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PUPILLOMETRICS: A PILOT STUDY TO APPRAISE ITS POTENTIAL AS A NON-VERBAL INSTRUMENT TO EVALUATE STUDENT ATTITUDES

DISSertation

Presented in Partial Fulfillment of the Requirements for the Degree Doctor of Philosophy in the Graduate School of The Ohio State University

by

John W. Schweikert, B.S., M.Ed.

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CHAPTER I

INTRODUCTION

The term "PUPILLOMETRICS" was first used in current literature by Eckhard H. Hess\(^1\) of the University of Chicago, in a report presented by him in 1960. He had been involved for some years in studies of eye movement, primarily to determine for advertising companies the pattern of eye movement as a subject viewed an advertisement; what part of the picture seemed to attract the eye the most, and in what pattern did the eyes move as they scanned a given picture?

More by accident than by intent, Hess relates that while he was looking at some strikingly beautiful animal photographs, his wife noted that his pupils seemed to be dilated more than ordinary, and suggested that his reading light was not adequate. He was certain that the light source was adequate, and on later experimentation with other subjects, he concluded that dilation might be occurring as a result of emotional, attitudinal or some cognitive processing unique to the given subject, and prepared a series of experiments to confirm his hypotheses. His early experiments have aroused the interest of psychologists and educators all over the world, with the

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result that many research projects have been initiated to examine
the response of the pupil of the human eye to stimuli other than
a change in light intensity.

As one might suspect, such experimentation has attracted the
attention of physiologists, physicians, surgeons and psychiatrists
who have contributed their current knowledge of the behavior of the
human organism as controlled by the central and the autonomic ner-
vous systems, both in normal and abnormal individuals. Many of the
laboratory findings appear to confirm some of Hess' early hypotheses,
and some have rejected his findings. A few experimenters have reason
to believe that stimuli, other than just visual, may also trigger the
pupil response, both for dilation and contraction, as the subject
performs cognitive analysis of auditory input, solution of mental
mathematical processes, smell of certain odors, taste of various
foods and liquids, and even a different response to the same picture
when presented in plain black and white as compared to a chromatic
presentation.

As each new bit of evidence has been revealed in publications,
industry and advertising firms have been quick in attempts to exploit
the findings as a means of determining a consumer's attitude toward
a given product. Such enthusiasm has perhaps resulted in varied
levels of disappointment as limited research has yet to prove the
satisfactory reliability or validity of this method of non-verbal
communication of a subject's (S's) interest, emotions, though proc-
esses, or attitudes when presented with a given stimulus.
During this same time period, since the early publication by Hess,\(^2\) there is little evidence of educators showing specific interest in adapting the process of pupillometrics as a possible means of reaching the exceptional child. This would include those students who will not communicate their feelings to their parents, teachers, or counselors by verbal or paper-and-pencil methods. We might add to this our handicapped youth, that group of deaf, mute, genetically incomplete at birth, and those made defective by disease or injury after birth. As educators, we should use every means at our disposal to aid all of these persons to become self-sufficient, including experimentation with new and unproved methods. It is the apparent gap in the use of this new technique that has spawned this particular research effort to investigate the feasibility of using the process of pupillometrics as an adjunct to our limited portfolio of non-verbal instruments to determine at any given time the nature of the emotional blocks that may be preventing a student from performing to his full potential.

**Definition of Pupillometrics**

Responsible for introducing the word, Eckhard Hess defines pupillometrics as, "The psychological science dealing with the response of the pupil of the eye to any perceived stimulus other than a change in light intensity."\(^3\) Thus stimulus may be auditory, visual, tactile, \(^2\)E.H. Hess and J.M. Polt. "Pupil Size as Related to Interest Value of Visual Stimuli," *Science* (1960), pp. 349-350.

\(^3\)Ibid., p. 349.
gustatory, or olfactory in nature, so long as the experimental subject (S) is aware of its presence and is capable of interpreting it through cognitive processes. Through interpretation the S experiences an emotion or attitude change related to the total stimulus, or to some significant part of it. His resultant behavior, whether overt or covert, will result in a dilation or contraction of the pupil of the eye. The scientist involved in observing the changes in the S's pupil learns to interpret the S's emotion or attitude as one of acceptance or rejection, pleasure or displeasure. Some direct relationship between emotion or attitude "change in intensity" and pupil "change in magnitude" is expected and is studied.

**Historical Background**

Historical records indicate that for many centuries man has recognized that the eye may be one of the mirrors of the mind, and of mental processes related to feelings, attitudes, and emotions. Only recently have we learned enough of the physiology of the body and the nervous system to confirm that the muscular control of the iris of the eye that determines the size of the pupil dilation and contraction is under the control of the autonomic nervous system, and apparently is outside the range of willful, conscious control as is respiration and, to some extent, blood pressure.

Chinese history relates that ancient jade merchants watched the eyes of their customers to determine their interest in, or
rejection of a given specimen of jade offered for sale. It is related that they shielded their eyes with smoked lenses to avoid detection of interest. We know that modern day poker players watch their opponent’s eyes to interpret reaction to visual interpretation of their cards as they are dealt and played. Folklore relates that mothers can tell whether their children are telling the truth by watching the pupils of their eyes when under questioning. Lovers look for dilated pupils as an indication of relaxation and pleasure on the part of their companion as love play progresses.

About 1960, a psychologist, Dr. Eckhard Hess of the University of Chicago, re-stimulated interest in the potential of interpreting emotions through the observation of the changes in the pupil of the eye. His initial experiments have stimulated other scientists to design and test various configurations of electronic equipment for use in the examination of this human response to various families of stimuli, and to develop working hypotheses for further investigation.

Purpose of this Study

This is a pilot study intended to open up the possibilities of using pupillometrics for educational ends. The first necessity is to have a simplified equipment design readily obtainable by any educational system, and a program of activity which can reveal whether or not responses in the form of eye pupil changes can be accurately observed and recorded by trained observers without the necessity for mechanical recording. These observations must be
reliable indicators in the identification and diagnosis of emotional changes experienced by the S as a result of perception of some visual stimulus presented to him by the examiner that is related to the educational process in general, or to some specific segment thereof, such as vocation or career selection.

**Statement of the Problem**

Can ways be found to demonstrate the reliability of pupillometrics as a non-verbal instrument for use in education in the determination of student attitudes?

**Hypotheses**

1. By means of pupillometrics, it is possible to detect changes in a given S's attitude as a program of different visual stimuli are presented, without verbal communication between S and observer.

2. Using a given method of non-verbal direct visual observation, and given a stimulus picture, a correlation will be found, significant at the 0.05 level of confidence, between responses of the pupil of the eye and responses recorded by the S on a related paper-and-pencil test.

3. By means of a given method, trained observers can make reliable interpretations of the meaning of pupil changes directly from the TV monitor without the need for further mechanical recording.
**Definition of Terms**

All terms which are used in this text which are not of a general educational vocabulary nature will be defined at the time of their introduction into this paper. Certain specific terms are defined herein.

1. **Closed Circuit TV** - The conventional system whereby the television camera observing the pupil of the eye of the S is directly connected by coaxial cable to the television monitor unit, this monitor unit usually located at some point remote from the immediate environment of the S being tested.

2. **TV Camera** - A conventional black-and-white television camera equipped with a special optical system to multiply the diameter of the pupil of the eye under observation by 15x. (Signal was pre-set for standard TV channel six).

3. **TV Monitor** - May be either a special video monitor or any conventional television RF receiver, locked to receive the signal from the camera on channel six (6) only. For this study a conventional 21" screen TV was used.

4. **Coaxial Cable** - A special shielded cable, connecting the television camera to the television monitor unit, with impedance matched to camera specifications.

5. **Optical System** - A series of special portrait-type lenses fitted to the standard television camera lens, with a maximum power of 15x and a focal length of 6.35 centimeters.

6. **Rear Projection Screen** - A Kodak transluscent screen, permitting rear projection of the chromatic slides presenting the stimulus pictures, and thereby reducing the glare and reflection from the typical glass-beaded front-projection screen.

7. **Recording Camera** - A standard 8-mm movie camera, loaded with high speed ASA 500 achromatic fine grain film for recording the data presented on the TV monitor screen, and simultaneously recording the stimulus picture being observed by the S. The camera was electrically controlled for single-framing at any desired rate, from ten frames per second to one frame per second, the latter used in this study.

8. **Experimenter-observer** - Refers to observers who watched the changing pattern of pupil dilation and contractions on the television monitor, and recorders who evaluated the changes visually as the test progressed.
9. **Control Central** - An electric console from which one experimenter-observer can control all functions of the experiment, including voice communications (on rare occasions) with the S being tested, and switch controls for operating the remote recording camera, including advancing the next stimulus picture to be projected from the 35-mm slide projector.

10. **Slide Projector** - Any standard 35-mm slide projector with remote control capability, capable of holding up to fifty slides. The lens must be of appropriate focal length to adapt to close-coupled projection to a rear projection screen.

11. **Pupillometrics Examining Chair** - A comfortable, upholstered TV-type swivel armchair, with the left arm support modified to accommodate a vertical column, from which the head-rest and TV camera ensemble is swiveled into position and adjusted for the comfort of each S as he is seated to be tested.

12. **Attitude** - An "at-the-moment" reaction of the S indicating his acceptance or rejection of a given visual stimulus as noted by an increment in the S's eye pupil to denote acceptance and a decrement in the S's eye pupil to denote rejection.

**Limitations Imposed by this Pilot Study**

The nature and objectives of this pilot study imposed certain limitations

a. on the kind and number of Ss used,

b. on the criteria for, and the modes of, recording,

c. in the selection of the paper-and-pencil tests,

d. and in the stimuli pictures selected.

Attention will be focused on those variables which may limit the ability of the examiner to accurately observe and record the S's pupil response as an indication of the S's attitude or emotional response of pleasure (acceptance) or displeasure (rejection) as the net result of cognitive interpretation of the message conveyed by the stimulus picture.
Since this is a pilot study involving many interlocking variables, no direct attempt will be made to generalize from the statistical findings to the total population for which the small number of Ss, thirty-two college students, might be thought to be a fair sample.

The quest is not for quantitative data on the characteristics of people in general, but for a way of designing a pilot study which can lead to data of eventual qualitative value leading to a better understanding of a new educational tool that relates pupil change to attitude change when selective visual stimuli are presented to any S.

Summary and Overview

Chapter I has presented the background, rationale, and historical origin of pupillometrics as it is now understood. It has included a statement of the problem, the several hypotheses to be tested, a definition of some of the basic terms to be used in this study, including a brief description of very special equipment that will be covered in greater detail in later sections of this report. The limitations of the study in general and the pilot study in particular have been defined.

Chapter II reports what the search of the literature has to say concerning the body of knowledge available, and identifies support for the specialized approach techniques unique to this study.
Chapter III describes the methodology involved in the planning and implementation of this research study, and a detailed description of the special equipment design. Included in the procedures is a declaration of the dependent and independent variables known to exist in the design of the study, as well as precautions planned to help prevent other unwanted variables from interfering with the validity of the design.

Chapter IV reports the data collected in the pilot study, and presents several tables to illustrate the level of success in testing the three hypotheses cited.

Chapter V includes a summary, conclusions, and recommendations for further applications of pupillometrics in the field of education, and certain observations about limitations of this method of non-verbal examination of attitudes and feelings based on visual response to varied stimuli.
CHAPTER II

SURVEY OF THE LITERATURE

A survey of the literature reveals very little on the subject of pupillometrics prior to 1960 in this country, and only a few references to a possible relationship between emotion and pupil diametral change from foreign publications. Textbooks on ophthalmology cite some studies of pupil adaptation to factors other than light intensity, and provide some clues to the nervous system's complicated control over the iris muscles in relation to pathology and genetic anomalies of the eye. Textbooks on psychiatry merely mention the eye as one of the factors to be observed in clinical analysis of abnormal behavior, using such terms as "eye contact avoidance," comments on traits of nervous individuals as being "shifty-eyed," etc., and the general comment that the eye is often dilated in trauma or death. Several references were found relating to commercial advertising attempts to use the tools of pupillometrics to evaluate potential consumer acceptance of products, based on observation of the eyes of potential customers when they were viewing pictures of selected products.

Equipment design has varied from the very crude and simple, to some very complicated and sophisticated electronic devices that provide automatic readout of data.
Survey

In technical publications, one of the earliest references to the relationship between emotion and eye reaction is contained in Charles Darwin's book, *The Expression of the Emotions in Man and Animals.*¹ He mentions a "widening and narrowing of the eyes" as signs of strong human and lower animal reaction to such emotions as fear and anger. He makes no quantitative comment except to note that such changes occur regardless of the light intensity of the environment impinging on the retina.

The next reference found in chronology is to experiments conducted by Sherrington using artificial pupils.² The observer matched two lights seen in binocular vision. One light beamed equal intensities to the two retinas, while the other projected asymmetrical combinations of light to the two retinas. The former served as the dependent variable, the latter as the independent variable. No units of measurement are given, but since artificial pupils were employed, one can multiply all the values by a single arbitrary constant, selected to bring the decreasing curve of the data near to the straight line of the increasing curve after minimal values are reached and the curve ascends again, illustrating the trend of our own pupil "matches." These findings are confirmed by Alpern and


tenDoesschate in 1968 in their study of photoexcitation of the two retinas on pupil size. While neither of these studies contributed directly to pupil reaction to emotional stimuli, they are important because they established some early concepts about pupil response as being symmetrical for the two eyes in normal individuals.

Another early contribution to the range of pupil dilation and contraction was made in 1918 by Reeves. His pioneering experiments revealed that under equilibrium conditions, the pupil is smaller when both eyes view than if either is occluded. This study says virtually nothing in a quantitative way about this effect, and makes it difficult to infer the amount of effective retinal illumination because of uncertainty as to how much of the response results from the respective excitation of rods, on the one hand, and of cones on the other. His study is of special interest to this study because of the possibility of differential cognitive interpretation of the stimulus by the S when presented with achromatic pictures that are perceived primarily by the rods as compared to chromatic pictures that are perceived by both rods and cones, with more receptors involved. The additional phenomena of darkness adaption differential between rods and cones adds another factor that may become an important variable to be investigated in future testing.

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Early studies to determine just what part of the nervous system is responsible for controlling the pupil of the eye in dilation and contraction should include the work of Kuntz.\(^5\) His experimentation with the control of the constriction and dilation of the pupil by the sympathetic and parasympathetic divisions of the autonomic nervous system was mostly concerned with light reflex, but he opened the door to much discussion as to other factors that might also cause similar changes in the pupil diameter. He was able to confirm that the light reflex, which is a change in pupil size due to changes in environmental light conditions, is controlled by the parasympathetic division through the action of the ciliary ganglion. The role of the sympathetic division in determining the size of the pupil is more complex; Kuntz insists that "strong emotional states are accompanied by general sympathetic stimulation" and that "deep emotions of pleasure as well as fear are commonly accompanied by pupillary dilation."\(^6\)

Additional evidence that control of pupillary dilation by the sympathetic division of the autonomic nervous system, as governed by the hypothalamic centers, is discussed by Gellhorn, who concludes that "pupillary dilation is one of the most constant symptoms observed


\(^{6}\)Ibid., p. 74.
on stimulation of the hypothalamus. An extension of this conclusion is contained in the report of Gibbs and Gibbs, who found that hypothalamic stimulation will elicit purring in cats, a reaction which is generally considered to be an emotional expression of pleasure by that animal.

Somewhat remote from our present interest in the response of the pupil of the eye to visual stimuli, but of related interest, is the work done by Hahn and his associates in Germany in 1938, testing pupil response to the stimulation of various beverages presented to the Ss in certain sequences. He found both a definite variation in degree of response among Ss, and in recovery time. Hahn found that almost complete receptor recovery can be expected in a twenty second interval when liquids were used as a stimuli. No similar specific data has been reported on recovery time when using visual stimuli. Recovery time may be an important independent variable to be considered in all future studies.


Several studies have been made concerning the problem of pupil adaptation to light or any continued stimulus over a period of time. These studies are important for this research attempt because they laid the groundwork for some of the care taken in the design of this study to assure adequate time for light adaptation before any of the stimulus pictures were presented to the S, and also identified the need for re-stabilization of the pupil diameter on a neutral pattern after each stimulus series.

Baker's study of the non-linearity of the human pupil system provides insight into the mechanisms involved in exciting both eyes simultaneously, and recording the pupil diameter of one eye. His attempt was to locate anatomically, and to clarify the nature of, the dominant nonlinear operators in the human pupillary system for reflex to light. This is important for this research study, as extreme care was taken to stabilize the light output of each projected picture. Baker's findings showing the similarity of results of the monocular and binocular cases suggests that the dominating nonlinear operation occurs after the summation of signals from the two eyes. This might suggest that photography, or observation, of any one eye would be sufficient after summation has occurred.

A more valuable conclusion drawn from Baker's work concerns his discovery that vertical displacement of the direction of gaze would cause errors in measurement of pupil size, causing the mean

value of the pupil size to appear to be smaller than it actually is. He concluded that in his study (as is the case in this research study) if interest is only in change of amplitude and not in total area, the error is not of any significance. With his equipment, if the center of the pupil was one millimeter vertically off center, his error was about 5 per cent for a two millimeter pupil change.

Physiologists have known for some time that the visual system is notably nonlinear in its transfer characteristics. Baker mentions the work of (Hartline, 1957) experimenters investigating the response of primitive receptors which show a logarithmic relationship between response and input stimulus amplitude, and this seems to hold in the more complex human retina. Other psychophysical investigators have intensively studied the dependence of the responsiveness of the visual system on its past light history. (This is another very good reason for the control of the gross light amplitude and time durations as each of a series of stimulus pictures is shown to a given S.) Amplitude and time dependent, or adaptational, nonlinearities therefore combine in compressing the range of operation of the visual system and therein influence the response of the pupil.

Light adaptation of the pupil was also the subject of a dissertation performed by Gad Hakerem in 1962. In his study, eight

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11Ibid., p. 1431.


levels of light adaptation were obtained by illuminating the eye with continuous light of different luminous levels for eighty seconds (step stimulus) after fifteen minutes of dark adaptation. The stimuli were presented with a Maxwellian view system, and subtended a visual angle of 3° centrally fixated. They were presented to the left eye while the pupillary reactions of the right eye were recorded. (This study holds deep inferences for the results of the current research design in which the right eye was stimulated with the pictorial presentation, and the left eye was measured.)

Hakerem's conclusions determined that (1) pupillary diameter at specific points in time late in the adaptation period were related to the adaptation luminance, the curves being sigmoid, reflecting a dilation of the pupil during continuous stimulation with light, and (2) the maximum velocity with which the pupil will contract in response to both pulse and step stimuli is a function of the luminance of the stimulus.14

It is now appropriate to mention another finding in the research of tenDoesschate and Alpern,15 previously cited, concerning pupils with equal binocular stimulation. Under such conditions, the size of the pupil of the left eye appears to be the same whether the left or the right retina alone is illuminated. Within the rather wide margin of experimental error, either retina is about equally

14 ibid., p. 95.
15 op. cit., pp. 565-566.
effective in making the pupil of the other eye respond, in what appears to be a linear manner for normal, healthy eyes. Wide variance between individuals has been noted, and older people invariably have smaller pupils in response to a given light source than do younger persons. One must note, however, the superiority of binocular over monocular viewing in producing smaller pupil diameters under the same light conditions. The nervous system does not add the lights linearly to produce the same pupil size if the illumination is doubled for one eye as for both eyes.

In a followup experiment, tenDoesschate and Alpern found some additional information on pupil matching. They replicated some of Sherrington's work in having an observer match two lights seen in binocular vision; one light was made up of equal intensity to the two retinas, while the other had various asymmetrical combinations to the two retinas. A single line resulted that described the results for brightness, at least as well as it did in the pupil results for which it was drawn. This was surprising, since it is generally believed that nerve fibers which carry signals from the two eyes for vision do not communicate with each other until after the fibers which carry the signals for photo-pupillary motion have separated off.


These experimental findings appear to suggest, however, that to the contrary, nerve fibers conveying signals for brightness and for pupil construction for the two eyes both converge at the same level or that convergence at radically different parts of the nervous system follow very quantitative rules. Therefore, in principle, such data might be used to obtain a family of curves showing the intensity of illumination one must give to one retina in order to obtain any desired pupil size in the other eye. It would be fascinating to anticipate that such linkage might also occur in the presentation of emotional visual stimuli, and cause one pupil to control the other for measurement. Such possibilities will be examined in this research study to be reported herein.

One research article was found that provided a caution to anyone attempting to measure pupil response to any given visual stimuli if the environment included any conversation while the tests were being conducted. An Experimental Psychology Abstract, Volume 41: 6553, mentions the work of Lehr and Bergum\(^\text{18}\) in which they examined the relationship between the pupillary response and the affective value of verbal stimulus on pupillary adaptation. They found these effects occur quite rapidly, and caution all researchers to be aware of conversation within the vicinity of testing.

In support of the hypotheses that there might be a relationship between pupil size and emotional words, a study was made by Guinan\textsuperscript{19} in 1966, in which he tested Ss responses to emotionally loaded words as compared to neutral words. The words were selected from a list that had previously been tested for GSR responses. Three words with the highest and lowest "emotionality scores" were chosen and presented to twenty-eight Ss, while their eyes were recorded photographically. Each word was presented for five seconds. The results indicated (1) that emotionally loaded words brought about larger pupil size than neutral words, and (2) when the data for the first 2.5 seconds and the last 2.5 seconds were analyzed separately, results showed that pupillary size during the first period was not significantly different for the two types of words, but clearly demonstrated that during the last period, emotionally loaded words brought about a significantly greater pupil size than neutral words. Such findings might suggest that a type of adaptation takes place as a result of cognitive processing of the words, and their association value to a given S might vary according to the intellectual level or moral value attached to such words.

Many researchers have wondered about the possible differences that might result if all chromatic stimuli were used instead of

achromatic excitation. Miller\textsuperscript{20} investigated this in 1966 at Michigan State University. His experimental hypothesis predicted that the pupil of the eye would manifest more responsivity, as measured by pupil diameter, when exposed to achromatic (neutral) stimuli. (This description is unfortunate, since a picture of war crimes would be emotional whether printed in chromatic or achromatic media.) However, he found support for his hypothesis. There was a significant color effect upon the pupil diameter ($p > .001$) and the mean pupil response to each of the chromatic stimuli was significantly greater than the mean pupil response to the achromatic stimuli ($p > .01$). The pupillary response was shown to be an initial contraction and return in response to any stimulus followed by a clear dilation in response to any chromatic stimulus, and little response to an achromatic stimulus. There was no mention in this report of any attempts to isolate differences due to pleasant versus unpleasant visual stimuli.

As one scans the literature, there is an apparent difference in the opinions of Hess and of Loewenfeld and Lowenstein (see page of this report). Loewenfeld supports those findings that indicate a consistent first dilation, possibly followed by contraction, while Hess finds either can occur first. Woodmansee\textsuperscript{21} also generated some


controversy when he selected persons who were known to be prejudiced against Negroes and matched them against a control group of non-prejudiced Ss. His findings are important in that they revealed an affect-related response which occurred early in the presentation of the visual stimuli, and then appeared to diminish. This phenomenon has been experienced by others, and is possibly due to differences in nervous system arousal. He assumed that pleasant or accepting stimuli cause the arousal system to be excited and the pupillary dilator muscle to be activated. The anticipation of an unpleasant stimulus also seems to cause the arousal system to be excited when concomitant expansion of the pupil, but the actual presence of the disliked stimulus serves as a relief from the excited anticipation. This latter sequence results in an apparent construction response of the pupil which is in reality the relaxation of the dilator muscle. There are those who would challenge this explanation, but in the light of limited research to the contrary, his conclusions are interesting to consider.

The literature is somewhat parsimonious in the description of equipment designed specifically for the study of pupillometrics. Most of it appears to be an outgrowth of equipment previously used for the study of eye movements, or of light reflex when activating the retina of the eye. We shall review some classic designs used by the pioneers in pupillometrics.
The Hess configuration\textsuperscript{22} as well as his technique is described in one of his pilot studies with homosexuals. He describes his procedure and apparatus in this manner.

In a dimly-lit room, a $S$ was seated before a viewing aperture, fitted with a headrest, which was inserted in a large plywood panel. The panel concealed the working of the apparatus from the subject. Resting his head against the aperture, the subject faced a rear projection screen, set in an otherwise black box, at a distance of $2\frac{1}{2}$ feet from his eyes. A 35-mm slide projector behind this screen projected a 9 x 12-inch picture onto it. Changing of the slides was controlled by the experimenter from his position behind the panel where he also operated a concealed 16-mm camera fitted with a frame counter. As the slides were being viewed, a half-silvered mirror placed at a 45-degree angle across the subject's line of vision permitted unobtrusive filming of the eye, at the rate of two frames per second. Illumination for this photography was furnished by a 100-watt bulb on rheostat control.

Fifteen picture slides, representations of the human figure, were shown . . . (to each subject) . . . The presentation of each of these stimuli pictures was preceded by the presentation of a medium gray 'control' slide. The total sequence was thirty slides in this order: Control A, Stimulus A, Control B; Stimulus B, etc., each shown for ten seconds, with a total viewing time of five minutes for the entire sequence . . . (There follows a lengthy description of each slide) . . .

The processed 16-mm film was (later) projected, frame by frame, onto the underside of an opal-glass insert in a table, to a magnification of approximately twenty times. The diameter

of the pupil in each frame was measured with a millimeter rule and recorded, giving a set of 20 measurements for each control presentation and a set of 20 for each stimulus picture. . . . (He then proceeds to describe in detail his method of scoring.) . . .

There have been numerous criticisms of the crude or unsophisticated equipment used by Hess and his associates, but it has reappeared many times since in slightly altered form, even to use by such advertising consulting firms as Marplan in New York, for the purpose of testing the housewife's reaction to many different consumer products before placing them on the market.

Equipment very similar to that used by Hess was used by Nunnally\(^{23}\) and his associates at Vanderbilt University in 1967, to test pupil reactions while various physical and mental tasks were being performed. He found highly regular relationships between pupil size and degree of muscle strain while working a hand dynamometer.

Credit is given to a German scientist, Drischel\(^{24}\) for the first use of infra-red light source and electronic measurement of pupil diameter.

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The primary objection to the very sophisticated equipment used by Lowenstein and Loewenfeld\textsuperscript{25} in 1958 is its cost and complexity. Few universities or research centers could afford to purchase or maintain such an elaborate set-up.

For those laboratories that already have some electronic equipment, including oscilloscopes and automatic pen recorders, Landauer and Feakes\textsuperscript{26} offer what they describe as a simple electronic circuit to provide continuous read-out of pen-recordings of pupillary size changes. In their method, a chopped infra-red light source is reflected from the S's entire iris, and a contraction of the pupil is recorded as an increase in reflectance, and pupillary dilation as a decrease in the amount of infra-red light reflected. They claim the system is easily calibrated to the eye size of each S. Gross movements of the eye and blinks are dampened by a simple capacitor filter in the system. Cost is modest.


SUMMARY

Chapter II provides a survey of the literature on the subject of pupilometry, and cited specific references in near chronological order that could be related to the recognition of changes in the pupil of the eye and various types of perceptual affects.

The case was developed for an understanding of man's long-time interest in the eye and what it might reflect of man's emotions or cognitive processes in response to environmental stimuli. It was shown that until man had learned enough about physiology and the nervous system to understand the chain of afferent and efferent nerve impulses that must take place to cause a change in the pupil of the eye, most scientists, philosophers, and poets were certain only of the change as a result of variation in light impinging on the retina. Little or no effort was directed to understand why some people responded to other stimulation than light.

Darwin was among the very first to note that both man and lower animals showed emotional changes in the pupil of the eye concurrent with overt behavior such as fighting in anger, relaxation in love and mating, delight in seeing a familiar person, place or object within his perceptual range.

What studies might have been made in Europe prior to World War I we do not know, but after the great war, man seems to have generated renewed interest in physiology, and attention to the new science of psychology brought increased interest in man's behavior as a result of his perceptions. Much concern was developed over
the difference in the reactions of people who were in the same environment, but perceived their surroundings with different emotional affects. Reeves and Sherrington were among the early pioneers to wonder what effect monocular versus binocular vision might have on the total affect charge of emotions. The medical profession delved more deeply into the functions of the sympathetic and parasympathetic divisions of the autonomic nervous system, and the effect of pupillary adaptation to darkness and subjection to the same stimulus for an extensive period of time.

Early attempts of Hess, Lowenstein, and Loewenfeld to relate pupil response to emotions on a hedonistic scale were discussed, and the problems of over-simplification were identified in their studies.

Attention was given to the studies made by Hahn on pupil response to taste differences in beverages, to Woodmansee and his study of racial prejudices detected by presentation of pictures depicting racial situations. Pupil reaction to muscle tension was described by Nunnally.

Since all of the investigations reported have been initiated by individuals largely to satisfy their own curiosity, and no standardization of method or equipment had been accomplished, some attention was paid to reports that showed the evolution of measurement devices from the very elementary to the use of space-age technology. There is good reason to believe that the pressure for commercial applications may force the development of some standard
method too soon, and thereby inhibit further creativeness among the scientists who wish to reap immediate rewards. There is ample evidence that we have merely touched on the surface of this fascinating new field of reaching the human subject by non-verbal methods, and we need improved validity and reliability of the instruments and methods.

The present challenge is to provide methods, techniques, and equipment that will be within the financial reach of more experimenters, within the scope of education as well as industry, and to encourage more publication of such studies that will define more areas of application. Such is the basic intent of this research study, to open the door to more potential applications related to elementary, secondary, and higher education for everyone's benefit.
The term "pupillometrics" was coined by Hess\textsuperscript{1} to describe the science dealing with the measurement of changes in the diameter of the pupil of the human eye in response to emotional stimuli, irrespective of, or in addition to, that reflex normally associated with change in light intensity striking the retina of the eye. The term now appears in literature interchangeably with pupillometry, a term in general use by ophthalmologists concerned with the physiology of nerves and muscles that control the dilation and contraction of the eye, primarily in adaption to varying light sources adequate for visual acuity.

The review of the literature on this subject revealed that various types of perception, including any one or combinations of the senses, might be responsible for an emotional response reflected by a change in pupil diameter.

In this study we shall be concerned only with the cognitive processes brought about as a result of visual stimuli, which may result in an emotional charge sufficient to be indicated by an increase or decrease in pupil size of the S. If and when such

emotional change is reflected in a pupil diametral change, experimental data is to be accumulated with appropriate equipment and an attempt made to prove the relationship between the physical and emotional factors.

The emphasis will be directed toward proving the validity and usefulness of pupillometrics as a non-verbal instrument, with reasonable correlation with an established paper-and-pencil instrument.

Basic Assumptions

With the above premise in mind and in terms of the theory of pupillometrics as defined by both Hess and Lowenstein, the following assumptions are presented in considering the relationship between responses found to a given stimulus picture by the process of pupillometrics and the same picture when responded to by the traditional method of paper-and-pencil response.

1. Stimulus pictures of various vocations, occupations, and professions would be equally valid and recognizable by both male and female college Ss.

2. Female Ss would either identify with the picture as an occupation with which they could be happy if they were employed themselves, or if their husbands were employed in this occupation.

\[ \text{Ibid.} \]

3. A valid appraisal of pupil reaction could be made by simple observation of the TV monitor screen, and an immediate decision made of acceptance or rejection of the stimulus by the S as indicated by his pupil dilation or contraction, and camera verification would not be necessary when experimental observers were properly trained. This would be verified by a high correlation between experimenter rating and camera verification.

4. A hedonistic approach is valid, in that a dilation indicates pleasantness or acceptance but a contraction would mean unpleasantness of emotion or rejection of the stimulus by the S. The criteria for dilation and contraction reactions will be stated in the experimental design criteria, and will be used consistently by all personnel involved in evaluating data, both directly from TV screen observation and from the camera record of the TV screen.

5. The search of the literature has provided sufficient evidence of the validity of photographing or observing by closed circuit TV only one eye as an example of equal response by the other eye to pupil changes as a result of either one eye or both eyes seeing and evaluating visual stimuli.

6. Since all Ss were college students involved in a study of experimental psychology, they are motivated to cooperate and give honest paper-and-pencil responses with no intent to invalidate their true feelings about the visual stimuli or to attempt to fake their pupil responses by closing their minds to the stimuli at hand and deliberately thinking about some other situation.
7. All Ss were previously tested to determine that they were not color-blind, but no attempt was made to determine that they might not reject some of the colors used in the art work in preparing the chromatic slides. It is assumed that all Ss accepted the chromatic stimuli pictures as comparable to other visual educational aids to which they were accustomed.

8. All Ss were assumed to have normal vision as corrected by regular eyeglasses or contact lenses, both of which could be used by the S in this research study.

9. Since all Ss were college students, it was assumed they were all career oriented to some vocation, which may or may not have appeared in the list of thirty stimulus pictures shown to them.

Research Design

Stimulus Pictures

A search for suitable stimulus pictures representing a reasonable spectrum of occupations, for which some standardization data was available, led to the use of Part II of the Picture Interest Inventory. Prior experience had verified this instrument as a reliable non-verbal tool for use in vocational counseling. These sketches were painted in water-color to provide a set of thirty chromatic stimulus pictures, each of which was then

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photographed on Kodachrome II film by a 35-mm camera, developed and light corrected to give the same total area illumination when projected. For the paper-and-pencil portion of the experiment, the standard Picture Interest Inventory booklet with its usual achromatic pictures was used. Only Part II was scored to the Manual instructions.

Stimulus pictures for use with the Mooney Problem Check List, College Form, were selected by a panel of six male and six female college students, from a set of over two-thousand Kodachrome slides, that were made especially for pupillometrics experiments by this research team, copies of pictures scavenged from months of gleaning every available popular American magazine, including technical journals, trade, comic, love, and picture magazines available on any newsstand. These pictures represented just about every social and economic situation current in the college press to which modern college students are subjected in home, college, and community environment. This student panel reduced the list to one hundred pictures which were then shown to a class of one hundred students, who ranked the pictures as representing those things most likely to bring about some emotional response from them, either positive or negative. From this rank order list, another panel of ten students, five male

5R.L. Mooney and L.V. Gordon. The Mooney Problem Check Lists, College Form (New York: The Psychological Corporation, 1950), Part X.
and five females, selected the thirty pictures that they felt were
most represented by the three hundred and thirty items of the Mooney
Problem Check List, College Form. It so happened that ten of these
pictures selected matched items in Part X of the Mooney Problem
Check List, which deals with The Future: Vocational and Educational.
There are thirty items in Part X, therefore the stimulus pictures
related to vocations were in the ratio of one to three to the paper-
and-pencil items.

In order to avoid any halo effect, each of the Ss who parti-
cipated in the study were required to take the entire Mooney Problem
Check List of three hundred and thirty items, only thirty of them in
Part X being used in this research study at this time.

Pupillometrics Equipment

Most of the equipment for this research study was either
designed by the researcher for his special adaptation from some
standard television and photographic equipment, or evolved as a
hybrid configuration of off-the-shelf items readily obtainable
and modifiable by the average research experimenter.

The television camera used in photographing the pupil of the
eye evolved from a standard Squires-Sanders Model SS-310 television
camera fitted with a standard 8-mm movie camera lens, with a lens
adapter to hold a complex of seven stacked portrait lenses to give
a total of fifteen magnifications. This shortened the focal length
to a distance of two and one-half inches, somewhat inconvenient to
use because of the requirement to place the lens of the camera very
close to the S being examined, but no complaints were registered nor severe discomfort mentioned during the time required to view the total of thirty-six stimulus pictures shown at a single sitting. This series of pictures consisted of a standard Dvorine color chart with an embedded figure shown first, followed by five stimuli pictures, and then another slide of the Dvorine embedded figure, etc.

This Model SS-310 television camera is designed to transmit an RF signal factory set for channel six of any standard television receiver, or by internal switching, it will transmit a video signal that can be received by conventional video monitors available from any electronic supply house. When used with a standard television set receiver, shielded cable must be used and the coaxial cable must contain a 300/75 ohm matching transformer at the receiver input terminals.

The television camera is mounted on an appropriate adjustable stand suspension attached to the arm of the pupillometrics examining chair as shown in photograph Plate A in Appendix of this report.

The pupillometrics examining chair was a modified, swivel based, television viewing armchair, a type available at most furniture stores. The left arm support was modified to accommodate an adjustable column support for the television camera mount, including a head and chin-rest support which located the head of the S in the proper position for camera recording of the left eye of the S while he observed the stimuli pictures, as shown in Plate A of Appendix.
The recording camera was a modified 8-mm movie camera, with standard lens, and single framing capability. It was modified to accommodate an electric solenoid for tripping the shutter mechanism by remote control through a timing device, adjustable to provide for a single frame exposure at any rate from ten frames per second to one frame every second. For this study, photos were made at the rate of one per second, the 15° camera view angle provided by a standard F 1.9 lens being large enough to accommodate inclusion of (1) the picture of the eye greatly enlarged as seen on the television screen, (2) the serial number of the S being tested, and (3) the stimulus picture being viewed by the S at that given moment. See photograph Plate C in Appendix.

The television monitor was a standard commercial television set, with a twenty-one inch screen, with the controls locked at channel six to match the signal generated by the television camera. Over the viewing screen, a clear plastic mask was mounted containing a calibrated scale of vertical lines set one-eighth of an inch apart, this scale representing the actual pupil diameter converted so that each space on the screen represented 0.2 millimeters of pupil diameter.

The use of the plastic scale mounted directly on the viewing face of the television monitor tube was a distinct improvement over other experimental designs as noted in a review of the literature, since this configuration provided a direct, constantly calibrated scale for later reading of the film record regardless of the degree
of magnification by the projector. The line spacings of one-eighth of an inch apart were sufficient for accurate direct reading from the television screen by the trained experimenters as they observed pupil diametral changes exhibited by the S as he viewed each different stimulus picture. See photograph Plate D in Appendix.

The stimulus pictures were exhibited to the S by means of a remote-controlled Kodak carrousel type 35-mm slide projector, and were shown on a 10"x14" rear projection screen. This screen was placed five feet in front of and one foot above the center line of the S's eye level when seated in the pupillometrics examining chair. See photograph Plate D in Appendix. Such location of the stimulus pictures for viewing was found to be optimal in causing each S to open the eyelid sufficiently to expose 90% or more of the iris for scanning by the television camera.

An electric console for control of all of the equipment was located on the table to the left of the television monitor, and was operated by one experimenter responsible for programming the rate at which the stimuli pictures were presented to the S, and also to control the rate and number of photographs made of each picture shown to the S resulting in changes of pupil diameter as exhibited on the television monitor. This console, also, exhibited a lighted code number for identification of the S on the film record. See photograph Plate B in Appendix.

The film used in photographing the eye from the television screen was Dupont ASA 500 speed fine grain, achromatic, 8-mm movie
film, and most photos were made at 1/30th of a second at F1.9 lens aperture.

Appropriate mimeographed forms were used for obtaining the necessary data about the Ss, and for recording the visual record as seen in transition on the television screen as each S was tested. As many changes in diameter were recorded as the skill of the experimenter permitted in the ten second period that each stimulus picture was presented.

Selection of Sample

The Ss (subjects) for this study were drawn from a pool of 200 undergraduate students all enrolled in psychology courses at Ohio State University. The enrollment cards for this group were sorted into two piles, male and female, then each stack shuffled separately and cut. Every third card turned in each stack was utilized, in the ratio of four men for each woman, until twenty males and twelve females had been selected. These thirty-two candidates' name cards were then assigned to four groups, A, B, C, & D. A number was also assigned to each card, and this became the S's permanent record number throughout the study. An identical number of students were also selected from the same original sample for a control group, assigned to A, B, C, & D groups, but given different serial numbers, and intermixed in the total testing program so that no student knew who would be among those in the final sample. This was fortunate, since several of the students dropped out of college before the study was completed and some random replacements
to the experimental group had to be made, always replacing the exact sex and test sequence in a given group. It was assumed this method effectively avoided the introduction of any additional variables into the study. All subjects were between the ages of eighteen and twenty-four years, and single. None had any previous experience with a study of pupillometrics.

**Experimenter Teams.**

Psychology student volunteers, who were not among those chosen to be Ss in this study, were organized into teams of three persons. These teams were then thoroughly trained by the research director in all phases of the operations of the equipment, the seating of each S, and the adjustment of the equipment to each S in the pupillometrics examining chair. Each member was trained to rotate assignments when each new S entered the laboratory, taking turns at operating the control center, acting as visual recorder, or responsible for seating the S to be tested and scheduling the reel of stimuli pictures to be presented to the S. This procedure was intended to reduce or remove any halo effect associated with any specific recorder and S combination. Records were kept for later study of any major differences between performance of individual members of the team. Four different teams participated during the testing of the sixty-four Ss, most of the Ss completing three or more steps of the test program, and all completing the two different reels of stimuli pictures. This meant that twelve different recorders
performed during the visual evaluations of the one hundred and twenty-eight test runs of visual stimuli. This procedure should have ruled out any personal bias in recording by any one recorder from influencing results.

**Preparation of Subjects (Ss)**

Prior to being accepted as a S, each student was given a color-blind test to determine if he could respond to the chromatic pictures that would be used in the experiment. Those who passed were then assigned numbers and given a schedule for appearing at the research center for examination. On arrival for testing to the stimulus picture portion of the sequence, they were read the following instructions.

**READ TO EACH SUBJECT BEFORE HE IS SEATED IN CHAIR:**

Thank you for volunteering to be a S. We want you to be comfortable throughout the experiment, so one of the experimenters will now seat you in the pupillometrics examining chair and adjust the equipment in preparation to showing you some pictures that will be projected on a screen in front of you. Once you are comfortable and the equipment properly adjusted, we will ask that you try to hold your head position in the chin-rest locator throughout the entire sequence of pictures. On occasion we may ask you to move your head to bring your eye back into focus before proceeding to the next picture.

You may wear your contact lenses, but if you wear eyeglasses, please remove them. If you cannot see the stimuli pictures without your glasses, ask the experimenter to locate them in the clip on the headrest (not on your nose) and adjust them so you can see the stimuli pictures. A trial slide is available for this purpose.
The room lights will be dimmed, and you will be given two minutes to light-adapt your vision to a standard green-tinted slide. The pictures will then be shown to you in blocks of five, each block preceded by a standard eye adaption pattern slide. Each stimulus picture will be projected for ten to fifteen seconds. We ask that you think about each picture as it is shown, trying to form an opinion in your mind as to whether you accept or reject the total scene. In the case of vocational pictures, we suggest the males try to decide if that occupation would be acceptable to you as a career; for the women, we suggest that those occupations that are not female oriented, ask yourself if the occupation would be an acceptable career for your husband. Please do not respond verbally, since this will move your chin and change the focus of your eye on the TV camera.

At the end of any set of five pictures, while the test pattern is being projected, you may ask for time to relax or readjust your body and chin position.

If you desire interpretation of your responses, ask for an appointment with the research director at a later date. The experimenter is not permitted to give you an analysis at this time. Thank you for your cooperation and consult the schedule for your next appointment date and time.

Environment for Testing

Based upon the best available information found in the search of the literature, complete dark adaptation of the eye cannot be accomplished in less than thirty minutes, while twilight adaptation can be accomplished in less than five minutes for normal vision. For this reason, the laboratory environment was kept dimly lighted

at all times, an aid to both the recorders and other test personnel as well as to the S. The immediate environment of the S was lighted so that at reading distance (16-inches) from the eye, a book would be illuminated with five candlepower. The plain green tinted adaptation slide represented an illumination of one foot-candlepower at a distance of five feet from the S’s eye. All the stimuli pictures had been light balanced by photographic reproduction techniques to represent the same intensity of total illumination, plus or minus one foot-candlepower, when projected on the rear-vision screen. The slide illumination of each picture was equivalent to the light cast by a standard thirty-watt lamp placed one foot behind the view screen. Data collected showed that 95% of the Ss experienced less than a 4% diameter change when a series of Dvorine* test slides were shown in sequence with the time delay of the projector advance mechanism set at normal ten-second operation. This would appear to rule out any pupil diameter change due to endogenous light conditions within the laboratory environment. Once the examination started, no conversation was permitted within hearing distance of the S, except on those rare occasions when the experimenter in charge requested the S (always at the end of the ten-second camera recording period) to move a certain way to re-establish optimum focus of his eye on the TV screen.

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*Dvorine—Standard color chart with an embedded figure "26" in a chromatic pattern of random dots.
Method

The thirty-two Ss involved in this study were divided into four groups, A, B, C, and D, each group consisting of five males and three females, all college psychology students between the ages of 18 and 24 years. As shown in Table 1, Appendix, each group performed all four phases of the study, but in rotating sequence, as explained in the experimental design.

The laboratory set-up is shown in Plates A, B, C, and D in Appendix. For the stimuli pictures, each subject was tested on a series of thirty pictures related to vocations and thirty more stimuli pictures of social and economic situations common to the culture of college students, including ten pictures related to career plans. As noted in the experimental design, only those stimuli pictures related to occupations and careers were utilized in the results for comparison or correlation. The basic intent was to determine the feasibility of direct reading of the television monitor of changes in pupil diameter of a given S to a given stimulus picture, and to evaluate on the basis of this change whether the S had a positive or pleasant reaction, or a negative or unpleasant reaction as an evidence of emotions caused by cognitive analysis of the stimulus picture content or implications to the S.

Each subject was seated in the pupillometrics chair and the equipment adjusted to his comfort, so that his left eye would be observed by the television camera as he viewed a series of pictures
shown to him on a rear-projection screen, placed about five feet in front of him and elevated one foot above his horizontal line of vision. This viewing angle assured the S's eyelids would be wide open thereby assuring a better view of the entire iris and pupil. Closed circuit television projected the picture of the eye on a television monitor, where it was observed and read by a team of trained observers, and also photographed for a permanent record. The photos were made at the rate of one frame per second on 8-mm high speed film, as the S observed each stimulus picture for a period of ten to fifteen seconds (ten minimum, but longer if the visual observer needed the time to assure the S's pupil had stabilized before advancing to the next frame).

At the beginning of each series of stimuli pictures, the S was always given a period of eye light adaptation by observing a preliminary plain green slide for a period of two minutes in a room that was always dimly lighted to a reading level of five foot candle power. Then the first slide shown was a standard Dvorine color-blind test slide with an embedded chromatic figure.

The standard Dvorine slide was then followed by a series of five stimuli pictures, then another Dvorine slide to re-establish stabilization of the pupil before proceeding to another set of five stimuli pictures, etc. When all of the thirty stimuli pictures had been presented, the last slide was another Dvorine slide to see if there had been any major fatigue or light adaptation affect that might have clouded the expected results.
The schedule was arranged so that no S was required to take a second series of the stimuli pictures within a forty-eight hour period, so that the eyes had adequate time to return to any normal condition to which the S may have been accustomed before further testing.

The changes in the pupil of the eye were observed by one or more trained observers by recording the pupil changes in diameter as noted on the calibrated scale on the screen of the television monitor, and recording these changes in as rapid a sequence as they could in the ten second period each picture was shown. Simultaneously, these same changes were being recorded on film for later analysis and comparison with the visual interpretation. The senior recorder was responsible for the rate of progress of the test, indicating to the control-central operator when to advance to the next slide. No verbal communication was permitted between subject and any other person in the laboratory except to advise the S to change position to maintain focus of the camera on the eye; this was always done during a Dvorine slide stabilization period.

**Interpretation of Records**

After the camera film records had been developed, the experimental teams concentrated on the job of reviewing every frame of the film and recording these on standard forms for comparison with the visual records that were recorded by trained observers while the S was being tested. The task of film review was expedited because of the provision made in the test design, the use of a
transparent calibrated scale of vertical lines on the viewing screen of the television monitor. This scale was calibrated in units to read an actual pupil change of 0.2-mm of diameter for each unit on the screen. Ease of reading was also helped by having every fifth line on the scale inscribed in a heavier weight line than the intervening lines, making units of five and fractions thereof simple to define. It made no difference what size the resulting photo records were when projected on a screen for reading, because the units of measurement overlaid the pupil of the eye in every frame.

The criteria for interpretation were established before the beginning of testing in this study, and were based on preliminary examination of previous study data. To avoid any possible influence or prejudice by the examiners, no experimenter was allowed to interpret his own data, or to have the visual record on hand at the time the camera record was being evaluated.

In the analysis of both the visual record and the camera record for the same stimulus picture, the tenth frame of the camera record and the last recorded measurement made on the visual record was considered to be the stabilization size of the pupil for the start of the next slide in sequence. Therefore, the observer was looking for changes that indicated immediate dilation or contraction, followed by saccadic changes as the subject experienced emotional reactions to the picture. A steady pattern of measurements indicating a decline in pupil size over the regulated time period with a stabilization diameter smaller than the initial diameter.
was interpreted as rejection or displeasure, while a pattern of measurements indicating a dilation of the pupil over the same time period was interpreted as an acceptance or pleasure reaction on the part of the S being tested. Provision was made for the initial or shock affect evidenced by the pupil first dilating and then rapidly contracting when the implication of the picture was understood, often reversing the trend toward contraction as the cognitive processes developed a decision of acceptance or rejection.

Because the design of the equipment provided for the TV camera to photograph the eye as reflected from the 45° angle mirror, the position of the eye on the screen of the monitor was in true relationship to the eye of the S, and eye movements were true representations of the actual direction of movements of the S's eye as he scanned parts of the total picture. This method is a decided improvement over records made by many configurations of pupillometrics equipment which have reversed mirror images difficult to interpret. Skilled experimenters soon learned to give added interpretations to a S's behavior as he watched eye movements as well as pupil size as a given picture was observed. This human knowledge of the content of a picture containing more than one item of interest, enables the human observer to exceed the capabilities of the camera and to add clinical skill to the interpretation of what specific part of the picture the S seemed to react to the most. This factor was an unexpected variable that obviously appeared only in the data recorded by the observer as compared to the camera. Future studies should consider methods to control this variable.
**Criteria for the Analysis of Data**

The independent variables in this study were:

A. The set of stimuli pictures in chromatic presentation of Part II of the Picture Interest Inventory.

B. The set of achromatic stimuli pictures in the paper-and-pencil test with Part II of the Picture Interest Inventory.

C. The set of chromatic stimuli pictures used for the Mooney Problem Check List, ten of which were vocationally oriented, the remainder related to other factors in the Check List.

D. The paper-and-pencil response to the entire 330 items on the Mooney Problem Check List, only thirty of which in Part X were related to the vocational interest of the Ss.

E. The program of rotation of presentation of the four parts of the study to the various Ss in the four groups, A, B, C, and D. See Table 5, Appendix.

F. The method of selection of the sample of Ss used in this study.

G. The method of selection, training, and rotation of assignments of the members of the experimental teams.

H. The laboratory method of testing each S in accordance with the plan of the experimental design.

I. The design configuration of the pupillometrics test equipment used in this study.

J. The uncontrollable human variation within the Ss and the experimenters involved in the study due to social and economic
backgrounds, intellectual capabilities, and academic achievement levels, including the bias within the sample selection of all college students in psychology classes.

The dependent variables were:

A. The response of the Ss to the chromatic pictures of vocations as portrayed by the slides based on the Picture Interest Inventory.

B. The paper-and-pencil response to the chromatic representation of the same vocations as shown in the slides, but massed adjacent to each other on the same page in a booklet form, Part II of the Picture Interest Inventory.

C. The response of the Ss to the chromatic pictures representing the Mooney Problem Check List as portrayed on the thirty slides, only ten of which related to vocations.

D. The reaction and response of the Ss to the mass of 330 items on the Mooney Problem Check List paper-and-pencil test, not knowing which items were related to this study or how they might be interpreted.

E. The ability of trained recorders to accurately identify and record changes in the S's pupil as he responded to the chromatic slides in each of the two groups.

F. The reliability of visual methods of interpretation versus the camera record.

G. The validity of the criteria for evaluating a pleasant from an unpleasant reaction or a rejection from an acceptance of
the stimulus, as portrayed by the S's pupil dilation or contraction as he observed each slide.

Within the scope of recognition of the above variables, a set of criteria was developed for interpreting the measured units of pupil diametral change for each S for each stimulus picture. The same criteria were applied by all data interpreters to all record sheets, both visual recordings and those obtained from reading the camera records. Regardless of the number of readings made, which might be different in the visual versus the camera record for a given slide, the last recorded reading for a given stimulus picture was considered as the stabilized diameter of the pupil for that response, and that same reading then became the first recorded data for the next slide responses. The data recorded by the visual recorders was usually less than that recorded by the camera. On some occasions the observer did not immediately call for an advance to the next picture as soon as the camera recording period of ten seconds was completed, but in the analysis of the data, the same rules applied relative to the last reading becoming the stabilization diameter to be used for the start of the next picture.

The criteria for evaluation is illustrated in the following examples:

Slide "x": (units of diameter)
STABILIZATION    READINGS    ANALYSIS
16    19,21,23,19,20,21,22,21,23    + (accept or pleasant)

Slide 'y':
23    24,20,19,18,16,17,18,17,18    - (reject or unpleasant)

Slide 'z':
18    20,21,20,19,20,21,20,19,21    + (accept or pleasant)

As these examples show, the pupil of the eye may respond with narrow or wide variation in units of diametral change, but the trend to gradual increase or decrease was the important criteria. Weight was also given to whether the last reading was substantially higher (+) or lower (-) than the initial stabilization size. The first, or immediate, change was important only if it was sustained in general throughout the series of readings.

By the same logic, an immediate drop in pupil diameter on presentation of a new slide did not mean rejection unless this drop was significant and sustained, with a final stabilization lower than the start. Human behavior often includes saccadic eye changes, not only movement, but sharp cycling of the pupil diameter when surprise or cognitive recognition of highly controversial subjects causes a conflict of dissonance and consonance in decision making. It was entirely possible that in the slides on vocations, many new occupations were presented to the S for the very first time, and surprise alone could account for an immediate dilation, later corrected as cognition takes place.
When little or no apparent change took place, or the cycling seemed to negate any trend, the interpretation was made positive (+) for acceptance, or pleasantness as the over-all response, since there was never any real doubt about outright rejection, seen as a sharp and sustained contraction of the pupil.

It is an established physiological fact that most females have larger pupils than males, but this factor did not influence the criteria for determining a positive (+) or negative (-) interpretation. As will be noted in the data analysis, all changes were converted to percentage changes for one level of statistical analysis.
Summary

Chapter III on methodology began with a general view of the theory of pupillometrics. There followed a list of basic assumptions pertinent to this study, based upon pupillometrics theory and within the limits of the equipment and personnel involved in the study.

In the research design, a description was given of the method of selection of the stimuli pictures, how they were prepared to assure that when they were projected no picture would represent more light stimulus than any other picture, thereby assuring that only emotional response would be measured by pupil changes.

The design of the pupillometrics equipment was described and compared to equipment used by other researchers where special improvements had been made in this design. Each item of the equipment was described in detail for the convenience of any who might wish to replicate the study.

The method of selecting the sample of Ss was defined, including precautions taken to avoid undesirable variables from influencing the study. It was noted that the Ss did not represent a large population, but was specific to college students representative of those attending Ohio State University enrolled in psychology.

The method of selecting and training the experimental teams of students was described in detail, including the precautions taken to prevent or at least limit the introduction of personal bias into the test results.
The methods for standardizing the preparation of each S for pupillometrics testing was defined, and the basic instruction directions were stated in full. The laboratory environment was described, and precautions noted for avoiding the introduction of undesirable variables into the environment that might influence the results.

The method for testing a specific S for pupil response to visual stimuli was then described step-by-step, including the methods of recording the changes that occurred as emotions were reflected by pupil diametral changes. Extra attention was given to the reasons for providing for preliminary light adaptation and the logic in maintaining a twilight environment in the room in preference to complete darkness.

The plan for interpretation of recorded data was defined as it related to both the data compiled from visual records and from the camera records. It was noted that the same criteria must be used by all interpreters on all data, and no interpreter was permitted to evaluate the data he had collected himself as an observer.

Included in this section was a detailed description of the independent variables and the dependent variables known to be inherent in this study. Within the limits of experimental design, all reasonable precautions were taken to avoid the influx of other variables that might influence the results.

Examples were given to illustrate the criteria used in determining whether the pupil response was positive (+) meaning acceptance or pleasure, or whether it was negative (-) meaning rejection or displeasure as the emotion brought about as a result of cognition.
related to visual analysis of the pictures by the S. It was noted in most instances, the amount of data recorded by the visual method was less than that obtained by camera record, but in each case, identical rules governed the criteria for analysis and interpretation of any changes that took place in pupil diameter. Since the basic aim of the study was to show the reliability of direct visual recording of data without the need for camera verification, no correction was made on the data sheets derived from the two methods. A facsimile of the data sheet used in accumulating data is shown in Form B, in the Appendix. The data from both the observer’s visual record and the related camera record for the same S were translated into Fortran computer language for analysis by electronic data processing.

The quantity of data to be handled made the use of computer programs the most feasible method of approach to analysis. No attempt was made to predict or interpret the outcome of tests for any S until the computer results were available.
CHAPTER IV

RESULTS

All of the data collected from the four-step task performance of the sample of thirty-two college students was organized so that it could be translated into IBM Fortran language, and analyzed by the IBM 7094 Computer. The computer program employed the Pearson Product-Moment formula for correlations. These correlations were then converted into levels of significance by means of Table VI, page 306, in the text by Downey and Heath, Basic Statistical Methods, Second Edition. In some instances chi-square analysis was used to determine levels of significance, using Fisher's Table of Chi-Square, from R.A. Fisher, Statistical Methods for Research Workers.

The first concern was with correlations of each S involving his performance on the Picture Interest Inventory (hereafter referred to as PII) chromatic slides with the related PII pencil-and-paper test, and to evaluate the quality of the observer's visual records of the S's pupil changes in comparison with the camera records on the non-verbal performance of each S.

When perceiving the chromatic vocational slides, the observer's visual records of pupil changes by each of the Ss correlated with the camera record of the same S's pupil changes at an average of +0.47, at a 0.02 level of confidence, the range in correlations being +0.07 to +0.73.
When using the observer's visual records of pupil changes by each of the Ss, the responses on the chromatic vocational slides (based on the PII) correlated with the responses on the PII paper-and-pencil test at an average of +0.58, at the 0.01 level of confidence, the range in correlations being +0.31 to +0.82.

When using the camera record of pupil changes by each of the Ss, the responses on the chromatic vocational slides (based on the PII) correlated with the responses on the PII paper-and-pencil test at an average of +0.41, at the 0.05 level of confidence, the range in correlations being -0.20 to +0.86.

From these correlations, it is noted that the observer's visual records of eye pupil changes appear to correlate more closely with both the PII chromatic vocational slides and the PII paper-and-pencil test, than do the camera records. An attempt to explain this phenomenon will be made in the following discussion section. Tables 1, 2, 3, 4, and 5 will display the relationships as they were found in this pilot study.

The correlations between the data obtained from all Ss on the tasks related to the PII and the Mooney Problem Check List, Part X, ranged from -0.01 to +0.10, and were of no statistical significance. We were unable to establish the factors accounting for this result and have not undertaken, in this study, to deal further with the meaning of this finding.
Table 1
Pearson Product Moment Correlations and Levels of Confidence (N=32)

<table>
<thead>
<tr>
<th></th>
<th>PI1 Vocational Slides</th>
<th>PI1 Vocational Slides</th>
<th>Mooney Vocational Slides</th>
<th>Mooney Pencil &amp; Part-X</th>
</tr>
</thead>
<tbody>
<tr>
<td>PI1</td>
<td>r = +0.47</td>
<td>r = +0.58</td>
<td>r = +0.01</td>
<td>r = -0.0</td>
</tr>
<tr>
<td>Vocational Slides</td>
<td>p &gt; .02</td>
<td>p &gt; .01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observer's Visual Record</td>
<td>p &gt; .02</td>
<td>p &gt; .01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PI1</td>
<td></td>
<td>r = +0.41</td>
<td>r = -0.01</td>
<td>r = +0.02</td>
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<tr>
<td>Vocational Slides</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Camera Record</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mooney Vocational Slides</td>
<td>r = -0.01</td>
<td>r = -0.0</td>
<td></td>
<td>r = +0.10</td>
</tr>
<tr>
<td>Part-X</td>
<td></td>
<td></td>
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</tbody>
</table>
Table 2

Number of Ss at Each Level of Confidence
Based on Pearson Product Moment Correlations
(N=32)

<table>
<thead>
<tr>
<th>Correlations Sets</th>
<th>Level of Confidence</th>
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</thead>
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<tr>
<td></td>
<td>.001</td>
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<tr>
<td>Observer's Visual Record           vs</td>
<td>7</td>
</tr>
<tr>
<td>Camera Record</td>
<td>On PII Chromatic Slides</td>
</tr>
<tr>
<td>Observer's Visual Record           vs</td>
<td>15</td>
</tr>
<tr>
<td>PII Paper-and-Pencil Test</td>
<td></td>
</tr>
<tr>
<td>Camera Record                       vs</td>
<td>3</td>
</tr>
<tr>
<td>PII Paper-and-Pencil Test</td>
<td></td>
</tr>
</tbody>
</table>

Discussion

The results of this pilot study clearly support the first hypothesis. It was demonstrated that it is possible by means of pupillometrics and without benefit of verbal communication between S and observer to detect changes in a given S's attitude when a program of visual stimuli is presented.

The second hypothesis was supported by the results of this study. The direct visual method of interpreting the S's attitude changes to visual stimuli was supported by an average correlation
Table 3
Number of Ss at Each Level of Confidence
Based on Chi Square ($X^2$) Correlations
(N = 32)

<table>
<thead>
<tr>
<th>Correlation Sets</th>
<th>.001</th>
<th>.01</th>
<th>.02</th>
<th>.05</th>
<th>Rejected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observer's Visual Record</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>vs Camera Record</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On Pll Chromatic Slides</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observer's Visual Record</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>vs Pll Paper-and-Pencil Test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Camera Record vs Pll Paper-and-Pencil Test</td>
<td>10</td>
<td>16</td>
<td>22</td>
<td>24</td>
<td>6</td>
</tr>
</tbody>
</table>
| of +0.58 when compared to a related paper-and-pencil test by the same S. This performance exceeds the 0.05 level of confidence predicted; as noted in Table 2, twenty-five of the thirty-two Ss obtained correlations at the 0.01 level of confidence. A total of twenty-nine of the thirty-two Ss obtained correlations at the 0.05 level of confidence as predicted. Correlations at the 0.001 level of confidence for fifteen Ss exceeded predictions.

The third hypothesis was supported at a level greater than expected. The data indicated that the level of performance of
the observers was of such quality that the correlations based on
data obtained by visual recorders exceeded in accuracy the data
obtained by the camera record. This would appear to be improbable,
since no reasonable scientist is likely to predict human stability
to exceed that of a machine. This difference can best be explained
by the fact that the design of the experiment allowed the camera
to take only ten one-second interval exposures for each stimulus
picture (a factor introduced for film economy) in the belief that
prior test experience had indicated this was enough. The observer
was allowed to hold the picture for an additional period of ten
seconds if he was in trouble (forced to write too fast), or if he
felt that the S had not stabilized his pupil diameter due to pos-
sible accumulative cognitive processing, or because the S exhibited
some nervous affectation. Perhaps this additional time allowed
the observer to gain more exact evidence of true attitude change
than the limited camera record.

Although all three hypotheses were supported by ample evi-
dence, the research teams felt some unpredicted variables may have
influenced the results. For instance, the chromatic slides were
shown only one at a time, for a brief interval, and the entire
sequence was never available for comparison, one with the other,
as was the case when the booklet form of the PII paper-and-pencil
test was used. The Manual for Interpretation of the Picture
Interest Inventory makes no mention of any proximity effect on the
S taking the test. However, it was suspected from examination
of the scratch-out marks on the response sheets of several Ss that some persons did weigh one vocation against another on the same page of the printed PII paper-and-pencil test. It would seem improbable that the same S could recall enough of prior impressions to relate one projected chromatic slide with another not immediately adjacent. This condition should be examined by further testing.

Some definite variations were observed in the data between groups (see Table 4). Several major differences between sexes infer that some factors may not have been controlled as independent variables. It is probable that the females were more inclined to react to vocations for their intended husbands with greater intensity and clarity because women are reputed to be more security conscious than men. The implied socio-economic status of some vocations may have had greater meaning to status-conscious females than to some of the males, since males often express job liking in terms of personal satisfaction first, and family status second. This premise should certainly have further testing.
CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

A study was made to appraise the potential of pupillometrics as a non-verbal instrument to detect student attitudes. To accomplish this objective, a pilot study was designed with direct educational implications.

Three hypotheses were made regarding the potential of pupillometrics as a non-verbal instrument for use by educators and scientists. It was hypothesized that (a) it is possible for an observer to detect changes in a given S's attitude without using verbal communication while the S is observing visual stimuli; (b) when such observations are made, a correlation will be found between responses of the pupil of the eye and responses recorded by the S on a paper-and-pencil test (0.05 level of confidence); and (c) by means of a TV monitor, trained observers can make reliable interpretations of the meaning of the pupil changes without the use of further mechanical recording.

In order to test the hypotheses, a sample of 32 college undergraduate students were selected at random from the total school population currently taking general psychology courses. This sample was then divided into four groups, and in sequential
rotation, required to perform four tasks. The first task was to respond visually to a series of stimulus pictures on vocations; the second task was to respond to a paper-and-pencil test on the same vocational pictures; the third task was to respond visually to a series of varied social situations on pictures, some of them concerning careers; and the fourth task was to respond to another extensive paper-and-pencil instrument which contained personal problems, some of which were taken to be related to careers.

The data collected in response to the first two tasks supported the three hypotheses; data on the tasks three and four did not produce observable relationships.

Conclusions

The primary conclusion to be drawn from this pilot study is that pupillometrics is a technique that can be applied to some educational situations. It has been demonstrated that students do exhibit an emotional response to visual stimuli when the stimuli are meaningful to them; changes in attitude are reflected in a corresponding change in the diameter of the pupil of the eye. This change in diameter is meaningful, and observers can be trained to directly interpret such meaning from the TV monitor display of the S's pupil changes, recorded by a remote closed-circuit television camera observing the S's eye as he views the stimulus picture presented to him.
This pilot study has demonstrated some important facts relative to equipment and technique, suggesting that the method is within the economic reach of the average educational institution. It has shown that meaningful stimulus pictures are available in some areas for direct comparison with standardized paper-and-pencil instruments, a great asset in overcoming opposition to the use of this new technique in meeting some of our most demanding educational tasks, including the understanding of the feelings of those who cannot or will not communicate verbally with their teachers and counselors.

Implications and Applications

The results of this study would seem to support the assumption that pupillometrics can become a promising tool for use in the education of youth and adults. We now have clear evidence of at least one research effort wherein the examiners demonstrated their ability to recognize and properly interpret a S's emotional reactions to a series of visual stimuli. It is now apparent that trained examiners can detect the difference between acceptance and rejection by the S of the implied message in a picture, as evidenced by the respective dilation or contraction of the pupil of the eye when the proper criterion for interpretation is available.

At this stage of development, it would be presumptuous to even suggest that this demonstrated method could be applied across the board to any or all situations where verbal communications have failed or cannot be used. With further effort and a liberal
imagination, however, it should now be possible to apply the technique of pupillometrics to the detection of attitudes and emotions as a valuable non-verbal aid in meeting some of the aggravating problems of communication and diagnosis where direct verbal counseling and paper-and-pencil methods fail, or where they are impractical to use.

We have demonstrated some of the possibilities of the pupil-lometrics as an instrument that may enable teachers, counselors, psychologists, and social workers to more easily penetrate the wall of defense that many people build around themselves. The natural appeal to the S of being on television, plus the universal language of pictures, provides the clinician with a double-barreled weapon with which to fight ignorance, apathy, and underachievement.

Some of the possible applications for immediate consideration by educators and social welfare organizations to examine through further research would include the following high priority situations. No attempt has been made to arrange them in rank order of immediate need or ease of implementation.

**Educational Classroom Environment**

Within the scope of the present public and private school responsibilities for standard and remedial teaching and evaluation situations, pupillometrics may be applied within these groups.
1. Pre-school Level

a. To identify adverse home conditions.
b. To detect sibling and peer rivalry.
c. To identify racial prejudice.
d. To investigate personal hygiene habits.
e. To identify food preferences.
f. To detect school interest and motivation.
g. Aid in selecting play preferences.
h. To diagnose unusual perceptual tendencies.
i. To probe sex interests and behavior.
j. To determine readiness for team play.

2. Early Elementary School Level

a. To determine attitude toward entry into school.
b. To identify acceptance or rejection by peers.
c. To determine blocks against reading.
d. To identify any negative feelings about the teacher or any other authority figures in the school.
e. To identify home problems that may be worrying the student.
f. To identify cafeteria and playground problems.
g. To identify social maturation level of the student in relation to his age or grade level.
h. To determine prejudices against race, creed, color, and physical handicaps of others.
i. To identify tendencies toward extremes of introversion or extroversion.
j. To aid in identifying personal emotions about separation from home and mother, dress, physical limitations (poor eyesight, hearing).

3. Middle Elementary Level

a. Attitudes about physical development.
b. Attitudes about social and economic status of self and family with relation to peers.
c. Attitudes about sex, and mixed play activities.
d. Indication of development of team or cooperative spirit.
e. To detect emotions related to academic achievement, or outright failure.
4. Junior High School Level

a. Emotions related to pre-puberal and early puberal problems of sex and social adjustment.
b. Early development of vocational interests.
c. Evidences of rebellion against parents.
d. Evidences of increased concern about academic achievement and related preferences for certain academic disciplines.
e. To identify specific blocks against certain teachers or curriculum.
f. Evidences of early leadership interest.
g. Acceptance or rejection of certain sports or social activities.
h. Tendencies toward early school drop-out.

5. High School Level

a. Attitudes on career and vocational selection
b. Attitudes about higher education.
c. Detection of early drop-out tendencies.
d. Detection of latent or active homosexuals.
e. Attitudes on leadership, sports vs. academic.
f. Evidences of unsatisfactory social adjustment.
g. Detection of problems related to dating, necking, petting, and pre-marital relationships.
h. Detection of extreme or unusual parent rejection.
i. Detection of resentment for law and authority.

6. Vocational or Technical School Level

a. Detection of vocational interests.
b. Attitudes toward authority figures.
c. Sexual interests and conflicts.
d. Home and family aid or interference to the school program.
e. Peer group acceptance or rejection.
f. Concern over military service, and detection of interests in specialized training.
g. Attitudes toward marriage and family responsibilities.
h. Detection of possible drop-out and leaning toward crime.
i. Detection of problems of personal health.
j. Attitudes toward a specific training program.
7. Higher Education Level
   b. Identification of self-concept.
   c. Detection of social, sexual, and peer problems.
   d. Identification of attitude toward certain academic disciplines.
   e. Detect fear of failure.
   f. Detect problems related to life in college residence, including attitude toward certain foods, dress, study hours, etc.

8. Mentally Retarded
   a. To determine alertness to visual perception as an indicator of possible learning or performance level.
   b. To determine attitude on personal hygiene.
   c. To test for cognitive retention after reading to student.
   d. To determine rejection by peer-age students in school; also rejection by siblings and parents.
   e. To determine attitude work involving manual skills within capability of student.
   f. To evaluate effectiveness of academic teaching aids used to train retarded children.
   g. To identify food preferences.
   h. To aid in determination of maturation level of student regardless of chronological age.

9. The Deaf and/or Mute
   a. To establish a norm of communications through pictures that evoke desired emotional response from the student.
   b. To evaluate attitude toward other teaching methods.
   c. To identify feelings about family, home, parents, siblings.
   d. To identify interests that may lead to effective vocational training.
   e. To identify student's feelings about food, clothing, institutional rules, recreation, etc.
   f. To aid in diagnoses of physical problems including diseases and location of pain.
10. Orphan and Foundling Home.

a. To identify feelings of rejection by any parent figures or authorities.
b. To identify things they are afraid of, and toys or games they might prefer.
c. To identify food, clothing and roommate problems they cannot or will not describe verbally.
d. To establish the type of persons they might accept as foster parents.
e. To investigate types of parent brutality inflicted on the children before they came to the institution.

11. Anti-Poverty Programs

a. To identify problem areas of welfare applicants who cannot or will not communicate verbally.
b. To verify verbal claims of applicants relative to work interests and potential vocational background.
c. To enable illiterate persons to identify their feelings on social and economic situations through picture stimulation of emotions.
d. To identify prejudices toward race, creed or color of welfare personnel serving them.
e. To determine level of understanding of fundamental hygiene, child care, and family planning.
f. To identify problems of home care, housekeeping knowledge, planning nourishing meals.
g. To identify sex problems that may lead to broken homes and abandoned children.
h. To identify real or potential drug users or alcoholics.
i. To identify attitudes toward rehabilitation training and attending specialized schools when needed.
j. To identify attitudes toward religion and moral issues.
k. To identify ability to understand local and national issues and candidates for whom they vote.
l. To determine level of motivation for self-aid as compared to remaining on welfare forever.
12. Prisons, Work Camps, and Related institutions

a. To identify homosexuals.
b. To identify those who have work experience or interests that they might develop to a higher level of skills.
c. To aid in reaching those belligerant inmates who refuse to communicate verbally.
d. To help identify underlying causes that led the person into crime.
e. To determine self-concept and level of self-esteem.
f. To help identify their fears related to release into the world of people after their term is completed.
g. To identify feelings of rejection by peers.
h. To identify feeling of rejection by relatives.

These are but a few of the many potential applications for which pupillometrics might be employed as a tool by educators and welfare agencies when they find that verbal techniques are rejected or not feasible.

It is hoped that this research study and these suggestions will result in many more graduate students becoming involved in research that will be meaningful and directly applicable to our many problems in reaching all of our people with the best possible education techniques available in our space-age environment, including a proper role for pupillometrics as a promising aid in the form of a non-verbal instrument that the average teacher and educator can learn to use with a minimum of training.
Table 4

Differences in Emotional Reactions by Sex to Visual Chromatic Vocational Pictures and Related Vocational Paper-and-Pencil Tests (N=32-Ss)
Total of 30 Pictures

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Visual</strong> + Responses (mean)</td>
<td>14</td>
<td>17</td>
</tr>
<tr>
<td><strong>Chromatic Record</strong> - Responses (mean)</td>
<td>16</td>
<td>13</td>
</tr>
<tr>
<td><strong>Pupil Diameter % Change (mean)</strong></td>
<td></td>
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</tr>
<tr>
<td>Increase</td>
<td>13.3</td>
<td>26.7</td>
</tr>
<tr>
<td>Decrease</td>
<td>13.6</td>
<td>26.1</td>
</tr>
<tr>
<td><strong>Paper &amp; Pencil Test</strong> (mean)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accept</td>
<td>11.5</td>
<td>17</td>
</tr>
<tr>
<td>Reject</td>
<td>18.5</td>
<td>13</td>
</tr>
<tr>
<td><strong>Mooney Vocational</strong> (mean)</td>
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<td>Circled</td>
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<td>2.0</td>
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<tr>
<td>Total</td>
<td>4.2</td>
<td>6.4</td>
</tr>
</tbody>
</table>
Table 5

Differences in Emotional Reactions by Group to Visual Chromatic Vocational Pictures and Related Vocational Paper-and-Pencil Tests (N=32-Ss) Total of 30 Pictures

<table>
<thead>
<tr>
<th>Pupil Diameter Change to Vocational Chromatic Pictures % change (mean)</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>19.0</td>
<td>13.9</td>
<td>18.6</td>
<td>15.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vocational Pll Paper &amp; Pencil (mean) Test Response accept</th>
<th>14</th>
<th>13</th>
<th>14</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>16</td>
<td>17</td>
<td>16</td>
<td>17</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mooney Part-X Vocational Paper &amp; Pencil (mean) Test Response circled</th>
<th>2</th>
<th>2</th>
<th>2</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>6</td>
<td>4</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

Sequence of Tasks Performed by Groups:

Group- A. Sequence 1,2,3,4
Group- B. Sequence 2,3,4,1
Group- C. Sequence 3,4,1,2
Group- D. Sequence 4,1,2,3

See page 65 for description of each task to be performed by each subject in each group.
Table 6
Comparison of Responses on Vocational Stimulus Slides
(All Subjects, N=32)

<table>
<thead>
<tr>
<th>Slide No.</th>
<th>Observer Visual</th>
<th>Camera Record</th>
<th>Paper-and-Pencil Record</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%+</td>
<td>%-</td>
<td>%+</td>
</tr>
<tr>
<td>1</td>
<td>53</td>
<td>41</td>
<td>53</td>
</tr>
<tr>
<td>2</td>
<td>47</td>
<td>53</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>69</td>
<td>31</td>
<td>47</td>
</tr>
<tr>
<td>4</td>
<td>40</td>
<td>60</td>
<td>40</td>
</tr>
<tr>
<td>5</td>
<td>31</td>
<td>69</td>
<td>37</td>
</tr>
<tr>
<td>6</td>
<td>56</td>
<td>44</td>
<td>47</td>
</tr>
<tr>
<td>7</td>
<td>65</td>
<td>35</td>
<td>53</td>
</tr>
<tr>
<td>8</td>
<td>50</td>
<td>50</td>
<td>53</td>
</tr>
<tr>
<td>9</td>
<td>53</td>
<td>47</td>
<td>56</td>
</tr>
<tr>
<td>10</td>
<td>44</td>
<td>56</td>
<td>53</td>
</tr>
<tr>
<td>11</td>
<td>65</td>
<td>35</td>
<td>53</td>
</tr>
<tr>
<td>12</td>
<td>75</td>
<td>25</td>
<td>65</td>
</tr>
<tr>
<td>13</td>
<td>47</td>
<td>53</td>
<td>40</td>
</tr>
<tr>
<td>14</td>
<td>62</td>
<td>38</td>
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<tr>
<td>15</td>
<td>62</td>
<td>38</td>
<td>62</td>
</tr>
<tr>
<td>16</td>
<td>47</td>
<td>53</td>
<td>40</td>
</tr>
<tr>
<td>17</td>
<td>59</td>
<td>41</td>
<td>72</td>
</tr>
<tr>
<td>18</td>
<td>40</td>
<td>60</td>
<td>50</td>
</tr>
<tr>
<td>19</td>
<td>40</td>
<td>60</td>
<td>59</td>
</tr>
<tr>
<td>20</td>
<td>31</td>
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</tr>
<tr>
<td>21</td>
<td>62</td>
<td>38</td>
<td>72</td>
</tr>
<tr>
<td>22</td>
<td>34</td>
<td>66</td>
<td>31</td>
</tr>
<tr>
<td>23</td>
<td>44</td>
<td>56</td>
<td>53</td>
</tr>
<tr>
<td>24</td>
<td>53</td>
<td>47</td>
<td>78</td>
</tr>
<tr>
<td>25</td>
<td>50</td>
<td>50</td>
<td>47</td>
</tr>
<tr>
<td>26</td>
<td>69</td>
<td>31</td>
<td>47</td>
</tr>
<tr>
<td>27</td>
<td>53</td>
<td>47</td>
<td>62</td>
</tr>
<tr>
<td>28</td>
<td>47</td>
<td>53</td>
<td>47</td>
</tr>
<tr>
<td>29</td>
<td>28</td>
<td>72</td>
<td>47</td>
</tr>
<tr>
<td>30</td>
<td>34</td>
<td>66</td>
<td>50</td>
</tr>
</tbody>
</table>

Mean for
Males 44 56 45 55 36 67 47 54
Mean for
Females 52 48 55 45 53 47
Mean for
All Ss 51 49 52 48 46 54

** Most Accepted Slide #11, 12, & 17. 72%
* Most Rejected Slide #30. 91%
Plate A

Pupillometrics Examining Chair
Plate B
Pupillometrics Monitor and Observation Table
Plate C

Remote Controlled Recording Camera
Plate D

View of Monitor, Control Central, and Rear Projection Screen Orientation
FORM A

Picture Interest Inventory

Examples of Vocational Pictures Used in Both Chromatic Slides and Paper-and-Pencil Tests

(The author regrets that he was unable to obtain permission from the California Test Bureau of Hollywood, California, for the inclusion here of examples of the vocational stimulus pictures used in this research study.)

Titles of Chromatic Vocational Slides

1. Judge
2. Real Estate Salesman
3. Photographer
4. Gardener and Groundskeeper
5. Canning Factory Worker
6. Laboratory Technician
7. Teacher
8. Restaurant Cashier
9. Lithographic Artist
10. Farmer, Truck Garden
11. Movie Studio Cameraman
12. Archaeologist
13. Barber
14. File Clerk
15. Stage Hand Carpenter
16. Veterinarian
17. Draftsman
18. Pharmacist
19. Policeman
20. Store Clerk, Grocery
21. Sculptor
22. Farmer Operating Combine
23. Printer
24. X-ray Technician
25. Hospital Orderly
26. Bank Executive
27. Concert Pianist
28. Farmer, Potato Combine
29. Appliance Repairman
30. Meat Inspector
**PUPILLOMETRICS RECORD FORM**

(choose one)

- Visual Record
- Camera Record

<table>
<thead>
<tr>
<th>S's No.</th>
<th>S's Name</th>
<th>Age</th>
<th>Class</th>
<th>Visual Record</th>
<th>Camera Record</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group</th>
<th>Eye Color</th>
<th>Reel No.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Slide No.</th>
<th>Start Reading</th>
<th>Reaction Readings</th>
<th>Stabilization Reading</th>
<th>Accept=+</th>
<th>Reject=-</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dark Adapt</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dvorine</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Dvorine   |                |                   |                       |          |         |
| 6.        |                |                   |                       |          |         |

Dvorine

| 29.       |                |                   |                       |          |         |
| 30.       |                |                   |                       |          |         |

---

FORM B
<table>
<thead>
<tr>
<th>Picture Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>*1.</td>
<td>Girl in a skuba suit.</td>
</tr>
<tr>
<td>*2.</td>
<td>Hospital scene, orderly and nurse wheeling a patient on a stretcher cart.</td>
</tr>
<tr>
<td>*3.</td>
<td>Negro boxer facing crowd in prize-fight ring.</td>
</tr>
<tr>
<td>4.</td>
<td>Man in shower, upper torso nude, smiling.</td>
</tr>
<tr>
<td>5.</td>
<td>Fifteen adult men jogging down a road.</td>
</tr>
<tr>
<td>*6.</td>
<td>Negro central figure with two men, counseling.</td>
</tr>
<tr>
<td>7.</td>
<td>A backyard tenement district, laundry on line.</td>
</tr>
<tr>
<td>8.</td>
<td>Several men in hunting lodge, seated before an oven, prepared to broil some meat on trays; heads bowed as though they are praying.</td>
</tr>
<tr>
<td>9.</td>
<td>A beautiful home bar in a family room.</td>
</tr>
<tr>
<td>11.</td>
<td>Young couples dancing, handsome boy foreground.</td>
</tr>
<tr>
<td>*12.</td>
<td>Two men and a woman in a boat, fishing.</td>
</tr>
<tr>
<td>13.</td>
<td>Young adult group playing party games on floor.</td>
</tr>
<tr>
<td>*14.</td>
<td>Four girls, two men, costumed, Swedish folk-dance.</td>
</tr>
<tr>
<td>*15.</td>
<td>Overhead view, twelve men at poker table.</td>
</tr>
<tr>
<td>16.</td>
<td>About thirty mixed adults, sunning in closely packed beach chairs.</td>
</tr>
<tr>
<td>17.</td>
<td>Four attentive females around one stud male.</td>
</tr>
</tbody>
</table>

Those items marked with an asterisk (*) are related to the vocational section Part X of the Mooney Problem Check List.
<table>
<thead>
<tr>
<th>Picture Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>*18.</td>
<td>Police quelling a riot, fallen Negro on ground.</td>
</tr>
<tr>
<td>19.</td>
<td>A smiling young couple, facing each other with martinis in hand.</td>
</tr>
<tr>
<td>20.</td>
<td>Mixed youth crowd on highway, bearing street signs, with a band following them.</td>
</tr>
<tr>
<td>21.</td>
<td>Lonely girl in a bikini, seated on seashore.</td>
</tr>
<tr>
<td>22.</td>
<td>Surprised father figure looking at new baby.</td>
</tr>
<tr>
<td>*23.</td>
<td>Single word &quot;FAILURE&quot; in large block letters.</td>
</tr>
<tr>
<td>*25.</td>
<td>&quot;Uncle Sam&quot; pointing finger at you!</td>
</tr>
<tr>
<td>26.</td>
<td>Young couple, girl tenderly kissing boy on the cheek.</td>
</tr>
<tr>
<td>27.</td>
<td>A pair of male and female hands, his fingers placing a wedding band on her finger.</td>
</tr>
<tr>
<td>28.</td>
<td>A man and a woman in a &quot;compromising&quot; position in a bed, located in a shack; hovering over them is a man with a camera.</td>
</tr>
<tr>
<td>29.</td>
<td>Young-love scene, with bashful boy facing a smiling girl who is caressing his face.</td>
</tr>
<tr>
<td>30.</td>
<td>Wedding picture (of a celebrity) of a bride in a wedding gown, cutting the wedding cake in the presence of the groom and onlookers.</td>
</tr>
</tbody>
</table>
BIBLIOGRAPHY

Books


Periodicals


Lehr, Donald J. and Bergum, Bruce O. "Note on Pupillary Adaptation," *Perceptual and Motor Skills*, 23 (1966), 917-918.


