

ELECTRICAL ENGINEERING

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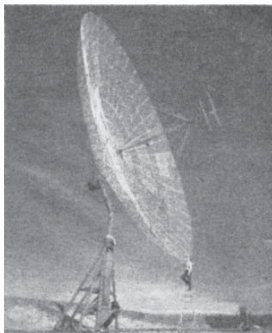
**SPEED OF VISUAL PERCEPTION
SEMICONDUCTOR PRINCIPLES
HOME ELECTRIC HEATING • PLANT MORTALITY
SYSTEMS ENGINEERING—A GROWING CONCEPT**

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THE COVER: Stanford Research Institute has transformed one of the rolling hills west of Palo Alto, Calif., into an experimental radar station with installation of a giant 61-foot diameter antenna and 100-megacycle transmitter. Story on page 171.

Contents

Systems Engineering—A Growing Concept	E. W. Engstrom	
An explanation of the concept of systems engineering in terms of its evolution and characteristics		113
Electric Heating in the Home	S. L. Forsyth	
The various types of electric heating are described in this comprehensive report, with a comparative analysis of these systems		118
Digital Computers Can Aid Utilities	F. J. Maginniss	
A broad picture of the most common and obvious applications of the digital computer in the public utility field		124
Eye Protection in Radar Fields	W. G. Egan	
The design of protective goggles to be worn by personnel exposed to microwave fields is discussed		126
Adjustable-Voltage Drive for the Operation of Ore Bridges	S. G. Smith	
A description of the applications of adjustable-voltage drives to ore bridges and unloaders, including a discussion of some outstanding advantages		128
Plant Mortality	J. F. Brennan	
Simplified approach to problem of determining life expectancy of equipment, utilizing technique of analyzing a parabolic frequency distribution of failures		131
Speed Control of Induction Motors Using Saturable Reactors	P. L. Alger, Y. H. Ku	
A method of induction motor speed control, using feedback-controlled saturable reactors in series with the motor windings, is described and evaluated		136
First Principles of Semiconductors	C. A. Escoffery	
A brief review of semiconductor phenomena which has been stripped of the jargon of the physicist		142
Some Studies in the Speed of Visual Perception	G. C. Sziklai	
Results of several tests that have been devised in order to measure the perception speed of the participating observers		150

CONTENTS CONTINUED

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SOME STUDIES IN THE SPEED OF VISUAL PERCEPTION

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Summary

Statistical studies of television signals indicated a high degree of correlation between successive elements, lines and frames. A continuous test run indicated that the normalized detail content of actual broadcast signals run lower than 5 percent.

The fact that most transmitted television scenes thus measured contained very little detail compared to some artificial subjects indicated that the observer's preference has influenced the subject to be transmitted. In order to verify this assumption, some tests were devised to measure the perception speed of observers. These tests included certain reading and character recognition tests and finally a test consisting of object recognition in precisely measured periods was devised.

In order to evaluate the perception rate in bits, a relationship between the gestalt concept and the binary choices was sought. Assuming a limited number of picturable nouns to correspond to the gestalt experience of the observer, each object recognized was assigned a value of ten bits (corresponding to 1024 picturable nouns). Several series of these tests indicated that the visual perception speed of a normal observer is between 30 to 50 bits per second, that this value holds for periods of one-tenth to two seconds, and that the first thing observed is the center of the picture. These values are similar to the values obtained by Licklider, Pierce and others for reading speeds.

Introduction

The statement that the television signal is highly redundant and therefore very wasteful of channel capacity became almost a cliché. Various types of redundancies have been measured of different subject matters, and indicated the truthfulness of that statement.¹⁻³ A method proposed by Gouriet¹ provides a continuous indication of the entropy based on successive elements joint probability distribution, if an exponential distribution is assumed. The particular instrument called the "detail meter" differentiates the signal, provides an integrated value of the absolute value of the derivative, obtained by full wave rectification in a normalized form, where a maximum change at every picture element

is called 100% detail. This instrument gives the maximum reading for a television signal corresponding to vertical bars (or a checkerboard) with the maximum resolution of the system (325 lines) but gives a reading of only 33% for a noise spectrum since the criteria of the exponential distribution is not satisfied. More significantly however when the instrument is connected to a video program line the reading is normally less than 3% and seldom is a reading in the order of 6% obtained. In the laboratory special subjects may be selected with substantially higher readings, however these scenes would not be considered pictures with entertainment value.

The detail meter thus indicated that there is a viewer preference of low detail or information content. Although some work in this field analyzed so called typical pictures we did consider to embark upon the project of finding either typical or preferable pictures. A clue was supplied by the psychologists, particularly by Prof. Y. LeGrand of Sorbonne, who performed some perception tests with images, which were to be sketched by an artist after a short exposure. These tests indicated that even after several second exposures only the contours are perceived. This is of course simply in line with the gestalt recognition of subject.

At this point the problem was then to establish a relationship between the gestalt concept and some unit familiar to the communication engineer, to provide a display which exposes the subject for a variable but precisely measured time and to find a suitable way for obtaining a measure of the observation.

One may consider each letter of the alphabet, or each number a gestalt and then knowing that random letters correspond to 4.7 bits per symbol, a relationship between a class of subject and the gestalt may be established. The perception of random letters however cannot be measured too easily and they form a rather limited class of gestalts. Nevertheless some reading speed tests and short exposure tests were performed and some of these results will be reported upon at another time.

The Test Setup

In order to control the exposure period precisely, an electronic switching

system was developed to switch video signals. The switching gear operates from the video synchronizing pulses, switching from one signal to another at the beginning of a field and switching back to the first signal again after 2, 4, 8, 16, 32, 64 or 128 fields (or correspondingly after approx. 1/30, 1/15, 2/15, 1/4, 1/2, 1 and 2 seconds). The exposure time to the second signal can be set beforehand and the changeovers can be actuated when the observers are ready by a switch.

The use of a steady image, which is interrupted by the test image was adopted with the idea that the reappearing steady image does not permit the storage of the test image on the retina. This effect could be verified easily by using a uniform, white gray or black field as the steady image. In most of the tests the picture shown in Fig. 1 was used as the steady image.

The display device used was a TV station monitor with a 12 inch kinescope. The observers were asked to view the screen as they would view a television receiver. Generally a distance from 5 to 7 of the picture height was used. As a preliminary experiment the slide shown in Fig. 2 was flashed on for about twenty observers and they were asked to recite what they have seen as soon after being exposed to the picture as possible and a stenographer took down their remarks. For two fields of exposure (1/30 second), the observers noticed a change but could not tell what they saw. For an exposure of four fields they recognized either the

horse or the house but not both. In 16 fields (approx. 1/4 sec.), they observed two connected objects such as: "a white horse pulling something", or "house and trees", "house with windows", and even reported inventions such as "a pony with a rider", "a house and a street and I think there was a car in the street".

In connection with these experiments it was already notable that (1) the center of the picture was perceived first; the majority of the observers, after recognizing one object, tried to name more by conjecture; (3) the number of objects recognized by the different observers for the same periods were remarkably uniform, and (4) a given total exposure seemed to yield the same amount of recognition whether it was taken in one exposure or in two exposures, each lasting half of the total period.

In the next experiment an attempt was made to evaluate the perception in bits and to eliminate any relationship between the recognizable objects. The slide shown in Fig. 3 was prepared and the evaluation of each object in bits was based on the following reasoning. Ogden⁴ lists 200 picturable nouns among his 1000 basic words. Four of the five objects were among these, the pyramid however was not. Since it would have been a formidable job to count all the picturable nouns in a complete dictionary, a sampling technique was used and a factor of 4.7 was found for the letter B and a factor of 5.1 for the letter S, between the basic English list and the



Fig. 1



Fig. 2

Webster dictionary⁶. This provides an estimate of 1000 picturable nouns or for each gestalt approx. 10 bits of information ($\log_2 1024$). On the basis of this estimate then it was possible to test the perception speed in a bits per second scale.

The procedure of the test with slide 3 was the same as with the previous slide. The first tests with 8 fields (approx. 1/8 second) was inadequate for all observers to recognize any of the objects. A typical answer was, "approx. eight small figures in three columns that appeared to be line drawings of mythical animals". With an exposure of 16 fields (approx. 1/4 sec.) all observers recognized the fish. The test with an exposure period of 32 fields (approx. 1/2 sec.) was performed with 50 observers including engineers, stenographers, janitors, etc. Only one out of the 50 could name three objects. With one exception the rest named the fish and one more object, the one exception named the pipe and the scissors in that order. In all the tests with any exposure periods (about 120 tests altogether), if an object was recognized at all, the center figure was the first named.

The recognition of two independent objects corresponds to 20 bits and since the exposure was 1/2 second, it corresponds to 40 bits per second perception speed. It may be interesting to compare this figure with the capacity of a television signal channel. The number of different messages that can be constructed with 200,000 picture elements per frame with 100 distinguishable brightness levels

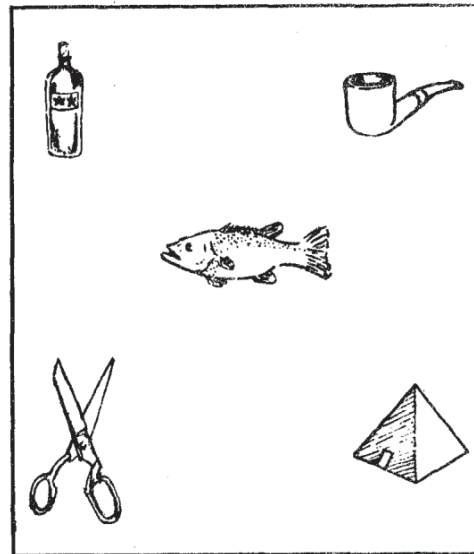


Fig. 3

is $10^{400,000}$. On the basis of the relationship of

$$2^X = 10^{400,000}$$

$$X = \frac{400,000}{\log_{10} 2}$$

this corresponds to approx. 1.3 million bits per frame or 40 million bits per second.

It was felt that once the technique described above was developed, the perception speed should be verified with gestalts of smaller classes, and therefore shorter periods. One experiment with a slide which had objects with names all starting with the letter B, failed to produce a greater object recognition higher than two per 32 fields after the observers were instructed about the restriction. On discussing the observation with some of the viewers, it was evident that this type of restriction imposes a difficult mental process, which apparently causes a slowing down in the perception speed.

Another experiment in which the observer was shown the chart of 16 symbols shown in Fig. 4 beforehand and then asked to recognize one of these symbols, yielded excellent consistency between tests and the results obtained with the general class of picturable nouns. By flashing the single symbol (corresponding to four bits) for 4 fields (1/15 of a second) therefore 60 bits per second only one out of twenty observers guessed the correct symbol, which might even be accounted for on the basis of chance. When the exposure period was doubled (8 fields,

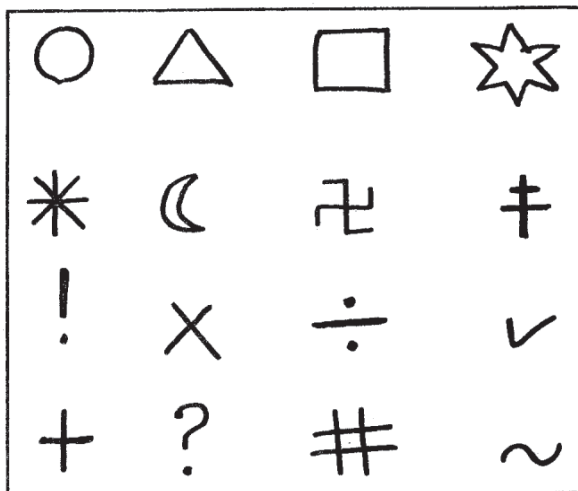


Fig. 4

2/15 sec.) and therefore the perception rate demand was reduced to 30 bits per second, only one of another batch of 20 observers failed to recognize the right symbol.

The importance of the steady picture before and after the exposure of the unknown picture was demonstrated easily by the use of the symbol test. While with the steady picture, the symbol could not be recognized in 8 fields; if the exposure to the symbol was followed by a blank screen, even one field (1/60 of a second) was enough to pick the right symbol. Based on these tests it is believed, that the type of tests, where an image is flashed on and off by optical means, the

retinal retention is tested rather than the perception speed.

One further test involved the instruction of the observer that the symbol to be shown is a choice of two of the symbols from Fig. 4, thus each recognition corresponding to 1 bit of information received correctly. The speed for this test was set at 1/30 of a second and we expected to perform a large number of tests in order to get an average, however the 30 bits per second provided perfect recognition every time and accordingly ten tests were considered conclusive.

The author gratefully acknowledges the help of Mr. R. Staffin with the tests. Mr. Staffin also constructed the timing switch.

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