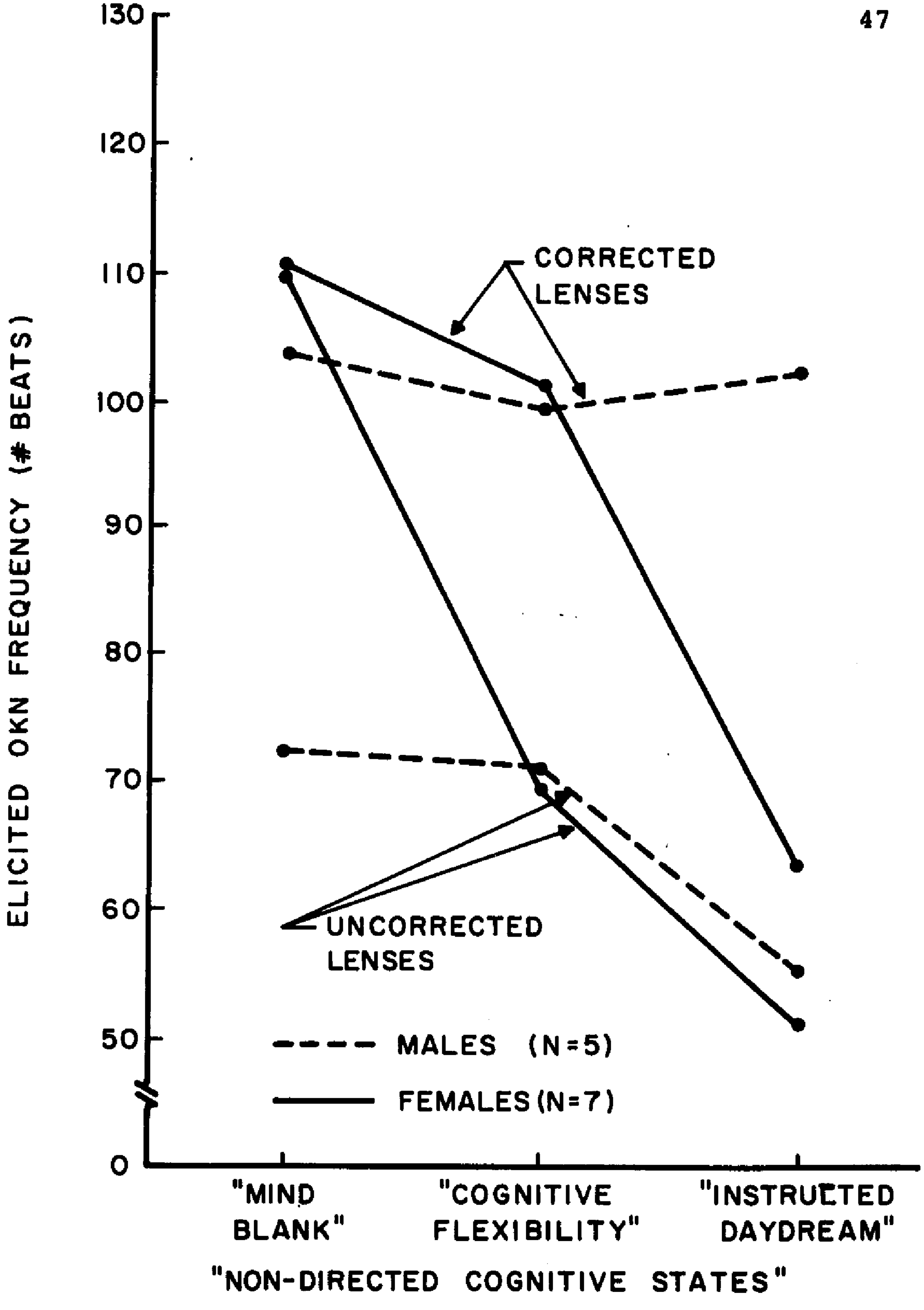


FIGURE 5
MEAN FREQUENCY ELICITED OKN BY SEX FOR EACH OF THE THREE "NON-DIRECTED COGNITIVE STATES" AND TWO "LENS" CONDITIONS

accommodative change as a mechanism in attention shift are suggested by these findings. In the "Non-Directed Cognitive States" class, the probability that there was a differential sex use of accommodative change as a mechanism in attention shift was most dramatically illustrated. It is here that we found, in addition to the elevation of elicited OKN in the corrected lens conditions, that the males also manifested a difference in intra-class trend. In the corrected lens condition they displayed no corresponding decrease in elicited OKN during the "Instructed Daydream" task thereby manifesting the pattern of results predicted by the hypothesis that accommodative alteration is the controlling mechanism! This finding taken together with the general elevation of elicited OKN and the sizeable reduction in attention rating correlations in the corrected lens condition strongly suggests that accommodative alteration was involved in producing some of the observed differences in elicited OKN between the conditions of especially the "Non-Directed Cognitive States" class of cognitive activity. But because of the post hoc nature of these findings no conclusive inferential generalization seems possible without further investigation.

CHAPTER IV

DISCUSSION

The scope and intent of the present investigation was quite complex. It sought to study the effects of variations in instructed cognitive activity (viz. attention direction, alertness and long and short term memory) on the reflex optokinetic nystagmus, and in addition attempted to evaluate the role of accommodative alteration under such conditions. The facts and implications of the results are then not suprisingly any less complex. The following discussion will be organized so as to analyze the results in the order followed in the "Results" section, with critical examinations of implications for theory and future research.

A. EVALUATION OF "GATING-ALERTNESS" HYPOTHESES

The evidence suggests that neither the notion of a simple "gating-out" process nor the state of "alertness" of an individual suffice as sole, mutually exclusive explanatory models across all classes of instructed cognitive activity.

Support for the "gating-out" model required that as the ("attention") demand for operating on either short and/or long term memory increased that elicited OKN would decrease. This was based on the notion that in order to engage in attention demanding ("internal") cognitive activity that the "irrelevant" stripe stimulation ("external") would have to be correlatively "gated-out." Just the reverse of this prediction was evidenced in the "Arithmetic Problem Solving" tasks where elicited OKN rather lawfully increased as a function of increasing short-term memory load.

In the "Non-Directed Cognitive States" conditions, as the proportion of instructed cognitive content devoted to long-term memory (analog of daydreaming mentation) increased, elicited OKN manifested a correlative decline. This, of course, coheres well with the prediction made by the "gating" model.

The elevation of OKN in the short-term memory conditions coheres well with the prediction of the "alertness" model. As cited earlier, in a parallel, though not directly analogous study of the effects of "mental set" on "vestibular" nystagmus (elicited by rotational rather than visual stimulation), Collins (1962) found that while "reverie" states resulted in a decline of the nystagmic response a mental arithmetic condition resulted in much higher nystagmus output. He concluded that one of the main factors in the maintenance of vestibular nystagmus is the state of alertness of subjects during stimulation. That is to say that even when subjects reported being subjectively "unaware of the external environment" (i.e. "attention" focused "internally"), vestibular nystagmus was maintained as a function of the extent to which they were alert.

Similarly in the Gardner-Weitzman (1967) study cited earlier in Chapter I where optokinetic nystagmus was studied, the results suggested that OKN was a function of the sleeping-waking continuum. OKN dropped out during sleep and was strongest when subjects were "aroused" by doing an arithmetic task or when shocked.

In the present study the situational context was such that the subjects performed in a darkened, sound attenuated booth, i.e., a sensory deprived situation typically associated with reduced arousal. Such a situation was structured so as to allow isolation of relevant stimulus parameters, but in the process it seems plausible to infer that a situation was created which interacted with task demands. The elevation of OKN as a function of increased short-term memory load may be conditional on the prior task-related need for stimulation in a sensory deprived environment rather than a simple negation of the "gating-out" hypothesis.

It was intended in the design of the study that the moving stripe stimuli necessary to elicit OKN should be "external" and "irrelevant" to the performance of both the short and long term memory operations. Indeed they do seem to have been "irrelevant" as far as the content of the operations to be performed went (i.e. there was no evidence spontaneously reported or otherwise that the stripes were used in performing the arithmetic tasks ((except perhaps rhythmically)) or in the instructed daydream). But they may have been "relevant" in the sense of being appropriately suited to meeting the subjects' need for an alertness level sufficient to allow them to perform the numerical counting and transformation tasks and presumably to meet the thought-interrupting demand of the "mind blank" task.

The present study suggests that OKN varies in probably lawful ways. It may not provide sufficient evidence to describe such laws in full. A critical question which is to be answered is whether if alertness were to be maintained independently (e.g. by interposing lively band music between trials as done by Antrobus & Singer (1964) of (especially the arithmetic) tasks, whether OKN would then vary in accordance with the "gating-out" model? In such an arousing context would OKN indeed vary as a function of attention direction and demand? Or, alternatively, is OKN linked to a (perhaps more primitive) system which is primarily a function of the alertness level of the organism and independent of cognitive attention demand?

One strong possibility suggested by the pattern of the present results is that to make a clear polarization between the "gating-out" and "alertness" models may have been, and could continue to be, a misleading oversimplification. It is important to remember that "alertness" (variously called "arousal," "activation," etc.) is a complex, heterogeneous construct operationally defined in many ways which often do not intercorrelate well (See Bindra, 1959): e.g. physiological measurement, naturalistic observation, subjective report, functionally through inferred load of tasks, etc. In the Gardner-Weitzman (1967) study the gross distinction between sleeping and waking was made through fairly reliable electrical techniques, but the "within-waking" statements were made by considerably less reliable subjective reports of drowsiness. In the Collins (1962) study, statements as to "alertness" were inferences made from an intuitive assessment of the alerting capacity of the tasks.

In our study we might similarly make such inferential judgments to the effect that in the "daydreaming" condition subjects were less "alert" than in the arithmetic task and use the finding of lower elicited OKN in the former to conclude that OKN varied as a function of subjects' "alertness level." But is it legitimate to infer that operating on long-term memory requires less alertness/concentration than operating on short-term memory? Or is this an artifact of a situation where external stimulation is greatly reduced?

It would seem more parsimonious and closer to the operations studied to suggest that the present results be explained with the formulation that OKN varies as a function of the relative proportions of long and short-term memory components in any given (waking) cognitive moment. When short-term memory operations predominate, OKN is stronger and drops off as the proportion of long-term memory operations grows (e.g. as in our "instructed daydream" condition). Surely some components of "alertness" would be certain to correlate with such variables, but which ones, and the extent to which they do requires additional detailed measurements through experimental investigations which were beyond the scope of the present study.

What is suggested by the present results is that the conception of "attention direction" cannot be understood merely by reflecting on the undifferentiated proportion of "internal" vs. "external" cognitive operations at any moment. That there must be a transactional consideration of the external stimulus context, the measured alertness or arousal level of an organism as well as consideration of the strong possibility suggested by the present results that long and short-term memory operations may require different gating rules, would seem imperative.

The latter proposition is indeed an intriguing one. As noted earlier it seems reasonable to assume that the observed variation in OKN probably to some extent relates to some alertness component(s). It may be true that even independent maintenance of arousal between trials will not produce a "gating-out" of the stripes in the short-term memory conditions or even that such a procedure might inhibit subjects' ability to carry out the "instructed daydream" condition. What is suggested here is the possibility that in everyday waking situations, the requirements for "gating-out" external stimulation may be greater for long-term memory operations (e.g. daydreaming) than in short-term memory tasks such as arithmetic computation. A reduction in alertness might serve to aid in fulfilling such a requirement, but the effect would be a "gating-out." Perhaps in order to process arithmetic computations a higher "alertness level" is needed and this is partially maintained through allowing admittance of certain categories of external stimulation and gating-out others. In fact, in the present study the demand for a verbal response in the problem solving tasks probably acted to reinforce the alertness levels during these tasks. The rules for admitting and gating-out may be very different from long-term memory operations requirements. Given this model, we could infer that in the present study the stripe stimulation did not fall in the category to be gated out, whereas had we required the subjects to simultaneously engage in a complex visual recognition task, the alertness advantage might have been outweighed by a cognitive interference effect.

It was pointed out in the Introduction that very often there is a direct competition among short and long-term memory operations, e.g. as when a daydreaming thought interrupts problem solving. In such situations it would seem unlikely that the interference effect could be understood merely in terms of the alertness level of the organism. Alertness variability might alter the probability of such a competition occurring, but it seems likely that motivational factors such as task interest and novelty, future plans, situational context, physical needs, etc. would function in a similarly important fashion.

Finally, one further factor which might have influenced the pattern of the present results should be noted. There is some experimentation currently being conducted (Antrobus, et al, 1970) which suggests that there is a greater competition between "internal" and "external" cognitive processing when both such operations are conducted in the same sensory modality. In the present study this notion would seem to provide an additional explanation for the relatively greater "gating-out" of OKN during the Instructed Daydreaming condition. Since daydreaming-type mentation occurs primarily in the visual modality, while arithmetic problem solving is more verbal and auditory, the above evidence would have correctly predicted that the visual OKN stripe stimulation would face greater competition from the daydreaming mentation than from the mental arithmetic. Given its apparent relevance to the pattern of the present results further experimentation with this hypothesis seems warranted.

B. ROLE OF ACCOMMODATIVE ALTERATION

The notion that the maintenance of accommodation beyond the plane of regard at visual infinity may be implicated as a mechanism employed by individuals to enforce a "gating-out" of "irrelevant" visual stimulation (in this case the moving stripes) was studied. The corrected lenses which involuntarily prevented the eyes from focusing beyond the stripes did result in a significant elevation of elicited OKN across both classes of instructed mentation, but did not cause a significant alteration in the trend of intra-class difference (both sexes combined). As noted in the Results section this would have seemed to rule out accommodative alteration as the sole or primary mechanism involved or in control in explaining the obtained differences.

The condition in which a "gating-out" of the stripe stimulation seemed to be most dramatically illustrated was the "instructed daydream" condition. Significantly lower OKN was elicited when subjects were engaged in this type of mentation. (Importantly, the "gating-out" was not complete even here - some implications of this will be discussed below.) It was in this condition that a sex difference was manifested with the male subjects ev idencing no drop in elicited OKN when performing this task with lenses preventing their focusing beyond the plane of regard. This behavior fit well the pattern of results predicted by the hypothesis implicating accommodative alteration as a controlling mechanism in enforcing a gating-out of the stripes.

This finding, along with the sizeable reduction in the correlation between subjects' attention directions ratings and elicited OKN in the corrected lens conditions, suggests that at least for men accommodative alteration plays some role in effecting a "gating-out" irrelevant visual stimulation when and if such a gating process occurs. Because of the post hoc nature of especially the sex difference findings no conclusive inferential generalization should be made without further investigation. Nevertheless it seems worthwhile to explore the implications of this finding further.

In spite of the fact that accommodative alteration does not seem to be the mechanism used by them, the female subjects also manifested a marked decrease in elicited OKN during the "instructed daydream" condition. As was noted earlier in the Results section, their overall performance in the study supported Witkin's (1962) findings that females are more "field dependent" than males. Another salient finding of Witkin and his co-workers was to the effect that field-dependent individuals are more prone to employ a repressive "defensive" style. While for men, accommodative alteration may function so as to at least partially "gate-out" of the visual system "irrelevant" or competing stimuli (e.g. in this study, the moving stripes) so as to facilitate selective attention, the present results suggest that in line with the Witkin findings that the females may have had to resort to more "truly repressive," i.e., intrapsychic (higher cortical) inhibition to accomplish similar functional ends.

It is a uniquely valuable trait of optokinetic nystagmus to be a higher cortical reflex operation with a more "peripheral face" (i.e., typically elicited by visual stimulation and manifesting an oculo-motor response). The fact that OKN was suppressed in the "instructed daydream" task for the females and given the probable ruling out of their use of accommodative alteration, suggests that OKN is also responsive to "central" as well as "peripheral" inhibition and control.

The existence of such a "central " relationship would certainly cohere well with the evidence collected and discussed by Broadbent (1958), Deutsch and Deutsch (1963), Neisser (1967) and many others who maintain that some diffuse and non-specific central organizing system is necessary as a part of the mechanism subserving selective attention. Future investigation of cortical linkage between the oculomotor system and the reticular formation is certainly given further impetus by the nature of the present results.

C. SOME FURTHER THEORETICAL IMPLICATIONS

In his comprehensive and incisive book on Cognitive Psychology (1967), Ulric Neisser postulates at least a two-level perceptual system which seems to cohere well with the results of the present study and suggests a theoretical explanation for the absence of total OKN suppression. His notion of a primary level "pre-attentive" processing system where the organism makes global discriminations with temporary storage in "iconic memory" would account for our findings of the failure of OKN to be completely suppressed and the lack of evidence for accommodative alteration acting to keep the "irrelevant" stripe stimuli out of the system completely. Analogically this would explain why drivers do not go off the road during those times in which they later have realized they were not "paying attention" to the road (and often wonder how they arrived at their destinations). Neisser declares: "In these cases the behavior is steered entirely by the pre-attentive analyzers (p. 92)."

Whereas our stripe stimuli were extremely demanding in terms of duration, omnipresence and intensity, as noted earlier in the Discussion no competing recognition or long-term recall process involving this visual stimulation was demanded. As was postulated earlier we might expect a different set of results were such demands made. For example, if words or symbols were randomly flashed on the screen with a demand for later recall presumably what Neisser calls second-level "focal attention" constructive, synthesizing process mechanisms would be called into play with a probability that a more pronounced interference with internal processing would be evidenced due to a more "focal attention" demanding stimulus situation.

What is suggested by Neisser's thesis and by our results is that a conscious, subjective experience of being "aware" (i.e. of "paying attention") most probably is not a sufficient indicator of when external stimulus or other (e.g. memory) information is being processed. This would cohere well with the evidence of our study and the Collins (1962) study where subjective report indicated focal attention to be directed away from the external environment during arithmetic tasks while nystagmus which in both instances depended on external environmental stimuli for elicitation was strong. What is further suggested by these situations is that more precise study of the phenomenological "feel" of subjects would be relevant and might reveal subtle differences between, for example, report of attention direction in more directed "internal" processing (such as arithmetic problem solving) and less directed mentation such as daydreaming. This would relate to the possibility of different "gating" rules as postulated earlier. Certainly Kahnemann, Beatty and Pollack's (1967) findings of subjective reports of blindness during arithmetic transformation tasks warrants closer examination in light of this analysis and our results.

D. THE USEFULNESS OF ELICITED OKN

Complete suppression of OKN for long time periods did not eventuate as predicted by Gardner and Weitzman (1967). Nevertheless, the pattern of the results fits well with Neisser's (1967) model which provides a persuasive theoretical basis for the functional relevance of such an outcome. Importantly, the measurable manifestation of sufficient significant variability in frequency and amplitude of elicited OKN clearly reinforces the present and future usefulness of this reflex measure. The inferential statements, questions, and research suggestions made in this investigation certainly warrant further pursual and refinement.

CHAPTER V

SUMMARY

Twelve subjects with tested normal vision were exposed to an optokinetic stimulus (moving stripes) while carrying out instructions which consisted of varying two classes of cognitive activity ("Arithmetic Problem Solving" and "Non-directed Cognitive States") each over three conditions designed to operationally specify differential degrees of "attentional involvement" and mental effort, alertness and direction. All subjects further underwent all conditions with both normal and corrected lenses, with the latter involuntarily focusing the eyes at the plane of regard thereby preventing focusing at visual infinity. Measurement of optokinetic nystagmus (OKN) eye movements were recorded by continuous electro-oculograms.

In the Arithmetic Problem Solving conditions elicited OKN increased, as task difficulty (primarily short-term memory load) increased, whereas in the "Non-Directed Cognitive States" conditions, as the proportion of cognitive content devoted to long-term memory (analog of daydreaming mentation) increased, elicited OKN manifested a correlative decline. It was suggested that neither the notion of a simple "gating-out" process nor the state of "alertness" of an individual sufficed as sole, mutually exclusive explanatory models across all classes of instructed cognitive activity. Rather it was deemed more parsimonious to infer that OKN varies as a function of the relative proportions of long and short-term memory components in any given (waking) cognitive moment. That there must be a transactional consideration of the external stimulus context, the motivational matrix and alertness or arousal level of an organism, as well as consideration of the strong possibility suggested by the present results that long and short-term memory operations may require different "gating" rules seemed imperative and the facts and implications of such a paradigm were explored.

In the "instructed daydream" condition a sex difference was manifested with the male subjects evidencing no drop in elicited OKN when performing this task with lenses preventing their focusing beyond the plane of regard. This finding along with some others, suggested that at least for men accommodative alteration played some role in effecting a "gating-out" of irrelevant visual stimulation when and if such a gating process occurred. The results for females suggested that they may have to resort to more "truly repressive," i.e. intrapsychic (higher cortical) inhibition to accomplish similar functional ends. But because these different findings resulted from post hoc analysis no conclusive inferential generalizations about accommodative alteration can safely be made without further investigation.

The absence of complete suppression of OKN was examined in the light of Neisser's (1967) model of a two-level perceptual system. The facts and implications of the present results suggested among other things that a conscious subjective experience of being "aware" (i.e. of "paying attention") most probably is not a sufficient indicator of when external stimulus or other (e.g. memory) information is being processed.

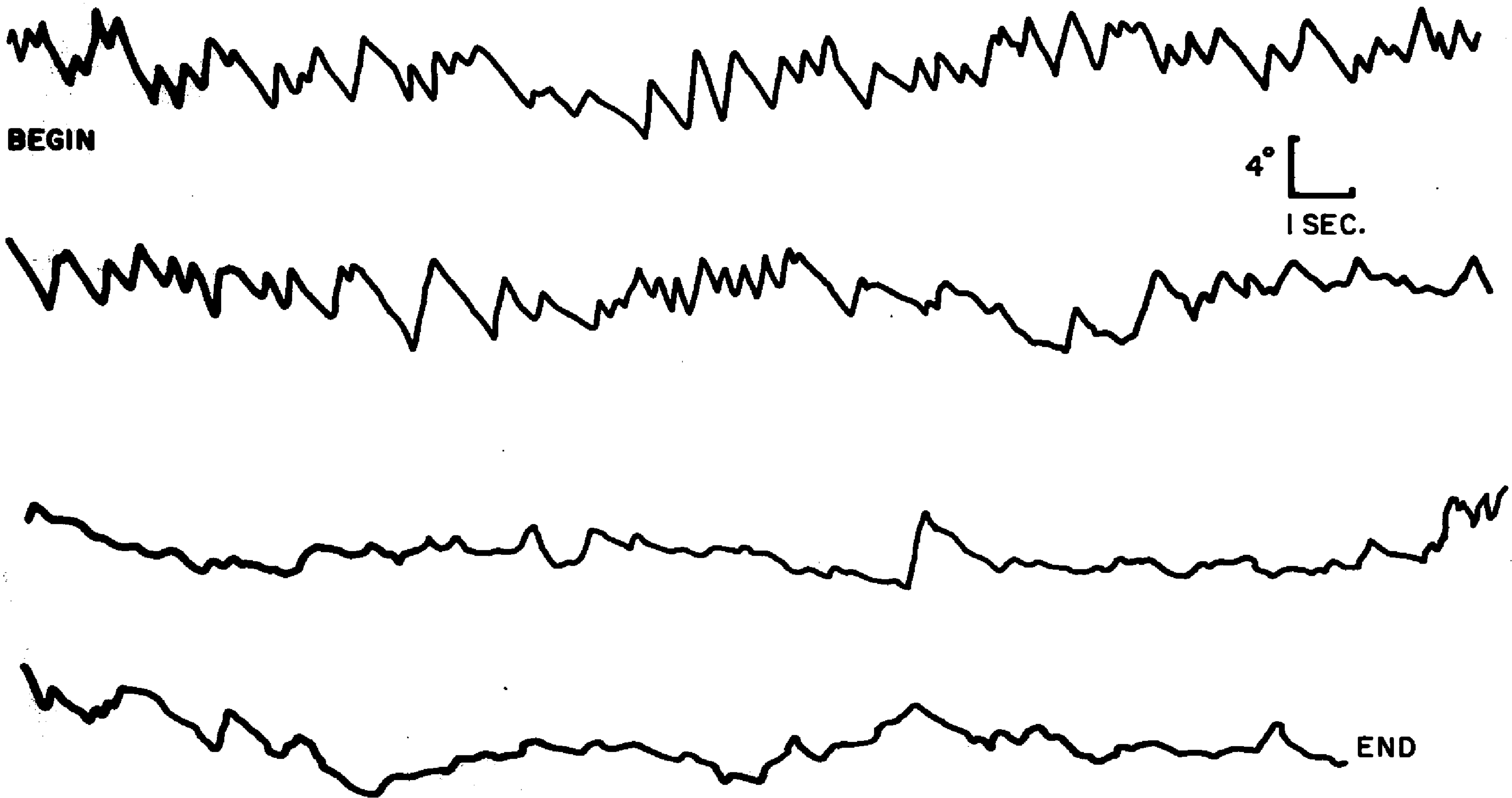
Support for the postulation of some central organizing and selecting system subserving selective attention was evidenced and implications for theory and future research were discussed. The potential usefulness of elicited OKN for elucidating further insight in this area was noted.

APPENDIX A

EXAMPLES OF ACTUAL EOG RECORDINGS OF ONE FEMALE SUBJECT

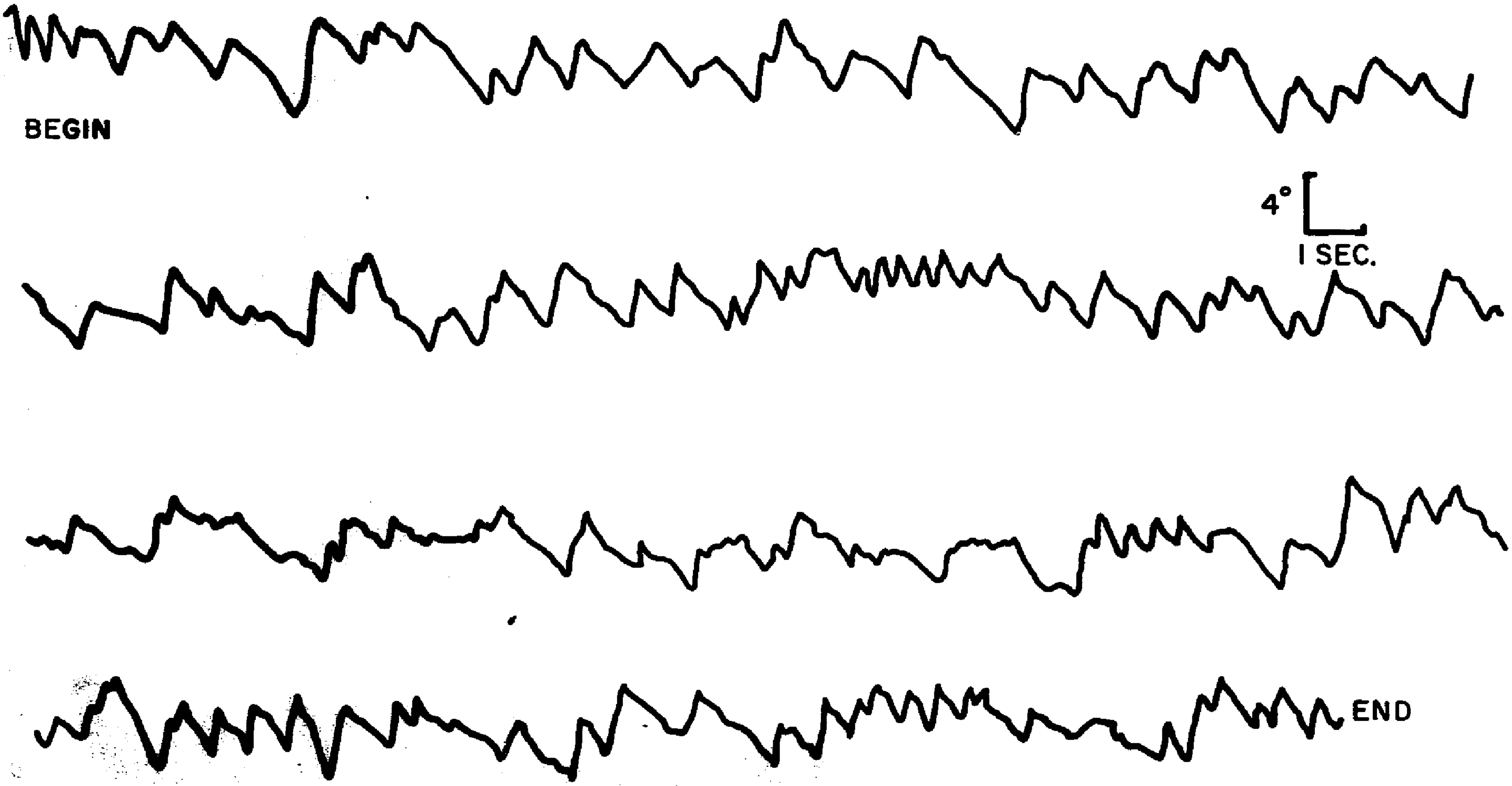
Each of the following six pages represents a tracing of a continuous D.C. horizontal bipolar EOG recording of a complete ninety-second trial (all with subject wearing uncorrected lenses). They are presented in the following order:

1. ARITHMETIC PROBLEM SOLVING (SHORT-TERM MEMORY LOAD)
    a. Simple Counting (low).
    b. $N, N+1 = N_2 \ldots$ (medium).
    c. $N, N+1 = N_2 - 1 \ldots$ (high).
2. NON-DIRECTED COGNITIVE STATES
    a. Mind Blank
    b. Cognitive Flexibility
    c. Instructed Daydream



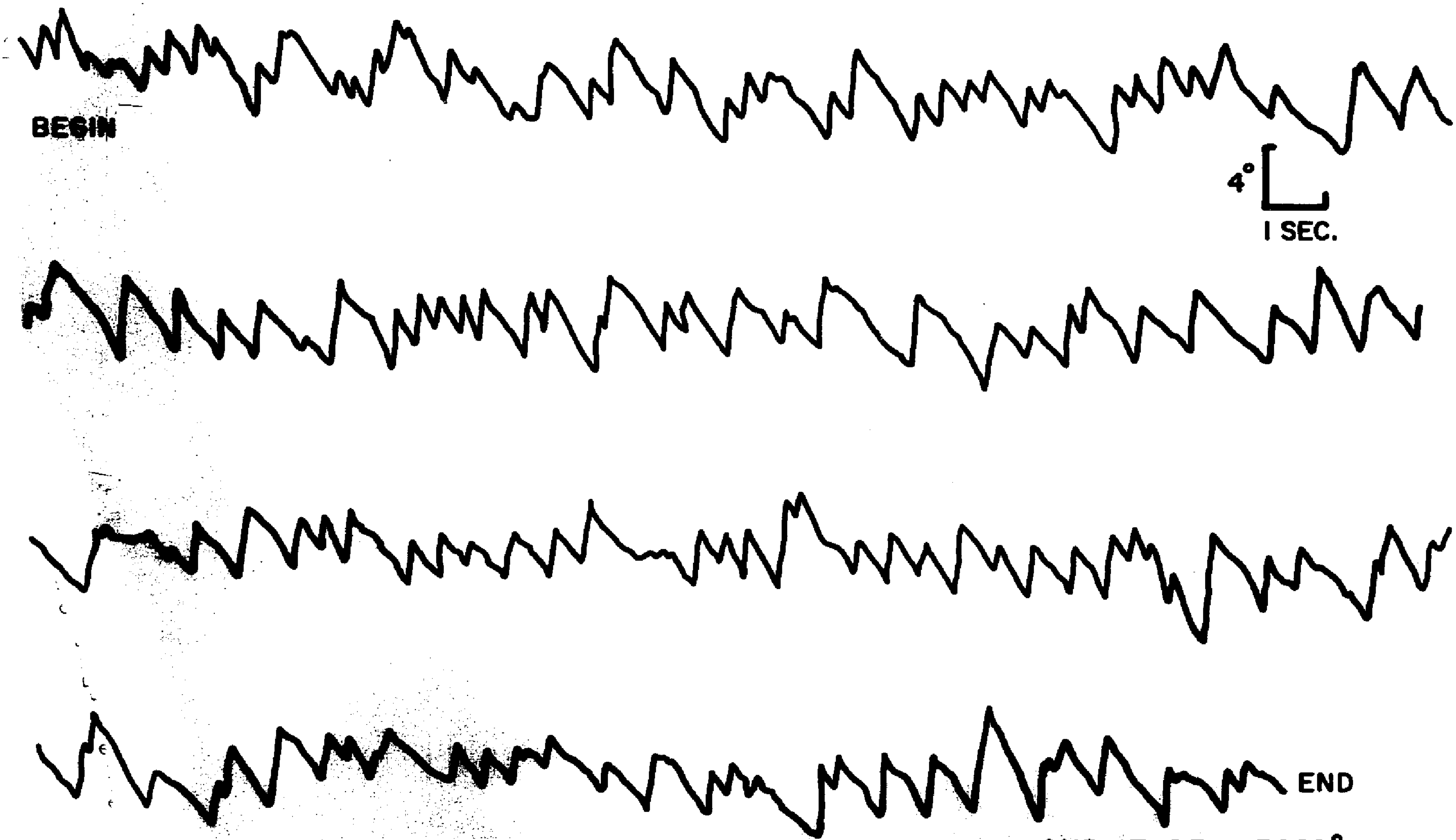
AMPLITUDE - 1477°
FREQUENCY - 81

SIMPLE COUNTING (LOW)



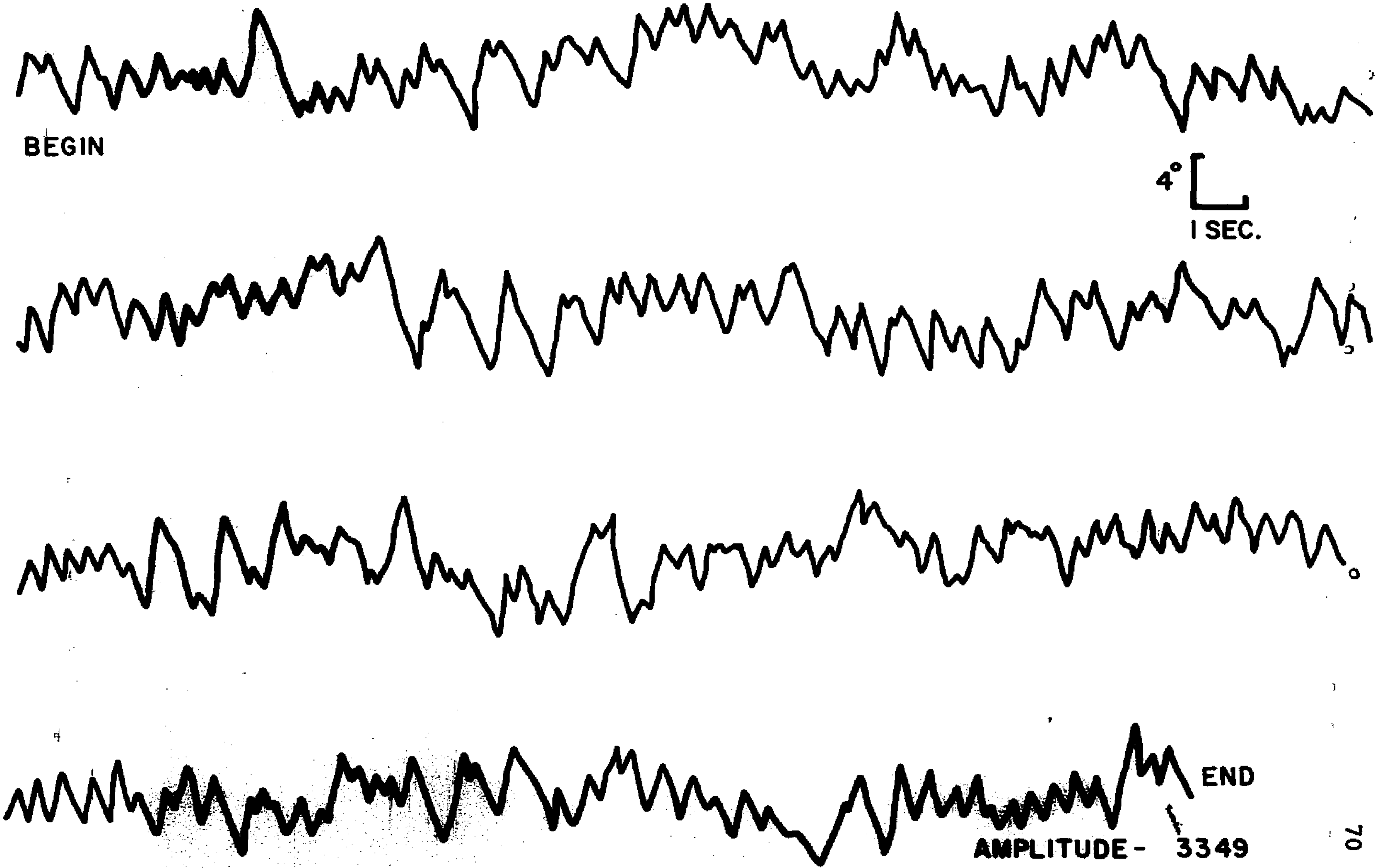
AMPLITUDE - 2170°
FREQUENCY - 112

N_1 $N+1 = N_2$... (MEDIUM)



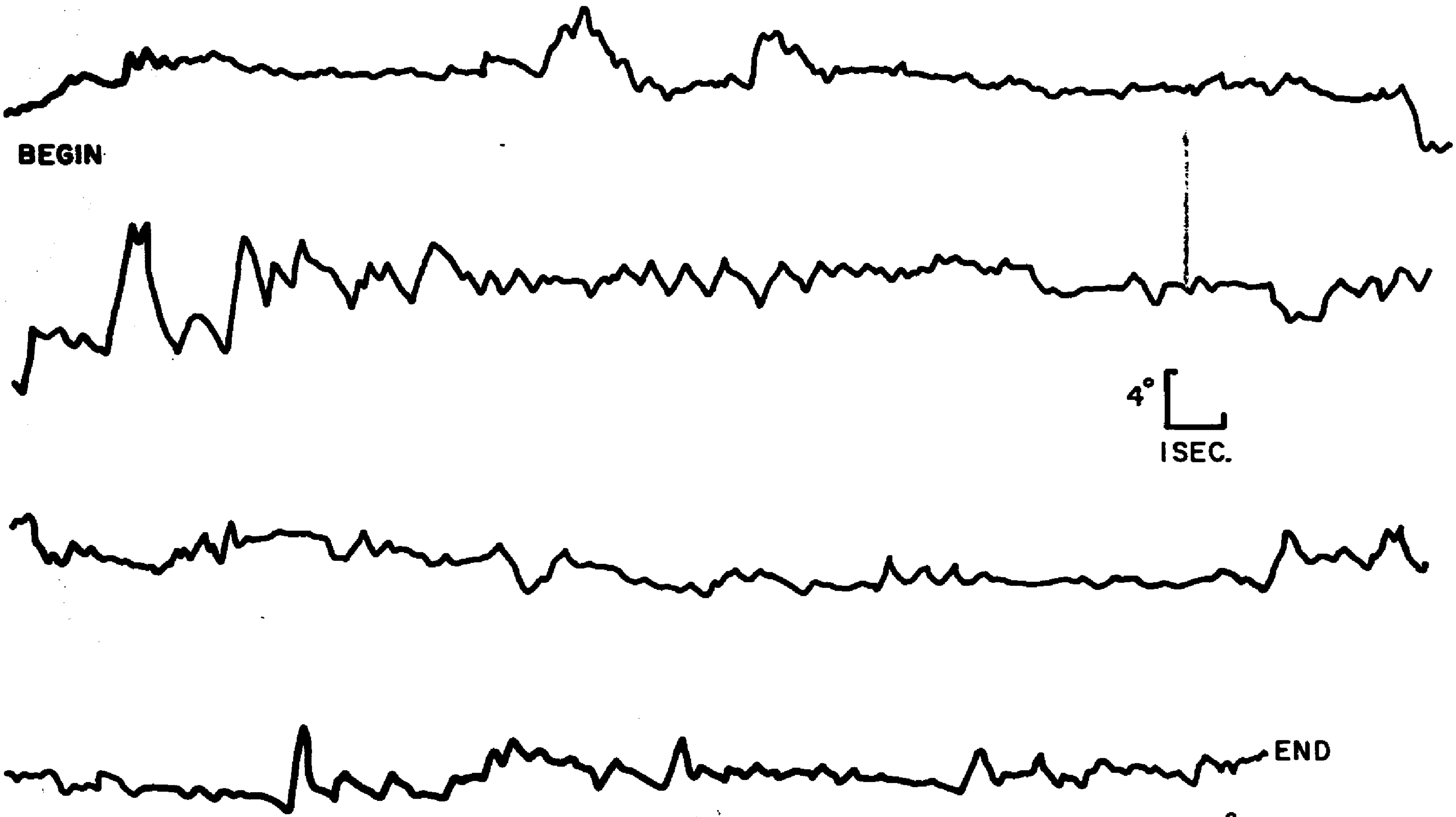
AMPLITUDE - 3028°
FREQUENCY - 137

N_1 $N+1 = N_2$, $N_2 - 1$... (HIGH)



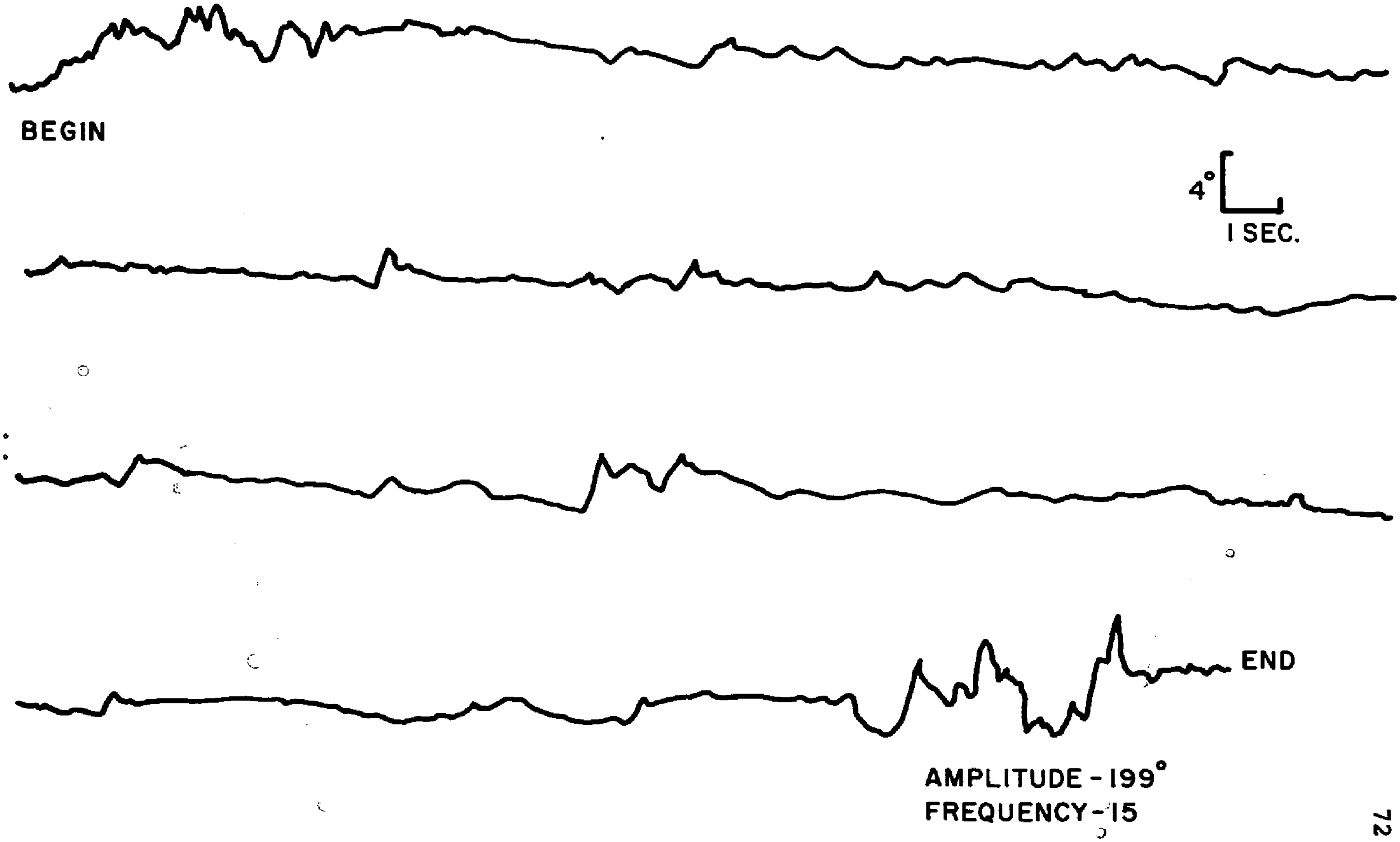
AMPLITUDE - 3349
FREQUENCY - 183

"MIND BLANK"



AMPLITUDE 584°
FREQUENCY 42

"COGNITIVE FLEXIBILITY"



"INSTRUCTED DAYDREAM"

APPENDIX B

OPTOMETRIC QUESTIONNAIRE

SHEET A

Name:

Telephone No.: Date of Birth:

1. Have you ever worn glasses?
2. Have you ever been treated for any neurological or eye condition?
3. To the best of your knowledge, do you have 20/20 vision in each eye?

To assist us in correlating our experimental findings with variations in subject condition it is important that we have the most precise information possible as to the following:

1. Are you under any medical treatment at present?
2. Are you currently taking any medication or drugs?
3. Do you experience any eye discomfort for:
    a. Distance tasks (movies, driving, etc.)?
    b. Near tasks (reading, etc.)?
4. Does your vision ever blur or double?
5. Any other eye symptoms?
6. Has anyone in your family been diagnosed as having an eye disease? If so, for what condition?

OPTOMETRIC QUESTIONNAIRE

SHEET B

1. OKN Yes______ No______

2. V.A.

Distance	Near
OD	OD
OS	OS
OU	OU

3. Cover Test

Distance________________

Convergence_____________

Near____________________

4. Retinoscopy	RED - GREEN
OD	OD
OS	OS

5. Supplementary Tests

APPENDIX C

AVERAGE FREQUENCY OKN PER INSTRUCTED CONDITION ELICITED FROM EACH OF TWELVE SUBJECTS WHILE WEARING UNCORRECTED (U) AND CORRECTED (C) LENSES

SUBJECT	ARITH. PROB. SOLVING			NON-DIR. COGNITIVE STATES		
	Low	Med.	High	Mind Bl.	Flex.	Daydr.
Female						
U	108	124	128	133	87	52
C	113	120	122	146	107	106
Female						
U	43	77	65	64	24	10
C	98	121	101	121	65	14
Male						
U	87	60	10	100	85	85
C	77	76	81	111	129	113
Male						
U	181	142	124	129	140	115
C	187	140	154	117	110	132
Female						
U	73	90	125	182	51	70
C	51	95	112	174	59	16
Male						
U	81	92	114	4	2	45
C	24	75	96	106	113	96
Male						
U	47	34	67	64	90	73
C	130	45	49	125	129	78
Male						
U	69	43	69	139	97	14
C	82	107	134	123	170	151
Female						
U	119	178	173	71	70	25
C	40	139	135	60	115	43
Female						
U	104	152	130	98	116	98
C	133	169	135	52	160	138
Male						
U	33	23	8	33	23	8
C	21	62	61	26	41	20
Male						
U	38	60	48	38	60	48
C	151	207	206	116	3	125

REFERENCES

Antrobus, J. S. & Singer, J. L. Visual signal detection as a function of rate of stimulus presentation and sequential variability of simultaneous speech, J. exp. Psychol., 1964, 68, 6, 603-610.

Antrobus, J. S., Antrobus, J. S. & Singer, J. L. Eye movements accompanying daydreaming, visual imagery and thought suppression. J. anbnorm. soc. Psychol., 1964,

Antrobus, J. S., Singer, J. L. & Greenberg, S. Studies in the stream of consciousness: experimental enhancement and suppression of spontaneous cognitive processes. Precept. mot. skills, 1966, 23, 399-417.

Antrobus, J. S. Information theory and stimulus-independent thought. Br. J. Psychol., 1968, 59, 4, 423-430.

Antrobus, J. S., Singer, J. L., Goldstein, S., & Fortgang, M. Mindwandering and cognitive structure. Trans. N. Y. Acad. Sci, 1970, 32, 2, 242-252.

Bindra, D. Motivation: A Systematic Reinterpretation. New York: Ronald Press Co. 1959.

Broadbent, D. E. Perception and Communication. New York: Pergamon Press, 1958.

Cochran, W. G. and Cox, G. M. Experimental Designs. (2nd Edition) New York: Wiley, 1957.

Collins, W. E. Effects of mental set upon vestibular nystagmus. J. exp. Psychol., 1962, 63, 2, 191-197.

Dayton, G. O., Jones, M. H., Patrick, A., Rawson, R. A., Steele, B., & Rose, M. Developmental study of coordinated eye movements in the human infant. I. Visual acuity in the newborn human: a study based on induced optokinetic nystagmus recorded by electro-oculography. Arch. Ophthal., 1964, 71, 865-870.

Deutsch, J. A. and Deutsch, D. Attention: Some theoretical Considerations. Psychol. Rev., 1963, 70, 80-90.

Edwards, A. L. Experimental Design in Psychological Research. (Revised Edition) New York: Holt, 1960.

Gardner, R. & Weitzman, E. D. Examination for optokinetic nystagmus in sleep and waking. Arch. Neurol., 1967, 16, 415-420.

Gorman, J., Cogan, D. & Gellis, S. An apparatus for grading the visual acuity of infants on the basis of optokinetic nystagmus. Ped., 1957, 19, 1088-1096.

Gunther, G., Notebloom, E. & Plotz, C. Objective determination of visual acuity. Graefe Arch. Ophthal., 1957, 159, 180-190.

Hernandez-Peon, R., Scherrer, H. & Jouvet, M. Modifications of electrical activity in cochlear nucleus during "attention" in unanesthetized cats. Science, 1956, 123, 331-332.

Hernandez-Peon, R. & Donoso, M. Influence of attention and suggestions upon subcortical evoked electrical activity in the human brain. EEG clin. Neurophysiol. Epilep., 1959, 3, 385-396.

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

Kahnemann, D., Beatty, J. & Pollack, I. Perceptual deficit during a mental task. Science, 1967, 157, 218-219.

Luborsky, L., Blinder, B. & Mackworth, N. Eye fixation and recall of pictures as a function of GSR responsivity. Percept. mot. skills, 1963, 16, (Monogr. Suppl. #5), 469-483.

Miller, G. A. The magical number seven, plus or minus two, or some limits on our capacity for processing information. Psychol. Rev., 1956, 81-97.

Neisser, U. Cognitive Psychology. New York: Appleton, 1967.

Nicholai, H. Further experience in the area of the objective determination of visual acuity through optokinetic nystagmus. Klin. Monatsbl. Augenh., 1954, 124, 81-86.

Ohm, J. Detection of simulations of total blindness by means of optokinetic tests. Klin. Montasbl. Augenh., 1952, 121, 226-228.

Pheiffer, C. H. Book retinoscopy, Am. J. Optom. & Arch. Am. Acad. Optom., 1955, 32, 10, 540-545.

Pheiffer, C. H. T.V. retinoscopy. Am. J. Optom. & Arch. Am. Acad. Optom., 1955, 32, 11, 595-598.

Rechtschaffen, A. & Foulkes, D. Effect of visual stimuli on dream content. Percept. mot. skills, 1965, 20, 1149-1160.

Reinicke, R. D. Review of optokinetic nystagmus from 1954-1960. Arch. Ophth. (Chicago), 1961, 65, 609-615.

Reinicke, R. D. & Cogan, D. G. Standardization of objective visual acuity measurements: optokinetic nystagmus vs. Snellen acuity. AMA arch. ophthal., 1958, 60, 418-421.

Schumann, W. P. Notes on the objective determination of visual acuity through optokinetic nystagmus. Am. J. Optom., 1961, 38, 646-654.

Singer, J. L. Daydreaming: An Introduction to the experimental study of inner experience. New York: Random House, 1966.

Smith, J. L. Optokinetic Nystagmus. Springfield, Ill.: C. C. Thomas, 1963.

Weigelin, E., Heindricks, H., Leonardi, F. & Neisel, P. The relations of subjective visual acuity and the results of objective examination. Klin. monatsbl. Augenh., 1955, 127, 174-182.

Williams, E. J. Experimental designs balanced for the estimation of the residual effects of treatments. (1949) In: Cochran, W. G. & Cox, G. Experimental Designs. (2nd Edition) New York: Wiley, 1957, pp. 133-141.

Witkin, H. A., et al. Psychological Differentiation. New York: Harper, 1962.