PHYSIOLOGICAL AND COGNITIVE CORRELATES OF SIGNAL DETECTION IN AN AUDITORY VIGILANCE TASK

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ABSTRACT

PHYSIOLOGICAL AND COGNITIVE CORRELATES OF SIGNAL DETECTION IN AN AUDITORY VIGILANCE TASK

By

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This study was undertaken to examine the relationship between autonomic activation and performance on a sustained vigilance task and also to examine the interrelationships between physiological, personality and cognitive measures that have been previously employed to study attention. Thirty-one college males took a series of tests which included the Hidden Figures Test, the Stroop Color-Word Test and the Eysenck Personality Inventory. Each subject also completed a 48 minute auditory vigilance test during which time continuous recordings of heart rate, skin conductance and GSR were made.

The physiological results indicated that a high level of physiological activity, or arousal, improves vigilance performance in that highly aroused subjects showed little or no detection decrement. These physiological results were statistically significant for high

and low heart rate groups, while GSR magnitude and GSR amplitude results were in the predicted direction. The physiological results were discussed in the context of activation theory.

None of the other measures related meaningfully to either vigilance performance or to the physiological measures. An explanation of this lack of relatedness was that the sustained attention measured in the vigilance situation is a quite different process from the short term attention measured in the other tests.

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INTRODUCTION

Vigilance tasks have been used by a number of investigators as a measure of attention (Buckner and McGrath, 1963; Bakan et al., 1963; Eysenck, 1964). In such a task the subject is required to detect signals which occur infrequently and at irregular intervals. These signals are generally interspersed among more numerous nonsignal stimuli. The making of successful detections, then, requires the subject to attend to the task constantly, as a lapse in attention quite often results in a missed signal. Hence, number of detected signals is generally used as the measure of attention. Most investigators have found that the number of correct detections generally decreases as the task progresses. This implies a general decrease in attention. After 45 minutes, decrement usually becomes quite marked, with the average subject detecting 24% fewer signals than he did initially (Bakan, et al., 1963).

Although the decremental trend is typically found for groups, the amount of decrement as well as total detections are subject to wide individual differences. Previous investigations have attempted to relate these individual differences in attention to physiological, personality and cognitive measures with moderate success (Stern, 1964; Stern, 1966; Bakan et al., 1963; Claridge, 1966; Eysenck, 1964). However, these investigations have dealt with quite fragmentary aspects of the attention process. The present study was designed to define the attention process more completely in terms of physiological, cognitive and personality measures. The diversity of the measures employed in this study necessitates separate reviews of the literature. The physiological background will be dealt with initially by reviewing the general arousal theories which consider arousal or activation to be intimately related to attention. Theoretical implications will be considered along with research conducted outside the theoretical framework. The second part of this review is concerned with other measures related to attention. The relationship between these variables along with some additional physiological distinctions will be examined.

Physiological Background

An adequate level of physiological arousal is thought to underly good vigilance performance, or attention. The most popular theories dealing with this assumption include activation theory (Lindsley, 1951; Hebb, 1955; Duffy, 1962; Malmo, 1959), and the theory of John Lacey (1963, 1967).

Lindsley (1951) was the first to coin the term, 'activation theory' and his work was elaborated by a number of theorists including Hebb (1955), Malmo (1959), and Duffy (1962). Basically, activation theory depicts a continuum of arousal ranging from deep sleep to excited states of behavior where arousal is measured by magnitude of autonomic or EEG activity to a stimulus or stimulus situation. Activation or arousal processes are thought to reveal the intensive rather than directional aspects of behavior and presumably correlate with measured adequacy of performance in an inverted-U fashion where highest performance levels correspond to moderate physiological activation.

Malmo (1965) cites a number of relevant studies that support activation theory. He reports rising gradients in skeletal muscle tension, heart rate and respiration during mirror drawing and tracking tasks, both of which demand sustained attention. Activation theory, however, fails to explain an apparent decrease in skin conductance while gradients in other subsystems were rising. EEG measures, too, were found to be gradated only under special conditions. Ignoring these EEG and skin conductance findings, Malmo concludes that 'tonic' background level of physiological activity is required by the organism for sustaining a relatively even level of attention from the beginning to the end of a task.

Stern (1964) verified that a high level of physiological activity is related to a task requiring attention. He found that subjects under conditions of sensory deprivation, but engaged in a vigilance task, sustained a higher level of physiological activity than a group instructed to ignore the stimulus used in the vigil and simply relax. Stern's task-involved group maintained their pretest heart rate while the control group's heart rate fell to 85% of its original level. Although base conductance decreased for both groups, the decrease was significantly greater for the controls. The two groups did not differ in breathing rate although the respiration amplitude of the controls fell to below 80% of their original level while the experimental group maintained their initial depth as reflected in respiration amplitude.

Sokolov (1963) proposes a theoretical approach which shares many similarities to activation theory. He states that increased sympathetic activity has an excitatory and facilitating effect on some types of performance in that it serves to provoke or maintain cortical activation which results in increased receptor sensitivity. The facilitating effect of increased sympathetic activity is readily apparent in work done on the orienting reflex (OR). The OR is a centrally organized system of autonomic, somatic, neural and neuromotor reactions to any novel stimulus. Properties of a novel stimulus would include any increase, decrease or qualitative change in the stimulus field. Specifically, responses include alpha desynchronization, pupil dilation, decreased skin resistance and vasomotor change consisting of cephalic vasodilation and peripheral vasoconstriction. Heart rate acceleration is also implied by the Sokolov model (Sokolov, 1963; Lynn, 1966; Razran, 1961; Graham and Clifton, 1966).

The function of an OR is thought to be facilitation of the reception of stimuli resulting from the increase of discriminatory power of sensory systems. And, as Maltzman and Raskin (1965) point out, the operations which define an OR correspond in part to the conscious-centered concept of attention, i.e., stimulus change, increased cerebral blood volume and decreased blood volume in the limbs. Evidence from studies of individual differences appear to support this in that a number of investigators have found autonomically active subjects are more 'aware' or attentive than their more inactive counterparts (Maltzman and Raskin, 1965; Israel, 1966; Courter et al., 1965).

Although the OR patterned reaction does appear to facilitate sensory discriminations, it is not directive in the consummatory sense. It merely 'opens the organism up' and does not really allow for 'management' of the stimulus (Razran, 1961). You will note the similarity again to the intensive, undirected aspects of behavior ascribed by 'arousal' in the activation framework.

In spite of the similarities between Sokolov and the activation theorists, procedural and methodological differences make the two schools of thought far from synonymous. Patterns of response discussed by the activationists usually rely on evidence from tracking or mirror drawing tasks. These tasks are usually 30 seconds to 10 minutes in length. The response measures taken are generally known as tonic responses, or responses which change slowly, e.g., skin conductance base level. Sokolov, on the other hand, is mainly concerned with phasic responses, or responses which occur immediately after stimulus presentation. The phasic response is brief and discrete, such as a GSR response. So, although both theorists would probably agree that high levels of physiological activity accompany states of greater awareness or attention, the common conclusion is based on quite divergent methodologies.

The work of Lacey (1967) points to a substantial amount of evidence which is in direct opposition to activation theory. He cits pharmacological and lesion work that give evidence of simultaneous physiological arousal and behavioral somnolence as well as the reverse. He also refers to work done by Malmo (1966), Elliott (1964) and Mirsky and Cardon (1962), all of whom were unable to detect changes in all systems paralleling performance.

Lacey concludes from this evidence that arousal is not a unidimensional process, but can be viewed as several processes, each one being a type of arousal in itself. More specifically, electrocortical, autonomic and behavioral indices are separate arousal systems which are intimately related, but not always operating simultaneously or congruently. Instead, increases in these systems depend to a large extent on the situation as well as the individual subject; the aim or goal of behavior is represented as well as the intensive function. For example, it is known that subjects have idiosyncratic patterns of response in that individuals do not respond with equal increments or decrements in all subsystems. These idiosyncratic patterns of response are produced in subjects under different stimulus conditions. He has found conductance increases under all environmental conditions while heart rate response varies with the type of situation. Decelerations occurred when the subject was required to attend to visual and auditory inputs while acceleration occurred when the subject was required to resort to internal activities which involve storage, retrieval, and recombination of information. Lacey concludes that conductance is a generalized response while heart rate is a response with more specific correlates. He proposes that cardiac deceleration accompanies, and perhaps even facilitates, environmental intake while cardiac acceleration accompanies and facilitates environmental rejection. Obrist (1963) was successful in replicating Lacey's findings utilizing different tasks.

Campos and Johnson (1966), however, found evidence which conflicted with the Lacey theory. Using Lacey's original tasks, they found heart rate deceleration only when subjects did not have to verbalize their observations. If a subject was required to verbalize either at that time or at a later temporal period there were highly significant increases in both heart rate and skin conductance. These accelerations were apparent even in those tasks dealing with environmental intake where Lacey predicts deceleration.

The theories both have face validity in that each is supported by a substantial amount of evidence. However, neither explains all the observations that have been reported. Again, procedural and methodological considerations are quite important. Lacey, unlike either Sokolov or Malmo, characteristically uses the minute preceeding and the minute following stimulus presentation as the basis for response measurement. His tasks are also quite diverse, ranging from mental arithmetic to the cold pressor test. Obviously the nature of Lacey's tasks, as well as his units of measurement, are quite different from the 10 minute tasks of Malmo and the immediate responses examined by Sokolov. It is therefore not surprising that the conclusions of these theorists are not identical.

In spite of the differences, all three theorists appear to be dealing with the same general problem: autonomic concomitants of various cognitive tasks, including 'attention' or what can be inferred (e.g., Sokolov, OR) to be at least part of the attention process. The basis for each supposition however, is mainly short term tasks or brief stimulus presentations. Whether the physiological concomitants are maintained in tasks of greater length, such as a vigilance task, is still open to question. Stern (1964) found that subjects engaged in a vigilance task maintained initial levels of response while subjects who were not task-involved showed decreasing physiological gradients. His results lend strong support to an activation position. Other work done outside the theoretical framework with sustained vigilance is not as clear cut. The most consistent findings are electrodermal results. Dardano (1962), Eason, et al. (1965), Ross et al. (1959), and Stern (1966) all found a decrement in conductance base level to be related, to some degree, to performance decrement.

Dardano's was a visual task where the subject was required to detect a sine wave .5 inch higher in amplitude than the background sine wave which was continually blinking on and off. The conductance level of the subjects showing least decrement decreased to 88% of its original level during the three hour task. The high decrement group, on the other hand, showed a 67% decrease in skin conductance. Eason, et al. (1965) also used a visual task. Here, the signal consisted of a light which stayed on for .8 seconds rather than the nonsignal duration of .5 seconds. Although only group data are reported, a significant base level decrement accompanied the group's performance decrement. Rate of signal presentation (240/2 hours vs. 60/2 hours) was found to be unrelated to either performance or physiological responsiveness.

Conductance levels were found to be more tenuously related to performance in the Ross et al. (1959) study. The subject was instructed to detect a double jump in a clock watching task while skin conductance readings were taken at five minute intervals. Results of a cluster analysis appeared to suggest a relationship between high basal conductance and better performance. The results were in the predicted direction, but statistically nonsignificant.

Stern (1966), too, found group trends of decreasing arousal as reflected in rising resistance base levels during a visual vigilance task. He also examined signal frequency where one group of subjects was exposed to 120 signals per hour and the other group to 60. The high frequency group detected a higher percentage of signals but had higher base resistance (lower arousal) than the infrequent signal group.

Heart rate and EMG were also investigated by both Stern and Eason *et al*. Neither found a change in heart rate over the vigil while EMG level results were inconsistent. Eason *et al*'s data revealed an overall increase in neck muscle tension while Stern's data showed differences for groups in frequent and infrequent signal conditions. The subjects who received frequent signals showed decreasing neck muscle tension while the infrequent signal group showed much greater variability with no clear cut trend.

Two other variables, skin potential response and EEG amplitude, have also been related to vigilance performance and appear to support an activation hypothesis. Skin potential work was done by Surwillo (1965). He found a larger number of spontaneous skin potential responses before detections of double jumps of a clock than before undetected jumps or missed signals. Frequent spontaneous responses are believed to accompany states of higher sympathetic activation.

The study dealing with EEG responses was performed by Haider et al. (1964) who utilized a visual task requiring the subject to detect dim light flashes that were interspersed among more numerous bright flashes. Their results revealed a decrease in amplitude of average visual cortical evoked responses that paralleled performance decrement. Since size or amplitude can be considered an indication of strength of response, or arousal level, the decreasing size would predictably parallel attention decrement according to the activation model.

Activation theory appears to be supported thus far in that conductance base level (excepting Stern), skin potential response frequency and EEG amplitude parallel performance measures. However, the heart rate stability in the face of other changing systems is difficult to explain in the activation framework. The conflicting EMG results, too, pose a difficult problem for either theory. Lacey's theory, on the other hand, would most likely predict the conductance results and could probably explain the heart rate data within his theoretical framework. A vigilance task could be viewed as what Lacey calls an 'intermediate stimulus' which involves both paying attention to incoming stimulation and the "internal manipulation of symbols and retrieval of stored information". The prediction of no significant heart rate change in a situation where response tendencies cancel each other out would be well supported.

The studies reveiwed so far have treated physiological activity as the dependent variable. A number of other studies have reversed the picture and have investigated performance on vigilance while manipulating sympathetic activity through the use of drugs. Generally, the results have favored an activation hypothesis in that increased arousal has generally improved performance by reducing or eliminating decrement while administration of sympathetic depressants have impaired performance (Callaway and Dembo, 1958; Callaway and Band, 1958; Mackworth, 1965; Bakan, 1961).

It is quite difficult to draw any hard or fast conclusions concerning arousal levels and vigilance performance from the work reviewed thus far. Procedural and methodological differences make any such comparisons quite tenuous. For example, although all the studies have used visual tasks, there were differences in the specific task utilized as well as in signal rate, intensity of signal, length of vigil and probably numerous other variables. Except for the Haider et al. (1964) study, all the main hypotheses under consideration were concerned with variables other than simply physiological measures of vigilance. Signal frequency, background noise and intensity were all examined in the above studies. In fact, in most studies reviewed here the physiological findings were secondary to other interests. The effects of other conditions such as differing signal presentation rate and background distraction could very possibly have had a confounding effect on the physiological observations.

It is also apparent that a limited number of measures have been utilized, base conductance being the most popular. The Haider et al. (1964) finding of decreasing EEG amplitude gives promising direction to a study of amplitudes in other systems such as electrodermal responses, particularly since 'tonic' and 'phasic' responses are believed to have different centers of control (Sokolov, cited in Graham and Clifton, 1965). If this is the case, GSR amplitude measures might provide some very interesting findings in an area of rather limited explorations.

One of the purposes of the present study is to more thoroughly examine the specific physiological concomitants of attention, or vigilance performance. Specifically, the role of arousal or autonomic activation will be examined in relation to vigilance performance. Substantial evidence from arousal theorists as well as from outside a theoretical framework suggest that arousal or physiological activation plays some part in the attention process. The specific relationship however is not clear for tasks that involve sustained attention.

This study is different from earlier work in that only one stimulus condition will be utilized so that the possibility of confounding variables will be reduced. The measures will also be expanded upon--heart rate as well as basal conductance, GSR magnitude and GSR amplitude will be examined. Hopefully, a clearer relationship between the physiological measures and vigilance performance will emerge.

Cognitive and Personality Measures

The Hidden Figures Test as well as the Stroop Color-Word Test have been used by investigators as measures of attention (Witkin *et al*., 1962; Karp, 1963). The Hidden

Figures Test requires the subject to specify which of five designs is "hidden" within a more complex geometric form. The form in which the figure is enclosed is very distracting so that good performance is thought to reflect the ability to overcome distraction (Witkin et al., 1962). Tests like the Hidden Figures have been found to load highly on attention and concentration factors (Karp, 1963).

The Stroop Color-Word Test also requires the subject to overcome a distracting context, but of a somewhat different nature. The test consists of three cards. The first is a card of color names which are printed in black letters on a white card (W-Card). The second card consists of rectangular blocks of colors (C-Card), while the third is composed of the color names which are printed in incongruous colors (CW-Card), e.g., the word BLUE is printed in red, the word YELLOW is printed in green. The subject's task is to read each card as fast as he can. The CW card is most difficult in that subjects are instructed to ignore the word and read only the color in which the word is printed. All subjects have some difficulty in doing this. A measure of the difficulty is computed by subtracting C-Card time from CW-Card time. This is known as the interference score; the higher the interference score, the more susceptible is the subject to distraction.

It has generally been found that performance on the Stroop Color-Word test is improved by high drive conditions (Agnew and Agnew, 1963) and by stimulant type drugs (Callaway, 1959). There is also evidence that depressants impair performance (Jenson and Rower, 1966). This line of evidence supports the activation hypothesis in that rising levels of sympathetic activation accompany better performance and vice versa.

In a somewhat different approach, Eysenck (1964) attributes differences in attention and arousal level to differing rates and degrees of cortical inhibition build-up in individuals. He claims that introverts build inhibition more slowly, to a lesser degree, and dissipate it more quickly. Extraverts, on the other hand, build up inhibition quickly, show high degrees of inhibition and dissipate it very slowly. As evidence for his theory, Eysenck cites the poorer performance of extraverts on tracking tasks in that they make more involuntary rest stops. These rest stops are due, he claims, to a slower dissipation of inhibition in extraverts. Extravert's performance on vigilance is also predicted to suffer for the same reason. Bakan, et al. (1963) found this to be the case. They found that extraverts had significantly greater decrement in an auditory vigilance task as compared to introverts.

The measures discussed up to this point, i.e., vigilance, physiological activity, the Hidden Figures Test, the Stroop Color-Word Test and the Eysenck Personality Inventory, all appear to share some basic similarities. The sustained attention measured by a vigilance test, for example, as well as the ability to overcome distraction on the Stroop Color-Word Test both seem to be aided to some degree by a higher level of autonomic activity. The personality traits of introversion-extraversion also seem to be related in part to physiological processes which are quite similar to those described as 'arousal', as well as to vigilance performance. These underlying physiological assumptions as well as the experimental evidence imply a relationship between arousal level and performance on these tests. It appears as though higher arousal levels improve performance in an activation type manner. The evidence also suggests common basic processes underlying sustained as well as short term attention processes. A greater understanding of the inter-relationships between these variables might further clarify the attention process and also provide evidence which might reveal sources of individual differences in attention. Hence, the second purpose of this study is to examine the inter-relationships of the physiological, personality, and cognitive measures that have been previously employed to study attention.

To summarize, the purposes of this study include:

1. The examination of the relationship between autonomic activation and performance on a sustained attention task.

2. The examination of the inter-relationships of physiological, personality and cognitive measures that have been previously employed to study attention.

The carry out these purposes, 31 male subjects took the following tests: a 48 minute auditory vigilance test during which time continuous heart rate and skin conductance recordings were made, the Hidden Figures Test, the Stroop Color-Word Test and the Eysenck Personality Inventory. Analyses of variance as well as correlational and factor analyses were performed on the resulting data.

METHOD

Subjects--Subjects were 31 male volunteers from an introductory psychology course. Their ages ranged from 18 to 21.

Apparatus--Zinc cup electrodes, 5/8 inch in diameter, were used for recording. Cotton pads soaked in a 1% zinc sulfate solution were placed within the cups and served as the electrolyte. GSR electrode placement was on the base of the left thumb and on the inside of the left forearm. Heart rate electrodes were placed on the right bicep and on the inside of the left ankle. The right forearm was the site of the ground electrode.

Response recording was made on a 2-channel Beckman Type RS Dynograph. GSR measures were fed into a Beckman Type 462 amplifier through a Beckman Type 9892A PGR coupler which utilizes a simple Wheatstone bridge circuit. A constant current of 2 microamperes was passed through the subject. Heart rate recording was done with a Beckman cardiotachometer coupler Type 9857 where heart rate in beats per minute was represented by output amplitude.

<u>Vigilance Task</u>--A copy of the vigilance tape used by Bakan *et al*. (1963) was employed. This tape is 64 minutes long and consists of digits which are spoken at the rate of one per second. The original tape was constructed by splicing so as to be uniform throughout. Each digit was recorded one time, played on an endless tape, and recorded to produce multiple recordings of the same digit. Pieces from these multiple recordings were spliced together to produce a tape in which the sound of any digit was constant throughout the tape.

This original tape was duplicated on a Viking 433 recorder. It was stereophonically recorded on one track while a tone was recorded on a second track at the onset of each signal. Although the tone was not audible to the subject, it served to close a sound activating switch which set off an event marker on the dynograph at the onset of each signal.

The tape began with a female voice saying, "The numbers will begin in 30 seconds", which was followed by 30 seconds of silence and then the presentation of the first number. The onset of the voice and the onset of the first number served as the two stimuli for initial OR measures.

The tape was played back through a Dyna SCA-35 Stereo Control Amplifier to Sharpe stereo earphones which were worn by the subjects.

Subjects were instructed to detect odd-even-odd combinations of digits that were all different and successive, e.g., 943, 725. The tape was divided into four periods of 16 minutes and there were ten signals, or odd-even-odd combinations, presented during each period. Although the task appeared continuous to the subject, there were actually four equivalent 16 minute periods, differing only in the specific signals to be detected. The distribution of signals over time was the same in each period, the time between signals being: 69, 152, 23, 181, 108, 102, 44, 13, 141 and 144 seconds.

Subjects were to press a button located in front of their right hand when they detected a signal. The button was a modified doorbell that was mounted on a wooden block for stability and convenience. It was connected to a second marker pen on the dynograph so that each detection response was recorded on the paper alongside the actual physiological responses. Consequently each subject's record consisted of continuous recordings of skin resistance, heart rate, detection responses, and critical detection points or signals. The paper speed was set at 1 mm/sec.

Procedure--Subjects were tested individually. Each subject was administered the Hidden Figures Test followed by the Stroop Color-Word Test. Upon completion of these tests, the subject was led to the experimental room where the electrodes were attached. Subjects were asked to remove their watches and place them in their pockets. The experimental room was adjacent to the room where the recording was done, so the subject was alone during the entire task. Care was taken to make the room as free from distracting stimuli as possible. A fan was used to mask noises from the relay and other sources.

While attaching the electrodes, the E explained what the electrodes were and briefly informed the subject what responses were to be recorded. When electrode placement was complete the subject was asked to read instructions for the vigilance task. The last page of instructions consisted of a practice set where the subject looked at a series of digits and was told to write down the appropriate odd-even-odd combinations. When the subject appeared to have completed the visual practice set, the E asked if he had any questions. If the subject had no questions the following instructions were read to the subject:

> The first part of this task is a practice period followed by a short rest. During the rest period you will be allowed to stretch and move around if you like. However, try to remain as still as possible while the practice and the actual test are going on. The electrodes, particularly those on the left side, are very sensitive to movement. So please try to keep movement, other than pressing the button, at a minimum. Get comfortable before the experiment begins. The actual test will follow the rest period. It will be identical in nature to the practice.

Earphones were placed on the subject and the E left the experimental room and took her place in the recording room. The dynograph was turned on and if all appeared to be in working order, the tape was begun. After the first 16 minute period, the recording apparatus and tape were turned off and the earphones taken off the subject. He was told the practice period was over and' asked if he had any questions. If there were no questions, he was given about five minutes to stretch and relax before resuming the task. The subject was not given specific knowledge of results, although he was told whether his performance was adequate or not. Subjects who responded very often or did not respond at all during the practice were asked to verbally repeat the instructions.

If the instructions were repeated correctly nothing more was said concerning the subject's performance. If however, the subject's report of the directions was inaccurate, the E would explain the procedure once again. This was found necessary in about five cases. Each subject was also offered a glass of water during the rest period.

After the rest period, the earphones were replaced and recording resumed as in the practice period, but for 48 minutes instead of 16. Continuous recordings of skin resistance and heart rate were made during this time as well as during the practice.

At the end of the 48 minutes, the earphones and electrodes were removed and the Eysenck Personality Inventory was administered. When the subject completed the test, the following questions were asked:

> What is your age?
> Are you taking any drugs?
> How much sleep did you get last night?
> Do you smoke? How much?
> How long would you estimate the numbers task took, from the end of the rest period on?

No subject admitted to taking any drugs for at least two weeks prior to the experimental session. The subject was then asked not to tell other members of his class what went on in the experiment so as to maintain the näiveté of other potential subjects.

The E showed the subject his physiological record and explained in more detail the significance of the various responses. This explanation was of an extremely general nature intending to simply familiarize the subject with psychophysiological recordings and also to alleviate any undesirable emotional effects of the experimental situation. The experimenter felt this procedure desirable as a number of students were obviously annoyed upon completion of the vigilance test.

Scoring--The Hidden Figures Test was scored in two ways: total number correct and per cent correct of those answered. The per cent correct score was found desirable in that subjects varied widely in the number of items attempted.

Three scores were obtained for the Stroop Color-Word Test: Color Card reading time, Color-Word Card reading time and an interference score. Interference was the difference between Color-Word reading time and Color reading time. The higher this score, the more interference in reading the Color-Word Card.

The Eysenck Personality Inventory yielded three scores: Extraversion, Neuroticism, and Lie. These tests were scored in the manner advised in the test manual (Eysenck and Eysenck, 1963).

Number of correct detections for each period constituted the vigilance score. An upper limit of five seconds was placed on response latency; responses made later than five seconds after signal cessation were not counted.

Conductance base level and GSR amplitude were computed at each detection point. Any response was scored if it began from one to six seconds after signal cessation. These resistance scores were then transformed into log conductance units. The transformation used was a modification of the Haggard method (1945) and is explained in detail by Raskin (in press).

Conductance base level, GSR magnitude, and GSR amplitude scores were averaged for each 16 minute vigilance period for each subject. In addition, the overall mean GSR magnitude and GSR amplitude for the entire test were computed for each subject. GSR magnitude scores are response measures that incorporate zero entries for trials on which there is no response, i.e., if there is no response, a score of zero is averaged with the changes recorded on othr trials. Amplitude scores are also response measures, however, zero responses are not incorporated; it is a measure of GSR size given that a response occurred (Prokasy, 1967).

Basal heart rate was computed for each subject by averaging the first three beats following signal onset at each detection point during the test periods. The scored beats always occurred prior to signal completion. This resulted in 30 scores for each subject. Mean basal heart rate for each period, as well as the mean basal heart rate for the entire test, were computed from these scores. The actual quantification of the machine output was accomplished by determining the amplitude of each response to the tenth of a millimeter. The amplitude of a response is a measure of heart rate in beats per minute. Figure 1 is a graphic explanation of the scoring method.

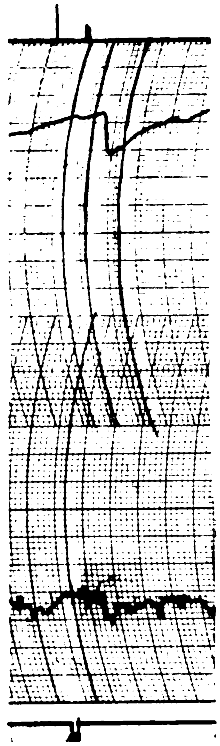

Figure 1. A sample record during signal presentation.

Paper speed was set at 1 mm/sec.

The pen deflection in the top margin signifies the subject's detection response. The penciled mark to the left of the detection response marks the onset of the signal. Consequently, the subject in this example responded 5 seconds after signal onset.

The GSR channel is pictured with the response interval marked. The area between 0-4 is counted as signal onset. Any response which began in the 4-10 second interval, or 4-10 seconds after signal onset, was scored as a GSR response.

Base level and peaks were scored by measuring the distance in mm from the top margin line to (B) the point at which the line first turned in a downward (-) direction, and the distance in mm from the top margin line to the point (P) at which the line changed direction again. This time in an upward direction (+) or to a slope of 0 (flat).

The marked line in the heart rate channel signifies signal onset. The three beats following signal onset were averaged at each detection point. The three beats in this example are marked by arrows. The scored beats always occurred prior to signal completion. Each beat was scored by measuring the distance in mm from the botton margin line to the extreme left-hand corner of each beat.

The pen deflection in the botton margin signifies signal onset.

Analysis--Analysis of the data included a correlation matrix of 40 variables and factor analysis as well as several analyses of variance which were computed on the conductance and heart rate data.

The correlation matrix included the following variables:

1. _Per cent correct on Hidden Figures_ (_%HF_) is the per cent correct of those attempted on the Hidden Figures Test.

2. _Hidden Figures Score_ (_HF_) is the total number of items answered correctly on the Hidden Figures Test.

3. _Stroop Interference Score_ (_Stroop Interf._) is calculated by subtracting subject's time in reading the Color Card from the time taken to read the Color-Word Card. The resulting difference is thought to indicate word interference, or difficulty in attending to the colors and ignoring the words. High interference scores are thought to be an indication of greater susceptibility to distraction.

4. _Extraversion Score_ (_Ex._). A high score on the Eysenck Personality Inventory Extraversion Scale indicates high extraversion.

5. Neuroticism Score (*N*). A high score on the Eysenck Personality Inventory Neuroticism Scale indicates high neuroticism.

6. Lie Scale Score (*L*). A high score on the Eysenck Personality Lie Scale indicates a high number of items reflecting dishonesty were answered.

7. V1 is the total number of correct detections made during the first vigilance test period. This is actually the second 16 minutes of vigilance, the first 16 minutes being considered the practice period (VP).

8. V2 is the total number of correct detections made during the second vigilance test period.

9. V3 is the total number of correct detections made during vigilance period 3, or the third test period.

10. Absolute Change V3-1 (V3-1) is a difference score computed by subtracting the number of detections made in period 1 (first test period) from those made in period 3 (last test period). Positive difference scores indicate an increment in detections over time whereas negative scores indicate a decrement in detections over time. For example, a subject who detected 8 signals in period 1 (V1) and 2 signals in period 3 (V3) would have a difference score of -6, i.e., he shows a decrement in

the number of signals detected from period 1 to 3. An increment in detections over time would be exemplified by a subject who detected 2 signals in period 1 and 8 signals in period 3. His score would be +6.

11. Total Vigilance Score (Tot. V) is the total number of detections for the three test periods, V1, V2, V3.

12. OR1 is the initial GSR response amplitude to the voice on the tape which occurred prior to the vigilance practice period.

13. OR2 is the initial GSR response amplitude to the first number on the tape which occurred 30 seconds after the voice and marked the beginning of the vigilance practice period (VP).

14. Commission Errors (CE) result from the subject responding in the absence of a signal.

15. $\bar{X}$ Mag V1 is the mean GSR magnitude for the first 16 minute test period, or V1. This score was computed by taking the mean of the response amplitudes at each detection point for the first test period. Since magnitude scores incorporate zero entries for trials on which there is no response, a score of zero was averaged with the changes recorded at other points when a response did not occur.

16. <u>$\bar{X}$ Mag V2</u> is the mean GSR magnitude for the second 16 minute test period, or V2. This score was computed by taking the mean of the response amplitudes at each detection point for the second test period. Since magnitude scores incorporate zero entries for trials on which there is no response, a score of zero was averaged with the changes recorded at other points when a response did not occur.

17. <u>$\bar{X}$ Mag V3</u> is the mean GSR magnitude for the third 16 minute test period, or V3. This score was computed by taking the mean of the response amplitudes at each detection point for the third test period. Since magnitude scores incorpprate zero entries for trials on which there is no response, a score of zero was averaged with the changes recorded at other points when a response did not occur.

18. <u>Absolute Change $\bar{X}$ Mag V3-1</u> (<u>$\bar{X}$ Mag3-1</u>) is a difference score computed by subtracting the mean GSR magnitude of period 1 (first test period) from the mean magnitude of period 3 (last test period). Positive difference scores indicate an increment in magnitude from period 1 to 3 whereas negative scores indicate a decrement in magnitude from period 1 to 3. For example, a subject

whose mean GSR magnitude in period 1 was 1.000 log conductance units and 0.500 in period 3 would have a difference score of -.500 log conductance units, i.e., he shows a decrement in GSR magnitude from period 1 to 3. An increment in GSR magnitude over time would be exemplified by a subject who had a mean GSR magnitude of .500 log conductance units in period 1 and 1.000 in period 3. His score would be +.500.

19. $\bar{X}$ LBC V1 is the mean log base conductance for the first 16 minute test period, or V1. The basal conductance level was determined at each detection point and averaged for the first test period.

20. $\bar{X}$ LBC V2 is the mean log base conductance for the second 16 minute test period, or V2. The basal conductance level was determined at each detection point and averaged for the second test period.

21. $\bar{X}$ LBC V3 is the mean log base conductance for the third test period, or V3. The basal conductance level was determined at each detection point and averaged for the third test period.

22. Absolute Change $\bar{X}$ LBC V3-1 ($\bar{X}$ LBC3-1) is a difference score computed by subtracting the mean log base conductance of period 1 (first test period) from the

mean conductance of period 3 (last test period). Positive difference scores indicate an increment in base conductance from period 1 to 3 whereas negative scores indicate a decrement in conductance from period 1 to 3. For example, a subject who had a mean base conductance of 2.500 log units in period 1 and 2.000 in period 3 would have a difference score of -.500, i.e., he shows a decrement in log base conductance from the first to the third period. An increment in basal conductance over time would be exemplified by a subject who had a mean base conductance of 2.000 in period 1 and 2.500 in period 3. His score would be +.500.

23. Absolute Change $\bar{X}$ Mag V3-2 ($\bar{X}$ Mag3-2) is a difference score computed by subtracting the mean GSR magnitude of period 2 (second test period) from the mean magnitude of period 3 (last test period). Positive difference scores indicate an increment in magnitude from period 2 to 3 whereas negative scores indicate a decrement in magnitude from period 2 to 3. For example, a subject whose mean GSR magnitude in period 2 was 1.000 log conductance units and 0.500 in period 3 would have a difference score of -.500 units, i.e., he shows a decrement

in GSR magnitude from the second to third periods. An increment in GSR magnitude would be exemplified by a subject who had a mean GSR magnitude of .500 units in period 2 and a magnitude of 1.000 log units in period 3. His score would be +.500.

24. Absolute Change $\bar{X}$ V3-2 ($\bar{X}$ V3-2) is a difference score computed by subtracting the number of detections made in period 2 (second test period) from those made in period 3 (last test period). Positive difference scores indicate an increment in detections from period 2 to 3 whereas negative scores indicate a decrement in detections from period 2 to 3. For example, a subject who detected 8 signals in period 2, and 2 signals in period 3 would have a difference score of -6, i.e., he shows a decrement in the number of signals detected from period 2 to 3. An increment in detections over time would be exemplified by a subject who detected 2 signals in period 2 and 8 signals in period 3. His score would be +6.

25. C-Card score is the reading time in seconds of the Stroop Color-Card.

26. CW-Card score is the reading time in seconds of the Stroop Color-Word Card.

27. Time. This is the subject's estimate of how long the vigilance task took.

28. Smoke. The subject was scored on smoking if he admitted to smoking ½ pack of cigarettes per day or more. The scoring here was discrete: 1=smoker, 0=non-smoker.

29. Coffee. The subject was scored as a coffee drinker if he admitted to drinking one cup of coffee per day or more. Scoring here was discrete: 1=coffee drinker, 0=non-coffee drinker.

30. $\bar{X}$ Amp V1 is the mean GSR amplitude for the first 16 minute vigilance test period, or V1. This score was computed by averaging the response size at each detection point in the period, given that a response occurred. No zero responses were incorporated.

31. $\bar{X}$ Amp V2 is the mean GSR amplitude for the second 16 minute vigilance test period, or V2. This score was computed by averaging the response size at each detection point in the period, given that a response occurred. No zero responses were incorporated.

32. $\bar{X}$ Amp V3 is the mean GSR amplitude for the third 16 minute vigilance test period, or V3. This score

was computed by averaging the response size at each detection point in the period, given that a response occurred. No zero responses were incorporated.

33. <u>% Change Amp 3</u> is the per cent change in GSR amplitude from vigilance periods 1 to 3, or the first and last test periods. The per cent change scores were computed by dividing the mean GSR amplitude in period 3 by the mean GSR amplitude in period 1. Scores under 100% indicate a decrement. For example, a subject whose mean GSR amplitude was 10.000 log conductance units in the first test period (V1) and 5.000 units in period 3, or the last test period would have a % Change score of 50%. This subject showed a decrease in GSR amplitude from the first to last test period. An increment in GSR amplitude, or scores over 100%, would be exemplifed by a subject whose mean GSR amplitude was 5.000 units in period 1 and 10.000 in period 3. His % Change score would be 200%.

34. <u>% Change Amp 2</u> is the per cent change in GSR amplitude from periods 2 to 3, or the second and third test periods. The per cent change scores were computed by dividing the mean GSR amplitude in period 3 by the mean GSR amplitude in period 2. Scores under 100% indicate a

decrement. For example, a subject whose mean GSR amplitude was 10.000 log units in V2 (second test period) and 5.000 in V3 (last test period), would have a % Change score of 50%. This subject showed a decrease in GSR amplitude from the second to third test period. An increment in GSR amplitude, or a score over 100% would be exemplified by a subject whose mean GSR amplitude was 5.000 log units in period 2 and 10.000 units in period 3. His % Change score would be 200%.

35. Absolute Change $\bar{X}$ Amp V3-1 ($\bar{X}$ Amp V3-1) is the difference score computed by subtracting the mean GSR amplitude of period 1 (first test period) from the mean GSR amplitude of period 3 (last test period). Positive difference scores indicate an increment in amplitude from period 1 to 3 whereas negative scores indicate a decrement in amplitude from period 1 to 3. For example, a subject whose mean GSR amplitude in period 1 was 10.000 log conductance units and 5.000 in period 3 would have a difference score of -5.000 log units, i.e., he shows a decrement in GSR amplitude from period 1 to 3. An increment in GSR amplitude over time would be exemplified by a subject who had a mean GSR amplitude of 5.000 log units in period 1 and of 10.000 units in period 3. His score would be +5.000.

36. % Change LBC 3 is the per cent change in log base conductance from vigilance periods 1 to 3, or the first and last test periods. The per cent change scores were computed by dividing the mean log base conductance in period 3 by the mean log base conductance in period 1. Scores under 100% indicate a decrement. For example, a subject whose mean LBC was 2.500 in V1 (first test period) and 2.000 in V3 (last test period), would have a per cent change score of 80%. This subject showed a decrease in basal conductance from the first to the last test period. An increment in conductance, or scores over 100%, would be exemplified by a subject whose mean conductance was 2.000 in period 1 and 2.500 in period 3. His % Change score would be 125%.

37. % Change LBC 2 is the per cent change in log base conductance from periods 2 to 3, or the second and third test periods. The per cent change scores were computed by dividing the mean base conductance in period 3 by the mean LBC in period 2. Scores under 100% indicate a decrement while scores over 100% signify an increment in basal conductance. (For an example, see variable #36).

38. Overall Mean Magnitude ($\bar{X}$ Mag) is the mean GSR magnitude computed from all three test periods, V1, V2, V3.

39. <u>Overall Mean Base Level</u> ($\bar{X}$ LBC) is the mean log base conductance computed from all three test periods, V1, V2, V3.

40. <u>Overall Mean Amplitude</u> ($\bar{X}$ Amp) is the mean GSR amplitude computed from all three test periods,V1, V2, V3.

RESULTS

Physiological and Analysis of Variance Results

Overall test period means for base level, GSR magnitude and GSR amplitude were found to correlate highly with each of their respective period means. These correlations all exceeded .94. Due to these high inter-correlations within the physiological measures, only the overall mean for the three test periods for each variable will be utilized in further analyses. Similarly, only the OR to the first number (OR2) will be referred to as the correlation of the OR to the voice and the OR to the first number was .85 ($p<.01$).

In order to determine how physiological differences relate to detection performance, several analyses of variance were performed. In these analyses, subjects were divided into high and low groups for each of the physiological measures. This resulted in high and low GSR magnitude, high and low GSR amplitude, as well as high and low heart rate groups. The group divisions were obtained from distributions of each subject's overall mean score for each variable. The median was calculated and served as the division point. Those subjects who scored above the median were designated as the 'high' group for that variable, while those falling below the distribution median were considered part of the 'low' group. Thus, the mean physiological scores served as independent variables while detections over trials served as the dependent variables.

The trends of subjects divided into high and low groups on the basis of basal heart rate which was averaged during the actual test are shown in figure 2. High heart rate subjects start off detecting fewer signals than do the low groups and show a decrement during the second 16 minute test period but come back during the last period to a rate of signal detection which is slightly higher than their initial level. Low heart rate subjects, on the other hand, initially detect more signals but exhibit a consistent decremental trend for the last two periods. The interaction, groups x test periods, was found to be significant, $F(2,48)=3.66$, $p<.05$. (See table 1)

A similar difference was obtained when subjects were divided into high and low groups on the basis of their mean basal heart rate during the practice period.

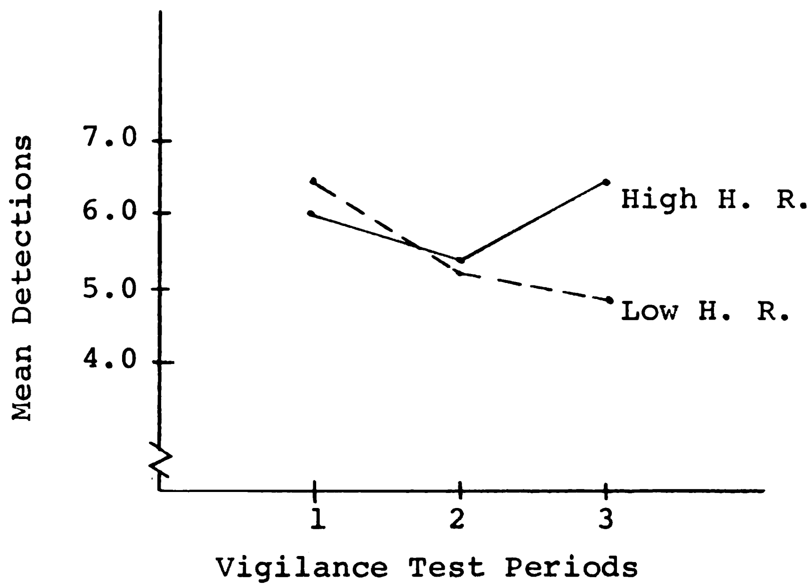

Figure 2.--Mean vigilance detections as a function of test periods for high and low basal heart rate groups where basal heart rate was averaged for the three test periods, VI, V2, V3.

Table 1. Summary of the analysis of variance of detections as a function of test periods for high and low basal heart rate groups where basal heart rate was averaged for the three test periods, V1, V2, V3.

Source	SS	df	MS	F
Groups (G)	3.71	1	3.71	-
Error (S's(G))	265.95	24	11.08	
Test Periods (T)	11.49	2	5.75	2.95
G X T	14.26	2	7.13	3.66*
Error (S's(G) X T)	93.62	48	1.95	
Total	389.03	77		

*$p < .05$

Unfortunately, four subject's records were not scorable during the practice period as the heart rate channel was turned off for the initial 16 minutes. Figure 3 shows the curves for the two groups where the N=22. It is very similar to figure 2 except that high heart rate subjects detect more signals than the low group in the initial test period. Again, the high group shows some decrement in period 2, but exceeds the initial performance level in period 3. Low heart rate subjects show a consistent decrement in detections over the three test periods. The interaction again, groups x test periods, was found to be significant, $F(2,40)=10.11$, $p<.01$. (See table 2)

Although not statistically significant, trends in a similar direction were obtained with GSR amplitude and GSR magnitude groups. Figure 4 depicts the high and low GSR magnitude groups. High magnitude subjects appear to detect a greater number of signals consistently over time and show no decrement. The low magnitude subjects, on the other hand, start off detecting fewer signals and show a sharp drop in the number of signals detected after the first test period. The low subjects never recover from this drop. The ANOV revealed differences between groups,

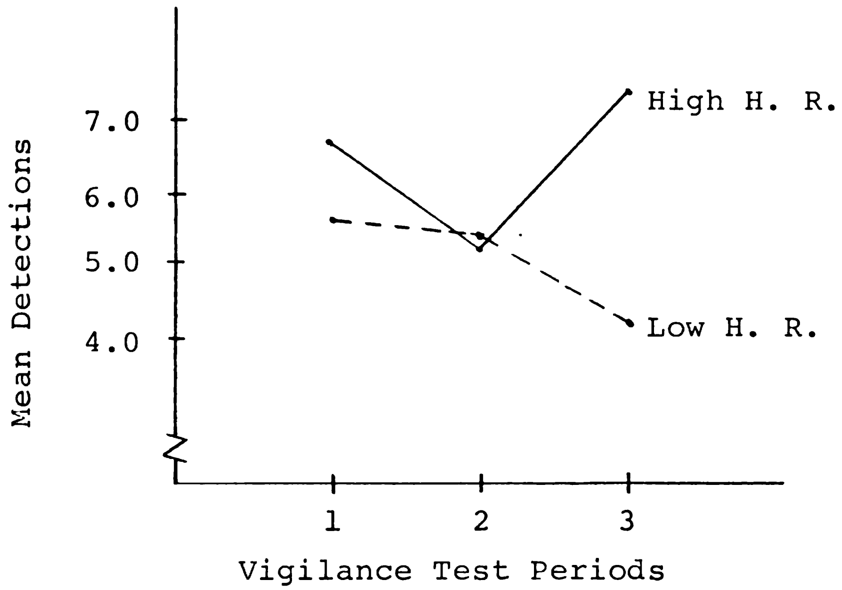

Figure 3.--Mean vigilance detections as a function of test periods for high and low basal heart rate groups where basal heart rate was averaged for the practice period, VP.

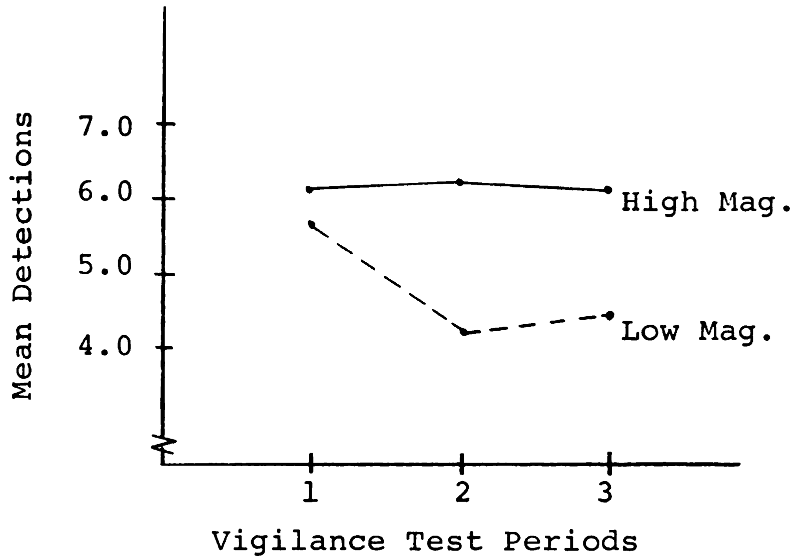

Figure 4.--Mean vigilance detections as a function of test periods for high and low GSR magnitude groups.

Table 2. Summary of the analysis of variance of detections as a function of test periods for high and low basal heart rate groups where basal heart rate was averaged for the practice period, VP.

Source	SS	df	MS	F
Groups (G)	29.34	1	29.34	2.77
Error (S's(G))	211.94	20	10.60	
Test Periods (T)	7.39	2	3.70	2.50
G X T	29.94	2	14.97	10.11***
Error (S's(G) X T)	59.37	40	1.48	
Total	337.98	65		

***$p < .01$

Table 3. Summary of the analysis of variance of detections as a function of test periods for high and low GSR magnitude groups.

Source	SS	df	MS	F
Groups (G)	40.00	1	40.00	3.69#
Error (S's(G))	303.15	28	10.83	
Test Periods (T)	8.96	2	4.48	2.50#
G X T	10.07	2	5.04	2.82#
Error (S's(G) X T)	100.32	56	1.79	
Total	462.50	89		

#$p < .10$

$F(1,28)=3.69$, $p<.10$, over test periods, $F(2,56)=2.50$, $p<.10$, and an interaction between groups and test periods, $F(2,56)=2.82$, $p<.10$. Table 3 summarizes these results.

Figure 5 depicts the detection trends of high and low GSR amplitude subjects. High amplitude subjects start off at a lower rate of detection than do the low amplitude subjects, however they maintain this rate throughout the task. Low amplitude subjects, on the other hand, initially detect more signals, but show a large decrement after the first 16 minute test period from which they nevery fully recover. In this analysis, the groups x test period interaction revealed differences, $F(2,56)=2.57$, $p<.10$. (See table 4)

An additional finding was that high amplitude subjects responded more frequently at detection points whether they detected the signal or not. These curves are shown in figure 6. High amplitude subjects gave more detectible GSR responses during a greater number of signal presentations than did the low amplitude subjects. These responses increased in number during the second test period and decreased slightly during the third period. The low group, on the other hand, showed a slight decrease in response frequency from period 1 to 2 and an increase from

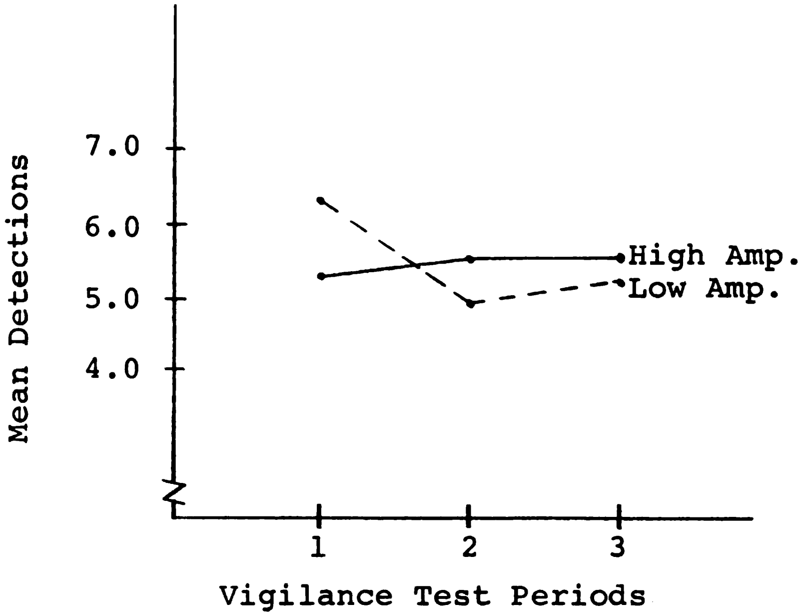

Figure 5.--Mean vigilance detections as a function of test periods for high and low GSR amplitude groups.

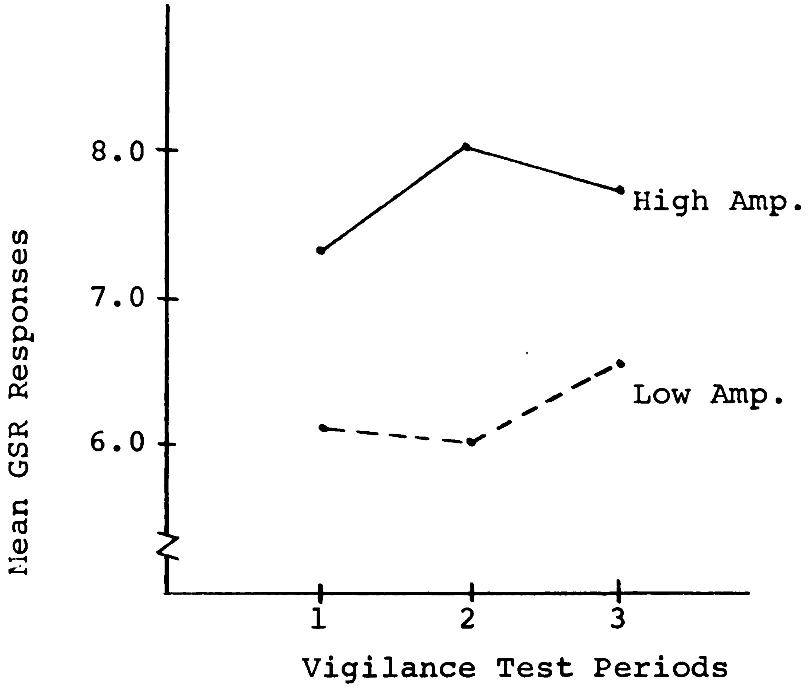

Figure 6.--Mean GSR responses as a function of vigilance periods for high and low GSR amplitude groups.

Table 4. Summary of the analysis of variance of detections as a function of test periods for high and low GSR amplitude groups.

Source	SS	df	MS	F
Groups (G)	0.00	1	0.00	-
Error (S's(G))	325.56	28	11.63	
Test Periods (T)^{S}	5.95	2	2.98	-
G X T	10.45	2	5.26	2.57#
Error (S's(G) X T)	114.54	56	2.05	
Total	460.77	89		

#p<.10

Table 5. Summary of the analysis of variance of mean GSR responses as a function of vigilance periods for high and low GSR amplitude groups.

Source	SS	df	MS	F
Groups (G)	48.45	1	48.45	6.13**
Error (S's(G))	221.37	28	7.91	
Test Periods (T)	2.50	2	1.25	-
G X T	3.20	2	1.60	-
Error (S's(G) X T)	107.13	56	1.91	
Total	382.65	89		

**p<.025

period 1 to 2 and an increase from period 2 to 3. The group effect was found to be significant, $F(1,28)=6.13$, $p<.025$. (See table 5)

Correlation Results

Detection Correlates--Detections for the three test periods, V1, V2, V3, all correlated significantly with total detections ($r=.87$, $.87$, $.85$, $p<.01$).

Mean GSR magnitude and total detections were significantly related ($r=.44$, $p<.05$); high detection scores are reliably accompanied by high GSR magnitudes. Vigilance decrement, or a decrease in detections over time, was positively related to a decrease in GSR magnitude over time ($r=.45$, $p<.05$). No such trend was found for change in base conductance or GSR amplitude change.

Per cent correct of those attempted on the Hidden Figures Test correlated significantly with total vigilance detections ($r=-.41$, $p<.05$). The negative correlation indicates that a higher per cent correct of those attempted on the test related to lower detection scores. These results are quite puzzeling and appear to lack a logical explanation.

Subject's time estimates are also related to vigilance performance ($r=-.37$). A negative correlation with total vigilance indicates that good vigilance performance is related to a low time estimate.

Detection decrement was found to be reliably related to neuroticism score and coffee drinking. High scoring neurotics show little decrement over time ($r=.50$, $p<.01$), while coffee drinkers are apparently more susceptible to detection decrement ($r=-.39$, $p<.05$).

Correlations Between the Physiological Measures--The GSR and conductance measures were found to be highly interrelated. Correlations between magnitude and base level ($r=.73$), magnitude and amplitude ($r=.92$), and base level and amplitude ($r=.72$) were all significant beyond the .01 level. The correlations between OR and base level ($r=.39$, $p<.05$), OR and magnitude ($r=.55$, $p<.01$), as well as OR and amplitude ($r=.59$, $p<.01$) were also found to be significant.

Changes over time between the GSR and conductance measures were also significantly related. Difference scores computed from period 1 to 3 resulted in significant correlations between base conductance and GSR magnitude ($r=.58$, $p<.01$), magnitude and amplitude ($r=.45$, $p<.05$), as well as base level and amplitude ($r=.63$, $p<.01$).

The relationship between heart rate and the other physiological variables is not reported as complete heart rate records were obtained from only 26 of the subjects. Mechanical difficulties and artifacts made it impossible to obtain scorable records from the others. As a result, heart rate was not included in the correlation matrix to avoid a further reduction of the N.

Miscellaneous Correlations--Number of commission errors are sizably and also significantly related to the conductance and GSR measures. Correlations with initial OR ($r=-.40$, $p<.05$) and GSR amplitude ($r=-.50$, $p<.05$) are both significant. Nonsignificant, but sizable correlations include commission errors and GSR magnitude ($r=-.31$) as well as commission errors and base conductance ($r=-.32$). These correlations suggest that subjects who make a large number of commission errors also show lower physiological responsiveness in terms of GSR magnitude, amplitude, and base conductance as well as initial OR amplitude. Other sizable, but nonsignificant correlations include commission errors and Stroop interference ($r=.34$), commission errors and per cent correct on Hidden Figures ($r=.34$), and commission errors and extraversion ($r=.35$).

Stroop interference correlated significantly with CW-Card reading time ($r=.90$, $p<.01$) but nonsignificantly with C-Card reading time ($r=.29$). A significant correlation between C and CW-Card reading time was obtained ($r=.65$, $p<.01$). Apparently reading times on the two cards are reliably related, but the interference score is mainly attributable to CW-Card reading time. High Hidden Figures scores relate significantly to lower reading times on the C and CW-Cards ($r=-.43$ and $-.40$, $p<.05$). High scorers on neuroticism, on the other hand, appear to take longer to read the cards ($r=.42$, $p<.05$).

Coffee drinkers show a significantly lower OR to the first number ($r=-.41$, $p<.05$) and consistently lower, although not significantly, GSR amplitudes ($r=-.34$). Smokers, on the other hand, exhibit a higher OR to the voice ($r=.40$, $p<.05$) and give reliably greater time estimates ($r=.46, p<.01$).

High time estimators show an increase or positive change in GSR amplitude over time ($r=.46$, $p<.01$).

Factor Analysis

The factor analysis is presented in table 6. Three main factors emerged from a quartimax rotation which respec-

Table 6. Factor analysis

	Variable	I	II	III
1.	%HF	.398	-.034	.558
2.	HF	-.059	-.298	.209
3.	Stroop Interf.	-.255	.308	.016
4.	Ex	-.112	-.213	.008
5.	N	-.031	.125	.189
6.	L	.131	.466	.311
7.	V1	.038	.042	-.825
8.	V2	.274	-.090	-.876
9.	V3	.235	.157	-.679
10.	V3-1	.235	.139	.081
11.	Tot. V	.212	.046	-.910
12.	OR1	.711	-.287	.091
13.	OR2	.647	-.344	.070
14.	CE	-.480	.023	-.358
15.	$\bar{X}$ Mag V1	.861	-.301	-.264
16.	$\bar{X}$ Mag V2	.851	-.149	-.391
17.	$\bar{X}$ Mag V3	.904	.087	-.222
18.	$\bar{X}$ Mag V3-1	.056	.717	.083
19.	$\bar{X}$ LBC V1	.852	-.065	-.090
20.	$\bar{X}$ LBC V2	.861	.144	-.129
21.	$\bar{X}$ LBC V3	.823	.306	-.165
22.	$\bar{X}$ LBC V3-1	-.101	.796	-.157
23.	$\bar{X}$ Mag V3-2	-.033	.479	.389
24.	V3-2	-.019	.283	.148
25.	C-Card	.274	.179	.068
26.	CW-Card	-.050	.275	.014
27.	Time	-.022	.287	.454
28.	Smoke	.111	-.139	-.206
29.	Coffee	-.404	-.118	-.133
30.	$\bar{X}$ Amp V1	.916	-.316	-.072
31.	$\bar{X}$ Amp V2	.862	-.142	-.176
32.	$\bar{X}$ Amp V3	.933	.063	.088
33.	% Chg Amp V3	-.182	.713	.180
34.	% Chg Amp V2	-.365	.304	-.220
35.	$\bar{X}$ Amp V3-1	-.041	.804	.339
36.	% Chg LBC V3	-.191	.795	-.284
37.	% Chg LBC V2	-.126	.620	-.275
38.	$\bar{X}$ Mag	.910	-.128	-.308
39.	$\bar{X}$ LBC	.862	.130	-.130
40.	$\bar{X}$ Amp	.940	-.139	-.059

tively account for .286, .127 and .117 proportions of the variance. Factor 1 appears to be a physiological factor as high loadings include OR1, OR2, GSR magnitudes V1, V2, V3, base conductance V1, V2, V3, GSR amplitudes V1, V2, V3, as well as overall mean GSR magnitude, amplitude and base conductance. Contributing to a lesser extent are commission errors, coffee drinking and per cent correct on Hidden Figures.

Factor 2 has the highest loadings on the change variables: GSR magnitude, GSR amplitude and base conductance change over time. Factor 3 is apparently a detection factor with the highest loadings on detection scores for the three periods as well as for total detections. Contributing is also Hidden Figures, GSR magnitude V2, and magnitude change from periods 2 to 3.

DISCUSSION

Physiological Results and Activation Theory

Activation theory contends that a certain amount of tonic background physiological activity is required for an organism to sustain attention. The intensive aspect of this physiological activity presumably correlates with adequacy of performance. Other work in this area has shown that physiological gradients in some subsystems do appear to rise during tasks involving attention, supporting activation theory in part. When drugs have been used to artificially lower or raise the arousal level of subjects it has been generally found to affect performance in the predicted direction, i.e., highly aroused subjects generally are superior to less highly aroused subjects in that they show less decrement. It follows from this that in the context of the activation hypothesis, subject's natural differences in arousal level should also affect attention performance with physiological active subjects performing better than less active subjects.

The ANOV data appear to support this position in part. Subjects who exhibited a high mean heart rate during the vigilance test were characterized by a lack of detection decrement from the first to last test period. In fact, performance in the last period was slightly superior to the initial performance. Although low heart rate subjects had a higher mean detection score during the first period, they dropped steadily in detections from period 1 to 3.

When subjects were divided into high and low groups on the basis of their mean basal heart rate during the practice period, the high group again showed no first to last period decrement while the low group's detection performance steadily declined from period 1 to 3. These practice period heart rate group results are quite impressive in view of the fact that there was always a time span of at least five minutes between the practice period and the test. In other words, the practice period measure on which subjects were divided was temporally independent of the actual test.

Although not statistically significant, the electrodermal measures also went in the same direction. High GSR magnitude and high GSR amplitude subjects showed consistent performance throughout the task; neither high group exhibited any performance decrement. The performance of the low electrodermal response groups, however, showed a drop in detections in the second 16 minutes of vigilance from which they never fully recovered. It is interesting to note that in spite of the decremental trend, low GSR amplitude subjects have a higher initial mean detection rate than do the high GSR amplitude subjects. These results are similar to the high and low heart rate groups that were divided on the basis of heart rate during the test period.

Generally, then it appears as though the heart rate and conductance data point to physiological processes for at least a partial explanation of the decremental trends. More highly aroused subjects, in terms of heart rate and electrodermal measures, show less decrement than do less highly aroused subjects. This pattern of performance being related to an intensive aspect of physiological activity is in strong support of the activation hypothesis. It is similar to Dardano's findings (1962). He found a greater decrease in basal skin conductance with subjects who showed greatest detection decrement while low decrement subjects had a significantly less decrease in conductance level. Consistent with the above is work done with drugs. When drugs are used to artificially raise or lower the arousal level, the decremental function is affected rather than total detection performance (Mackworth, 1965).

It is also interesting to note that Bakan et al. (1966) found similar decremental trends using extreme groups of extraverts and introverts. Eysenck's assumptions concerning the constitutional basis of these personality traits suggest that introverts are physiologically more active than are extraverts. In the Bakan et al. study introverts did, in fact, show significantly less decrement than the extraverts. These results were not obtained in the present study possibly because extreme groups were not used. The similarity of results, however, is quite suggestive and lends itself to further research.

The relationship between the conductance and GSR measures was quite interesting. High correlations were found between basal conductance and GSR amplitude which implies that phasic and tonic activity are highly related during a vigilance task. Further, it was found that high amplitude subjects also respond significantly more often at detection points irrespective of signal detection. The inter-relationships of these electrodermal measures is particularly interesting in view of the relative independence exhibited by the various measures during parametric studies.

Detections and Other Variables

The results indicate that high GSR magnitude is reliably related to better vigilance performance. The meaningfulness of this relationship, however, is open to question since magnitude is a measure of both response size and response frequency. Mean magnitude scores incorporate zero entries for trials on which there is no response, i.e., if there is no response, a score of zero is averaged with the changes recorded on other trials. Consequently subjects who miss many signals would have fewer GSR's and hence, more zeros incorporated into their magnitude scores. A low detector would, by definition, have a low magnitude score. The reverse holds true for high detectors. Therefore the meaningfulness of the relationship between detections and GSR magnitude should be evaluated in light of the possible confounding of the two variables.

Disappointingly few other variables were found to correlate with vigilance detection performance. The significant correlations included per cent correct on the Hidden Figures Test, subject's time estimates, neuroticism score, and coffee drinking. Although these correlations are interesting, they contribute little to an integrated picture of the attention process. The factor analysis, too, revealed the factor with high detection loadings to be quite separate from the other measures. The apparent lack of relatedness between vigilance performance and the other tests of 'attention' leads this author to conclude that attention is not a unidimensional process. It appears quite probable that the sustained attention required in a vigilance situation is quite different and involves different processes than the attention necessary in short term attention such as Hidden Figures or Stroop.

The inter-correlations between variables other than detection also proved to be interesting, but like the detection findings were fragmentary and difficult to interpret in terms of defining the attention process. The only promising exception was the commission error correlations. It appears as though the person who makes many commission errors also tends to show lower physiological responsiveness in terms of GSR magnitude, amplitude and base conductance as well as initial OR amplitude. He also tends to have greater Stroop interference, attempt more than he can answer on the Hidden Figures Test, and score highly on extraversion. Although only the amplitude and OR measures were found to be significantly related to the number of commission errors, the trend of these other sizable correlations suggest a rather impulsive person who is not very responsive autonomically. Very similar syndromes have been described by the Russians (Teplov, 1964) as well as some prominent Western theorists (Eysenck, 1964; Kagan *et al*., 1964).

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APPENDICES

APPENDIX A

INSTRUCTIONS FOR TESTS

Vigilance Instructions

This experiment was designed to learn something about how people behave in a situation where they have to listen for signals over a period of time and where they do not know just when a signal will occur. There are many situations in real life where it is necessary to watch for or listen for certain signals which come irregularly. Even though one does not know just when a signal will come it may be very important for him to be paying attention so that when a signal does come it is seen or heard. Examples of jobs where it is important to detect signals which may come in at any time are: the radar operator watching for pips on a radar scope which may mean enemy planes, the sonar operator listening for signals which may mean submarines, the factory inspector looking for tiny faults in some product coming off the assembly line, the schoolteacher looking for errors and many others.

In this experiment you are going to listen to a long series of one-digit numbers from 1 to 9, played on a record at the rate of one every second. Here is an example of what it will be like...1-5-6-3-2-1-4-9-8-6 and so on for the entire test period.

Your job is to pick out of this long series of digits certain sequences or groups of digits. Specifically, you will listen for <u>groups of three digits, all different, and coming one after the other in the order odd-even-odd</u>. Examples of the kinds of sequences of digits you are to listen for are <u>347</u> or <u>921</u> or <u>763</u>. Note that each of these sequences has <u>three digits</u>, <u>all different</u>, and <u>in the order odd-even-odd</u>. Every time you hear such an odd-even-odd group on the tape you will press the button which is located on the table next to your right hand.

The digits that you will hear do not come in groups of three but in one long continuous chain, so you will have to listen carefully to get these groups when they come. What makes this task a bit tricky is that you never know when an odd-even-odd sequence is coming since they do not come at regular intervals. An odd-even-odd sequence may come at any time and the only way to notice it when it does come is to listen closely <u>all</u> the time.

Now, for some examples: Suppose you were to hear the following digits coming off the recording: 5-2-6-3-3-7-4-8-<u>9-2-7</u>..... You will note that the last three digits, 9-2-7, make up a sequence of the kind you are listening for because:

a) The order is odd-even-odd.

b) The three digits are all different.

c) They come one after the other.

If sometime later you heard these digits, 6-2-3-5-1-4-6-2-3-6-1..., should you press the button? Here you note the sequence 3-6-1 meets the requirements:

a) odd-even-odd

b) all different

c) one after the other

You would therefore press the button and continue listening for the next groups.

But now suppose you heard these digits: 5-2-6-3-5-7-4-8-9-2-9. Should you write down the group 929? NO! Because even though the digits are odd-even-odd and one right after the other, they are not all different because the digit 9 appears twice. Groups like 929, or 363, or 545 are not good groups because the three numbers are not all different.

You are to listen for groups like 9-2-7, 3-6-1, 5-4-3 and so on, i.e., whenever you hear three successive, different digits in the order odd-even-odd.

Now to tell you about a few listening tricks that will make this task a bit easier. These tricks are concerned with when you remember numbers or keep them in mind and when you can forget them. The first rule is to always remember the last digit you hear if it is <u>odd</u>, i.e., if it is 1, 3, 5, 7, or 9, since any odd digit may be the start of an <u>odd-even-odd group</u>.

If the odd digit which you are remembering is followed by an even digit, for example if a 7 is followed by a 4, remember both digits, that is, 7-4 and listen for the next digit which may complete a group. You do not have to remember an even digit unless it follows an odd digit.

To summarize:

1. You remember the <u>last</u> digit you heard whenever it is an <u>odd</u> digit.

2. You remember the <u>last two</u> digits you heard whenever they appear in the order <u>odd-even</u>, e.g., 3-8.

3. You need never remember an even number which follows another even number. When pressing the button, the numbers will not stop so keep listening. Remember, an odd-even-odd sequence may come at any time and the only way to notice it when it does come is to listen closely <u>all</u> the time.

Practice--Write on the answer sheet the groups of three successive and different digits in the order odd-even-odd as they appear in the following sequence of digits:

3-3-9-6-8-3-7-2-7

2-6-2-7-7-4-3-3-1

2-4-8-3-4-9-7-3-4

9-6-6-3-8-5-4-5-6

1-6-7-2-2-2-4-6-8

3-4-6-7-4-7-6-7-9

5-4-4-8-7-3-4-5-6

Stroop Color-Word Test Instructions

W-Card Instructions--For this part of the experiment, I will give you a page with color names printed on it. When I tell you to begin, read the color names aloud. Please read rapidly as I will be timing you. If you make a mistake, please correct it before going on but remember you are working for speed. Read the page from left to right as though you were reading the page of a book.

Do not pause at the end of lines as you are being timed on the whole page rather than for individual lines. Please do not point to the words you are reading, and do not use a singsong voice.

Read the names as fast as you possibly can. The faster you can read the names, the better your score will be. When you finish the whole page say the word "Stop."

Do you have any questions?

C-Card Instructions--This part of the experiment is similar to the preceding part, except that the page contains a series of patches of color rather than words. You are to name the colors from left to right after I tell you to begin. Again, do not pause at the end of lines; work through the entire page. I will be timing you again so remember to work for speed as well as accuracy. If you make a mistake, please correct it before going on, but remember you are working for speed.

Name the colors as fast as you possibly can. The faster you can name them, the better your score will be. When you reach the end of the page, say the word "Stop."

Do you have any questions?

CW-Card Instructions--On this page you will find a series of words which are printed in different colors. Your task is to ignore the words and name the colors in which the words are printed. If, for example, the word, "Door" was printed in yellow and the word "Chair" was printed in red, you would say "yellow, red" and so on. Again, do not pause at the end of lines; name all of the colors on the page before stopping.

There are certain rules we would like you to follow. You are to name the colors one by one. Do not squint or de-focus your eyes to blur the words; do not point, and do not use a singsong voice. If you make a mistake, please correct it before going on again, remembering you are working for speed. When you finish the page say the word "Stop."

Remember, I will be timing you again, so work for speed as well as accuracy. Name the colors as fast as you possibly can. The faster you can name the colors, the better your score will be.

Do you have any questions?

APPENDIX B

TESTS AND ANSWER SHEETS

PLEASE USE ANSWER SHEET

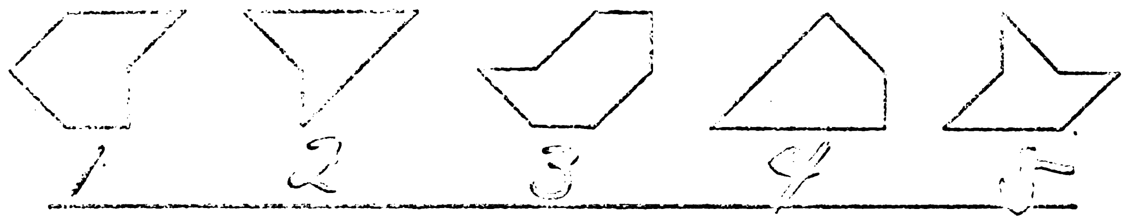
Name: ______________________________

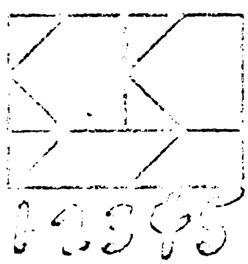
HIDDEN FIGURES TEST — Cf-1

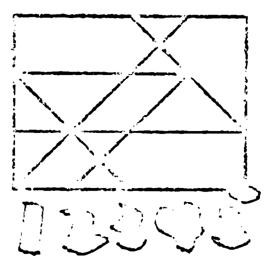
This is a test of your ability to tell which one of five simple figures can be found in a more complex pattern. At the top of each page in this test are five simple figures lettered ~~A, B, C, D,~~ and E. Beneath each row of figures is a page of patterns. Each pattern has a row of letters beneath it. Indicate your answer by putting an X through the letter of the figure which you find in the pattern.

NOTE: There is only one of these figures in each pattern, and this figure will always be right side up and exactly the same size as one of the five lettered figures.

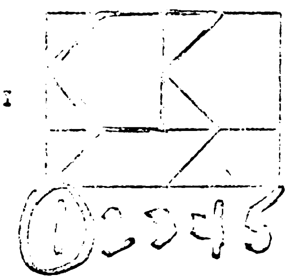
Now try these 2 examples.

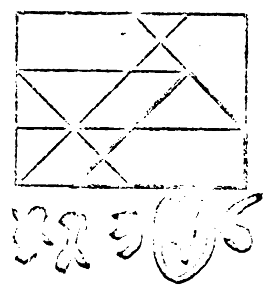


I 

II 

The figures below show how the figures are included in the problems. Figure A is in the first problem and figure D in the second.

I 

II 

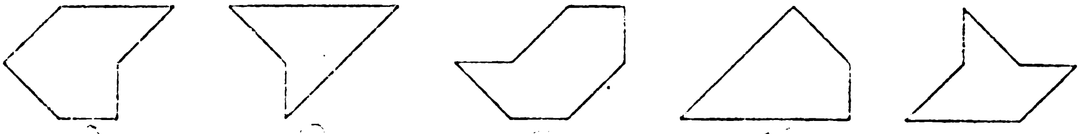
Your score on this test will be the number marked correctly minus a fraction of the number marked incorrectly. Therefore, it will not be to your advantage to guess unless you are able to eliminate one or more of the answer choices as wrong.

You will have 10 minutes for each of the two parts of this test. Each part has 2 pages. When you have finished Part 1, STOP. Please do not go on to Part 2 until you are asked to do so.

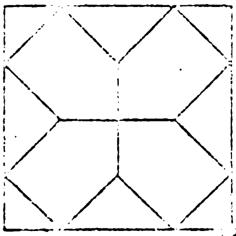
DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

Developed under NIMH Contract M-4186

Part 1 (10 minutes)



1 2 3 4 5

1. 

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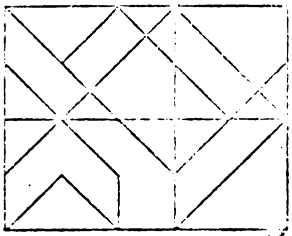
2. 

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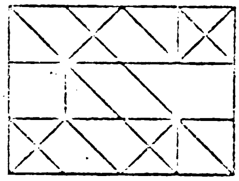
3. 

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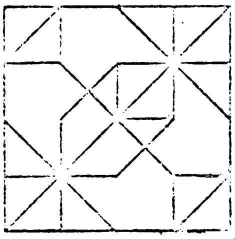
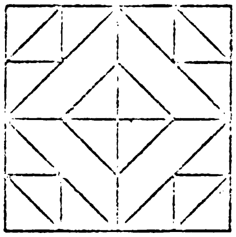
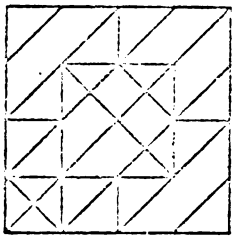
4. 

1 2 3 4 5

5. 

1 2 3 4 5

6. 

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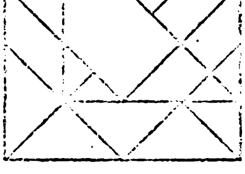
7. 

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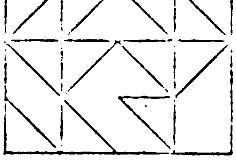
8. 

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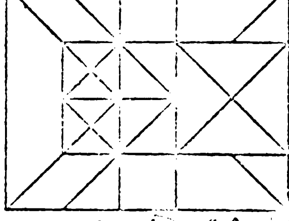
9. 

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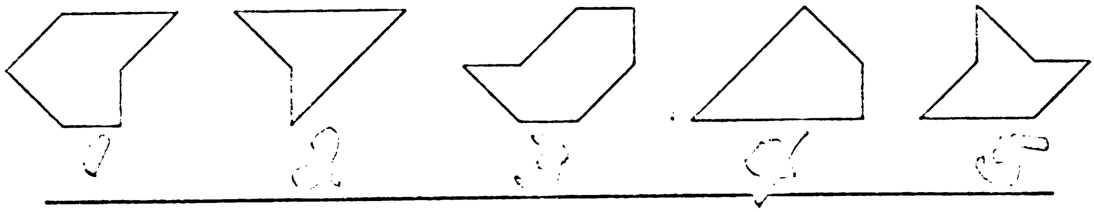
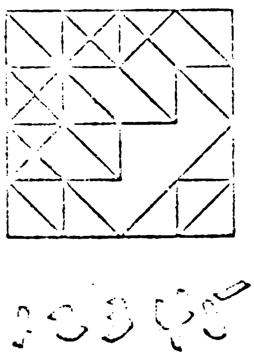
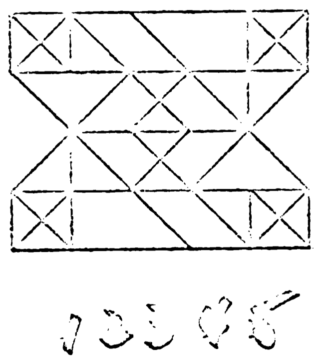
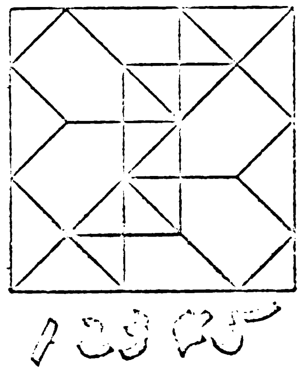
GO ON TO THE NEXT PAGE

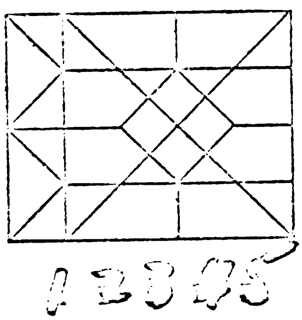
Part 1 (continued)

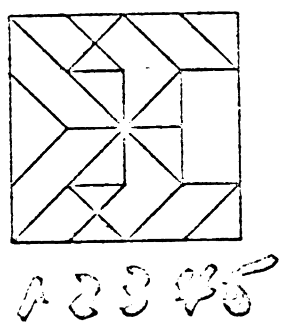


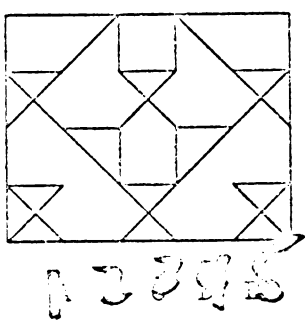
10. 

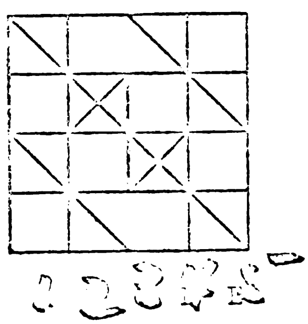
11. 

12. 

13. 

14. 

15. 

16. 

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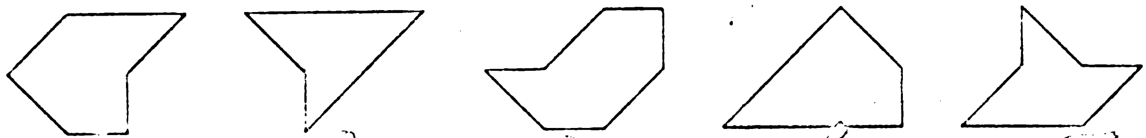
STOP.

Part 2 (10 minutes)



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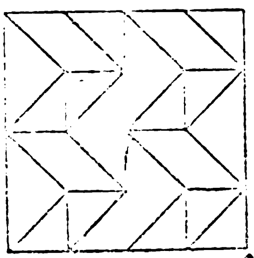
17. 

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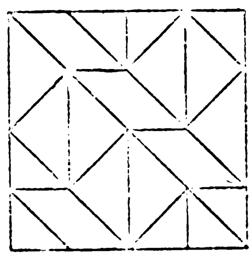
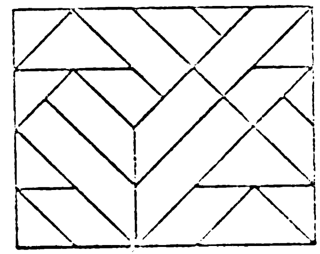
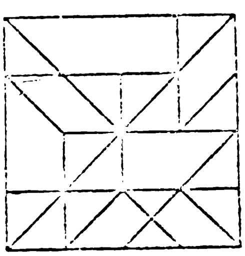
18. 

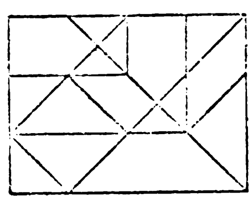
1 2 3 4 5

19. 

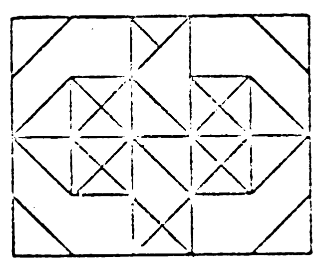
1 2 3 4 5

20. 

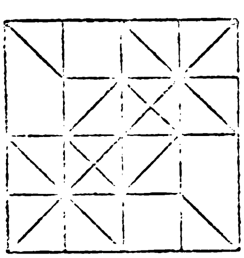
1 2 3 4 5

21. 

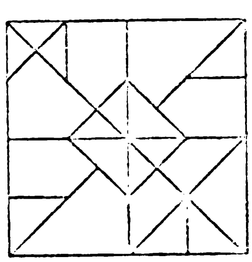
1 2 3 4 5

22. 

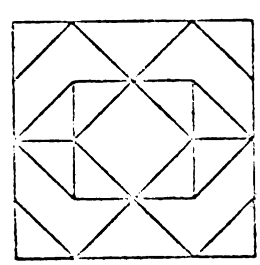
1 2 3 4 5

23. 

1 2 3 4 5

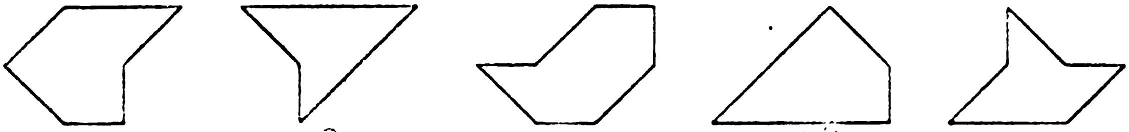
24. 

1 2 3 4 5

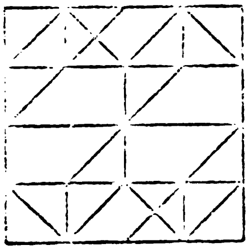
25. 

1 2 3 4 5

Part 2 (continued)

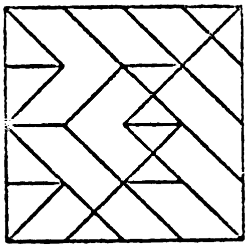


1 2 3 4 5



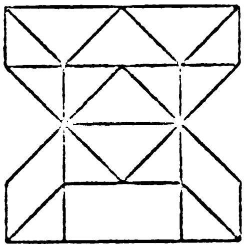
1 2 3 4 5

27.



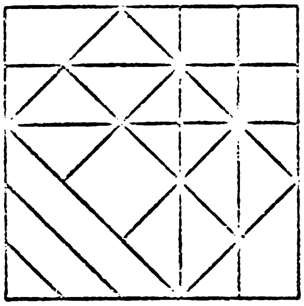
1 2 3 4 5

28.



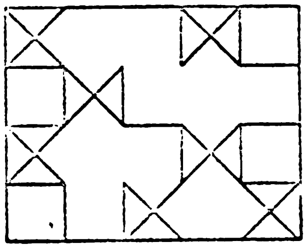
1 2 3 4 5

29.



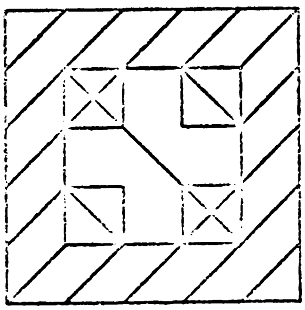
1 2 3 4 5

30.



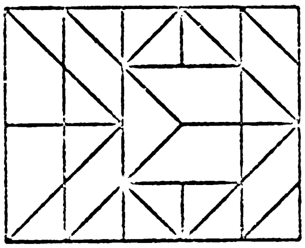
1 2 3 4 5

31.



1 2 3 4 5

32.



1 2 3 4 5

DO NOT GO BACK TO PART 1, AND

DO NOT GO ON TO ANY OTHER TEST UNTIL ASKED TO DO SO.

ANSWER SHEET FOR
Hidden Figures Test

Indicate your answer by putting an X through the number of the figure which you find in the pattern.

Part 1						Part 2					
1)	~~1~~	2	3	4	5	17)	1	2	3	4	~~5~~
2)	1	~~2~~	3	4	5	18)	1	2	~~3~~	4	5
3)	1	2	3	4	~~5~~	19)	1	2	3	~~4~~	5
4)	1	2	3	~~4~~	5	20)	1	~~2~~	3	4	5
5)	1	~~2~~	3	4	5	21)	~~1~~	2	3	4	5
6)	1	2	3	~~4~~	5	22)	1	~~2~~	3	4	5
7)	1	2	3	4	~~5~~	23)	1	2	~~3~~	4	5
8)	~~1~~	2	3	4	5	24)	1	~~2~~	3	4	5
9)	1	~~2~~	3	4	5	25)	1	2	~~3~~	4	5
10)	1	2	3	~~4~~	5	26)	1	2	3	4	~~5~~
11)	1	2	~~3~~	4	5	27)	1	2	3	~~4~~	5
12)	~~1~~	2	3	4	5	28)	~~1~~	2	3	4	5
13)	1	2	3	4	~~5~~	29)	1	2	3	~~4~~	5
14)	1	2	3	4	~~5~~	30)	1	2	3	4	~~5~~
15)	1	2	~~3~~	4	5	31)	1	2	3	4	~~5~~
16)	1	2	~~3~~	4	5	32)	~~1~~	2	3	4	5

E N L

1. Do you often long for excitement? . . . . Yes No

2. Do you often need understanding friends to cheer you up? . . . . Yes No

3. Are you usually carefree? . . . . Yes No

4. Do you find it very hard to take no for an answer? . . . Yes No

5. Do you stop and think things over before doing anything? . . . . Yes No

6. If you say you will do something do you always keep your promise, no matter how inconvenient it might be to do so? . . . . Yes No

7. Does your mood often go up and down? . . . . Yes No

8. Do you generally do and say things quickly without stopping to think? . . . . Yes No

9. Do you ever feel "just miserable" for no good reason? Yes No

10. Would you do almost anything for a dare? . . . . Yes No

11. Do you suddenly feel shy when you want to talk to an attractive stranger? . . . . Yes No

12. Once in a while do you lose your temper and get angry? . . . . Yes No

13. Do you often do things on the spur of the moment? . . . Yes No

.4. Do you often worry about things you should not have done or said? . . . . Yes No

5. Generally do you prefer reading to meeting people? . . Yes No

6. Are your feelings rather easily hurt? . . . . Yes No

7. Do you like going out a lot? . . . . Yes No

8. Do you occasionally have thoughts and ideas that you would not like other people to know about? . . . . Yes No

9. Are you sometimes bubbling over with energy and sometimes very sluggish? . . . . Yes No

0. Do you prefer to have few but special friends? . . . . . Yes No

1. Do you daydream a lot? . . . . Yes No

2. When people shout at you, do you shout back? . . . . . . Yes No

3. Are you often troubled about feelings of guilt? . . . . . . Yes No

4. Are all your habits good and desirable ones? . . . . . . Yes No

5. Can you usually let yourself go and enjoy yourself a lot at a gay party? . . . . Yes No

6. Would you call yourself tense or "highly-strung"? . . . Yes No

7. Do other people think of you as being very lively? . . . Yes No

8. After you have done something important, do you often come away feeling you could have done better? . . . . . Yes No

9. Are you mostly quiet when you are with other people? Yes No

0. Do you sometimes gossip? . . . . Yes No

31. Do ideas run through your head so that you cannot sleep? . . . . Yes No

32. If there is something you want to know about, would you rather look it up in a book than talk to someone about it? . . . . Yes No

33. Do you get palpitations or thumping in your heart? . . . Yes No

34. Do you like the kind of work that you need to pay close attention to? . . . . Yes No

35. Do you get attacks of shaking or trembling? . . . . Yes No

36. Would you always declare everything at the customs, even if you knew that you could never be found out? . . Yes No

37. Do you hate being with a crowd who play jokes on one another? . . . . Yes No

38. Are you an irritable person? . . . . Yes No

39. Do you like doing things in which you have to act quickly? . . . . Yes No

40. Do you worry about awful things that might happen? . . Yes No

41. Are you slow and unhurried in the way you move? . . . Yes No

42. Have you ever been late for an appointment or work? . Yes No

43. Do you have many nightmares? . . . . Yes No

44. Do you like talking to people so much that you would never miss a chance of talking to a stranger? . . . . . . Yes No

45. Are you troubled by aches and pains? . . . . Yes No

46. Would you be very unhappy if you could not see lots of people most of the time? . . . . Yes No

47. Would you call yourself a nervous person? . . . . Yes No

48. Of all the people you know are there some whom you definitely do not like? . . . . Yes No

49. Would you say you were fairly self-confident? . . . . . . Yes No

50. Are you easily hurt when people find fault with you or your work? . . . . Yes No

51. Do you find it hard to really enjoy yourself at a lively party? . . . . Yes No

52. Are you troubled with feelings of inferiority? . . . . . . Yes No

53. Can you easily get some life into a rather dull party?. Yes No

54. Do you sometimes talk about things you know nothing about? . . . . Yes No

55. Do you worry about your health? . . . . Yes No

56. Do you like playing pranks on others? . . . . Yes No

57. Do you suffer from sleeplessness? . . . . Yes No

PLEASE CHECK TO SEE THAT YOU HAVE ANSWERED ALL THE QUESTIONS.

EYSENCK PERSONALITY INVENTORY

FORM A

By H. J. Eysenck
and Sybil B. G. Eysenck

Name______________________________ Age__________ Sex__________

Grade or Occupation ______________________________ Date______________

School or Firm______________________________ Marital Status______________

INSTRUCTIONS

Here are some questions regarding the way you behave, feel and act. After each question is a space for answering "Yes," or "No."

Try and decide whether "Yes," or "No" represents your usual way of acting or feeling. Then blacken in the space under the column headed "Yes" or "No."

Section of Answer Column Correctly Marked

Yes	No
▌	⁞
⁞	▌

Work quickly, and don't spend too much time over any question; we want your first reaction, not a long drawn-out thought process. The whole questionnaire shouldn't take more than a few minutes. Be sure not to omit any questions. Now turn the page over and go ahead. Work quickly, and remember to answer every question. There are no right or wrong answers, and this isn't a test of intelligence or ability, but simply a measure of the way you behave.

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APPENDIX C

CORRELATION MATRIX

	1	2	3	4	5	6	7	8	9	10
1										
2	.531									
3	-.230	-.239								
4	-.067	.058	.260							
5	.067	-.103	.272	-.015						
6	.200	-.086	-.267	-.145	-.059					
7	-.406	-.050	-.197	-.085	-.297	-.006				
8	-.287	-.104	-.022	.004	-.182	-.278	.690			
9	-.379	-.195	-.112	-.295	.159	.016	.601	.613		
10	-.012	-.175	.078	-.255	.502	.025	-.357	-.015	.532	
11	-.412	-.137	-.126	-.150	-.113	-.099	.872	.878	.858	.079
12	.299	-.011	-.204	-.122	-.039	-.129	-.096	.230	.046	.155
13	.377	.230	-.270	-.138	.092	-.073	.021	.251	.162	.167
14	-.345	.009	.344	.357	-.127	-.287	.195	.241	-.051	-.266
15	.216	-.053	-.320	.020	-.102	-.113	.280	.440	.290	.043
16	.211	-.057	-.212	-.091	-.043	-.171	.248	.604	.385	.187
17	.287	-.041	-.177	-.152	.061	.078	.207	.446	.440	.295
18	.124	.022	.270	-.316	.301	.352	-.141	-.001	.266	.460
19	.133	-.171	-.226	.066	-.247	.215	.222	.275	.175	-.031
20	.183	-.186	-.221	-.001	-.253	.284	.244	.293	.208	-.015
21	.153	-.254	-.186	-.071	-.270	.284	.252	.307	.232	.004
22	.037	-.168	.096	-.295	-.038	.138	.053	.055	.113	.076
23	.112	.039	.101	-.104	.209	.509	-.119	-.402	.045	.179
24	-.136	-.118	-.109	-.354	.386	.320	-.039	-.360	.516	.644
25	.060	-.432	.294	.069	.421	-.049	-.183	-.019	-.118	.056
26	-.209	-.401	.903	.245	.362	-.248	-.212	-.001	-.109	.098
27	.161	-.111	.089	.073	-.183	.399	-.261	-.405	-.306	-.081
28	.018	-.029	.085	.215	-.077	-.338	.166	.282	-.005	-.182

	1	2	3	4	5	6	7	8	9	10
29	-.119	-.239	.099	.214	-.155	-.077	.072	.037	-.272	-.394
30	.330	.016	-.250	.022	-.034	-.162	-.011	.345	.213	.260
31	.280	-.013	-.217	.013	-.051	-.115	.025	.375	.238	.252
32	.453	-.040	-.109	-.031	-.042	.016	-.098	.194	.056	.169
33	-.102	-.197	.357	.057	-.102	.306	-.004	-.238	-.252	-.289
34	-.369	-.150	.101	-.054	-.130	.082	.067	-.028	.002	-.069
35	.217	-.127	.301	-.128	-.005	.382	-.182	-.346	-.321	-.182
36	-.068	-.152	.153	-.115	.019	.085	.175	.137	.136	-.026
37	.069	.084	.194	.103	.144	.135	.236	.148	.131	-.097
38	.248	-.053	-.247	-.078	-.030	-.075	.256	.521	.388	.182
39	.159	-.207	-.215	-.002	-.262	.266	.244	.297	.209	-.015
40	.365	-.016	-.203	.005	-.041	-.090	-.029	.320	.181	.242

	11	12	13	14	15	16	17	18	19	20
11										
12	.069									
13	.168	.857								
14	.142	-.256	-.401							
15	.386	.614	.534	-.296						
16	.475	.581	.543	-.311	.896					
17	.423	.571	.529	-.300	.853	.880				
18	.056	-.094	-.025	-.000	-.297	-.054	.246			
19	.256	.549	.455	-.354	.782	.672	.686	-.197		
20	.285	.497	.391	-.313	.734	.678	.716	-.053	.963	

	11	12	13	14	15	16	17	18	19	20
21	.302	.453	.322	-.290	.645	.644	.693	.071	.892	.971
22	.086	-.229	-.306	.154	-.329	-.091	-.017	.580	-.274	-.028
23	-.176	-.112	-.115	.071	-.226	-.392	.093	.588	-.079	-.035
24	.061	-.195	-.081	-.321	-.134	-.200	.036	.315	-.091	-.072
25	-.123	.158	.132	-.081	.209	.282	.211	-.004	.234	.252
26	-.123	-.092	-.171	.236	-.106	-.009	-.012	.173	-.019	-.024
27	-.373	.147	-.066	.029	-.198	-.361	-.214	-.024	.104	.153
28	.165	.407	.250	.293	.222	.127	.084	-.258	.136	.147
29	-.070	-.304	-.394	.145	-.185	-.222	-.415	-.415	-.244	-.239
30	.211	.709	.645	-.369	.907	.885	.842	-.144	.745	.695
31	.247	.575	.532	-.371	.836	.920	.839	-.016	.642	.647
32	.059	.640	.530	-.427	.787	.798	.839	.075	.721	.748
33	-.193	-.286	-.321	.004	-.379	-.361	-.210	.319	-.119	-.021
34	.015	-.383	-.378	.058	-.349	-.137	-.251	.188	-.377	-.313
35	-.327	-.199	-.293	-.121	-.327	-.260	-.081	.457	-.105	.056
36	.171	-.332	-.396	.250	-.345	-.116	-.074	.505	-.298	-.062
37	.195	-.327	-.307	.290	-.165	-.030	.000	.306	-.159	.044
38	.448	.615	.559	-.316	.956	.968	.950	-.038	.744	.739
39	.286	.510	.397	-.326	.735	.678	.712	-.062	.971	.997
40	.183	.669	.595	-.403	.877	.904	.873	-.031	.731	.725

	21	22	23	24	25	26	27	28	29	30
21										
22	.188									
23	-.007	.158								
24	-.059	.073	.489							
25	.249	.022	-.182	-.119						
26	-.009	.023	-.007	-.127	.656					
27	.163	.120	.341	.078	-.049	.019				
28	.142	.008	-.103	-.312	-.012	.042	.386			
29	-.235	.030	-.337	-.362	-.053	.024	.232	.362		
30	.623	-.292	-.224	-.123	.185	-.064	-.205	.164	-.347	
31	.611	-.095	-.301	-.125	.204	-.047	-.303	.053	-.302	.914
32	.739	.007	-.047	-.145	.244	.045	.004	.136	-.329	.886
33	.099	.472	.350	-.039	.148	.313	.353	-.086	-.004	-.416
34	-.233	.325	-.199	.032	.029	.068	-.184	-.323	.089	-.412
35	.189	.634	.387	-.004	.087	.212	.466	-.060	.091	-.323
36	.138	.947	.100	.012	.033	.070	.063	.058	.096	-.373
37	.103	.566	.063	-.006	.131	.146	.142	.180	.146	-.302
38	.689	-.151	-.189	-.107	.246	-.044	-.271	.150	-.284	.917
39	.973	-.040	-.041	-.075	.250	-.018	.143	.144	-.244	.702
40	.684	-.134	-.202	-.134	.221	-.024	-.177	.122	-.341	.972

	31	32	33	34	35	36	37	38	39	40
31										
32	.858									
33	-.327	-.026								
34	-.062	-.333	.262							
35	-.198	.152	.827	.187						
36	-.149	-.083	.522	.387	.623					
37	-.095	-.087	.354	.280	.462	.728				
38	.904	.843	-.332	-.254	-.234	-.185	-.067			
39	.646	.751	-.015	-.314	.046	-.077	-.005	.739		
40	.963	.949	-.271	-.278	-.135	-.210	-.167	.924	.727	

APPENDIX D

RAW DATA

S#	%HF	HF	Stroop	Ex	N	L	V1	V2	V3
1	93	13	30.0	12	7	2	6	8	5
2	94	15	38.5	20	9	4	5	3	5
3	100	8	28.7	6	4	4	4	4	6
4	100	14	29.2	14	11	5	4	3	3
5	100	12	47.3	10	17	2	6	8	8
6	100	12	14.8	17	6	2	10	9	7
7	87	13	47.5	13	13	2	7	5	9
8	100	24	32.8	11	4	2	5	6	5
9	64	9	35.8	15	5	0	7	6	4
10	75	6	48.0	19	5	3	3	3	1
11	57	8	30.2	16	5	3	7	7	9
12	70	7	23.6	13	19	3	5	6	10
13	100	16	27.0	17	4	1	6	6	5
14	94	16	26.7	13	11	3	1	1	2
15	75	12	31.1	19	11	1	4	3	2
16	33	4	49.5	14	15	2	8	7	8
17	77	17	48.8	18	9	2	7	6	3
18	89	8	32.0	15	11	4	6	7	6
19	52	11	54.0	16	5	2	9	7	7
20	81	17	35.5	7	11	1	6	3	5
21	95	20	22.8	13	5	0	5	7	5
22	100	23	19.0	14	10	5	8	3	7
23	43	10	27.3	12	1	4	8	5	8
24	31	4	46.2	11	16	2	9	4	4
25	100	22	57.0	22	14	1	2	5	5
26	92	22	20.8	19	5	3	7	5	4
27	53	10	51.4	19	6	1	7	9	8
28	88	15	37.7	17	14	2	3	2	3
29	100	5	55.0	17	10	3	2	1	2
30	100	15	32.8	14	3	5	7	7	4
31	93	25	26.9	18	4	5	9	7	9

S#	V3-1	Tot V	OR1	OR2	CE	$\bar{X}$MagV1	$\bar{X}$MagV2
1	-1	19	-	-	15	.6253	.8589
2	0	13	1.424	1.662	11	.9085	.7299
3	2	14	1.276	1.026	1	.5016	.8996
4	-1	10	1.673	1.496	3	.4529	.1602
5	2	22	2.528	2.198	1	1.6906	1.9687
6	-3	26	1.287	1.280	4	1.4795	1.6457
7	2	21	.661	.673	3	.6542	.6344
8	0	16	1.154	1.251	6	.8910	1.2127
9	-3	17	1.643	1.326	5	1.3360	1.3226
10	-2	7	.820	.192	4	.3395	.4608
11	2	23	1.090	.910	4	1.6920	1.4808
12	5	21	1.369	1.602	1	.5073	.8906
13	-1	17	1.268	1.368	7	1.0841	1.0458
14	1	4	.830	.693	2	.1823	.1663
15	-2	9	.787	.490	30	.4225	.2168
16	0	23	.462	.778	2	.4594	.6515
17	-4	16	.661	.799	58	.2098	.3809
18	0	19	1.056	1.153	0	.7246	.9463
19	-2	23	.697	1.014	24	.1041	.0845
20	-1	14	.384	.521	7	.0614	.1212
21	0	17	2.334	2.445	3	.7937	.8649
22	-1	18	.369	.763	3	.6185	.3387
23	0	21	1.116	.928	5	.2233	.3467
24	-5	17	-	-	9	.4201	.2878
25	3	12	.851	1.195	0	.3973	.9246
26	-3	16	1.579	1.558	6	.9277	.8127
27	1	24	.850	.148	70	.3770	.4630
28	0	8	.567	.700	11	.1675	.1789
29	0	5	1.427	1.105	2	.7358	.4954
30	-3	18	.616	.817	4	.5069	.8034
31	0	25	-	-	5	.5649	.6911

S#	$\bar{X}$MagV3	$\bar{X}$MagV3-1	$\bar{X}$LBCV1	$\bar{X}$LBCV2	$\bar{X}$LBCV3
1	.7907	.1654	2.8290	2.6969	2.6989
2	1.1993	.2908	2.7776	2.7255	2.6681
3	1.1098	.6082	2.6849	2.8385	2.9837
4	.7381	.2852	2.7649	2.7233	2.6801
5	2.0585	.3679	2.9248	2.9189	2.9062
6	1.4623	-.0172	2.8027	2.8643	2.8754
7	.8543	.2001	2.5008	2.5053	2.5010
8	1.0710	.1800	2.6432	2.6804	2.6200
9	.8427	-.4933	3.0622	2.9733	2.9259
10	.3922	.0527	2.5082	2.4924	2.5638
11	1.5281	-.1639	3.0052	2.8857	2.7923
12	.6596	.1523	2.5699	2.5795	2.5667
13	.6775	-.4066	2.6278	2.5844	2.5486
14	.1347	-.0476	2.2912	2.2556	2.1923
15	.2548	-.1677	2.5381	2.5237	2.5272
16	.5970	.1376	2.5090	2.4916	2.5039
17	.3512	.1414	2.3310	2.3343	2.3254
18	.7333	.0087	2.6575	2.6168	2.6054
19	.1362	.0321	2.5273	2.5171	2.5219
20	.1275	.0661	2.2716	2.2162	2.2319
21	.6914	-.1023	2.5623	2.4463	2.4396
22	.6943	.0758	2.6779	2.6807	2.6692
23	.3844	.1611	2.6843	2.6583	2.6839
24	.2613	-.1588	2.5511	2.5213	2.5003
25	.8070	.4097	2.6279	2.5918	2.5910
26	.5652	-.3625	2.7717	2.7608	2.7031
27	.5172	.1402	2.5059	2.5390	2.5613
28	.2862	.1187	2.4586	2.4750	2.4854
29	.4960	-.2398	2.8273	2.7885	2.7212
30	.6259	.1190	2.8387	2.8412	2.8115
31	.8839	.3190	2.5642	2.5902	2.6780

S#	$\bar{X}$LBCV3-1	$\bar{X}$MagV3-2	V3-2	C-Card	CW-Card	Time	Smoke
1	-.1301	-.0682	-3	40.0	70.0	40	0
2	-.1095	.4694	2	38.0	76.5	35	0
3	.2988	.2102	2	40.8	69.5	50	0
4	-.0848	.5779	0	37.0	66.2	60	0
5	-.0186	.0898	0	52.3	99.5	30	1
6	.0727	-.1834	-2	43.0	57.8	25	1
7	.0002	.2199	4	32.0	79.5	20	0
8	-.0232	-.1417	-1	31.5	64.3	20	0
9	-.1363	-.4799	-2	48.2	84.0	17	0
10	.0556	-.0686	-2	40.0	88.0	45	0
11	-.2129	.0473	2	39.8	70.0	15	0
12	-.0032	-.2310	4	46.2	69.8	15	0
13	-.0792	-.3683	-1	38.9	65.9	15	0
14	-.0989	-.0316	1	39.8	66.5	45	0
15	-.0109	.0380	-1	36.0	67.1	20	1
16	-.0051	-.0545	1	40.5	90.0	15	0
17	-.0056	-.0297	-3	46.4	95.2	10	0
18	-.0521	-.2130	-1	42.2	74.2	30	0
19	-.0054	.0517	0	41.0	95.0	45	1
20	-.0397	.0063	2	35.5	71.0	20	0
21	-.1227	-.1735	-2	30.2	53.0	30	1
22	-.0087	.3556	4	34.0	53.0	45	0
23	-.0004	.0377	3	32.5	59.8	45	0
24	-.0508	-.0265	0	40.8	87.0	23	1
25	-.0369	-.1176	0	41.2	98.2	15	0
26	-.0686	-.2475	-1	32.2	53.0	67	1
27	.0554	.0542	-1	32.8	84.2	60	1
28	.0268	.1073	1	49.8	87.5	45	0
29	-.1061	.0006	1	49.2	104.2	90	1
30	-.0272	-.1775	-3	39.8	72.6	30	0
31	.1138	.1928	2	31.2	58.1	25	0

S#	Coffee	$\bar{X}$AmpV1	$\bar{X}$AmpV2	$\bar{X}$AmpV3	%Chg AmpV3	%Chg AmpV2
1	0	.8262	.7894	1.1220	136	96
2	0	1.3348	1.6603	1.3110	98	124
3	0	1.1960	1.3878	1.7332	145	116
4	0	.7600	.2143	1.1060	146	28
5	0	2.0630	2.0574	2.1255	103	100
6	1	1.4795	1.7678	1.6690	113	119
7	0	.8677	.9296	.9492	109	107
8	0	1.4496	1.8203	1.6738	115	126
9	0	1.7081	1.6407	1.5110	88	96
10	1	.5967	1.0223	1.1920	200	171
11	0	2.1156	1.8056	1.5367	72	85
12	0	1.0146	1.2217	.6596	65	120
13	1	1.2780	1.1455	1.0130	79	90
14	1	.3830	.5790	.2415	63	151
15	1	.7683	.7227	.7225	94	94
16	1	.5325	.7832	.7340	138	147
17	0	.2997	.4495	.3857	129	150
18	1	1.1322	1.2484	1.2222	108	110
19	1	.1157	.1207	.1946	168	104
20	1	.0735	.0840	.0642	87	114
21	0	1.5874	1.2356	1.2436	78	78
22	0	.6564	.5777	.8937	136	88
23	0	.2791	.5444	.3820	137	195
24	0	.4668	.5925	.4210	90	127
25	0	1.3365	1.3554	1.3580	102	101
26	1	1.1593	1.1894	1.1168	96	103
27	1	.5210	.5144	.4591	88	99
28	0	.3923	.5320	.6917	176	136
29	1	1.1265	.8390	1.4580	129	74
30	1	.6709	.8616	.7100	106	128
31	1	.6141	.9873	.9821	160	161

S#	$\bar{X}$AmpV3-1	%Chg LBCV3	%Chg LBCV2	$\bar{X}$Mag	$\bar{X}$LBC	$\bar{X}$Amp
1	.2958	95	95	.7583	2.7416	.9125
2	-.0238	96	98	.9459	2.7237	1.4353
3	.5372	105	99	.8370	2.8357	1.4390
4	.3460	97	98	.4504	2.7227	.6934
5	.0898	99	100	1.9059	2.9166	2.0819
6	.1895	103	102	1.5291	2.8474	1.6387
7	.0815	100	100	.7143	2.5023	.9155
8	.2242	99	101	1.0582	2.6478	1.6479
9	-.1971	96	97	1.1671	2.9871	1.6199
10	.5953	102	99	.3975	2.5214	.9370
11	-.5789	93	96	1.5669	2.8944	1.8193
12	-.3550	100	100	.6858	2.5720	.9903
13	-.2650	97	98	.9358	2.5869	1.1455
14	-.1415	96	98	.1611	2.2463	.4011
15	-.0458	100	99	.2980	2.5296	.7378
16	.2015	100	99	.5693	2.5015	.6832
17	-.0297	100	100	.3139	2.3302	.3783
18	.0900	98	98	.8014	2.6265	1.2009
19	.0789	100	100	.1082	2.5221	.1436
20	-.0093	98	98	.1033	2.2399	.0487
21	-.3438	95	95	.7833	2.4827	1.3555
22	.2373	100	100	.5505	2.6759	.7092
23	.1029	100	99	.3181	2.6755	.4018
24	-.0458	98	99	.3230	2.5242	.4934
25	.0215	99	99	.7096	2.6035	1.3499
26	-.0425	98	100	.7685	2.7452	1.1551
27	-.0610	102	101	.4524	2.5354	.4981
28	.2994	101	101	.2108	2.4730	.5386
29	.3315	96	99	.5757	2.7790	1.1411
30	.0391	99	100	.6454	2.8304	.7475
31	.3680	104	101	.7133	2.6108	.8611

S#	$\bar{X}$HR
1	56.41
2	76.24
3	54.16
4	65.47
5	67.63
6	56.56
7	53.26
8	--
9	51.97
10	53.15
11	62.17
12	80.93
13	58.83
14	--
15	57.24
16	66.08
17	58.21
18	58.53
19	52.85
20	60.61
21	58.98
22	78.72
23	58.40
24	57.89
25	--
26	--
27	--
28	61.18
29	53.02
30	58.39
31.	68.70