THE CLINICAL VALIDATION OF THE PUPILLARY RESPONSE: THE EFFECT OF CHROMATIC AND ACHROMATIC STIMULI UPON PUPIL RESPONSIVITY

Thesis for the Degree of Ph. D.
MICHIGAN STATE UNIVERSITY
Richard Louis Miller
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THESIS

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ABSTRACT

THE CLINICAL VALIDATION OF THE PUPILLARY RESPONSE: THE EFFECT OF CHROMATIC AND ACHROMATIC STIMULI UPON PUPIL RESPONSIVITY

by Richard Louis Miller

This investigation was an attempt to validate the pupillary response as an objective measure of the generalized response by the organism to emotional excitation.

Thirty male Ss who were not color blind and who did not wear glasses were asked to look into the aperture of a specially constructed light-tight apparatus. Four experimental stimuli were projected onto a screen in the apparatus for five seconds each. While the Ss viewed the stimuli a 16 mm. motion picture camera photographed their pupils at the rate of four frames per second. The projected stimuli consisted of three chromatic slides (red, blue, and green) and one achromatic (gray). The four slides were each homogeneous and all four were equated for brightness intensity. Independent judges had previously rated the chromatic stimuli as having more emotional elicitation value than the achromatic stimulus. Rankings by the experimental Ss agreed with the judges ratings.

Richard Louis Miller

The experimental hypothesis predicted that pupils manifest more responsivity, as measured by change in pupil diameter, when exposed to chromatic (emotional) stimuli than when exposed to achromatic (neutral) stimuli. This hypothesis was supported. There was a significant effect of color upon 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 stimulus ($p. < .01$). The pupillary response was shown to be an initial contraction and return in response to all stimuli followed by a clear dilation in response to the chromatic stimuli and little response to the achromatic stimulus.

The results of the present investigation indicated that the pupillary response can be used as a measure of the generalized emotional response within the organism. Implications of these results were discussed and suggestions were made for further research.

Approved: Bill L. Kell
Committee Chairman

Date: April 19, 1966

THE CLINICAL VALIDATION OF THE PUPILLARY RESPONSE: THE EFFECT OF CHROMATIC AND ACHROMATIC STIMULI UPON PUPIL RESPONSIVITY

By

Richard Louis Miller

A THESIS

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When I look back I see a lifetime . . .

When I look forward I see a new world.

Dedicated,

With Love,

To my wife, Louise,

and my dear friends,

Josephine Morse and Bill Kell

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The process of enabling a student to actualize some of his creative potentials is undoubtedly far from being a mean task. I would like to express my sincere gratitude to my Chairman, Dr. Bill L. Kell and my Committee, Drs. William Mueller, David Raskin, and Norman Abeles for their "enabling" both during and after this investigation.

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INTRODUCTION

Review of the Literature

Throughout the history of psychology, there have been many attempts to develop an objective physiological measure of the internal affective state of the organism. One such measure that has come into consideration is pupil reactivity. Lowenstein and Loewenfeld (1962), drawing on 7,000 publications dealing with pupil innervation, have stated that:

> The pupillary sphincter muscle is activated by parasympathetic (cholenergic) nerve fibers from the ciliary ganglion, the dilator muscle by sympathetic (adrenergic) nerves from the superior cervical ganglion. The iris is thus a representative of all smooth muscle structures reciprocally innervated by the autonomic nervous system . . . the iris is, thus, at all times under the influence of a labile dynamic equilibrium of its autonomic innervation whereby sympathetic parasympathetic and supranuclear mechanisms are simultaneously active in varying degrees. p. 235

It follows from this that the pupil is almost in constant motion and that its activity is increased by sensory or emotional stimulation and by spontaneous thoughts and emotions. Even in a situation without light, the pupil may oscillate over a wide range (Lowenstein and Loewenfeld, 1962). A more recent publication is this area (Morgan,1965) corroborated these findings and stated that a sympathetic effect that may be seen during the experiencing of a strong emotion is that the pupils of the eyes dilate.

More than thirty years ago Bender (1933) noted that

> It is known that the iris is controlled by two reciprocating muscle fibers, the circular sphincter with oculomotor innervation of the parasympathetic type and the radial dilatator muscle fibers innervated from the superior cervical ganglion of the sympathetic type. p. 16.

Bender devised an experiment to investigate the effect of various emotional stimuli upon pupillary reflex activity. He found that emotional stimuli, namely a gunshot and presentation of a white rat caused inhibition of response to light. He concluded that pupillary changes could be brought about psychically as well as reflexly and that mental or emotional states of the organism could thus effect the pupil. This study did not attract much attention, since the methodology was extremely primitive. However, Bender must be credited with the idea of using motion picture frames in order to obtain a measure of pupil dilation and contraction in an "emotional" situation.

Although scientific methodology and scientific apparatus have since improved immensely, the literature concerning the nature of the pupillary response is a mass of confusion and contradiction. While textbooks continue to state that the pupil may be conditioned and that its response is affected by a variety of stimuli, scientific corroboration of these statements in greatly lacking. Some examiners have reported that they were able to condition the pupil (Cason, 1922; Hudgins, 1933; Baker, 1938; and Gerall and Woodward, 1958); however, replications as well as new and original attempts have yielded negative results (Steckle, 1936; Wedell, Taylor, and Skolnick, 1940; Hilgard, Miller and Olson, 1941; Hilgard, Dutton, and Helmick, 1949; Young, 1954; Crasilneck and McCranie, 1956; and Young, 1958). Explanations of such conflicting results are not convincing, and they vary from procedural differences to hippus--a disturbance of the integration of sympathetic and parasympathetic actions (Crasilneck and McCranie, 1956).

A recent attempt to study the relationship between pupil reactivity and the internal state of the organism has been made by Hess who has been attempting to measure pupil dilatation and contraction in response to such variables as interest (Hess and Polt, 1960), mental activity (Hess and Polt, 1964) and attitude (Hess, 1965). Considering, as did Bender, that the determination of pupil size is complexly related to the sympathetic division of the autonomic nervous system, Hess (Hess and Polt, 1960) began by investigating the effect of visual stimuli of various interest values upon pupil size in order

> to test the hypothesis that pupillary changes mediated by the sympathetic division, such as the changes we found in animals, could be used in human beings as both a quantitative and qualitative measure of greater or less interest value and pleasure value of visual stimuli. p. 239.

The study involved photographing the S's eye with a 16 mm. camera while S viewed a series of test pictures and control pictures. Hess stated that "Brightness was kept 'relatively' (this author's quotes) constant in order to rule out any effect of changes in level of illumination on the size of the pupil." He concluded that "these data show that there is a clear sexual dichotomy in regard to the interest value of the pictures."

In a second study, (Hess and Polt, 1964) using a light controlled environment, Hess measured the pupil response of the Ss while they were engaged in multiplication problems. He concluded that there is a correlation between pupil dilatation and problem difficulty.

In a third study Hess (1965) investigated the relationship between attitude and pupil size. In this experiment the S peered into a box and looked at a screen onto which the stimulus was projected. A mirror below the S's line of sight reflected the image of his eye into a motion picture camera. Based on data obtained by using stimuli that were matched in brightness with control stimuli, Hess reported that his technique yielded "more accurate representations of an attitude than can be obtained with even a well-drawn questionnaire or some devious 'projective' technique."

In his most current study (Hess, Seltzer and Shlien, 1965) interestingly enough titled "A pilot study," Hess reported that a measurement in changes of pupil size permitted clear cut discrimination between heterosexual and homosexual subjects.

The above described research certainly raises some thought provoking ideas concerning the emotional nature of the pupillary response. However, close examination of the methodologies involved revealed that many objections could be raised with regard to their scientific validity. In addition, in writing all four studies Hess furnished very sparse details, and his statistical analyses were questionable at best. Furthermore, replication of Hess's experiments by this experimenter has been impossible. It would seem that a more rigorous investigation of the meaning of pupil response is needed if we are to know something of its usefulness as a measure of internal affective state.

It is the purpose of the present investigation to validate the pupil response as being an objective measure of an internal affective state. In brief, this study is an attempt to measure pupil response to chromatic and achromatic stimuli.

Scientific interest in color began in the latter part of the 17th century with the research of Newton on light and colors (Balaraman, 1962). It was during the 18th century that physicists postulated 3 primary colors which were all that were needed to reproduce all the known colors.

The connection between emotion and color dates back to the beginning of man (Schactel, 1943; Birren, 1961; Birren, 1962; Frazer, 1963). Regarding the primitiveness of the relationship between color and affect, Birren (1952, 1959, 1963) has emphatically stated that man has strong emotional feelings about color to the extent that color and affect are inextricably related. Guilford (1934) has maintained the view that color preference in man is an innate biological given. He studied the color preferences of 1,279 college students (Walton, Guilford, and Guilford, 1933) and found persistent differences in affective values for colors in spite of fluctuations form year to year and in spite of sex differences. He concluded that in addition to environmental variables there must be deep underlying biological factors that influence color preference. Goldstein (1939) has pointed out that different attitudes towards the world are caused by different colors and that color stimuli influence the speed and extent of volitional movements and the judgement about time intervals, weights, and distances. He has said that:

> It is probably not a false statement if we say that a specific color stimulation is accompanied by a specific response pattern of the entire organism. p. 264.

Luckiesh (1918) summing up the considerations at that time between color and emotionality concluded that "the eye is the normal gateway for the stimulus on its way to arousing a color sensation and finally an emotion." Experiments delving into the color-affect relationship also have a long history.

The following is a review of some of the more significant research over the past 65 years. At the turn of the century Ellis (1900, 1906) studied the development of color perception and color preference in infants. He found that perception begins with bright colors and proceeds down the spectrum and that color preferred at one point in this early development will not necessarily be preferred at another. Holden (1900) reported that order of preference develops from the red towards the blue end of the spectrum, until at age eight blue becomes the most preferred color. Valentine (1914) reported that color preference at 4 months was different than at 8 months, but yellow was still most preferred. Staples (1932) criticized the methodology used in previous color preference studies involving infants and used looking time and grasping as measures of infants' preferences. She found that colors could be distinguished at 12 through 15 months. Haas (1963) used frustration and stress in an attempt to change color preference over time and found this could not be done.

Studying the relationship between musical and verbal association of color and mood, Odbert, Karowski, and Eckerson (1942) found that certain colors were more often chosen to go with certain groups of words describing mood. Clark (1948) analyzed MMPI items and Rorschach protocols and found that the data were in accord with traditional Rorschach interpretations of color and affect. That is, maladjustment on the MMPI is correlated with high sum C. In 1952 Norman (Norman and Scott, 1952) surveyed the literature on color and affect and noted that the relationship had been studied from many angles--color preference, mood associations, personality traits, mental and emotional disorders--and that indeed a relationship did seem to exist. One year later a much stronger statement was made by Fortier (1953) who said that the experience of affect and color are quite comparable and thus one could examine affect by examining the response to color.

Wexner (1954) had her subjects match 8 colors with words previously judged to represent feelings or mood tones. Her results supported color-mood theories. Schaie (1961) had 20 professional judges rate the association between 11 adjective mood descriptions and 10 colors by means of a Q-Sort of 100 cards each containing a description and a color patch. His analysis confirmed previous findings of associative relations between color and mood tones. Schaie used this relationship as a rationale for the use of response to color as a means of personality study for he felt he had demonstrated that color associations conform to consistent group stereotypes. He then devised the color Pyramid Test (Schaie and Haas, 1964) "as a technique for the study of the role of emotion and affect as part of the personality structure of normal and abnormal Ss." This test was thus based upon the empirical evidence demonstrating the "direct stimulus value of color upon feeling, moods, and affect as mediated by the biological aesthetic and symbolic functions of color."

The argument over the affective nature of color and the Rorschach began with the publication of Rorschach's book (1942) in which he posited the existence of "color shock" as proof of the internal relationship which must exist between color percept and the dynamics of affectivity. Since that time, there have been an almost overwhelming number of studies in this area (see selected bibliography).

In general, the studies were poorly designed with regard to the variables being examined and, in many cases, each study had as its purpose the criticism of previous research. In view of this controversy, it is difficult to make a clear-cut statement regarding the nature of color shock.

Baughman (1958) did a massive review of the literature regarding color and the Rorschach and, although he used this review to argue against the presence of color shock, he readily admitted that color affects _S_s in their perference for particular blots and in the content elicited by the blot (interestingly enough none of the studies did content analysis of the protocols).

A recent investigation which had many implications for the Rorschach color shock controversy was the study by Drechsler (1960) who, attempting to demonstrate the affect-stimulating effects of color showed the Ss rectangles of red, green, and gray on a screen and followed each with a word-association test. He criticized many prior attempts to test the validity of the color-affect relationship because they directly depended on the Rorschach cards and rarely removed the color variable from the specific content of the cards. In his experiment Drechsler gave a recall test for all words after all association tests and stimulus conditions had been completed. His main hypothesis that color stimuli would elicit more emotional responses than gray was upheld.

Hypothesis

Examination of relevant literature indicated that the pupil is physiologically related to those areas of the nervous system which control emotion. A review of the empirical research regarding the color-affect relationship offered substantial avidence that color elicits an emotional response in the organism.

The hypothesis of the present study was that pupils manifest more responsivity, as measured by change in pupil diameter, when exposed to chromatic (emotional) stimuli than when exposed to achromatic (neutral) stimuli.

METHOD

Subjects

The subjects consisted of 30 male freshmen and sophomore college students selected from a basic psychology course at Michigan State University. Only *S*s who were not color blind and who did not wear glasses were selected.

Apparatus

The apparatus (see Appendix A) was designed and constructed by *E* and an assistant following Hess (1965) and Hess, Seltzer and Shlien (1965). Certain modifications and improvements were made on the prototype. The final apparatus consisted of a rectangular plywood box 32" long, 18" wide, and 16" high. At one end was a viewing aperture. When *S*'s head was in place, his right eye was directly in front of the aperture. On the opposite end of the apparatus was mounted a 6" x 8" rear projection screen on which a small cross was painted.

The visual target was projected onto this screen by a 500 watt Kodak Carousel slide projector. The distance from the projector to the screen was 18 inches.

Inside the apparatus a 9" x 20" silver-coated one-way vision mirror was placed at a 45° angle across the *S*'s line of vision. This mirror reflected the image of the *S*'s eye directly into the lens of a 16 mm. Eclair 16 II motion picture camera which was mounted on the side of the apparatus. The camera was fitted with an Angenieux 12mm-120mm Zoom lens and a +2 diopter close-up lens. The distance along the visual axis from the viewing aperature to the mirror was 9 inches. The illumination was furnished by the Carousel projector and by light reflected off the aperture and furnished by 2 lamps set at a 45° angle behind S. The amount of light reaching the viewing aperture was 48 foot candles.

Also within the apparatus, 20" from the aperture, was a plywood panel in which a 4" x 5.3" rectangular hole had been cut. The panel was positioned so that when looking through the aperture only the surface of the 6" x 8" rear projection screen was visible.

The interior of the apparatus from the aperture to the panel was painted flat black. The remainder of the interior was painted white enamel.

Procedure

The stimuli used in the present study consisted of 4 homogeneous targets projected onto the rear vision screen. Three of the targets were chromatic and one was achromatic.

The chromatic targets were red, blue, and green and the achromatic target was a very light gray. The four targets were specially constructed by E (with the aid of a technical representative of the Eastman Kodak Company) so that they were equal in brightness intensity. Equating for intensity was done by varying the density of the targets with the use of Wratten Neutral Density Filters.

In order to obtain an independent measure of the differential emotional elicitation value of the chromatic and achromatic stimuli, the following procedure was used. Sixty-seven freshman and sophomore college students enrolled in four separate sections of a basic psychology course were used as judges. These judges were not used again as experimental Ss. The judges were shown the experimental targets for 5 seconds each and asked to rate the targets from 1 to 10 with regard to their ability to elicit an emotional reaction. A low score indicated low elicitation value and a high score high elicitation value. The targets were then compared with regard to their emotional elicitation values. Following the literature it was expected that the chromatics would have higher emotional value than the achromatic.

The four targets were presented in random order to each of the 30 experimental Ss. The order of the targets for each S is presented in Appendix B.

The data were collected in the following way. Ss were seated before the apparatus and given the following instructions:

> Please place this eye patch over your left eye. Rest your forehead against the box and look into the hole with your right eye. Focus on the cross on the

> screen in front of you. We are going to project a series of slides onto the screen which you are now looking at. Please try to keep your eye on the screen at all times and just react to whatever you see. We would like you to remain silent while reacting to the slides.

After the slides were all presented the Ss were asked to rank the targets with regard to their ability to elicit an emotional reaction.

The E and an assistant were present during the experiment. After S was given the instructions the slide projector was activated and a yellow target of equal intensity as the experimental targets was shown for 20 seconds, in order to orient the subject to the total experimental situation. After 19 seconds the 16 mm camera was turned on in order to photograph the last second of the orientation slide. Immediately after the orientation slide each target was presented for 5 seconds in the pre-programmed order for the particular S. The camera was set for 4 frames per second with the lens set at 120mm and f 2.8, and the film was Kodak TRX 449. Thus, 20 photographs were collected of each S's pupil in response to each of the 4 targets. The time alloted to each target and the number of frames per second was determined both by a pilot study and by previously used techniques (Gerall, Sampson and Boslov, 1957; Gerall and Woodward, 1958; Lowenstein and Friedman, 1942; Young, 1958).

The 2,400 photographs were measured by use of a Bausch and Lomb Fish Scale Projector. This apparatus projected the images of the pupils, magnified 22 times, onto a screen from which they were accurately measured with a millimeter ruler.

Measures were not obtainable on one S as he closed his eye during the experiment. Thus, the analysis of the data was based on 2,320 photographs of 29 Ss.

RESULTS

An analysis of variance (Lindquist, 1956) was done on the ratings of the emotionality of the experimental stimuli by the 4 groups of judges. The analysis (see Table 1) indicated that the four experimental stimuli differed with regard to their perceived ability to elicit an emotional response ($p. < .01$).

Table 1.--Summary of the analysis of variance for the rating of the emotionality of the experimental stimuli by 4 groups of judges.*

	df	Sum of Squares	Mean Squares	F	P
Judges	3	3,259.69	1,086.56	9.89	.01
Color	3	21,857.69	7,285.90	66.33	.01
Color x Judges	9	988.56	109.84		
Total	15	26,105.94			

*The analysis was done on the groups of judges since the data on the ratings by the individual judges was lost.

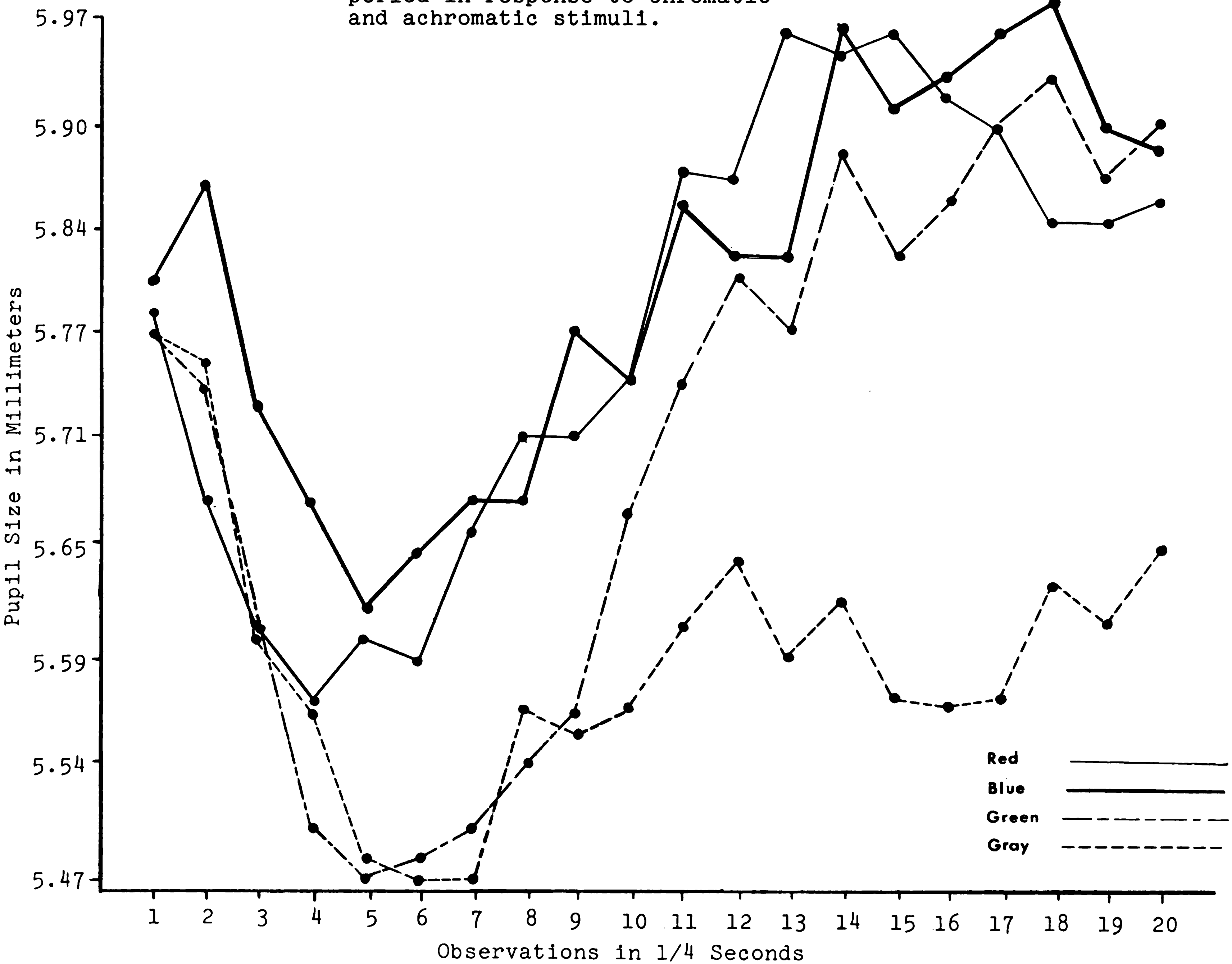
Scheffe's test for multiple comparisons (Edwards, 1960, p. 154) indicated that the responses to the three chromatic stimuli were each significantly larger than the response to the achromatic stimulus ($A > 2310$, $p. < .01$).

The mean rating of emotionality (1 being low, 10 being high) for each stimulus was: red = 8.36; green = 6.40; blue = 6.25; gray = 2.28 (see Appendix C).

The rankings of the emotionality of the 4 stimuli by the 30 experimental Ss were analyzed by the analysis of variance for ranked data (Winer, 1962, p. 136) and again the stimuli were found to be different (x^2_{ranks} = 55.80; $p < .001$). The mean ranking of each stimulus was: red = 3.53; blue = 2.70; green = 2.70; gray = 1.10. Observation of the data (see Appendix D) revealed that the neutral stimulus was ranked lowest with regard to emotional value by 28 of the 30 Ss. A coefficient of concordance (Winer, 1962, p. 137) computed on the ranked data indicated that there was significant agreement among the Ss in their ranking of the emotionality of the experimental stimuli ($W = .618$, $p < .01$).

Figure 1 contains a graphic representation of the pupillary response (measured change in pupil diameter) to the 4 experimental stimuli. The experimental hypothesis predicted that pupils would manifest more responsivity, as measured by change in pupil diameter when exposed to chromatic stimuli than when exposed to achromatic stimuli. The data, as represented in Figure 1, seem to support this hypothesis. Following the initial pupillary contraction and return which was evoked by all stimuli, the response to the chromatics was a dilation, whereas there was little response to the achromatic.

Figure 1.--Pupil diameter over a 5 second period in response to chromatic and achromatic stimuli.



In order to test whether or not the above described differences were significant, an analysis of variance of pupil diameter was performed. The analysis (Lindquist, 1956, p. 237) revealed that there was a significant effect of color upon pupil diameter (see Table 2).

Table 2.--Summary of the analysis of variance of pupillary diameter during 5 second exposures to each of the experimental stimuli.

Source	df	Sum of Squares	Mean Squares	F	P
Color	3	157.47	52.49	8.59	.001
Color x Subjects	84	513.54	6.11		
Intervals	19	253.87	13.36	7.22	.001
Intervals x Subjects	532	982.89	1.85		
Subjects	28	29,110.93	1,039.68	2,540.76	.001
Color x Intervals	57	119.37	2.09	5.11	.001
Color x Intervals x Subjects	1,596	653.12	.4092		
Total	2,319	31,791.19			

Furthermore, there was a significant effect over time; there was an interaction between the stimuli and time; and the differences among Ss accounted for a very large portion of the total variance. Since gray was treated the same as the other three stimuli in the analysis of variance, a separate statistical analysis was performed in order to ascertain whether there was more as well as differential pupil reactivity to the chromatic stimuli than to the achromatic stimulus.

Scheffe's test for multiple comparisons of the mean pupil diameter for each stimuli (Edwards, 1960, p. 154) indicated that the pupillary response to both red (A = 111) and blue (A = 152) was significantly larger than the response to gray (A > 74, p. < .01) and that green approached being significantly larger than gray. There were no differences among the chromatic stimuli. The mean pupillary diameters for the 4 experimental stimuli were: Blue = 5.81mm; Red = 5.78mm; Green = 5.69mm; and Gray = 5.59mm.

Since the graphic representation of the data suggested that there were two distinct pupillary responses to the stimuli, two additional analyses of variance of pupillary diameter were performed. The first analysis concerned itself with the pupillary reaction during the first 2.5 seconds that each stimulus was presented (see Table 3). There were

Table 3.--Summary of the analysis of variance of pupillary diameter during the first half of the 5 second exposure to each of the experimental stimuli.

Source	df	Sum of Squares	Mean Squares	F	P
Color	3	48.92	16.31	3.61	.05
Color x Subjects	84	379.40	4.52		
Intervals	9	83.35	9.26	7.07	.001
Intervals x Subjects	252	331.17	1.31		
Subjects	28	14,437.51	515.63	1,127.80	.001
Color x Intervals	27	20.47	.7581	1.66	.05
Color x Intervals x Subjects	756	345.71	.4572		
Total	1,159	15,646.53			

significant main effects of color, trials, and subjects and a significant interaction between color and time. The variability among subjects accounted for the greatest part of the variance. Scheffe's test on the mean pupil diameter in response to each of the 4 stimuli revealed no significant differences. The mean pupil diameter for each stimulus during the first 2.5 second period was: blue = 5.73mm; red = 5.67mm; green = 5.58mm; gray = 5.58mm. Thus, although there was a significant differential effect of color on pupil size during the first 2.5 seconds of stimulus presentation, the differences among the colors were not specifiable.

Table 4 below contains the analysis of variance of the pupil diameter during the second half of the 5 second presentation of the experimental stimuli.

Table 4.--Summary of the analysis of variance of pupillary diameter during the second half of the 5 second exposure to each of the experimental stimuli.

Source	df	Sum of Squares	Mean Squares	F	P
Color	3	108.55	36.18	22.75	.001
Color x Subjects	84	134.14	1.59		
Intervals	9	170.52	18.95	7.32	.001
Intervals x Subjects	252	651.72	2.59		
Subjects	28	14,673.42	524.05	1,288.85	.001
Color x Intervals	27	98.90	3.66	9.00	.001
Color x Intervals x Subjects	756	307.41	.4066		
Total	1,159	16,144.66			

As in the two previous analyses of variance, the results suggested by Figure 1 were corroborated in that there were main effects of color and trials and an interaction between the two. Scheffe's test indicated that the mean pupil response to each of the chromatics (Red, A = 128; Blue, A = 133; Green, A = 46) was significantly greater than the mean pupil response to the achromatic ($A > 19.3$, $p. < .01$). The means were: Blue = 5.90mm, Red = 5.89mm; Green = 5.85mm; and Gray = 5.61mm.

The S's mean pupil response to the experimental stimuli was ranked (see Appendix F) and an analysis of variance revealed the differences among the rankings to be significant ($x^2_{ranks} = 33.13$, $p. < .001$). A coefficient of concordance computed on the mean pupil response of each S to each stimulus indicated that Ss agreed in their differential responses to the 4 stimuli ($W = .3808$, $p. < .01$).

In conclusion, the statistical analyses corroborate the results suggested by the graphic representation of the data and support the experimental hypothesis. There was significantly more pupil reaction (change in pupil diameter) in response to the red and blue stimuli than there was to the gray stimulus ($p. < .01$). The pupillary response to the green stimulus was larger than the response to the gray stimulus but this difference was only significant ($p. < .01$) during the second half of the 5 second period of presentation of stimuli.

DISCUSSION

A survey of the literature revealed many experiments attempting to demonstrate that chromatic stimuli elicit more emotional response than do achromatic stimuli (Wexner, 1954; Drechsler, 1960; Schaie, 1961). The relationship between color and affect has been studied from many different angles and it certainly does seem to exist (Norman and Scott, 1952). The present results strongly support these previous findings as both the ratings by independent judges and the rankings by Ss themselves revealed the chromatics to have more emotional elicitation value than the achromatic. This finding further supports the use of chromatic targets as emotional stimuli and achromatic targets as neutral stimuli. It must be remembered that these ratings and rankings of emotionality were based on viewing the actual stimuli and not merely on associations to the words representing the stimuli (red, blue, green, and gray). This fact is important because the gray stimulus used in this study is probably best described as a "light neutral gray" and is certainly not a color that would readily elicit such responses as might the word gray, i.e. "bad weather" or "depression." Naturally, this leaves open the question of what the responses might be to varying saturations of achromatic stimuli.

The major purpose of this study was to validate the pupil response as being an objective measure of the generalized response by the organism to stimulation of an emotional nature. The results would seem to fulfill this goal. There was a significantly larger pupillary response to all three emotional (chromatic) stimuli than there was to the neutral (achromatic) stimulus. This finding is in direct support of Bender's (1933) statement that pupillary changes could be brought about psychically as well as reflexly.

Although the answer to whether or not there is contraction to emotionally negative stimuli is by no means resolved we are able to offer no evidence in support of Hess's (1965) contention that "constriction is as characteristic in the case of certain aversive stimuli as dilation is in the case of interesting or pleasant pictures." If this were the case, then the pupil response to emotional stimuli would have been greater contraction as well as greater dilation since the stimuli might certainly have had negative as well as positive meaning for the Ss. Red could stand for "hell" and "fire" as well as "warmth" and "love." Instead, there was greater pupillary response to the emotional stimuli but it was solely manifested in dilation.

The data did reveal that there were two distinct pupillary responses to the experimental stimuli. Initially, there was a pupillary contraction and return very similar to that described by Lowenstein and Friedman (1942) as being the normal reflex to light. Lowenstein and Friedman (1942) have demonstrated that the complete reflex takes approximately 2.5 seconds and our finding supports this. Although other investigators have also reported pupillary contraction in response to visual stimuli (Backer & Ogle, 1964; Shakhnovich, 1965) in the present investigation this initial pupillary contraction was a result of the light of the stimulus following the dark period resulting from the projector switching from one stimulus to the next. Backer and Ogle (1964) noted pupillary contraction upon presentation of visual stimuli and since they found this to be unexplainable, they called it a "transient pupillary constriction." Shakhnovich (1965) reported pupillary contraction in response to red and blue stimuli. He hypothesized that this was an orienting pupillary constrictive reaction to the form or the color in order to create the best optical condition for perception of the stimulus. During the first 25 second period of pupillary contraction and return the Ss in the present investigation did react differentially to the 4 experimental stimuli, however, these differences were not specifiable in terms of which stimulus evoked the largest pupillary response, the smallest pupillary response, etc. The differential pupil responsivity during this period may be a function of an emotional response beginning to "compete" with the reflex to light particularly toward the end of the 2.5 second period.

The second response to the stimuli was dilation. During this 2.5 second period not only did Ss respond differentially to the stimuli but there were also clearly specifiable differences between the emotional stimuli and the neutral stimulus. Each of the three emotional stimuli elicited a pupillary response larger than that elicited by the neutral stimulus. No statement could be made as to which was the "most powerful" elicitor of pupillary response. This second, differential pupillary dilation response to emotional and neutral stimuli would seem to verify the notion that pupil reactivity can be used as a sensitive and accurate measure of the organism's generalized response to emotional excitation. Furthermore, this differential dilation response suggests that Shakhnovich's explanation of pupillary reaction to red and blue stimuli needs elaboration and/or modification.

The fact that there was a change in light intensity when the projector changed stimuli is an aspect of the present methodology that definitely needs improvement. This contraction at the onset of each stimulus does not allow clear statements to be made about the latency of the emotional aspect of the response. Outside of this one factor the apparatus used in this investigation was a vast improvement over that used in the past. It is quite possible that the crude apparatus used by many investigators has led to the many conflicting findings. Certainly the days of observing pupils through a telescope and verbally reporting changes are over.

The results of the present investigation would seem to validate the pupillary response as an objective measure of the generalized response by the organism and such validation has far reaching implications for many areas of psychological research. If proper norms were established, the pupil response could be used in place of paper and pencil tests and verbal reports both of which are subject to various types of errors. An atlas of pupillary reactions to various stimuli by various categories of Ss could be made up, thus allowing immediate comparison of a particular S with many classifications of Ss. Such an atlas might contain pupillary reactions to vocational as well as psychodiagnostic tests. The present results may be interpreted as supporting the notion that chromatic components of the Rorschach elicit more emotional response than achromatic components. Further support for the color shock theory might be gained by comparing the differential pupillary responses to each card and also by comparing the responses to the standard cards with an identical set containing no color. One aspect of the controversy over whether or not psychotherapists respond to "non-verbal cues" may be at least partially resolved by a determination of whether trained therapists are better than non-therapists at attending to changes in pupil size.

Since an obvious explanation for the greater pupil response to the chromatic stimuli is learned emotional associations, it would seem indicated to use the same stimuli and test Ss of various developmental levels beginning with pre-verbal Ss. This might yield information regarding when in development emotional associations are learned in connection with various stimuli and also if and when language is necessary to mediate emotional associations. Such research might also shed some light on Guilford's (1934) statement that in addition to environmental variables there must be deep underlying biological factors influencing reactions to color.

A recent investigation by Guinan (1966) indicated that there was greater pupillary response to emotional as compared to neutral words. The present investigation revealed that certain chromatic stimuli elicit a measurable emotional response from the organism. In order to test the effect chroma may have upon other stimuli words found by Guinan (1966) be to neutral could be printed in chromatic and achromatic colors. Thus, the pupillary responses to neutral words printed in red, blue and gray could be compared. This could also be repeated with many other stimuli in the environment, thus possibly separating the response to a stimuli based on its chromaticity from responses based on other factors.

With a more sophisticated apparatus than that used in the present study many areas of the therapeutic relationship could be examined. Oftentimes a therapist finds himself assuming that he is meeting with resistance on a particular topic while the client insists the topic is simply not meaningful. Utilizing video tape, an analysis could be made of the pupillary reaction during the interview and thus, an objective assessment could be made to determine whether or not the client's behavior was a manifestation of resistance or whether the topic of discussion was just not meanginful. This same technique could be used to specify meaningful areas to therapy for after each interview the video tape could be analyzed in order to ascertain the topics or behavior which elicited emotional responses from the client. For example, after looking at the pupillographic records of clients with "mother problems" one could make a prediction based on pupil response for any given client as to whether or not he or she had "mother problems." This same methodology could be extended to any and all content of therapy.

Furthermore, the pupil response could be used as a measure of progress in therapy for as the client learns how to cope with topics and situations which were previously highly emotionally charged, his pupil reactivity to these situations should have less magnitude. If a client states that he is much more able to handle a particular situation than his pupillary response should be significantly less than when he was not able to handle the situation. In short, desensitization should lead to less pupillary response. Measured pupillary reaction could also be used in therapy follow-up studies for if the therapy is successful, the response to various topics and situations should be more similar to the response immediately following termination than during the initial therapeutic sessions.

These implications certainly warrant a replication of the present investigation with correction of the apparatus, a longer exposure to the experimental stimuli, a larger sample size including females and an analysis of possible personality differences between Ss manifesting differential magnitude of pupillary response.

SUMMARY

This investigation was an attempt to validate the pupillary response as an objective measure of the generalized response by the organism to emotional excitation.

Thirty male Ss who were not color blind and who did not wear glasses were asked to look into the aperture of a specially constructed light-tight apparatus. Four experimental stimuli were projected onto a screen in the apparatus for five seconds each. While the Ss viewed the stimuli a 16mm motion picture camera photographed their pupils at the rate of four frames per second. The projected stimuli consisted of three chromatic slides (red, blue, and green) and one achromatic (gray). The four slides were each homogeneous and all four were equated for brightness intensity. Independent judges had previously rated the chromatic stimuli as having more emotional elicitation value than the achromatic stimulus. Rankings by the experimental Ss agreed with the judges ratings.

The experimental hypothesis predicted that pupils manifest more responsivity, as measured by change in pupil diameter, when exposed to chromatic (emotional) stimuli than when exposed to achromatic (neutral) stimuli. This hypothesis was supported. There was a significant effect of color

upon 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 stimulus ($p < .01$). The pupillary response was shown to be an initial contraction and return in response to all stimuli followed by a clear dilation in response to the chromatic stimuli and little response to the achromatic stimulus.

The results of the present investigation indicated that the pupillary response can be used as a measure of the generalized emotional response within the organism. Implications of these results were discussed and suggestions were made for further research.

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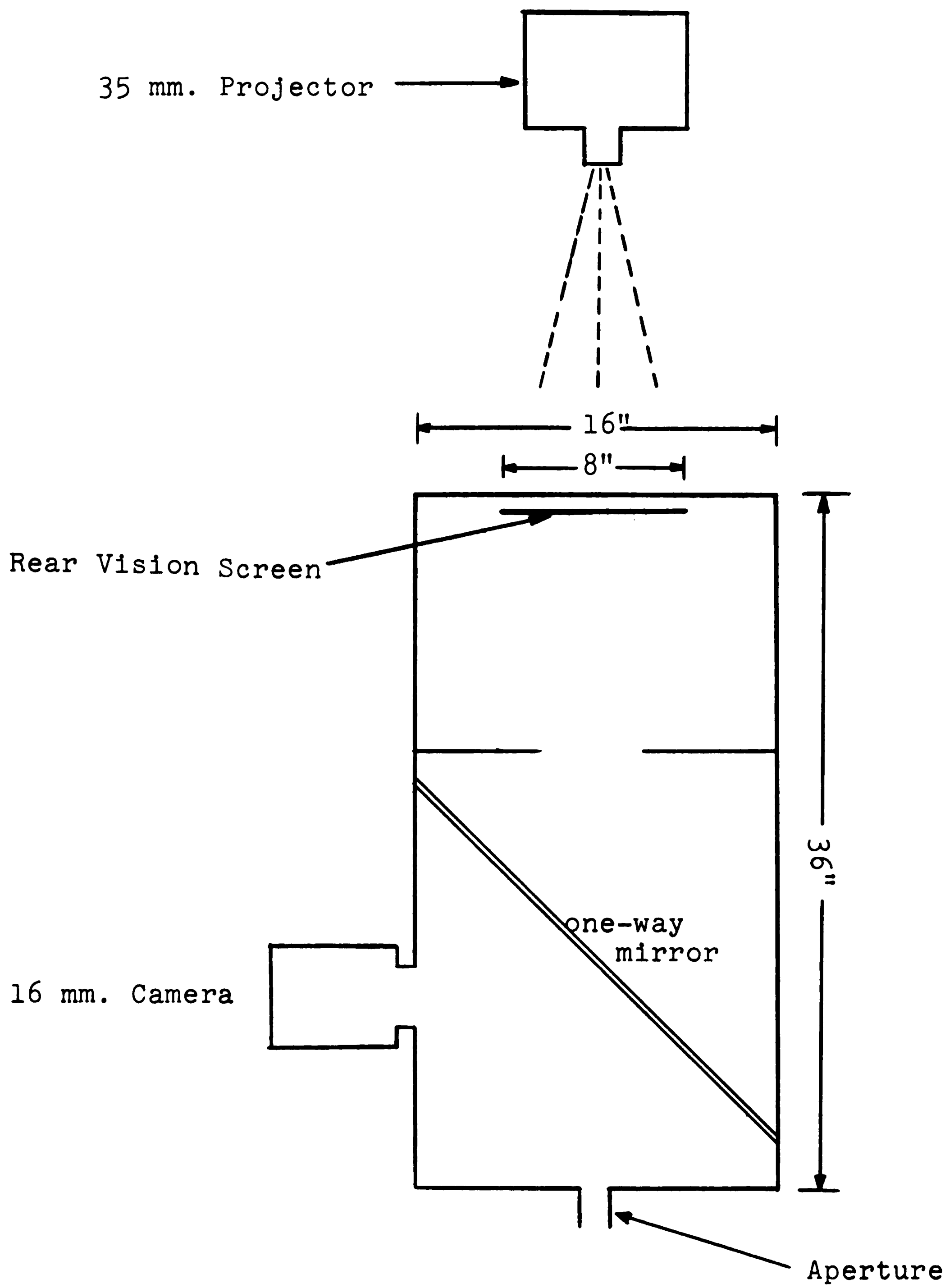
APPENDIX A

EXPERIMENTAL APPARATUS

APPENDIX A

Experimental Apparatus



APPENDIX B

RANDOMIZED ORDER OF PRESENTATION OF TARGETS

APPENDIX B

Randomized Order of Presentation of Targets

Subject	1	2	3	4
1	Blue	Red	Gray	Green
2	Green	Blue	Red	Gray
3	Red	Gray	Blue	Green
4	Green	Blue	Gray	Red
5	Gray	Blue	Red	Green
6	Green	Blue	Gray	Red
7	Blue	Green	Red	Gray
8	Green	Red	Blue	Gray
9	Blue	Gray	Green	Red
10	Blue	Green	Red	Gray
11	Blue	Gray	Red	Green
12	Red	Gray	Green	Blue
13	Gray	Red	Blue	Green
14	Green	Blue	Gray	Red
15	Gray	Green	Blue	Red
16	Blue	Gray	Green	Red
17	Red	Green	Gray	Blue
18	Red	Blue	Gray	Green
19	Red	Green	Blue	Gray
20	Gray	Blue	Red	Green
21	Gray	Green	Blue	Red
22	Green	Blue	Gray	Red
23	Blue	Green	Gray	Red
24	Gray	Green	Red	Blue
25	Gray	Green	Red	Blue
26	Gray	Green	Red	Blue
27	Blue	Green	Gray	Red
28	Red	Gray	Blue	Green
29	Green	Blue	Gray	Red
30	Blue	Gray	Green	Red

APPENDIX C

RATING OF EMOTIONALITY OF EXPERIMENTAL STIMULI BY 4 GROUPS OF JUDGES

APPENDIX C

Rating of Emotionality of Experimental Stimuli by 4 Groups of Judges

	Group I N = 18 EX	II N = 17 EX	III N = 14 EX	IV N = 18 EX	$\bar{X}$
Red	146	148	117	149	8.36
Green	121	106	81	121	6.40
Blue	118	132	77	92	6.25
Gray	51	39	18	45	2.28

N = number of judges in group.

EX = total rating of emotionality by judges in the group.

$\bar{X}$ = mean rating of emotionality across all judges.

APPENDIX D

RANKING OF EMOTIONALITY OF EXPERIMENTAL STIMULI BY EXPERIMENTAL Ss

APPENDIX D

Ranking of Emotionality of Experimental Stimuli by Experimental Ss

Subjects

Stimuli	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Red	4	3	4	4	4	3	4	4	4	3	4	4	4	2	2	3	3	4	3	3	3	4	4	3	4	4	4	3	4	4
Green	3	4	2	3	3	2	2	2	2	4	3	2	3	3	3	2	4	3	2	4	2	2	3	2	3	3	3	2	3	1
Blue	2	2	3	2	2	4	3	3	3	2	2	3	2	4	4	4	2	2	4	2	4	3	2	4	2	2	2	4	1	2
Gray	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	3

APPENDIX E

PUPILLARY RESPONSES OF $\underline{S}$s TO EXPERIMENTAL STIMULI

APPENDIX E

*Blue

Subjects	Observations																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	7	7	6	7	7	7	7	7	8	8	8	8	8	8	8	8	7	7	8	9
2	12	12	12	12	12	12	12	11	12	10	11	12	12	13	12	12	12	13	13	13
3	12	12	12	12	12	12	12	13	14	14	13	13	13	12	12	12	12	13	12	13
4	6	6	5	6	5	4	5	6	6	6	7	7	6	7	6	7	7	7	7	6
5	12	12	12	12	12	12	12	13	13	13	13	13	14	14	13	13	13	14	13	13
6	10	10	9	9	9	9	8	9	8	8	8	9	8	9	9	9	9	9	9	9
7	6	6	7	6	6	5	5	6	6	6	7	6	6	7	7	6	7	7	5	6
8	16	15	15	13	14	14	14	13	15	15	15	15	16	16	15	15	15	14	13	14
9	11	12	10	9	9	11	12	11	10	11	14	14	13	14	14	15	15	14	12	12
10	19	20	19	20	21	21	21	19	20	18	19	18	19	19	18	18	19	19	19	19
11	8	9	8	9	9	9	8	8	8	7	8	8	9	9	9	8	8	9	10	9
12	14	12	12	12	11	12	13	12	13	13	13	14	14	14	15	14	15	16	15	15
13	8	9	9	11	9	9	11	10	9	10	9	9	9	9	9	9	8	7	7	7
14	12	12	11	10	11	11	10	10	11	12	11	10	9	9	10	13	12	12	12	12
15	11	12	11	12	12	11	12	12	12	12	12	11	12	13	12	12	11	11	10	10
16	14	16	15	15	15	15	15	15	16	15	16	16	15	16	16	15	16	15	14	14
17	4	4	3	3	3	3	3	3	3	4	4	4	3	4	4	4	5	6	6	6
18	11	11	10	9	10	11	11	11	12	12	11	11	11	12	11	10	10	12	12	11
19	12	12	13	13	12	13	13	12	12	13	13	14	13	13	13	14	14	13	13	14
20	19	19	19	18	17	17	18	19	20	19	18	16	17	17	17	17	18	17	18	18
21	7	8	7	6	6	6	5	6	7	7	8	8	8	9	7	8	8	9	8	7
22	12	11	11	12	9	11	11	12	11	13	15	15	16	14	13	13	12	12	12	12
23	15	16	16	16	15	14	13	12	13	12	12	13	14	15	15	14	15	14	15	15
24	10	9	10	9	8	8	9	11	12	10	11	11	10	11	11	11	11	10	11	11
25	13	12	12	12	13	13	14	14	13	13	13	12	12	14	14	14	14	14	14	14
26	6	6	6	5	5	5	5	5	6	5	6	4	4	5	6	6	6	7	6	6
27	12	12	13	11	12	12	12	11	11	12	13	13	12	12	12	12	12	12	12	12
28	9	10	10	10	10	10	8	8	8	7	7	8	9	9	10	10	10	11	11	10
29	16	16	14	13	12	12	13	13	12	12	13	13	13	14	15	16	15	15	15	14

*To obtain actual pupil size add 8 and divide by 3.3.

APPENDIX E

Red

Subjects	Observations																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	7	7	8	7	7	7	8	7	7	8	7	6	6	7	7	7	7	7	8	7
2	12	10	10	11	10	11	11	11	11	10	10	11	11	12	11	12	12	12	12	12
3	12	13	12	12	12	12	13	13	12	13	12	12	13	13	13	14	14	14	13	12
4	5	5	6	5	4	5	5	5	6	6	6	6	6	6	6	6	6	6	5	6
5	13	12	11	11	10	10	10	11	12	12	12	12	12	12	12	13	14	12	12	13
6	9	10	9	9	10	9	9	9	9	9	9	9	9	9	8	9	9	8	9	9
7	7	7	7	8	8	7	7	6	5	6	5	5	6	7	7	7	7	6	6	7
8	14	14	13	12	13	12	15	14	13	13	14	15	15	14	16	16	15	13	14	13
9	14	13	13	14	15	14	14	15	14	14	15	15	15	16	16	15	14	15	16	14
10	19	18	20	19	19	19	18	18	18	18	19	18	18	19	18	19	20	19	19	19
11	9	9	8	8	8	9	9	8	8	9	10	9	10	8	9	8	7	8	9	10
12	12	11	12	12	11	12	13	13	13	13	13	13	13	14	14	13	14	15	15	15
13	8	7	8	10	11	11	11	10	9	8	10	8	8	7	7	8	7	7	9	10
14	11	10	9	9	10	10	10	10	10	10	11	12	13	11	11	11	11	11	11	11
15	11	12	12	13	13	12	11	12	12	12	12	12	13	13	14	13	12	12	11	10
16	16	15	14	15	17	16	15	17	15	15	16	15	16	17	17	17	16	16	15	15
17	6	5	5	4	5	4	5	4	3	4	5	5	4	4	5	5	5	5	4	4
18	9	10	10	9	10	10	11	11	11	11	11	11	11	11	11	11	11	11	11	11
19	12	13	13	12	12	12	12	13	13	12	13	13	13	14	13	12	12	12	13	13
20	20	19	19	16	15	15	15	16	17	17	19	20	20	20	21	20	20	20	20	21
21	7	5	5	4	4	4	3	4	4	3	4	4	5	5	7	6	7	6	6	6
22	12	12	11	12	12	12	12	12	13	13	14	15	15	15	14	14	13	11	11	11
23	15	16	14	15	14	13	12	13	13	14	15	15	15	14	13	14	15	14	14	13
24	9	9	9	8	8	9	9	9	10	10	10	10	10	10	10	10	11	11	10	11
25	13	13	12	12	12	11	14	15	16	17	17	17	16	14	15	14	14	15	14	15
26	5	5	4	4	4	5	6	6	6	6	6	6	7	6	6	5	5	6	6	6
27	12	12	11	11	12	12	12	11	11	12	13	13	13	13	13	12	12	12	12	12
28	9	8	7	7	7	9	9	10	10	11	11	11	11	10	9	10	10	10	10	10
29	14	12	13	12	11	11	11	12	12	12	11	11	13	15	14	13	12	12	12	12

APPENDIX E

Green

Subjects	Observations																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	7	7	7	6	7	7	7	7	8	8	8	8	8	7	7	7	7	7	7	7
2	11	11	11	11	10	10	10	11	10	11	12	11	11	11	11	12	11	12	12	13
3	12	12	12	12	12	12	12	13	12	12	12	13	14	13	14	14	14	14	13	14
4	6	6	5	4	4	4	4	4	5	6	6	6	6	6	6	6	6	6	6	6
5	14	13	12	12	12	13	13	12	12	13	13	13	14	14	13	14	13	13	13	13
6	10	11	10	10	10	9	9	10	10	10	10	10	10	10	10	10	11	11	11	11
7	6	6	6	5	6	6	7	6	6	5	5	4	4	5	5	5	6	6	5	7
8	15	14	15	14	14	14	13	12	12	13	12	12	14	14	15	14	15	15	14	15
9	14	13	14	14	14	13	13	14	15	16	16	16	15	16	14	13	14	14	14	14
10	19	18	18	18	18	19	19	19	19	19	19	19	18	18	18	19	19	20	19	19
11	9	9	9	9	9	8	8	8	9	8	9	9	9	10	10	10	10	9	8	8
12	14	14	13	13	12	11	12	11	12	11	12	13	12	12	12	13	13	13	13	13
13	8	8	7	7	8	8	7	8	7	8	9	10	9	8	8	7	8	7	8	8
14	13	13	12	10	10	11	10	9	8	10	9	11	12	13	12	12	10	12	11	10
15	10	10	10	10	11	11	11	10	11	12	12	12	12	11	11	10	11	10	10	10
16	15	16	15	12	13	12	14	15	13	13	14	14	14	15	16	16	16	16	17	18
17	4	3	3	3	3	2	3	2	2	2	3	4	4	5	4	4	4	5	5	5
18	11	12	11	10	9	9	11	10	9	10	11	12	11	12	11	12	12	12	12	12
19	12	12	12	12	13	13	13	14	14	13	13	13	13	13	12	13	12	13	12	11
20	19	18	17	16	16	16	15	17	17	16	18	17	18	19	18	19	17	16	17	17
21	6	6	5	5	5	5	5	4	5	7	6	7	7	8	7	7	7	8	7	7
22	10	10	10	11	10	10	10	11	11	11	11	12	12	14	14	12	14	15	15	15
23	14	15	15	13	12	12	13	11	12	13	14	14	14	14	13	15	16	16	15	15
24	9	9	8	9	8	9	8	10	10	11	11	11	10	10	10	11	11	12	11	12
25	12	11	11	11	10	11	12	14	13	12	14	13	12	12	12	12	13	12	13	12
26	5	6	5	5	5	5	5	4	5	6	6	6	5	6	5	5	5	6	5	5
27	11	12	12	12	11	11	11	12	12	12	12	12	12	12	12	12	13	12	12	12
28	10	9	7	7	7	8	8	8	9	9	8	8	7	8	9	9	9	9	9	9
29	15	14	13	13	12	12	11	12	12	14	13	14	14	15	16	15	15	14	14	14

APPENDIX E

Gray

Subjects	Observations																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	7	7	6	6	6	6	6	7	6	7	7	7	6	6	7	6	7	7	7	7
2	13	11	10	9	8	9	9	10	10	11	11	11	10	11	10	10	11	11	10	11
3	12	12	12	12	12	12	12	13	13	13	12	13	13	13	12	12	12	12	12	12
4	7	5	4	4	3	3	4	5	4	4	4	4	5	4	4	4	4	5	6	6
5	11	11	11	11	11	12	11	11	12	11	11	12	13	13	12	12	12	12	12	13
6	9	9	9	9	8	8	8	9	9	9	9	8	8	8	9	8	8	8	8	8
7	7	6	6	5	5	5	4	4	4	5	6	5	5	6	5	6	6	6	6	7
8	15	15	13	13	13	12	14	13	14	14	15	15	13	13	13	13	12	13	14	15
9	14	14	13	13	12	12	14	13	12	13	14	14	15	14	15	14	13	14	14	13
10	19	20	19	17	18	18	19	18	17	17	17	17	17	17	17	18	17	18	19	18
11	9	9	9	9	9	9	9	9	9	8	8	9	7	8	7	7	7	8	9	9
12	14	15	13	13	12	12	12	12	12	12	12	13	13	13	14	12	11	11	11	11
13	8	7	7	9	8	8	9	10	9	7	7	7	8	7	7	7	8	8	7	8
14	11	12	11	12	10	9	8	10	11	11	11	11	11	10	10	12	12	12	12	12
15	11	10	9	10	11	11	10	11	10	11	11	10	11	10	10	9	9	9	9	9
16	15	17	15	14	13	12	12	13	13	13	13	13	13	13	13	14	16	15	14	13
17	4	5	5	3	3	3	3	3	3	2	2	3	3	3	3	4	4	4	4	5
18	11	11	11	12	11	11	12	12	12	12	11	10	9	10	11	12	12	12	11	11
19	12	12	13	13	12	13	12	13	12	12	13	13	13	14	13	13	13	12	11	12
20	19	19	18	17	16	17	16	15	16	17	17	17	18	18	17	16	17	18	19	19
21	6	7	8	7	8	7	7	7	6	6	5	6	6	6	6	7	6	7	6	6
22	12	13	11	12	13	12	10	10	12	12	12	13	13	13	12	11	12	11	11	12
23	15	14	12	13	12	13	12	12	13	14	14	13	12	13	13	12	13	13	12	12
24	9	8	9	9	9	8	8	8	9	10	11	11	10	9	8	9	10	11	10	11
25	10	10	11	11	11	11	12	12	12	12	12	13	14	14	13	12	10	11	11	10
26	5	5	6	5	6	5	4	6	5	4	5	5	5	6	6	5	5	5	5	5
27	12	12	12	11	11	11	11	11	12	12	12	12	11	12	12	12	12	12	12	11
28	10	9	7	7	7	7	9	9	8	8	9	8	8	8	7	8	8	8	9	10
29	14	14	14	14	14	15	14	14	14	13	14	15	13	14	15	15	14	14	14	13

APPENDIX F

RANKING OF S's ACTUAL PUPIL SIZE IN RESPONSE TO EXPERIMENTAL STUMILI

APPENDIX F

Ranking of S's Actual Pupil Size in Response to experimental stimuli

Subjects	Red	Blue	Green	Gray
1	2	4	3	1
2	2.5	4	2.5	1
3	3	2	4	1
4	3	4	2	1
5	2	3	4	1
6	3	2	4	1
7	4	3	2	1
8	3	4	1	2
9	4	1	3	2
10	2.5	4	2.5	1
11	3	2	4	1
12	3	4	2	1
13	3	4	2	1
14	1	4	2.5	2.5
15	4	3	2	1
16	4	3	2	1
17	4	3	2	1
18	1	2.5	2.5	5
19	2	4	3	1
20	4	3	1	2
21	1	4	2	3
22	4	3	2	1
23	3	4	2	1
24	2	4	3	1
25	4	3	2	1
26	3.5	3.5	2	1
27	4	3	2	1
28	4	3	2	1
29	1	3	2	4