TACHISTOSCOPIC STUDIES ON VISUAL PERCEPTION

May - 1940 Vol. 1 No. 8

We have called attention in previous papers to the primary importance for perception of the organization of the visual field into a figure-ground structure. Perception really consists essentially in the emergence of a figure upon a ground.

Figure has shape and appears solid and highly structured. Ground is weak as to form and exists as undifferentiated substance. Generally, figure has surface color; that is to say, its color is localized on its surface and is resistant to penetration. The color of the ground is filmy, soft and yeilding, and not sharply localized. Spacially, the figure appears separated from its ground and this separation may be seen in front of or behind the actual surface of the ground. Figure usually possesses sharp and strong contour, but this is not a universal and essential property of figure. Where the figure is uncontoured and of equal brightness with the ground, although differently colored from it, the figure will appear also unstable and ill-defined. When contour is introduced, the figure becomes stable, well-defined and localized, and with its color hard and glossy, rather than soft and spongy. Figure generally has "thing character" and is more insistent and more central in awareness and is more likely to have connected with it various meanings, feelings and aesthetic values. Figure is named sooner and remembered better because of its greater strength in impression.

Wever* has studied extensively the phenomenon of the emergence of figure from the ground in perception. Of the eight stages which he describes, the first four, which are necessary to the emergence of the simplest figure, are completed in a period as short as ten milliseconds. These stages are as follows :

1. Heterogeneity between the figure and ground, each of which forms a unit;
2. A minimum brightness difference between the two which gradually increases; this stage is simultaneous with 1;
3. A range of separation which appears when 2 has reached a certain magnitude and eventually narrows down to become the contour;
4. Shape, however, appears before the contour is definite; as the figure-ground experience progresses, 5 and 6 put into appearance and may be completed in a further period of 7 ms;
5. Protrusion of the figure out and away from the ground;
6. Definite depth localization of the figure;
7. Surface texture of the figure, filmy texture of the ground;
8. Halo around the figure which is a simultaneous contrast effect.

The durations given by Wever are minimum figures.

*American Journal of Psychology, 1927, 38, 194.

Other investigators have shown that the time necessary for the figure to become perceptible varies with the complexity and degree of meaning of the figure. A tachistoscope is a device which enables the experimenter to control the duration of the exposure, the size of the visual field, the quality and intensity of the illumination, the size of the eye-opening, the set or instuction under which the observer operates and a number of other similar factors. There are a number of different designs for instruments of this type. They differ from one another largely in terms of the particular variables which one wishes to control. Where exposures of very short duration are to be used, it is, of course, quite necessary to control accommodation and convergence. In our instrument this is accomplished by passing a small point-source of light through the card containing the test object. A small projector controlled by the observer places a spot of light containing a black cross about three millimeters in diameter directly over the point-source which is then immediately extinguished. The observer, although partly dark-adapted, fixates the cross at a warning signal which is given about one and one-half seconds previous to the exposure.

The exposure is controlled by two types of light-chopping devices. The first is a gravity focal-plane shutter. With this we are able to secure exposures accurately from one-half millisecond to 275 milliseconds. The accuracy of the time of exposure is checked by mounting pieces of highly sensitive photographic material on a disc driven by a synchronous motor which rotates at the rate of thirty revolutions per second. The angle subtended by the image of the light track then indicates the actual time of exposure. In our instrument, the difference between such actual times and the calculated times is less than 2%.

The second method is a magnetic shutter. The blades of this shutter are activated by a toggle lever. These shutter blades part in the center of the field. An appropriate lens system flattens the beam from the illumination source to a band of light which measures 3 by 5 mm. For exposures of a quarter of a second and over, the lag in the magnet is negligible.

Our earliest studies on the speed of visual perception were made in 1933-4. At that time, Dr. Salo Finkelstein, a Polish lightning calculator, visited our laboratory. This man could perceive and remember lists of numbers from exposures shorter than had ever been recorded for any human being. The writer became interested in the problem of the nature of the process utilized by this individual in the extreme rapidity with which he could memorize numbers as well as perform the usual kinds of calculations. The preliminary series of studies on the problem led to the development of better apparatus and a series of studies on the perception of forms in short exposures which are still in progress.

One of the things revealed to us by this kind of a study of vision is that by means of the short exposure we can study the process of perceiving in its early stages by stopping it after the stimulus has been acting for any duration we select. Numbers are an excellent material because they can be presented in either small or large groups and they have no hampering associations.

One of the first important problems which we have studied extensively is the relation between the length of the material exposed to the eye and the time required to perceive and reporduce it. The amount of material which can be reproduced in a single brief exposure is generally called the span of visual apprehension. The number of digits, letters, words, or figures which can be apprehended in a single exposure has been said to be limited to about seven. The presumption has been that the chief limiting factor is the size of the image at the retina in relation to the size of the macula. We have been able to show that the paramacular field can be greatly extended through training. 17-letter English words, double-spaced, which subtend a visual angle of about 14 degrees at the lens, could be perceived and reporduced correctly in an exposure of one millisecond. Consider what this means in relation to the fact that the latency of the visual mechanism is of the order of 20 to 30 ms. Such speed in visual perception is, of course, only possible under the condition where the material presented to the eye is seen as unitary.

If we expose letters in 36 point type on 5 by 8 white cards, we may determine the speed with which digits of varying lengths can be perceived. Dr. Finkelstein established the following records which are a few taken from a larger number established in the investigation.

NUMBER OF DIGITS	TIME OF EXPOSURE IN SECONDS
8	.003
9	.030
10	.264
11	.531
12	.824
14	1.16
16	1.73
18	2.44
20	3.55
21	4.43
25	7.01
32	25.4
42	45.0

These figures are worthy of careful study. They represent essentially world records. The average individual will require from 20 to 70 seconds, or more, to perceive and memorize a 15-digit number the first time he tries it. The magnitude of the gains from practice is the first striking fact revealed by these studies. It will be noted that the addition of a single digit to 8 digits increases ten-fold the time required for visual perception. Further, whereas 8 digits requires but three thousandths of a second, 16 digits requires almost sixty times as much exposure. If these figures are plotted with the number of digits against the logarithms of the times of exposure, it will be noted that there is a sharp change of trend in the curve at 11 or 12 digits. Up to this size of number, digits are perceptually amalgamated into a unitary impression without grouping. Numbers containing more digits than this are seen first as aggregates of smaller sub-groups. The process of training means that these groups undergo a gradual expansion. For example, 16 digits may be seen as four groups of four; as five groups of three plus one, and so on. It may also be seen as two groups of eight, or as a group of ten plus six, or as a unitary, coherent group comprising all sixteen. If we photograph the eye movements of the perceiver early in the stage of his practice, we observe the characteristic stepwise movements seen in ordinary reading. When we have trained this same observer to the point where he now perceives in a tenth to a twentieth of the time originally required, photographs show that the eye makes a single sweep, without pausing, throughout the expanse of the visual material, even though, in phenomenal experience, the learner may still introduce subjective grouping. There does not seem to be any correlation between perceptual units and the movements of the eyes.

When we use lists of consonants, meaningless geometrical forms or meaningful English words, we get essentially the same kind of results. The process is the same regardless of the contextual material.

Many interesting and important facts were revealed by an analysis of the observer's behavior before, during and after the exposure. The tendency of the novice is, of course, to name or pronounce what he is seeing concurrently with the visual exposure. All observers soon discovered that this provided a serious handicap. Verbal activity during the exposure weakens and inhibits the visual impression. Furthermore, at the termination of the exposure, if the attempt to reproduce by speech what was seen is begun too quickly or too slowly, the amount and accuracy of reproduction diminishes. A good rule to follow is to advise any person, who wishes to use vision with maximal effectiveness, to engage in no other activity during the period of visual impression.

The question may arise as to whether the above results, secured upon a world famous expert in dealing rapidly with numbers, do not represent a function different from that found in ordinary persons. In order to check such a postulation, we trained a number of ordinary university students in order to determine how much we could extend their capacity to rapidly memorize visual material in short exposures. About a dozen such cases were recorded. In every case, the shape of their curves is identical with that given in the above figures for Salo Finkelstein. In every case, also, as improvement progressed the curves of the student moved gradually in the direction of the limits set by Finkelstein; and in two cases of extended practice, we not only trained ordinary students to equal Finkelstein's best performance, but in a few instances they exceeded him. Here we have a fact of great importance. The limit to which visual perception can be extended through proper training is still unknown. We are certain that it can be improved to an almost incredible extent provided the observer is willing to work, and provided he utilizes the proper methods. The difference between the expert and the novice in the rapid and accurate perception of visual material is the same difference between the expert and the novice in the performance of any skillful act. We have to learn to see just as we have to learn to swim, to play the piano or to speak French. This can be done with skill and efficiency or it can be done haltingly and ineffectively. When we train children to learn to spell English words by replacing the wasteful and inefficient disjunctive method of seeing words with the proper method of visual perception, spelling difficulties disappear. Not only does a child spell accurately and easily, but he comes to enjoy spelling. An incidental by-product also is that his rate of reading and index of comprehension automatically show a corresponding improvement. Once and for all, let us be sure that we do not make the mistake of assuming that this skill in seeing is the development of a so-called photographic eye. There is no such thing as a photographic eye. If I were to show you a line drawing of an unfamiliar meaningless design for a brief exposure and ask you to draw or reproduce what you saw, then took from you your drawing and gave you another sheet of paper and another exposure and had you to draw it again and again, after as many succeeding exposures as would be required for you to reproduce the figure so that it would duplicate the original, you would find that the development of your perception of the shape of this figure is an enormously complicated process. It is literally true that we see only in part. It is also true that we tend to see and reproduce as much or more the frames of reference which we bring to the stimulus situation as the actual test object exhibited to the eye. If, early in the series of exposures, we give a name to the figure, then the tendency will be to stereotype and conventionalize subsequent drawings to fit the pattern rather than to reproduce what was seen.

My object in calling attention to these facts is to impress upon optometrists again the importance of psychological optics. Many persons who consult you professionally are the victims of visual difficulties which are non-refractive in character. To the extent to which you can understand and control these functions you can render a superior service to your patients.