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A Preliminary Investigation of the Relationship between Visual Fusion of Intermittent Light and Intelligence

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and the stimulus design we have been using. The source of illumination is a 60-w incandescent bulb, 5 in. above the center of the stimulus card and 5 in. above the center of the front of the episcotister. It is arranged so that it illuminates the stimulus object as well as the front of the episcotister. In another model it might be better to have independent sources of illumination for the stimulus object and the episcotister. It seems that a more intense complementary color is produced if the stimulus object receives more light than the episcotister, although the latter has to be strongly illuminated also. Lamp, stimulus object, and the upper part of the episcotister are encased in a metal box painted white, while the inside of the rest of the apparatus is painted black.

The episcotister is made of plywood or metal (diam 8.5 in.). Half of it is painted white; the other half of the episcotister is covered with black velvet (and of this part a sector of 30° is cut out to serve as a window, behind which the stimulus object is presented).

The stimulus object consists of a card 5 in. × 6 in. with the design as shown in the illustration. The arrows are black, the two circles bright red, the background white. Letters, numbers, or pictures may be used instead of the ''abstract'' design, but associations to meaningful stimuli would probably introduce into the set another psychological variable, mainly determined by neurophysiological factors. Red as a stimulus color produces the best afterimage under the conditions of this experiment.

The polaroid assembly consists of two round polaroid glass filters of fairly neutral gray tint. They are mounted under a scale on which the angle of rotation of the filter is read.

The subject is instructed to look with both eyes through the filters at the stimulus object. The filters are set at zero, i.e., maximum brightness. The subject hears the noise of the motor but is often unaware of the fact that an episcotister is rotating between the eyepiece and the design he sees. He is asked to describe what he sees and to name the color of the design. The filter is then rotated about 80°, thereby changing the color of the circles from light green to red. The filter is returned to the zero setting, and the subject is asked to indicate at which point the color change from green to red is completed. On our instrument the lowest reading of one subject was 40° while others gave readings between 75° and 80°. The majority of readings lay between 50° and 70°.

Observations to be published in detail have shown the a.i.d.b. to be influenced by fatigue, cerebral anoxia, and pharmacological agents. A.i.d.b. also changes with the age of the individual. Children before puberty and some patients with mental disorders may show qualitative deviations and may be unable to see the complementary color. Patients with convulsive disorders seem to possess certain characteristics with regard to their susceptibility to negative afterimages. A certain relation between critical flicker fusion frequency (c.f.f.f.) and afterimage disappearance brightness seems to exist, but there is little doubt that the c.f.f.f. and a.i.d.b. measure two different functions of the perceptual apparatus.

The theory of afterimages is still under discussion. The instrument described here could certainly be improved. It provides, however, for the first time, a means to study objectively some aspects of a complex problem.

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A Preliminary Investigation of the Relationship between Visual Fusion of Intermittent Light and Intelligence

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The evidence that critical flicker frequency is a centrally limited phenomenon is so strong, it seems possible that it may furnish a method for the study of some aspects of the central nervous system in its natural habitat. Halstead (*3*) presented evidence that the point of fusion is related to other central phenomena, but is not related to visual acuity. Misiak (*4, 5*) reported that the point of fusion for individuals is not related to visual acuity, varies with age above 30 years in a manner very similar to the raw scores of the Wechsler-Bellevue Intelligence Test, and does not improve with practice. Halstead, however, found only low correlations between his flicker-fusion frequency scores and scores on two intelligence tests. These correlations, nevertheless, were positive.

Halstead's apparatus employed a 10-μsec light flash. For frequencies of the magnitude reported by Halstead —approximately 20 cycles/sec—a 10-μsec flash means that the light-dark ratio was 1: 5,000. Bartley (*2*) reported that the subjective brightness of intermittent light varies with frequency at frequencies below fusion in such a manner that brightness could very easily have functioned as a confusing variable. For light-dark ratios of 1: 1 or greater, the subjective brightness becomes greater as frequency increases until the alpha frequency of brain waves is reached, and then decreases until it reaches the Talbot level at the point of critical flicker frequency. Subjective brightness reaches at its maximum a level that is about as far above that of a steady stimulus of an equivalent intensity as the Talbot level is below. Only an experimental study could determine the extent to which subjective brightness may have been a confusing factor in Halstead's study.

A second factor in Halstead's study that may have affected his findings was the fact that the frequency of the stimulus was varied by the observer. To what extent, if any, such a procedure influences the determination of a subjective phenomenon such as flicker-fusion is not known, but it may have been significant.

Bartlett (*1*) reported that, for an intermittent stimulus, the duration of the shortest noticeable dark interval becomes shorter as the length of the light flashes[1] increases, becoming a constant for light flashes longer than some critical duration. This suggests that measures of the critical point of fusion of intermittent light may have more meaning for such studies as Halstead's if the light-dark ratio of the stimulus is large.

This paper is a preliminary report of the relationship between several measures of visual fusion and test scores on the A.C.E. Psychological Examination, College Edition. The measures of visual fusion employed cover a wide range of light-dark ratios, running from less than 1–4 to approximately 200–1. The technique employed is to measure the shortest noticeable dark interval for a given length of light flash. It was thought that four flash durations ranging from 8 to 84 ms in an approximate geometric progression would offer a representative sample of the phenomenon of visual fusion for the purposes of this study. The results for this range were of such a nature that it was deemed advisable to add two longer flash durations to the investigation. It is to be noted that the measures of the duration of the shortest noticeable dark intervals are reciprocally related to frequency measures, and consequently negative correlations in this study would correspond in direction to the positive correlations in Halstead's study.

Electronic apparatus was used (*7*). The timing circuits consisted of two single-cycle multivibrators triggering each other to furnish continuous operation. One controlled the light time per cycle, and the other, the length of the dark time. The circuits operated an electronic switch that permitted a gas discharge light to present an intermittent stimulus. The intensity of the light was constant. Both time intervals were calibrated by picking up the actual light output with a photoelectric tube and observing the output on an oscilloscope, the sweep of which was driven by a Dumont low-frequency time base generator. Normally the apparatus presents no stimulus, but by the operation of a single spring switch the experimenter can present either a steady or an intermittent stimulus. The light source was placed in a dark viewing tunnel, when the only opening was the eyepiece against which the subject's face fit tightly. The stimulus source was 36 in. from the subject's eyes and subtended a visual arc of 1°.

The procedure consisted of a preliminary period of moderate dark adaptation, followed by determinations of the shortest noticeable dark intervals made by a method of serial explorations. Toward the end of a 5-min period during which he looked into the viewing tunnel, the subject was told that there would be a series of light stimuli 5 sec in duration—separated by rest periods of 15 sec, to maintain a reasonably constant level of adaptation throughout the experiment. The subject was required to judge whether each of the stimuli was flickering. He was given no indication of the procedure, nor of the proportion of stimuli that would actually be flickering.

The experimenter operated all the controls. For each setting of light flash duration an exploratory procedure from flicker to fusion was first followed. During this procedure the dark interval was changed in large steps from stimulus to stimulus. When the approximate point of fusion was located, a series from fusion to flicker and one from flicker to fusion were run, the dark period being changed in small steps. The first changed responses in each of these two series were averaged, and this was considered the shortest noticeable dark interval for that length of light flash. In order to make it possible to investigate four light flash durations at a single sitting without introducing an element of fatigue, only one determination was made for each length of light flash.

[1] The term "light flash" is used in this report to refer to the light fraction in a single cycle of a repetitive stimulus.

TABLE 1

CORRELATIONS BETWEEN VISUAL FUSION AND A.C.E. RAW SCORES OF 25 MALE STUDENTS AT UNIVERSITY OF FLORIDA

Light flash duration for which fusion measured	Quantitative score	Language score	Total score
8 ms	−.063	−.190	−.182
16 "	−.211	−.127	−.193
38 "	−.236	−.156	−.233
84 "	−.434	−.060	−.264

In the first study (*6*), the shortest noticeable dark intervals were determined for each of the 25 subjects for light flash durations of 8, 16, 38, and 84 ms, in that order. In the second study, determinations were made for 21 subjects for light flash durations of 38, 84, 135, and 250 ms, in that order. In the second study there were two changes of significance. The light flash was reduced in intensity by the introduction of a filter. Also, subjects were tested only in the morning, a detail that was not considered in the first study. Because of the change in intensity of the light flash in the second group, it was not deemed advisable to combine the two groups. The results are shown in two tables of correlations, Table 1 representing the results of the first study.

The highest correlation between the shortest noticeable dark intervals and the Q-Score is for a light flash of 84 ms. It is significant at the 5% level of confidence. However, all the coefficients are negative, and there are definite trends toward increase in the magniture of the coefficients with an increase in length of light flash for both Q-Score and Total Score. The question arose as to the possibility of this trend continuing with a further increase in the length of light flash, and to answer this in the second study, light flashes of 38, 84, 135, and 250 ms were used, in that order. By using this order, it could be determined whether the high values previously obtained for the 84-ms flash were to be attributed to the absolute length of the flash or to some type of learning on the part of the subjects.

The second study was conducted entirely with morning appointments, and then only when the subjects had eaten breakfast at least an hour in advance. Observation of the scatter diagrams of the data from the first study showed that the correlations might have been considerably higher had it not been for three subjects. Interviews revealed that one of them had not eaten breakfast at the time of testing, whereas the other two came direct from afternoon naps. Table 2 shows the results of the second study. Only one of the subjects was tested in both groups.

TABLE 2

CORRELATIONS BETWEEN VISUAL FUSION AND A.C.E. RAW SCORES OF 21 MALE STUDENTS AT UNIVERSITY OF FLORIDA

Light flash duration for which fusion measured	Quantitative score	Language score	Total score
38 ms	−.405	−.515	−.513
84 "	−.478	−.532	−.485
135 "	−.114	−.161	−.147
250 "	−.121	−.172	−.147

Here there are five correlations significant at the 5% level of confidence, and again all the coefficients are negative. It is very interesting to note that light flashes longer than 84 ms do not yield increasingly higher correlations between A.C.E. scores and measures of visual fusion. In this second study, however, the correlations for the 38-ms interval are of the same general magnitude as those for flashes of 84 ms. The L-Scores and Q-Scores do not show the differences which occurred in the first study.

Because time often appears as an exponent in equations describing certain energy relationships,[2] there is the possibility that the relationships under consideration may not be linear. Logarithmic transformations of the data were made, and coefficients of correlations were calculated between (1) A.C.E. scores and logarithms of visual fusion measures, (2) logarithms of A.C.E. scores and visual fusion measures, and (3) logarithms of A.C.E. scores and logarithms of visual fusion measures. In general, resulting correlations were higher than the linear relationships, particularly for the Q-Scores and T-Scores, but the differences were not great.

The correlations between the visual fusion measures for the 84-ms light flash and the A.C.E. scores are strikingly high in view of the homogeneity of the groups studied—namely, college students representing a highly selective group in range of intelligence. It is probable that results for a more heterogeneous group would show even better correlation. In view of the order of determinations of the measures of visual fusion, the results indicate that the relationship was not a function of learning.

The writer is considerably puzzled, however, by the way the coefficients increase with the increase in the length of light flash up to 84 ms and then decrease with a further increase in length of light flash. The shortest noticeable dark intervals averaged 2.75 ms for the 84-ms light flash in the first group, and 6.44 ms in the second study, the difference being attributed to the change in intensity. The total time for a cycle is such that the frequencies represented are within the range of the alpha frequencies of brain waves.

From the results of this experiment, it may be concluded that the shortest noticeable dark period for a light flash of some critical length promises to be a significant physiological correlate of intelligence. It must now be studied for a larger and more heterogeneous group, and be compared to performance on standard intelligence tests and other physiological variables.

[2] The charge of a condenser at any time is expressed by the equation $V = E_{bb}(1 - e^{-t/RC})$.

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Studies on the Mechanism of Nitrate Assimilation in *Neurospora*

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Although studies concerned with the assimilation of nitrate by plants have indicated the complex nature of this reduction process, in no case has the chemical mechanism involved been clearly demonstrated (see reviews by Burström [*3*], Street [*12*], and McKee [*9*]). Available evidence indicates that the process is enzymatically catalyzed, but there is no general agreement as to the nature of the products of this reduction (*4, 13, 15*). Granick and Gilder (*5*) demonstrated the importance of a porphyrin in the reduction of nitrate to nitrite by *Hemophilus influenzae,* and other studies have implicated molybdenum (*10*) and manganese (*2*). (See, however, Arnon [*1*]). The actual site and mechanism of action of these metals are at present unknown.

In an effort to gain greater insight into the process of nitrate assimilation it appeared that the technique of genetically blocking specific chemical steps would prove fruitful, not only in identifying the intermediates in this chain of reactions, but also in demonstrating catalytic components of the system. Over 100 mutant strains of *Neurospora crassa* (microconidial—Tatum), obtained in this laboratory, were unable to grow on nitrate as a sole nitrogen source. These were tested for their ability to utilize nitrite and ammonia. It was found that several mutants which fail to utilize nitrate can grow normally when supplied with nitrite. By mixing these mutants, two at a time, in a liquid basal medium containing only nitrate nitrogen, it was possible to show that there are