ATTITUDE AND PUPIL SIZE

Dilation and constriction of the pupils reflect not only changes in light intensity but also ongoing mental activity. The response is a measure of interest, emotion, thought processes and attitudes

by Eckhard H. Hess

One night about five years ago I was lying in bed leafing through a book of strikingly beautiful animal photographs. My wife happened to glance over at me and remarked that the light must be bad—my pupils were unusually large. It seemed to me that there was plenty of light coming from the bedside lamp and I said so, but she insisted that my pupils were dilated. As a psychologist who is interested in visual perception, I was puzzled by this little episode. Later, as I was trying to go to sleep, I recalled that someone had once reported a correlation between a person's pupil size and his emotional response to certain aspects of his environment. In this case it was difficult to see an emotional component. It seemed more a matter of intellectual interest, and no increase in pupil size had been reported for that.

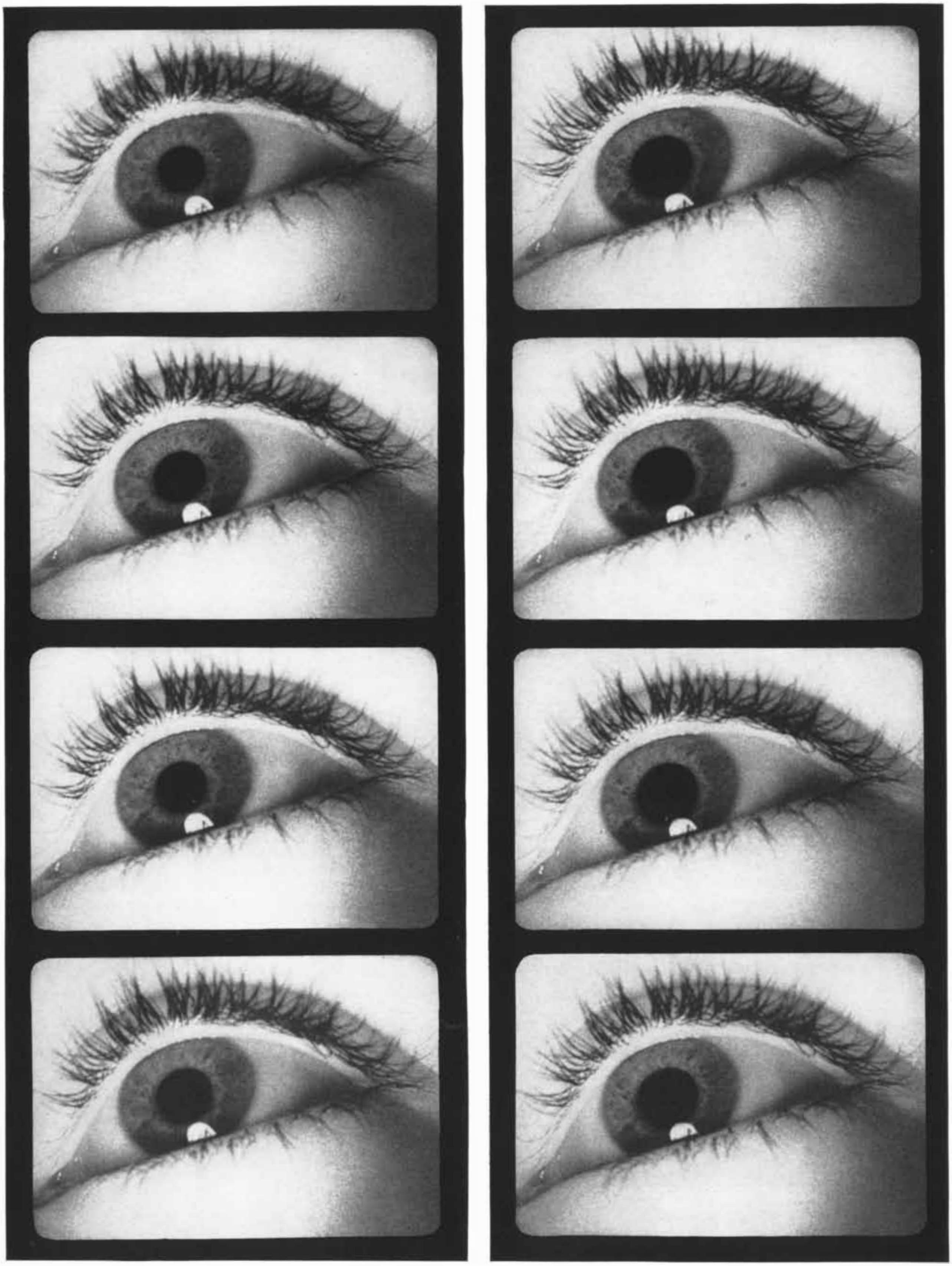
The next morning I went to my laboratory at the University of Chicago. As soon as I got there I collected a number of pictures—all landscapes except for one seminude "pinup." When my assistant, James M. Polt, came in, I made him the subject of a quick experiment. I shuffled the pictures and, holding them above my eyes where I could not see them, showed them to Polt one at a time and watched his eyes as he looked at them. When I displayed the seventh picture, I noted a distinct increase in the size of his pupils; I checked the picture, and of course it was the pinup he had been looking at. Polt and I then embarked on an investigation of the relation between pupil size and mental activity.

The idea that the eyes are clues to emotions—"windows of the soul," as the French poet Guillaume de Salluste wrote—is almost commonplace in literature and everyday language. We say "His eyes were like saucers" or "His eyes were pinpoints of hate"; we use such terms as "beady-eyed" or "bug-eyed" or "hard-eyed." In his *Expressions of Emotion in Man and Animals* Charles Darwin referred to the widening and narrowing of the eyes, accomplished by movements of the eyelids and eyebrows, as signs of human emotion; he apparently assumed that the pupil dilated and contracted only as a physiological mechanism responsive to changes in light intensity.

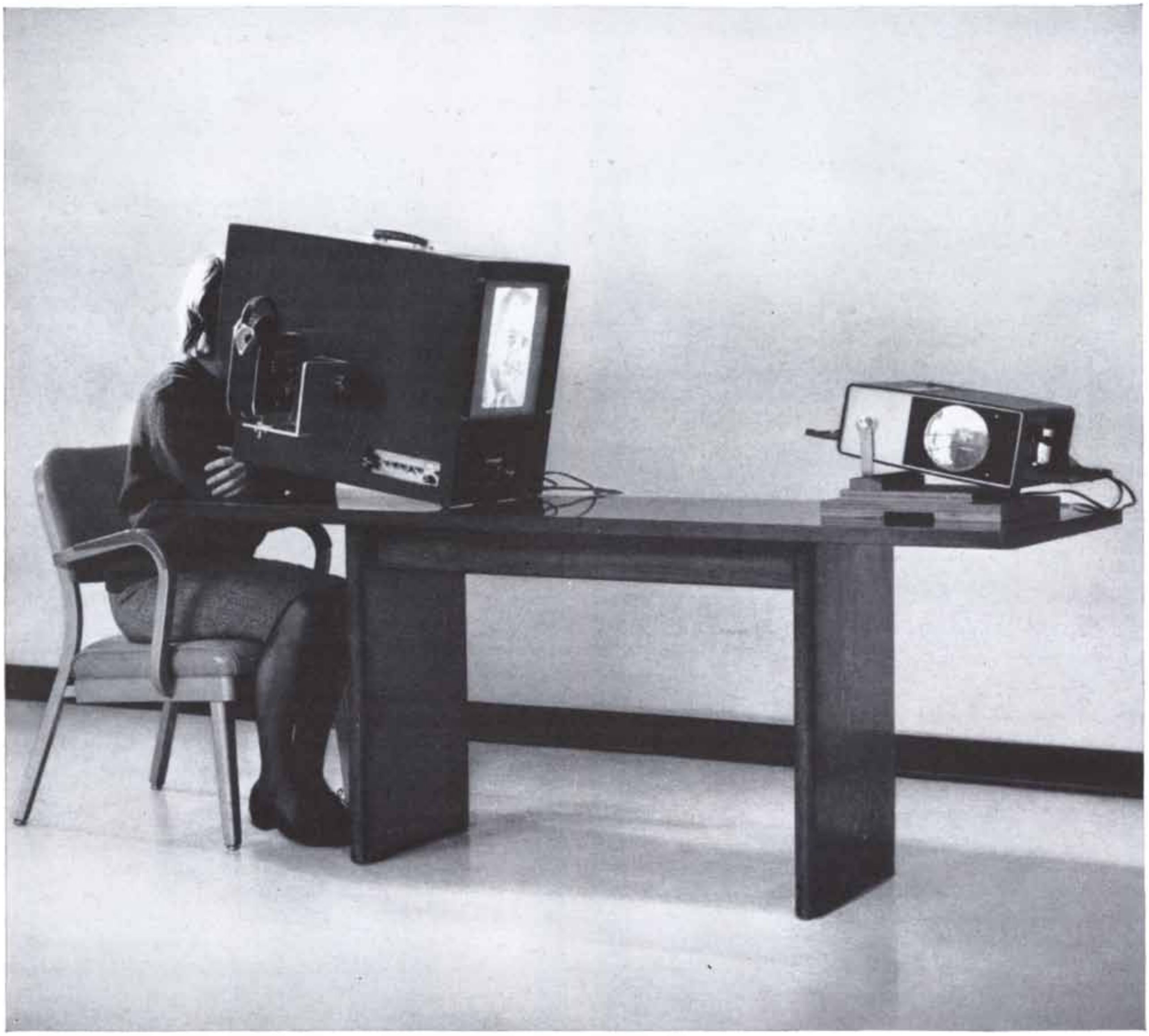
This light reflex is controlled by one of the two divisions of the autonomic nervous system: the parasympathetic system. Later investigators noted that pupil size is also governed by the other division of the autonomic system—the sympathetic system—in response to strong emotional states and that it can vary with the progress of mental activity. On a less sophisticated level some people to whom it is important to know what someone else is thinking appear to have been aware of the pupil-size phenomenon for a long time. It is said that magicians doing card tricks can identify the card a person is thinking about by watching his pupils enlarge when the card is turned up, and that Chinese jade dealers watch a buyer's pupils to know when he is impressed by a specimen and is likely to pay a high price. Polt and I have been able to study the pupil response in detail and to show what a remarkably sensitive indicator of certain mental activities it can be. We believe it can provide quantitative data on the effects of visual and other sensory stimulation, on cerebral processes and even on changes in fairly complex attitudes.

Most of our early experiments related pupil size to the interest value and "emotionality" of visual stimuli. Our techniques for these studies are quite simple. The subject peers into a box, looking at a screen on which we project the stimulus picture. A mirror reflects the image of his eye into a motion-picture camera. First we show a control slide that is carefully matched in overall brightness to the stimulus slide that will follow it; this adapts the subject's eyes to the light intensity of the stimulus slide. At various points on the control slide are numbers that direct the subject's gaze to the center of the field. Meanwhile the camera, operating at the rate of two frames per second, records the size of his pupil. After 10 seconds the control slide is switched off and the stimulus slide is projected for 10 seconds; as the subject looks at it the camera continues to make two pictures of his eye per second. The sequence of control and stimulus is repeated about 10 or 12 times a sitting. To score the response to a stimulus we compare the average size of the pupil as photographed during the showing of the control slide with its average size during the stimulus period. Usually we simply project the negative image of the pupil, a bright spot of light, on a screen and measure the diameter with a ruler; alternatively we record the changes in size electronically by measuring the area of the pupil spot with a photocell.

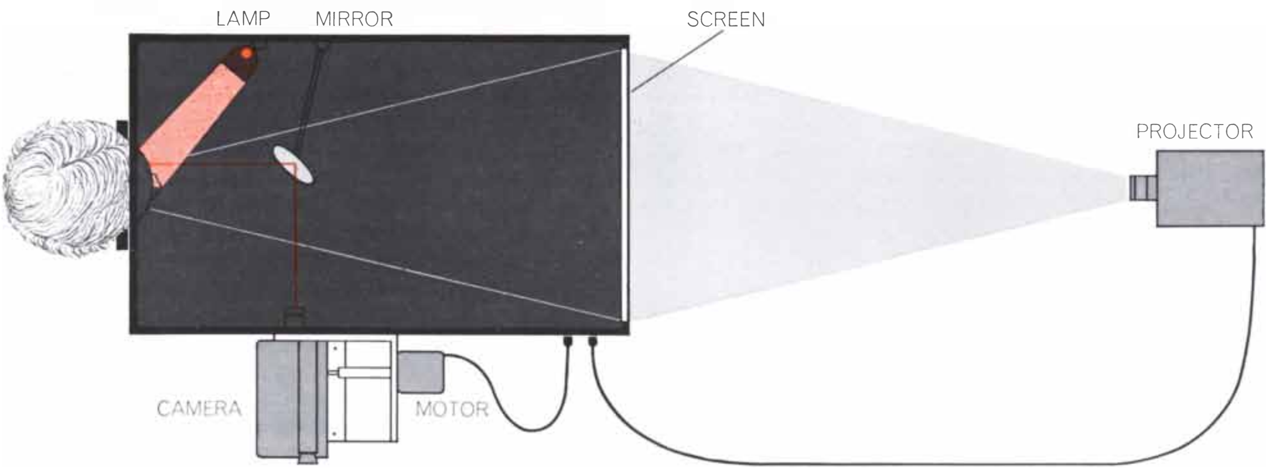
In our first experiment, before we were able to control accurately for brightness, we tested four men and two women, reasoning that a significant difference in the reactions of subjects of different sex to the same picture would be evidence of a pupil response to something other than light intensity. The results confirmed our expectations: the men's pupils dilated more at the sight of a female pinup than the women's



PUPIL SIZE varies with the interest value of a visual stimulus. In the author's laboratory a subject's eye is filmed as he looks at slides flashed on a screen. These consecutive frames (*top to bottom at left and top to bottom at right*) show the eye of a male subject during the first four seconds after a photograph of a woman's face appeared. His pupil increased in diameter 30 percent.



SUBJECT in pupil-response studies peers into a box, looking at a rear-projection screen on which slides are flashed from the projector at right. A motor-driven camera mounted on the box makes a continuous record of pupil size at the rate of two frames a second.



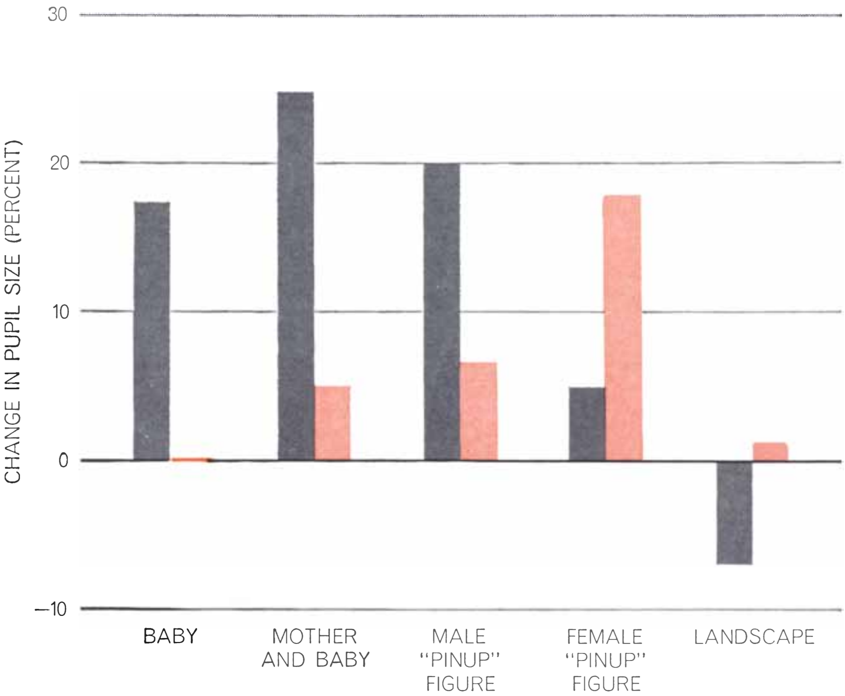
PUPIL-RESPONSE APPARATUS is simple. The lamp and the camera film work in the infrared. A timer advances the projector every 10 seconds, flashing a control slide and a stimulus slide alternately. The mirror is below eye level so that view of screen is clear.

did; the women showed a greater response than the men did to a picture of a baby or of a mother and baby and to a male pinup [*see illustration at right*]. We interpreted dilation in these cases as an indication of interest.

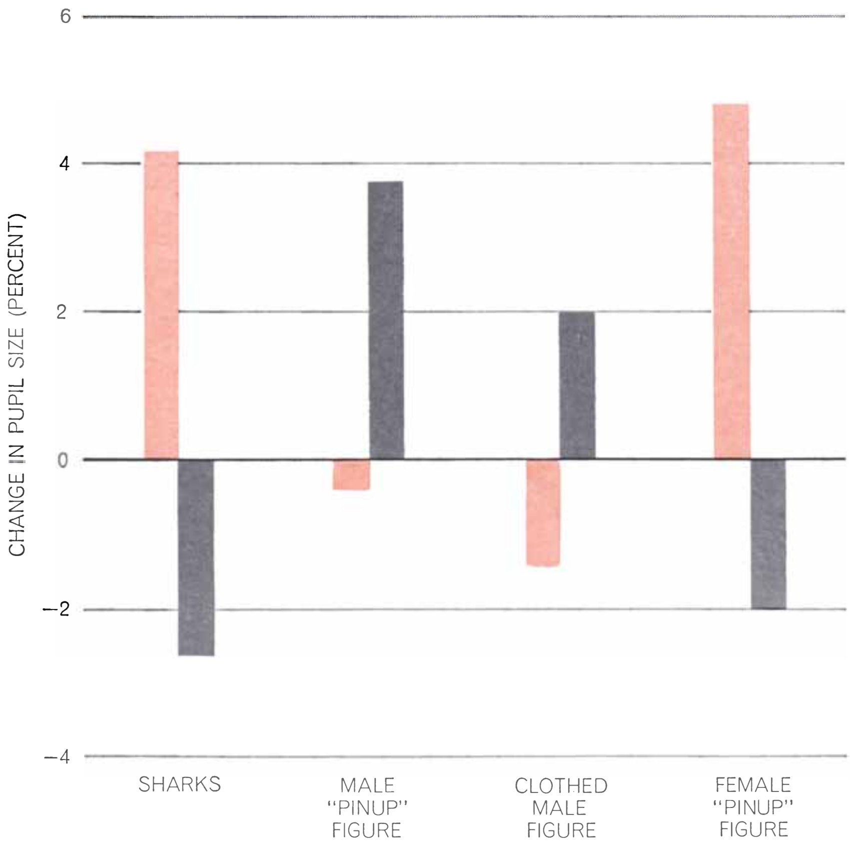
We then undertook another demonstration designed to eliminate the role of brightness. In this experiment we did not show a control slide; only the general room lighting illuminated the rear-projection screen of the apparatus during the control period. When the stimulus slide came on, every part of the screen was therefore at least somewhat brighter than it had been during the control period. If the eye responded only to changes in light intensity, then the response by all subjects to any stimulus ought to be negative; that is, the pupil should constrict slightly every time. This was not the case; we got positive responses in those subjects and for just those stimuli that would have been expected, on the basis of the results of the first study, to produce positive responses. We also got constriction, but only for stimuli that the person involved might be expected to find distasteful or unappealing.

These negative responses, exemplified by the reaction of most of our female subjects to pictures of sharks, were not isolated phenomena; constriction is as characteristic in the case of certain aversive stimuli as dilation is in the case of interesting or pleasant pictures. We observed a strong negative response, for example, when subjects were shown a picture of a cross-eyed or crippled child; as those being tested said, they simply did not like to look at such pictures. One woman went so far as to close her eyes when one of the pictures was on the screen, giving what might be considered the ultimate in negative responses. The negative response also turned up in a number of subjects presented with examples of modern paintings, particularly abstract ones. (We were interested to note that some people who insisted that they liked modern art showed strong negative responses to almost all the modern paintings we showed them.) The results are consistent with a finding by the Soviet psychologist A. R. Shachnowich that a person's pupils may constrict when he looks at unfamiliar geometric patterns.

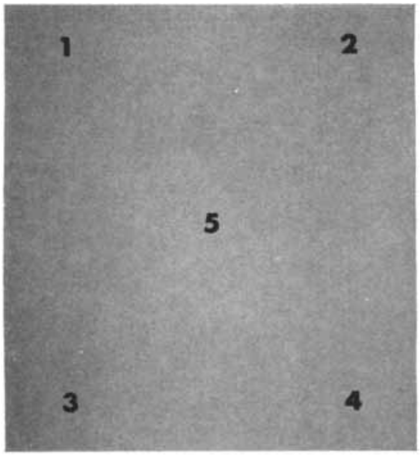
We have come on one special category of stimuli, examples of which are pictures of dead soldiers on a battlefield, piles of corpses in a concentration camp and the body of a murdered gang-



DIFFERENT RESPONSES to the same picture by female subjects (*gray bars*) and male (*colored bars*) established that the pupil response was independent of light intensity. The bars show changes in average area of pupils from the control period to the stimulus period.



ROLE OF BRIGHTNESS was also eliminated in an experiment in which the screen was unlighted before the stimulus appeared. Whereas responses to light alone would therefore have resulted in constriction, some pictures caused dilation in men (*colored bars*) and women (*gray*). In this experiment pupil diameter was tabulated rather than area.



CONTROL SLIDE provides calibration for experiments involving direction of gaze (*opposite page*). The subject looks at the five numbers in sequence and the camera records the resulting movements of his pupil.

ster. One might expect these to be "negative," and indeed they do produce extreme pupil constriction in some subjects, but they elicit a very different pattern of responses in others. On initial exposure the subject often responds with a large increase, rather than a decrease, in pupil size. Then, with repeated presentations, there is a shift to a negative response; the shift is usually accomplished after three to five exposures, and the time interval between those exposures seems to make little difference. Our impression was that these were negative stimuli with an additional "shock" content that prompted a strong emotional reaction. To check this hypothesis we attached electrodes to the hands of some of our volunteers and recorded their galvanic skin response, a measure of the electrical resistance of the skin that has been correlated with emotional level and is a component of most so-called lie-detector tests. As we had anticipated, stimuli we had classified as "shocking" got a high galvanic skin response along with the initial high pupil response in most subjects. After repeated presentations the skin response decreased rapidly as the pupil response shifted from dilation to constriction.

Although we have dealt primarily with positive stimuli, the evidence suggests that at least with respect to visual material there is a continuum of responses that ranges from extreme dilation for interesting or pleasing stimuli to extreme constriction for material that is unpleasant or distasteful to the viewer. In the presence of uninteresting or boring pictures we find only slight random variations in pupil size.

One of the most interesting things about the changes in pupil size is that they are extremely sensitive, sometimes revealing different responses to stimuli that at the verbal level seem to the person being tested quite similar. We once demonstrated this effect with a pair of stimulus photographs that in themselves provided an interesting illustration of the relation between pupil size and personality. In a series of pictures shown to a group of 20 men we included two photographs of an attractive young woman. These two slides were identical except for the fact that one had been retouched to make the woman's pupils extra large and the other to make them very small. The average response to the picture with the large pupils was more than twice as strong as the response to the one with small pupils; nevertheless, when the men were questioned after the experimental session, most of them reported that the two pictures were identical. Some did say that one was "more feminine" or "prettier" or "softer." None noticed that one had larger pupils than the other. In fact, they had to be shown the difference. As long ago as the Middle Ages women dilated their pupils with the drug belladonna (which means "beautiful woman" in Italian). Clearly large pupils are attractive to men, but the response to them—at least in our subjects—is apparently at a nonverbal level. One might hazard a guess that what is appealing about large pupils in a woman is that they imply extraordinary interest in the man she is with!

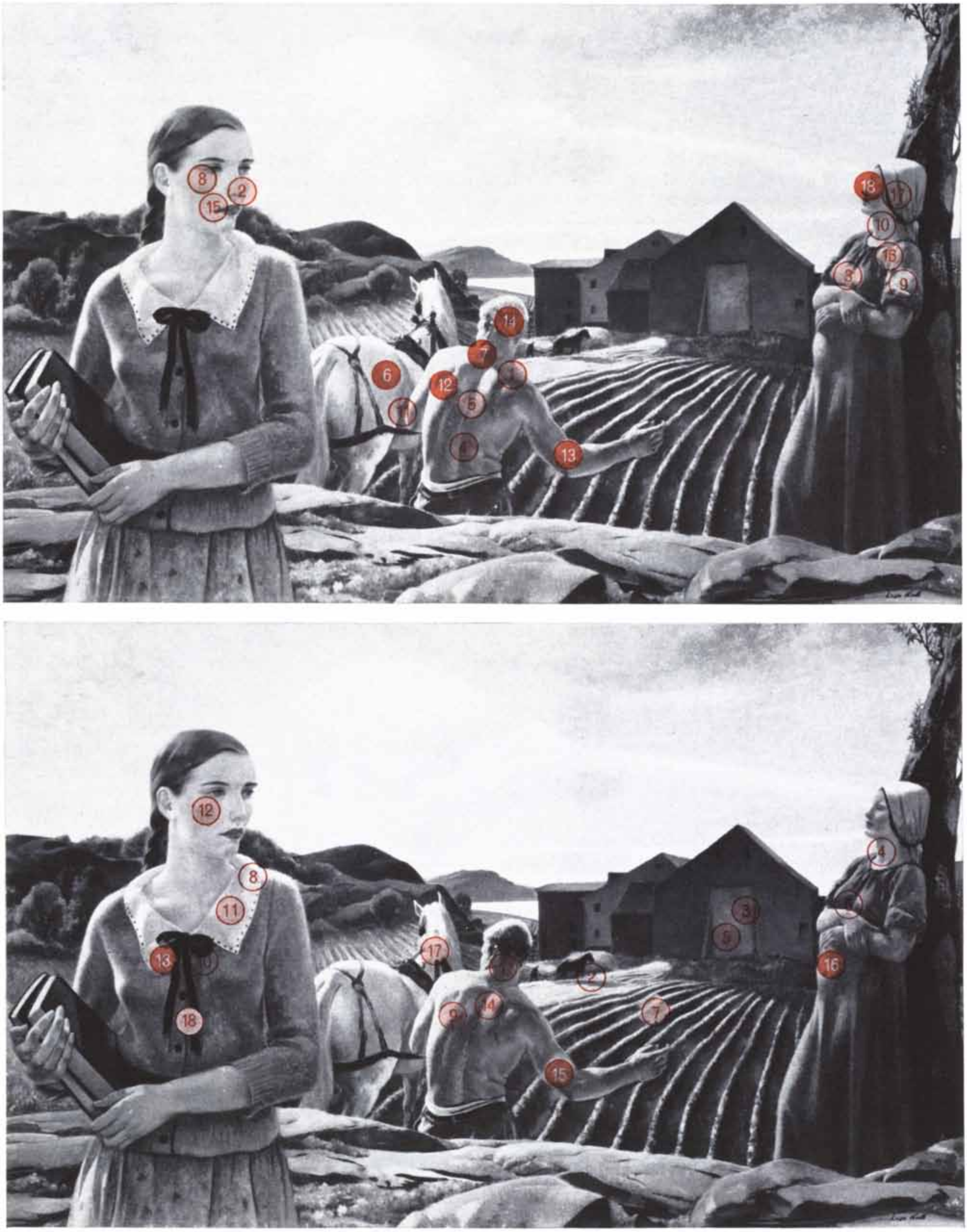
Pupillary activity can serve as a measure of motivation. We have investigated the effect of hunger, which is a standard approach in psychological studies of motivation. It occurred to us that a person's physiological state might be a factor in the pupil response when we analyzed the results of a study in which several of the stimulus slides were pictures of food—rather attractive pictures to which we had expected the subjects to respond positively. The general response was positive, but about half of the people tested had much stronger responses than the others. After puzzling over this for a while we checked our logbook and found that about 90 percent of the subjects who had evinced strong responses had been tested in the late morning or late afternoon—when, it seemed obvious, they should have been hungrier than the people tested soon after breakfast or lunch.

To be sure, not everyone is equally hungry a given number of hours after eating, but when we tested two groups controlled for length of time without food, our results were unequivocal: the pupil responses of 10 subjects who were "deprived" for four or five hours were more than two and a half times larger than those of 10 subjects who had eaten a meal within an hour before being tested. The mean responses of the two groups were 11.3 percent and 4.4 percent respectively.

Interestingly enough the pupils respond not only to visual stimuli but also to stimuli affecting other senses. So far our most systematic research on nonvisual stimuli has dealt with the sense of taste. The subject places his head in a modified apparatus that leaves his mouth free; he holds a flexible straw to which the experimenter can raise a cup of the liquid to be tasted. During the test the taster keeps his eyes on an *X* projected on the screen, and the camera records any changes in pupil size.

Our first study involved a variety of presumably pleasant-tasting liquids—carbonated drinks, chocolate drinks and milk—and some unpleasant-tasting ones, including concentrated lemon juice and a solution of quinine. We were surprised to find that both the pleasant and the unpleasant liquids brought an increase in pupil size compared with a "control" of water. Then we decided to test a series of similar liquids, all presumably on the positive side of the "pleasant-unpleasant" continuum, to see if, as in the case of visual material, some of the stimuli would elicit greater responses than others. We selected five "orange" beverages and had each subject alternate sips of water with sips of a beverage. One of the five orange beverages caused a significantly larger average increase in pupil size than the others did; the same drink also won on the basis of verbal preferences expressed by the subjects after they had been through the pupil-size test. Although we still have a good deal of work to do on taste, particularly with regard to the response to unpleasant stimuli, we are encouraged by the results so far. The essential sensitivity of the pupil response suggests that it can reveal preferences in some cases in which the actual taste differences are so slight that the subject cannot even articulate them—a possibility with interesting implications for market research.

We have also had our volunteers listen to taped excerpts of music while

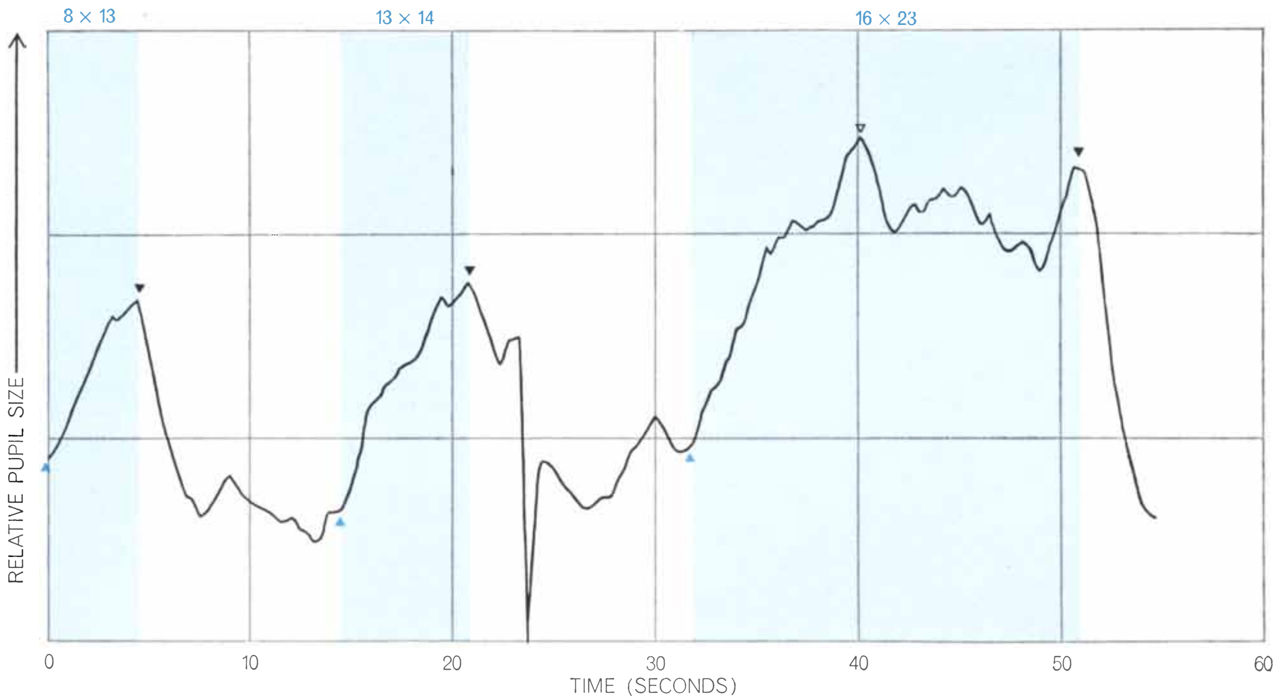


DIRECTIONAL ANALYSIS reveals where a subject was looking when each frame of film was made as well as how large his pupil was. Superposed on the upper reproduction of Leon Kroll's "Morning on the Cape" are symbols showing the sequence of fixations by a female subject looking at the painting; a man's responses are shown below. The light-color symbols indicate a pupil size about the same as during the preceding control period; open symbols denote smaller responses and dark-color symbols larger responses. The experimenters determine the direction of gaze by shining light through the film negative; the beam that passes through the image of the pupil is projected on a photograph of the stimulus (in this case the painting) and its position is recorded.

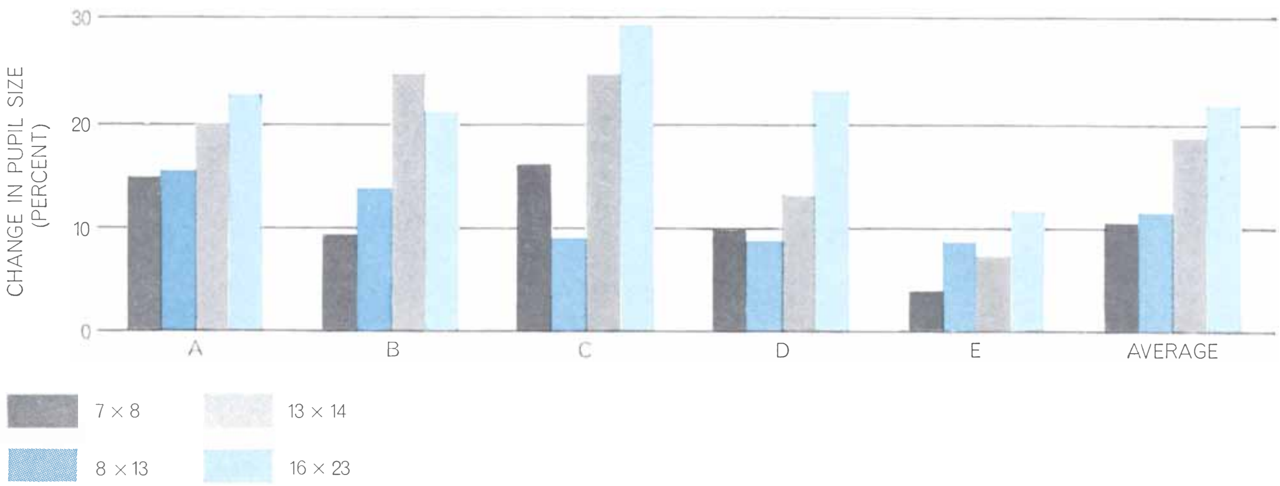
the camera monitors their pupil size. We find different responses to different compositions, apparently depending on individual preference. As in the case of the taste stimuli, however, the response to music seems always to be in a positive direction: the pupil becomes larger when music of any kind is being played. We have begun to test for the effect of taped verbal statements and individual words, which also seem to elicit different pupil responses. Research in these areas, together with some preliminary work concerning the sense of smell, supports the hypothesis that the pupil is closely associated not only with visual centers in the brain but also with other brain centers. In general it strongly suggests that pupillary changes reflect ongoing activity in the brain.

It is not surprising that the response of the pupil should be intimately associated with mental activity. Embryologically and anatomically the eye is an extension of the brain; it is almost as though a portion of the brain were in plain sight for the psychologist to peer at. Once it is, so to speak, "calibrated" the pupil response should make it possible to observe ongoing mental behavior directly and without requiring the investigator to attach to his subject electrodes or other equipment that may affect the very behavior he seeks to observe.

More than 50 years ago German psychologists noted that mental activity (solving arithmetical problems, for ex-



CHANGES IN PUPIL SIZE are traced in a subject doing the three mental-arithmetic problems shown at the top. Beginning when the problem is posed (*colored triangles*), the pupil dilates until the answer is given (*solid black triangles*). This subject appears to have reached a solution of the third problem (*open triangle*) and then to have reconsidered, checking his answer before giving it.



INDIVIDUAL DIFFERENCES in pupil response while solving multiplication problems reflect the fact that two of the five subjects, *D* and *E*, could do mental arithmetic with less effort than the others. The change in pupil size was computed by comparing the average size in the five frames before the problem was posed with the average in the five frames just before the answer was given.

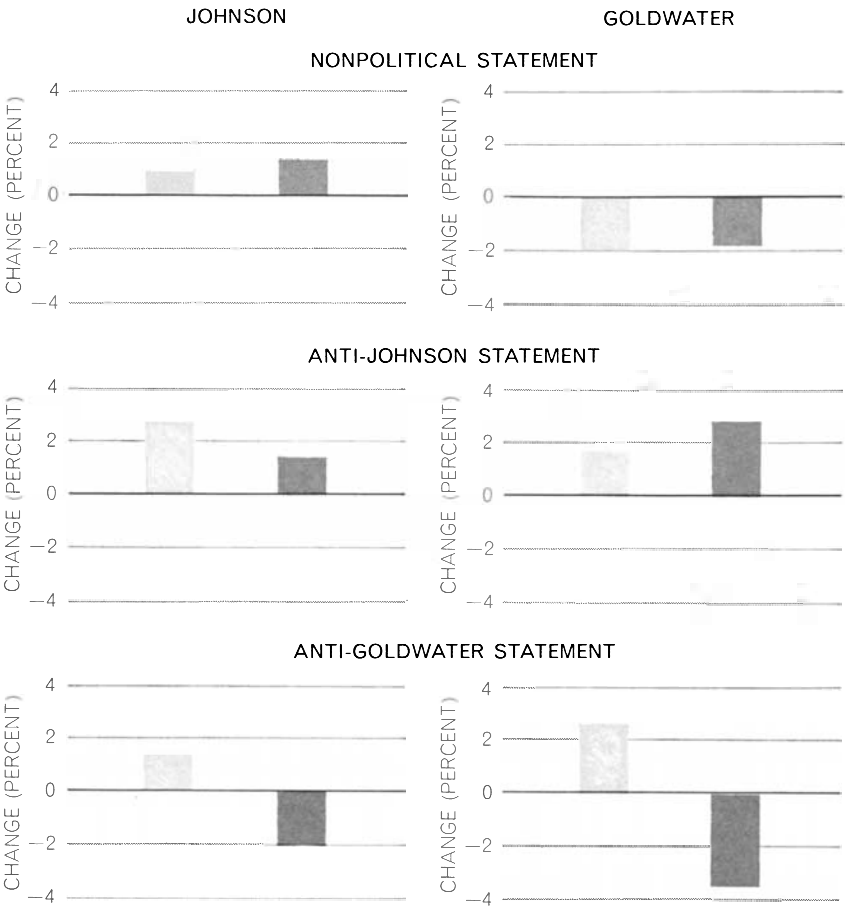
ample) caused a gross increase in pupil size. We decided this would be a good area for detailed study in an effort to see how precise and differentiated an indicator the response could be. We present mental-arithmetic problems of varying difficulty to volunteers and then obtain a continuous trace of their pupil response by measuring the filmed images of the pupil with a photocell [*see upper illustration on opposite page*]. As soon as the problem is presented the size of the pupil begins to increase. It reaches a maximum as the subject arrives at his solution and then immediately starts to decrease, returning to its base level as soon as the answer is verbalized. If the subject is told to solve the problem but not give the answer, there is some decrease at the instant of solution but the pupil remains abnormally large; then, when the experimenter asks for the solution, the pupil returns to its base level as the subject verbalizes the answer.

In one study we tested five people, two who seemed to be able to do mental arithmetic easily and three for whom even simple multiplication required a lot of effort. The pupil-response results reflect these individual differences [*see lower illustration on opposite page*] and also show a fairly consistent increase in dilation as the problems increase in difficulty. Individual differences of another kind are revealed by the trace of a subject's pupil size. Most subjects do have a response that drops to normal as soon as they give the answer. In some people, however, the size of the pupil decreases momentarily after the answer is given and then goes up again, sometimes as high as the original peak, suggesting that the worried subject is working the problem over again to be sure he was correct. Other people, judging by the response record, tend to recheck their answers before announcing them.

We have found a similar response in spelling, with the maximum pupil size correlated to the difficulty of the word. The response also appears when a subject is working an anagram, a situation that is not very different from the kind of mental activity associated with decision-making. We believe the pupil-response technique should be valuable for studying the course of decision-making and perhaps for assessing decision-making abilities in an individual.

It is always difficult to elicit from someone information that involves his private attitudes toward some person or concept or thing. The pupil-response technique can measure just such attitudes. We have established that the correlation between a person's expressed attitude and his "measured pupil" attitude can vary widely, depending on the topic. For example, we tested 64 people with five pictures of foods and also asked them to rank the foods from favorite to least preferred. When we matched each person's verbal report with his pupil response, we obtained 61 positive correlations—a result one could expect to get by chance only once in a million times.

The correlation is poor in an area that involves social values or pressures, however. For example, we do not get such good agreement between pupillary and verbal responses when we show women pictures of seminude men and women. Nor did we get good correlation when we did a political study last fall. We showed photographs of President Johnson and Barry Goldwater to 34 University of Chicago students, faculty members and employees. Everyone professed to be in favor of Johnson and against Goldwater. The pupil-response test, however, had indicated that about a third of these people actually had a slightly more positive attitude toward Goldwater than toward Johnson.



ATTITUDE CHANGES are revealed by responses to Johnson (*left*) and Goldwater (*right*) before (*light bars*) and after (*dark bars*) subjects read a statement supplied by the experimenter. Nonpolitical material had no appreciable effect. The anti-Johnson material had the expected effect. Bitter anti-Goldwater material made response to both candidates negative.

To be sure, the pupil test may overemphasize the effect of physical appearance; certainly our data do not prove that a third of the subjects went on to vote for Goldwater. But the results do raise the interesting possibility that at least some of them did, and that in the liberal atmosphere of the university these people found it difficult to utter any pro-Goldwater sentiment. The results suggest that our technique, by which we measure a response that is not under the control of the person being tested, may yield more accurate representations of an attitude than can be obtained with even a well-drawn questionnaire or with some devious "projective" technique in which a person's verbal or motor responses are recorded in an effort to uncover his real feelings.

For me the most interesting aspect

TWO PHOTOGRAPHS, almost identical, elicited very different responses from a group of male subjects. One in which a girl's eyes were retouched, as at left, to make the pupils large got a greater response than one in which the pupils were made small (*right*).

of our work has been the measurement of changes in attitude. We begin by determining the pupil response of one of our volunteers to someone's picture. Then we have the subject read some kind of informative material, we retest for the response and compare the "before" and "after" scores. In one case the reading material consisted of a passage indicating that the man whose picture had been displayed was the former commandant of the concentration camp at Auschwitz. When we then remeasured the subject's pupil response to the man in question, we found that a more negative attitude had clearly developed as a result of the intervening reading.

Take another and more hypothetical example: Suppose a patient seeking psychotherapy has a fear of people with beards. We ought to be able to get a pupillary measure of his attitude by showing him photographs of bearded men, among others, and then be able to check on the course of treatment by repeating the test later. Regardless of whether what intervenes is straightforward information, psychotherapy, political propaganda, advertising or any other material intended to change attitudes, it should be possible to monitor the effectiveness of that material by measuring changes in pupil size, and to do this with a number of people at any desired interval.

One recent study along these lines will illustrate the possibilities. We showed five different photographs of President Johnson and five of Goldwater, along with a single photograph of former presidents Kennedy and Eisenhower, to three groups of people. One group thereupon read anti-Johnson material, another read anti-Goldwater material and the third read some excerpts from a psychology journal that had no political content. Then each group was retested.

Now the people who had read the anti-Johnson material showed a slightly smaller response than before to Johnson and a slightly larger response than before to Goldwater. Some extremely negative anti-Goldwater material, which one of my assistants apparently found very easy to write, had a different kind of effect. It did cause the expected decrease in the response to Goldwater, but it also caused a large drop in the response to Johnson and even to Eisenhower! The only person who was unaffected was Kennedy. This may indicate that bitter campaign propaganda can lower a person's attitude toward politicians in general, Kennedy alone being spared for obvious reasons.

The pupil response promises to be a new tool with which to probe the mind. We are applying it now in a variety of studies. One deals with the development in young people of sexual interest and of identification with parents from preschool age to high school age. In an attempt to establish personality differences, we are tabulating the responses of a number of subjects to pictures of people under stress and pictures of the same people after they have been released from the stressful situation. Our other current study deals with volunteers who are experiencing changes in perception as the result of hypnotic suggestion. In the perception laboratory of Marplan, a communications-research organization that has supported much of our work, Paula Drillman is studying responses to packages, products and advertising on television and in other media. Several laboratories at Chicago and elsewhere are employing our techniques to study such diverse problems as the process of decision-making, the effect of certain kinds of experience on the attitudes of white people toward Negroes and the efficacy of different methods of problem-solving. Those of us engaged in this work have the feeling that we have only begun to understand and exploit the information implicit in the dilations and constrictions of the pupil.

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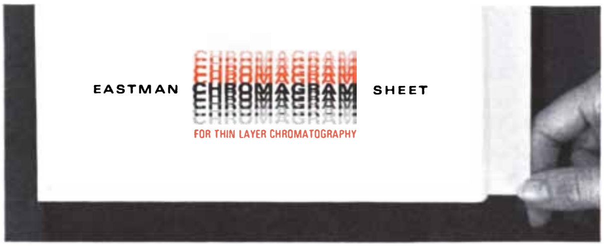

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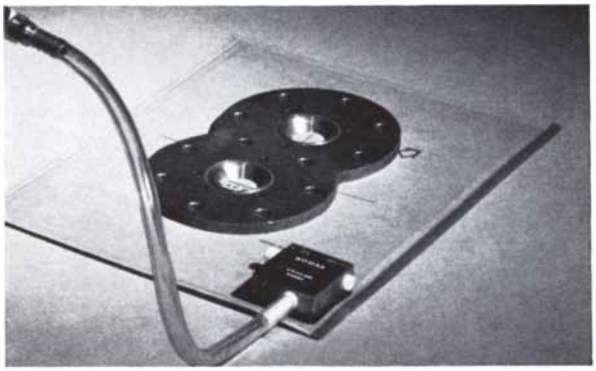

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