INTEROCULAR TRANSFER WITH CONTROL FOR CONJUGATE EYE MOVEMENT

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INTEROCULAR TRANSFER WITH CONTROL FOR CONJUGATE EYE MOVEMENT

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ABSTRACT

Such phenomena as stereoscopic vision and binocular rivalry in animals with binocular experience appears to be inconsistent with Hebb's idea that binocular experience builds up common visual pathways in the brain. Stereoscopic vision is not a simple superposition of two images: the effect is different if the stimuli for the two eyes are exchanged. Why should this exchange of stimuli make any difference if there is a simple fusion through a common path in the brain without respect to which eye originated the visual impulse?

Since one of Hebb's main arguments for common neural pathways is interocular transfer, consideration should be given to the problem of interocular transfer to see if it might be explained without recourse to the concept of common visual paths.

One such explanation might be that the interocular transfer is carried out through conjugate eye movement, by reinstating an "approach pattern" of eye movement in the original trained eye, even when it is covered. No common visual pathways would be needed.

This thesis is based on two experiments that were carried out to test the hypothesis that conjugate eye movement is not necessary for interocular transfer. The first experiment was concerned with interocular transfer of the ability to read inverted words; the second with transfer of mirror-tracing ability. Six experimental subjects were used

in the first experiment and five experimental subjects in the second experiment. All subjects were adult humans with considerable binocular visual experience. The hypothesis that conjugate eye movement is not necessary for interocular transfer could not be rejected in either experiment.

After these experiments had been carried out, the writer received unpublished experimental results from Dr. Chow that indicate that conjugate eye movement, in the absence of binocular vision, is not sufficient for interocular transfer. Dr. Chow's results, in conjunction with the lack of evidence from the present study for the necessity of conjugate eye movement in interocular transfer, suggest that other factors than conjugate eye movement will probably be more profitable for study to determine whether conditions other than common visual pathways in the brain might explain interocular transfer.

Hebb's concept of common neural pathways is not necessarily inconsistent with the concept of separate visual pathways: the region in the nervous system where the impulses from the two eyes arouse a common pattern may be beyond the region involved in stereoscopic perception and other phenomena that apparently necessitate a distinction between the impulses from the two eyes; i.e., certain perceptual processes may occur while the impulses from the two eyes are still distinct, whereas the paths may later converge into a common pattern of excitation.

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INTRODUCTION

The two experiments upon which this dissertation is based are concerned with interocular transfer of training for tasks learned with inverted vision.

The experiments may be understood without previous experience in the area of inverted vision, so the discussion of inverted vision is in Appendix B rather than in this introduction. Appendix B, entitled "Inverted Vision," briefly reviews the history of the use of inverted vision as an experimental technique, discusses what "right-side-up" means and outlines an experiment for obtaining an answer to the question "Is seeing things right-side-up innate or learned?"

To enable the reader to more adequately comprehend and evaluate the experiments which are the bases for this dissertation, a preliminary discussion of the relevance of interocular transfer experiments to psychology is essential. In the course of the discussion reference will be made to experiments performed by previous investigators in the area of interocular transfer, in order to aid the reader in visualizing certain aspects of the problem of interocular transfer.

Definition of Interocular Transfer

Interocular transfer is manifested by the influence of previous experience with one eye on current performance with the opposite eye. Expressed in another way, interocular transfer is a bilateral transfer of training from one eye to the other. Usually the amount of transfer that occurs is determined by a comparison of the number of trials required by either eye to reach a specific criterion for the same task. In a manner analogous to other tests for bilateral transfer, one eye is trained on a task and the opposite eye is tested on that task. For interocular transfer experiments, it is necessary to occlude the vision of one eye while the other is being trained, and then, for the test of interocular transfer, the shield is shifted to the trained eye. The amount of interocular transfer is customarily determined by the formula $\frac{X_1 - X_2}{X_1}$, X_1 being the number of trials to reach the criterion for the eye being trained and X_2 being the number of trials to reach the criterion for the test eye. Incomplete transfer is a term applied to any transfer greater than 0, but less than 100%. "Immediate transfer" and "complete transfer" are equivalent expressions. In this thesis, the amount of interocular transfer was measured in a different way: a comparison was made between the level attained by the trained eye immediately before it was occluded and the level attained by the test eye immediately after it was exposed.

The Relationship of Interocular Transfer Experiments to Psychology

The significance of interocular transfer experiments to psychology is largely through the implications that interocular transfer experiments have for two theories of perception: Lashley's field theory and Hebb's cell assembly theory.

Lashley's field theory. Lashley (1929) carried out learning experiments with rats after destroying regions of their brains. From these experiments he developed a theory opposing the specific localization of learning in the brain. The theory presumes that previous involvement of the specific cortical region is not a prerequisite for transfer of visual training. Lashley's field theory demands that there be an innate equipotentiality of the two retinas and optic pathways; i. e. what is learned with one eye is always learned with the other eye.

Hebb's cell assembly theory. Hebb (1937) has challenged the position that equipotentiality, whether between different parts of the same retina or between the two retinas, must be innately given. Hebb's complex neuropsychological theory of behavior proposes that interocular transfer is the consequence of neural associations, some possibly innate and some built up in the brain due to simultaneous or alternate stimulation of the two eyes. The neural associations serve as a type of common path so that stimulation of one eye arouses the same pattern of neural firing as does similar stimulation of the other eye. Thus Hebb's theory suggests that a certain part of the equipotentiality of the two retinas is due to simultaneous or alternate learning with the two eyes. So Hebb's theory implies that there is not complete interocular transfer if there has been no opportunity for simultaneous or successive stimulation of the eyes; if, for example, an animal were raised from birth with one eye occluded it would be predicted that what the seeing eye learned would not completely transfer to the other eye.

A few historical examples will show how experimenters have designed experiments that tested Lashley's and Hebb's conflicting theories (although this may not have been the experimenter's purpose).

History of interocular transfer experimentation. Levine (1945) experimented with interocular transfer in pigeons. Pigeons which were trained, with one eye blindfolded, to discriminate various stimuli, displayed bilateral transfer of these habits only when the stimuli were situated in their lower visual field. When the stimuli were in the upper visual field, no interocular transfer occurred. These results were obtained with two different experimental methods: a modified jumping stand and a pecking situation.

This relationship between the location of the stimuli in the visual field and the presence or absence of interocular transfer, could be accounted for by either Hebb or Lashley in terms of the involvement of different retinal regions: The pigeons had often used both eyes simultaneously for stimuli in the lower visual field and, in accordance with Hebb's theory, would have built up associations so a stimulus falling on the upper hemiretina of one eye was functionally equivalent to its falling on the upper hemiretina of the other eye. This explains the complete transfer when the stimuli were located in the lower visual field. Incomplete transfer occurred when the stimuli were in the upper visual field, because this position caused the image to fall on the lower hemiretina, and the pigeons had no experience in seeing things with both lower hemiretinas at once: no functional connections had been brought about through learning. But Lashley's theory would also be adequate here, if one notes that the association between the upper hemiretinas might have been innate, rather than acquired.

Siegel (1953) used doves as subjects. He used a plastic hood to cover the test eye. This plastic hood allowed diffuse light, but no patterned light to enter that eye. He found incomplete transfer of a form discrimination in doves that had been raised with one eye covered with the hood. Normally reared doves showed immediate transfer of the discrimination. It will be noted that Siegel raised his experimental animals from birth to control their visual experience, whereas Levine's pigeons had former visual experience. With his demonstration of the incomplete transfer for naive doves and complete transfer for visually experienced doves, Siegel clearly showed that doves, through experience, acquired transfer that was not innate. This opposes Lashley, and fits into Hebb's theory quite well.

Riesen and associates (1953) conducted extensive experiments with cats. They used twelve animals: six control and six experimental. The experimental cats were raised in darkness from birth to 14 weeks of age. They were then given diffuse light in one eye and patterned light in the other for 30 minutes daily until the age of 17 to 20 weeks; the control cats received patterned light in both eyes. At 17 to 20 weeks, training of one eye was begun. The experimenters covered the test eye with a diffusing goggle to allow unpatterned light to fall on that eye. Both form and brightness discriminations were required. For both types of discrimination, transfer tests to the test eye showed immediate (complete) transfer for the control cats and incomplete transfer for the experimental cats. Riesen and his co-workers had now shown that what Siegel had discovered in doves also held true for a higher form of animal, a mammal: animals deprived of binocular visual experience showed incomplete transfer on tasks where animals with binocular experience showed complete transfer. This further substantiated Hebb's theory.

Chow and Nissen (1954) trained two chimpanzees with patterned light to one eye, and diffused light to the other eye (1.5 hours per day for each eye). One chimpanzee was trained to discriminate horizontal versus vertical striations with the patterned light eye first; the other was trained on this discrimination with the diffused light eye first. Both of them showed incomplete transfer. Subsequently each of these chimpanzees was trained with the opposite eye on a red square versus blue square discrimination, and a circle versus triangle discrimination. Incomplete transfer again resulted. Since there was incomplete transfer in both directions: from the patterned light eye to the diffused light eye and then from the diffused light eye to the patterned light eye, in the same animal, the lack of complete transfer could not be attributed to anatomical or physiological deficiencies of the diffused light eye.

Phenomena indicating partial independence of the visual areas. Although the preceding experiments showed incomplete transfer in animals with no binocular experience, there was complete transfer in animals with binocular experience. Hebb's explanation for complete transfer in animals with binocular experience is that associations have been built up between the visual areas of the brain so that either eye arouses the same pattern of neural excitation, even utilizing the same neurones (common path). If this actually occurs, then in the experienced animal it would seem that there should be no way of distinguishing between the impulses arising from one eye and those arising from the other; there should be an inseparable fusion.

A superficial consideration of binocular vision might lead one to contend that, indeed, one can not distinguish between the impulses aroused by the two eyes. However, a consideration of binocular disparity of images in depth perception reveals that there can not be a simple fusion in the organism, without respect to which eye it was in which the impulse originated. Otherwise, we would have no binocular cues other than convergence to distinguish concavity from convexity.

A demonstration utilizing the stereoscope can show that even in the case of so-called binocular "fusion", the organism discriminates between impulses from the two eyes. The organism does not simply superimpose the two patterns. If it did, it would not matter if the stereoscope card were changed so that the pictures for the two eyes were reversed. But, as Carr (1935) said, "When the pictures are interchanged in position, the depth effect is inverted for diagrammatic drawings and simple pictures such as the surface of the moon where but few monocular cues are present. In pictures of landscape scenes in which many monocular cues are present the two groups of factors work in opposition, and the depth effect is primarily one of confusion."

The occurrence of binocular rivalry also favors the concept of a certain degree of independence between the two eyes. Woodworth (1938) on page 573 of "Experimental Psychology" said, "Radically different colors or figures presented simultaneously to corresponding areas of the two eyes are usually not combined. At first only one is seen, the other being entirely invisible, but sooner or later a shift occurs, what was invisible coming into view and what was visible disappearing. The reverse shift follows and the alternation becomes more rapid as the double exposure continues." This process is known as binocular rivalry.

The term "suppression" is sometimes applied to a situation in which a person does not see out of one eye while the other is open, but can see out of it when the other is closed. He "suppresses" (in a sense, ignores) the vision of one eye while the other is open. But to be able to ignore what is seen with one eye, the organism must be able to discriminate in some manner between what came in through one eye and what came in through the other. Binocular rivalry and ocular dominance (right- or left-eyedness) appear to have an element of "suppression" in them.

The preceding phenomena indicate a degree of visual independence, even in animals with considerable binocular experience. How can the impulses from the two eyes be distinguished by the organism if there is a common path as Hebb suggests? This is the question which led the experimenter to wonder whether the complete interocular transfer observed in various experiments actually utilized a "common path" of visual impulses. This consideration led him to this possibility:

Even in visually experienced animals, there is no common path for the impulses from the two eyes. The "complete interocular transfer" that has been observed actually does not involve a common path for visual impulses from the two eyes, but is a transfer through a different means--through conjugate eye movement. The following section will point out the feasibility of conjugate eye movement being the vehicle for "interocular transfer."

STATEMENT OF THE PROBLEM

This section is an attempt to show how observed cases of interocular transfer might be explained by conjugate eye movement.

Hebb (1949) points out that eye movements are involved in the early learning of form discrimination. He quotes Senden as saying that a patient was trained to discriminate squares from triangles over a period of 13 days, and had learned so little in this time "that he could not report their form without counting corners one after another." Hebb continues, "My point is not that eye movements are essential to perception by a sophisticated observer (nor, in the following paragraph, that they are completely necessary for an image), but that the perception is definitely clearer, more effective, with them than without. This is really an evident fact. It is to be interpreted in the light of all evidence, cited above, showing that the perception of a square or circle is slowly learned <u>and depends originally on multiple visual fixations</u> . . . Receptor adjustment (head-and-eye movement) is the most prominent feature of visual perception whether in rat, chimpanzee, or man--<u>except</u> in long-practiced habits." If one accepts the previous statements of Hebb, it could well be assumed that animals might tend to make definite eye movements when forced to discriminate between two geometrical forms. If the animals did make definite eye movements in learning the form discrimination task, then we could assume that the learning could be that of approach to a pattern arousing a certain eye movement pattern. Through conjugate movement of the eyes, the movement pattern set up in one eye is reproduced by the other eye. So, when the second eye is tested, as soon as it traces the "approach" geometrical form, the "approach" pattern is reinstated in the learning eye, just as it was in the original learning.

It should be pointed out that this study does not pertain to interocular transfer of brightness discrimination tasks. There is a basis for considering form discrimination separately from brightness discrimination: it has been shown that animals can still make brightness discriminations after their capacity for form discrimination has gone, when higher levels of the brain are removed. So it is conceivable that interocular transfer of brightness discrimination might occur in the absence of interocular transfer of form discrimination.

On the basis of the previous arguments it was considered that a study should be carried out to see if incomplete transfer would occur if the opportunity for transfer through conjugate eye movement is minimized. The hypothesis tested in this study is that conjugate eye movement is not necessary for interocular transfer. It is tested by using visually experienced animals and minimizing the opportunity for conjugate eye movement serving as the vehicle for interocular transfer. Significant lack of transfer under such conditions would suggest that conjugate eye movement is necessary for interocular transfer to occur: the rejection of the hypothesis.

INTRODUCTION: EXPERIMENT I

The first experiment was concerned with the transfer from one eye to the other of the proficiency in reading inverted words. The objective was to train one eye to read inverted words and then see if the acquired proficiency transferred to the other eye. Since language is ordinarily considered peculiar to man, this type of experiment could only be done with people. The opportunity for transfer through conjugate eye movement was considered virtually absent, since eye movements in tracing out the letters of a word would indeed be quite complicated to transfer.

The measure of proficiency in reading inverted words was the time from projecting the word onto a screen to the time when the subject spoke the projected word to indicate that he recognized it.

Inverted words were used for training the eye because the subjects were adult and already skillful in reading ordinary upright words. Conceivably a similar experiment might be carried out with children who cannot read, by teaching them to read ordinary upright words with one eye and testing their reading proficiency with the other eye.

If complete transfer of reading ability for inverted words should occur, how do we know that it is interocular transfer? Is it not possible that the subject learned that whatever looks like a "b" is a "p", and that whatever looks like a "d" is a "q" and so on? In such a case what appeared to be "interocular transfer" could occur even though the eyes operated completely independent of each other, because the person would have given himself a sort of verbal "conversion table" to convert new symbols into old: "verbal transfer." So the problem was whether an experiment could be set up that would measure responses that were so fast that it could reasonably be assumed that the subject did not have time to spell out the word to himself. If so, then the transfer of such fast responses could be considered to require interocular transfer.

Let us visualize the task of the subject in the experimental situation. He is looking at a slit of light on a screen when a word is flashed in the slit. It is a six-letter word and all the letters are inverted. Right-left relationships are not changed; the word is only inverted in the vertical dimension. The first letter of the word is still at the left. The subject, considering a letter at a time, eventually figures out all the letters. Then he goes over them again, this time spelling out the word. He recognizes the spelling and speaks the word into the microphone. The total time from time of flashing the word onto the screen until the subject says the word into the microphone is considered in this experiment as the time that it took the subject to recognize the word. It was believed that, as training proceeded, the subject would be able to immediately see this inverted "b" as equivalent to "b", without any talk like, "It looks like a 'p', so it must be a 'b'." This would be similar to our seeing "A" as equivalent to "a" in certain contexts. When he immediately sees all the letters of the inverted word as their upright equivalents, he sees the total word without spelling it out, just as we don't have to spell out the word CONTINENTAL even though we may never have seen it in capital letters previously. This was manifested during the execution of the experiment when subjects, after training, commented that they were beginning to "see" the words instead of spelling them out.

In a preliminary test, several subjects were timed to determine how rapidly they could spell out six-letter combinations when all the letters of the combination were familiar (upright). A total of 30 timings was made. The six-letter combinations in this test were not words, because the purpose of the test was to find out how fast the subjects could spell out a word if they had to look at each letter; if a six-letter familiar word had been presented, the subject would have been able to simply spell it from memory without looking at the individual letters. For all cases (30 timings) it took at least two seconds for a subject to spell out six letters to himself, looking at each letter, and then say "now" to indicate that he had spelled it out. It took at least two seconds for a subject to spell out a six-letter word, when he had to look at each letter, even when the letters were familiar to him.

So the experimenter decided that he could measure these faster responses that could only be transferred through interocular transfer, since he had already measured many responses made within 1/2 to 2 seconds in a pilot study.

The preliminary "speed test", the report of subjects that they began to "see" words, and the pilot study did not supply data used in the analysis or conclusions in this study, but rather served to aid the experimenter in carrying out the experiment.

METHODS AND MATERIALS

The experimental setup is schematized in Figure 1. A projector (a) for opaque material was adjusted to project onto a projection screen (b). To expose a word on the projection screen, the experimenter pulled back cover plate (c), thereby tripping switch (d), which activated the electromagnet (e). The electromagnet caused the stylus (f) to make a mark across the moving kymograph paper (g) and immediately return to its former position. When the subject recognized the word exposed on the screen, he said the word into a microphone (h) immediately in front of him and this completed a circuit through the voice key (i), activating electromagnet (e) again and making another mark across the kymograph paper. The voice key is a circuit-breaking device which can be adjusted for sensitivity to keep the microphone from activating the electromagnet through moderate background noises, such as those arising from the fan in the projector. Because the electric powered kymograph pulled the paper through at a constant rate of speed, the time to respond can be determined by measuring the distance between the two stylus marks across the kymograph paper.

Each roll of test material contained 100 words. Fifty of the words were upright and fifty were inverted. There was alternately an inverted word and an upright one. The inverted words were inverted in the vertical dimension only; right-left relationships were not changed. The inverted words appeared the way normal words do when the page is turned

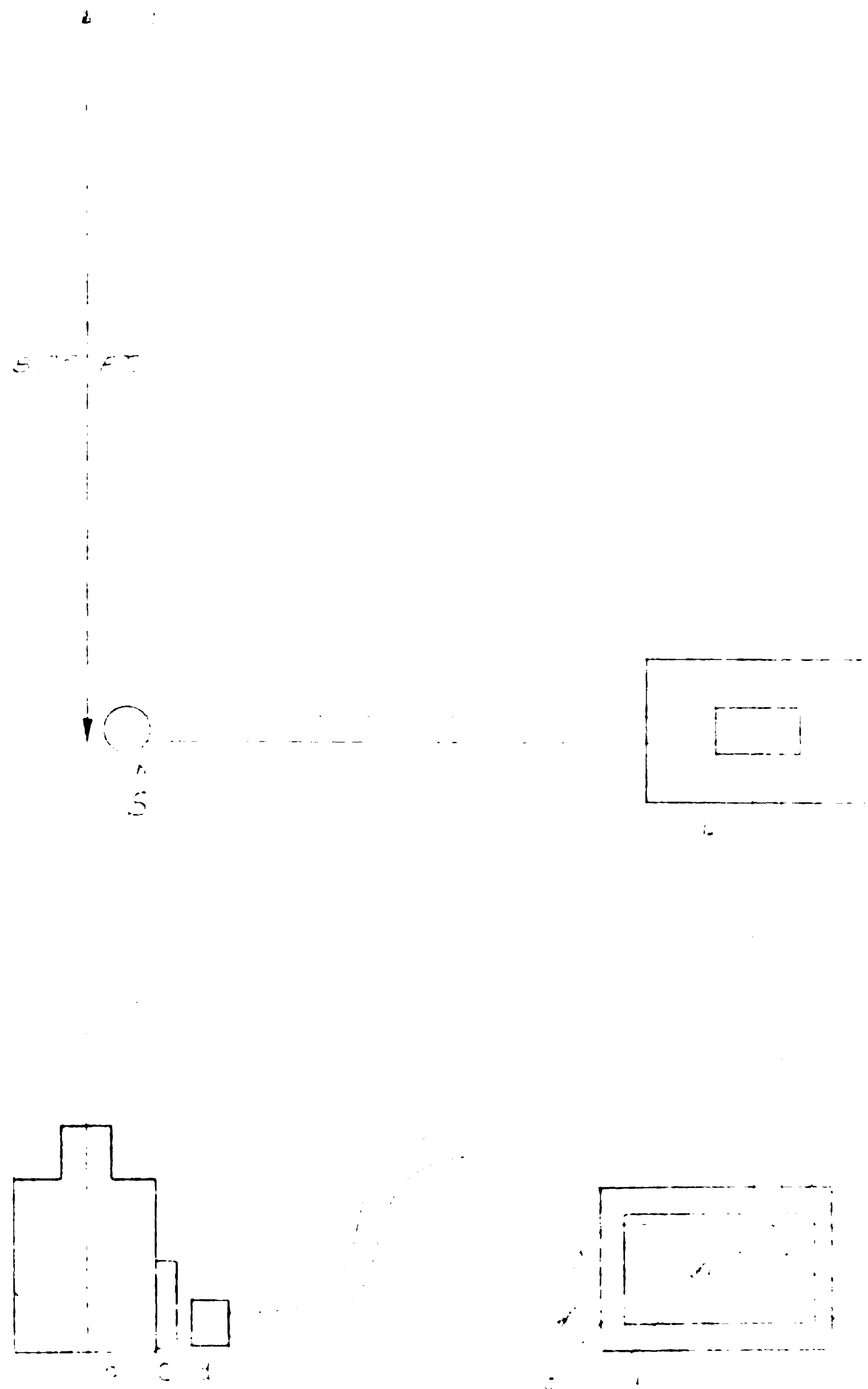


Figure 1. Set-up for inverted words experiment.

upside down and the words are looked at through the back of the page. All of the words were taken from Thorndike's word list. According to Thorndike's list, each word had a frequency of occurrence in written material of at least once in every million words. All of the words used were six-letter words. Due to the nature of the projector, the words had to be printed along the length of the roll in order to be projected properly. An L. C. Smith typewriter, with pica type, was used for typing on the rolls. Each roll consisted of several strips, which were typed separately and taped together. The inverted words were typed by placing a carbon paper between the paper and typewriter platen, with the carbon side touching the paper. A charcoal fixative was used on the inverted words to keep the carbon from smearing.

As previously indicated, the six rolls of test material were made up of words of the same length, and of moderately frequent occurrence to minimize inequality of difficulty. The rolls were made up in this way: six-letter words that showed a frequency of occurrence in reading material of at least once in a million words were written on slips of paper and placed in a container. Words that often have more than one pronunciation, such as "either", were not put in the container because it might be anticipated that such words could cause subjects to hesitate in their pronunciation after they had recognized the word. Also, no words containing a capital letter were used. The rolls were typed from the slips as they were randomly drawn from the container.

Table I shows the design for matching subjects, test sessions, and rolls of test material. Test sessions T-1, T-2, T-3, and T-4 indicate the first, second, third, and fourth test session, and I. T. represents the interocular transfer test session, which followed the fourth test session. A, B, C, D, E, and F are the six different rolls of test material.

Thus, the rolls were "rotated" to compensate for any inherent difference in difficulty that otherwise might tend to bias comparisons between test sessions.

An eye patch served to occlude one eye. The subjects were requested to keep the occluded eye open. This was done to relieve the tension or strain of holding one eye closed.

The subjects were six male college students between 20 and 30 years of age.

TABLE I

ROTATION OF TEST ROLLS FOR SUBJECT-TEST COMBINATIONS

Subject	Test Sessions				
	T-1	T-2	T-3	T-4	I. T.
1	A	B	C	D	E
2	F	A	B	C	D
3	E	F	A	B	C
4	D	E	F	A	B
5	C	D	E	F	A
6	B	C	D	E	F

The 10-day schedule for each subject was as follows:

Day	Task
1	Determination of equality of vision
2	Test 1 (T-1)
3	Practice Session 1
4	Practice Session 2
5	Test 2 (T-2)
6	Test 3 (T-3)
7	Practice Session 3
8	Practice Session 4
9	Test 4 (T-4)
10	Test of interocular transfer (I.T.)

The schedule was for ten consecutive days.

Determination of Equality of Vision

One hundred upright words were presented monocularly, fifty to each eye, alternately occluding the right and left eye. This test was used to screen out subjects whose vision in the experimental situation was better for one eye than for the other. There are two essential differences between this test and test sessions 1 through 4:

1. Right and left eye were occluded in this test, in contrast to occluding only one for test sessions 1 through 4.
2. Only upright words were used in this test, whereas the other tests included both upright and inverted words.

Except for these two differences, the procedure was the same as that for the other tests discussed below under "Test Sessions."

Test Sessions

For Tests 1, 2, 3, and 4 the same eye was occluded. For three of the subjects the occluded eye was the right eye for these tests; for the other three it was the left eye. For the test of interocular transfer on the tenth day, the patch was shifted to the opposite eye. While putting the patch over the eye on the day of the test for interocular transfer, the experimenter told the subject, "I just want to test your other eye again to make sure this one is as good as the first one."

The instructions to the subject were to speak the word into the microphone as soon as he recognized it. They were told not to guess and that guessing wrong would only slow down their response time because the experimenter would measure their response time from the time the word was presented until the subject said the correct word. They were told that this was a test to find out how rapidly subjects could learn a new visual task, such as reading inverted words, when only one eye could be used. After fifty words were presented there was a rest break of ten minutes. A word was presented about five seconds after the previous word was recognized. About two seconds before a word was exposed on the screen the experimenter cued the subject by saying "normal" (meaning upright) or "inverted" so that the subject knew which kind of word to expect. As mentioned previously, upright and inverted words were alternately presented. If a word was not recognized within a minute, the experimenter told the subject what the word was, and proceeded to the next word. The subject was always given at least 30 seconds to figure out a word before he was prompted.

Practice Sessions

For each practice session, inverted typewritten passages from a book were projected, so that several lines of words were on the screen at a time, instead of a single word. About 1500 inverted words were in the passages for each day. The passages were chosen from a book and slightly altered, so that none of the words presented in practice sessions were used in test sessions. The subjects were not timed during the practice sessions.

RESULTS

The response time is the time from the exposure of a word to the time when the subject spoke the word. If the subject was incorrect when he spoke, the experimenter said "wrong" and marked out the response mark on the kymograph paper. The subject would then continue until he determined what the word was. The response time used in the analysis of the data was the time from exposure to correct recognition of the word (recognition being indicated by speaking into the microphone). There were very few instances in which a subject's first response was wrong.

The responses were measured to the nearest quarter-second. Appendix A shows the number of responses for each quarter-second time interval for each subject on each test.

Graphs A, B, C, D, and E were made by plotting the response times against number of responses, for all subjects combined, for each test, from the data in Appendix A. Then curves were visually fitted to these data, (except for Graph A). No curve was fitted to the data in Graph A, because the trend of the data is indefinite. Test 1, which gave the data for Graph A, was administered before any training was given the subjects. Each of these graphs shows the points used in determining the curve.

Graph F shows the curves plotted on Graphs B, C, D, and E all on the same graph. This graph shows that Tests 2, 3, and 4 (labelled T-2, T-3, and T-4) and the interocular transfer test (labelled I.T.) yield curves of essentially the same shape.

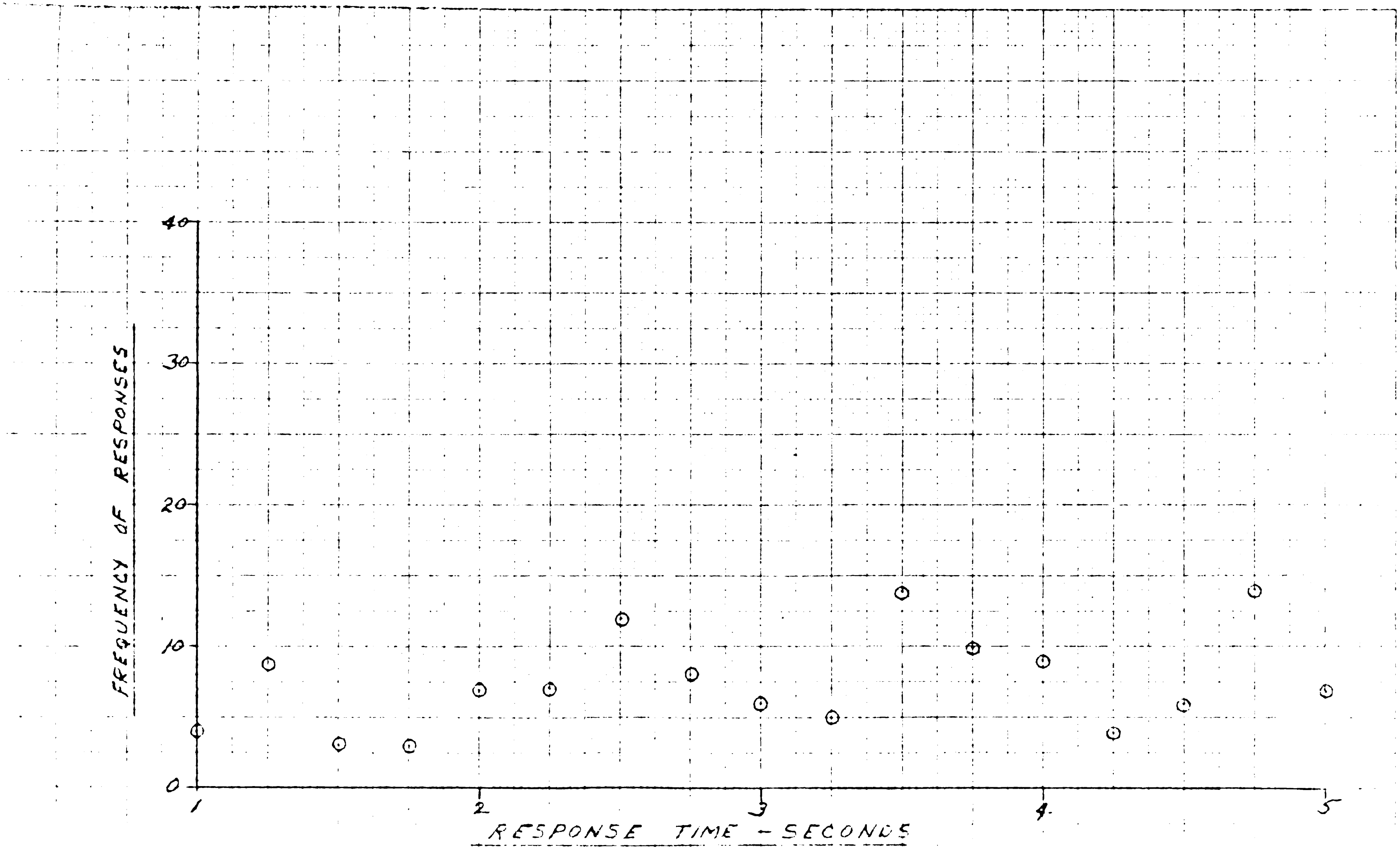
The T-2, T-3, T-4 and I.T. curves fitted by eye resemble a curve known as the logarithmico-normal curve, seldom used in the analysis of psychological data. The logarithmico-normal curve, like the normal curve, is a family of curves, all derived from the same formula by simply varying the parameters: m and σ .

Method of Analysis

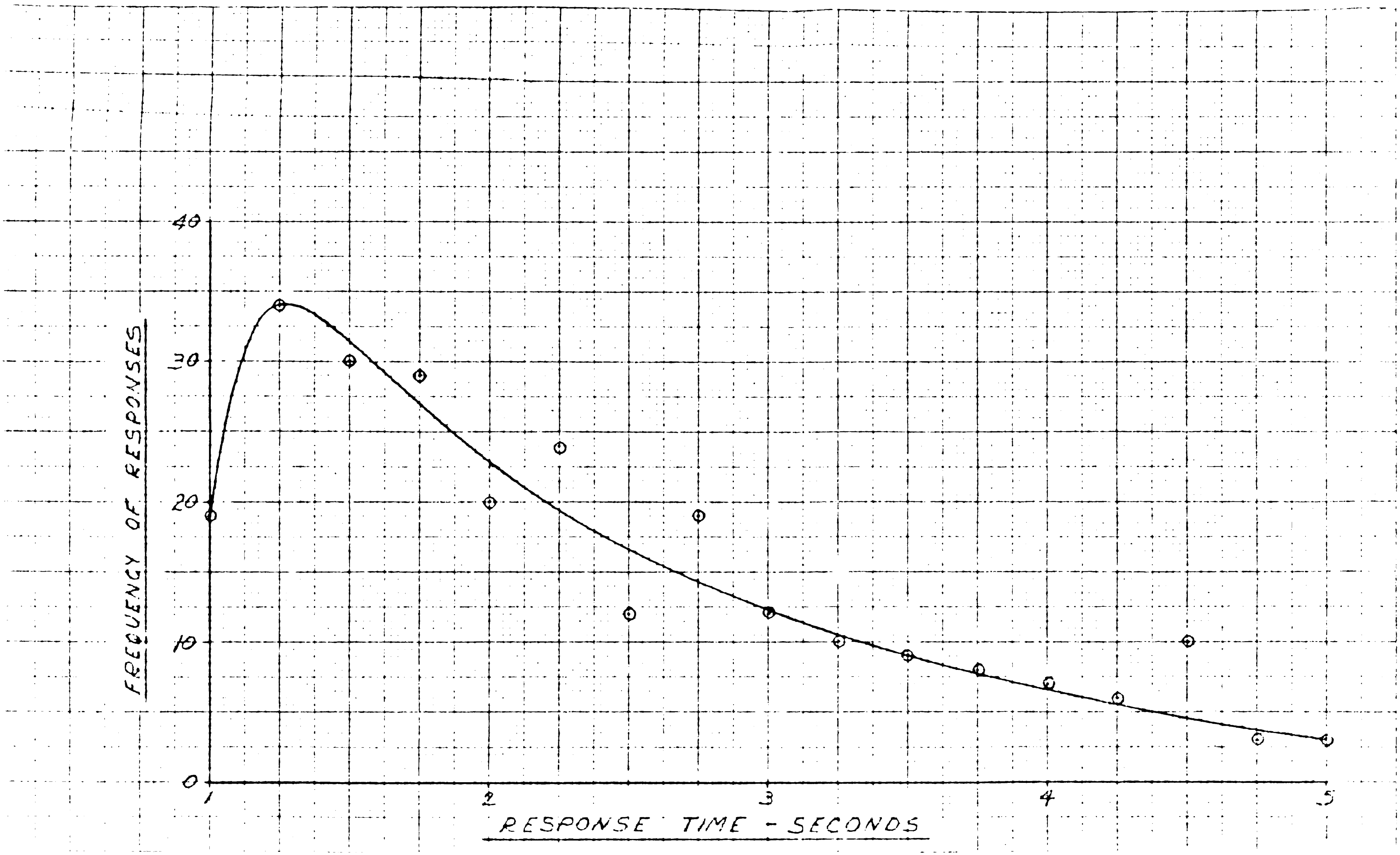
The logarithmico-normal curve becomes an ordinary normal curve when the natural logarithms of the units on the X axis are scaled instead of the original units. So the values for m and σ for the logarithmico-normal curve are computed in the same manner as any other m and σ for a normal curve. It must be emphasized however, that this m and σ are in logarithmic units, because those are the units which are normally distributed.

If a person had data that he thought was normally distributed and he wished to see how closely it fit a normal distribution, two easy approaches would be:

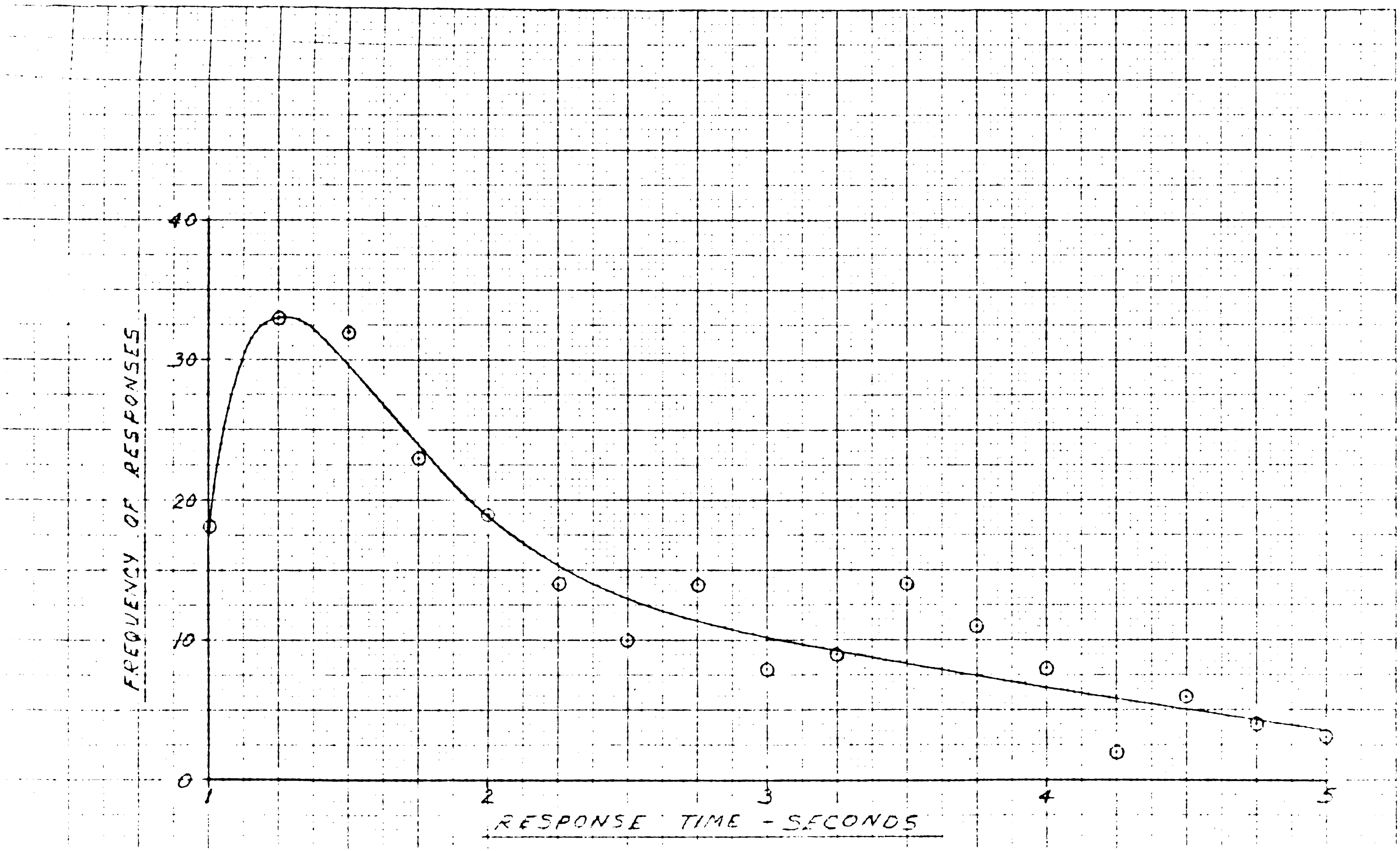
1. Plot the data and fit a curve by eye (as was done by Graphs B, C, D and E).
2. Construct a normal curve by substituting into the normal curve formula the m and σ determined from his sample of data and superimpose this mathematical curve over his raw data.



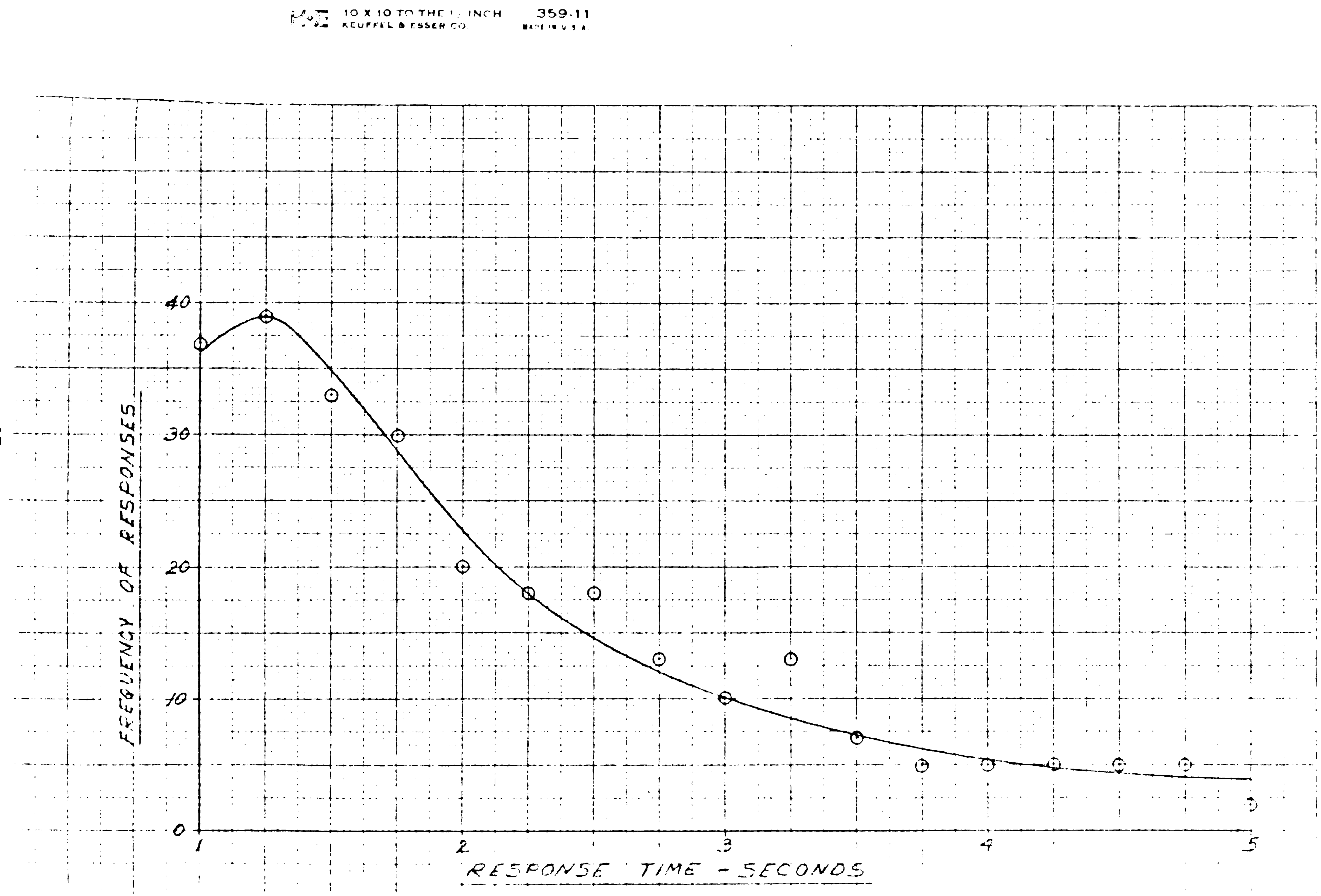
Graph A: Frequency of responses per time interval: Test 1.



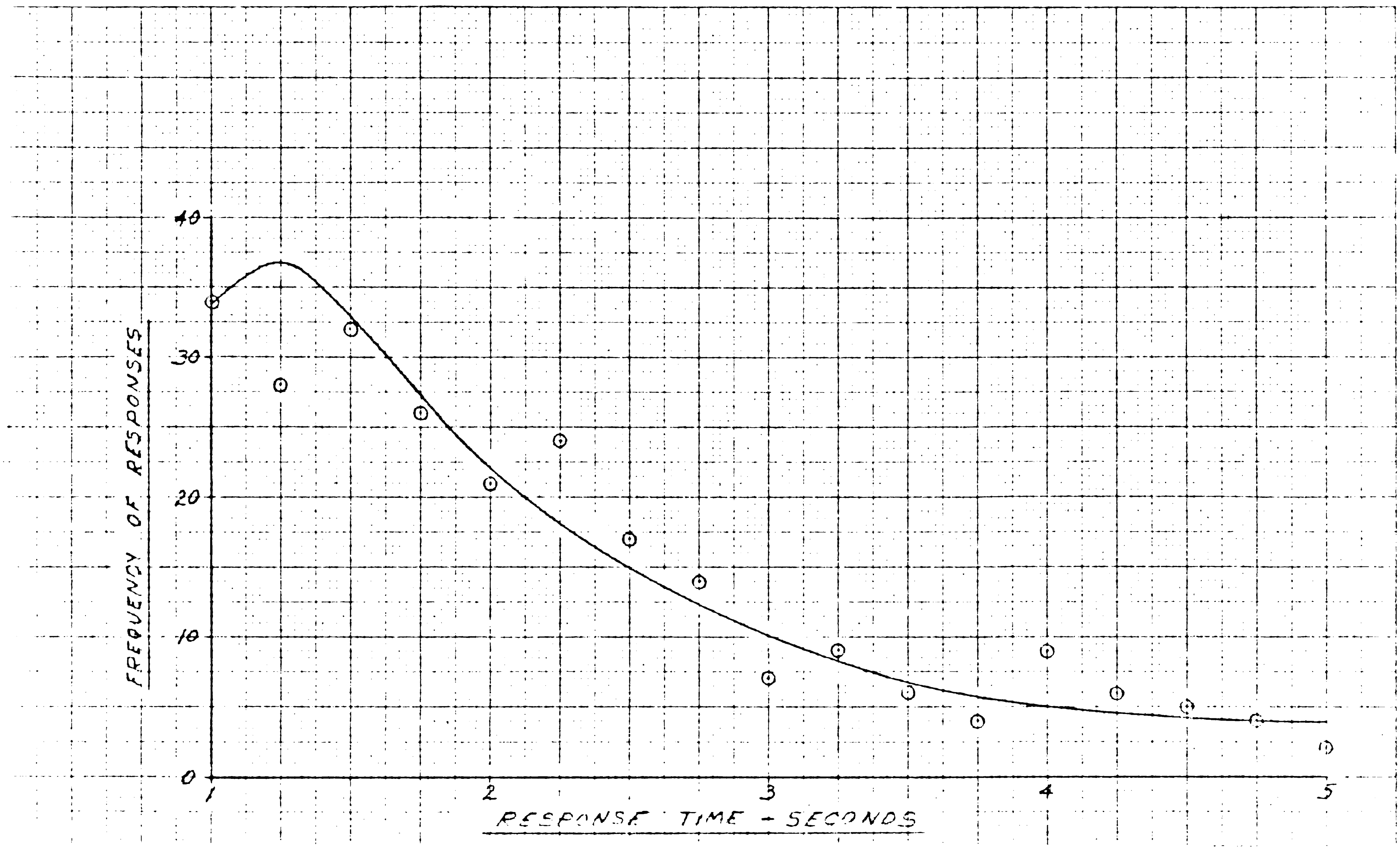
Graph B: Frequency of responses per time interval: Test 2.



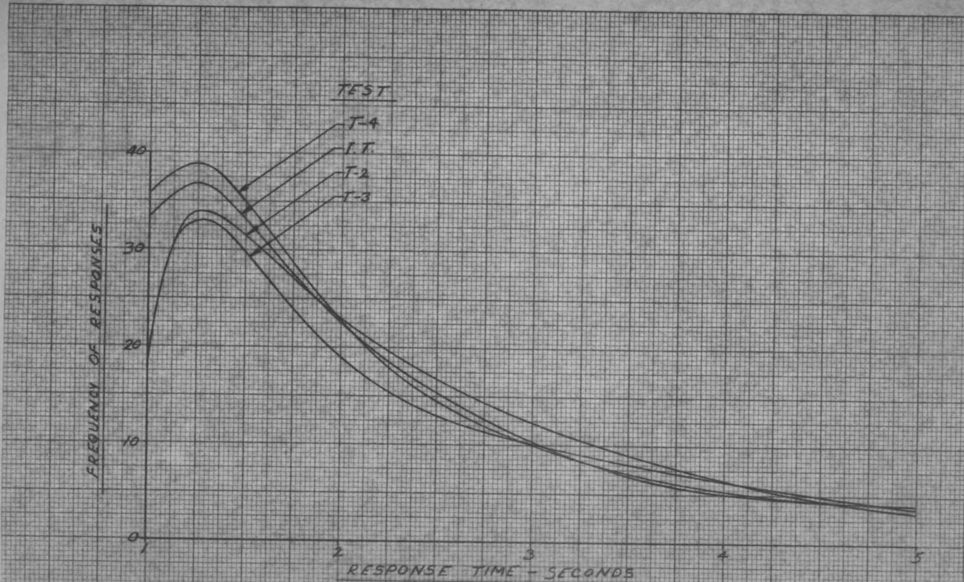
Graph C: Frequency of responses per time interval: Test 3.



Graph D: Frequency of responses per time interval: Test 4.



Graph E: Frequency of responses per time interval: Interocular transfer test.



Graph F: Frequency of responses per time interval: composite of all tests.

Since approach 1 revealed a curve similar to the logarithmic-normal rather than the normal, approach 2 was used to see how a theoretical logarithmico-normal curve, constructed from m and σ of the data, would fit the data. The parameters needed for the theoretical logarithmico-normal curves were σ, m, and α. α is a constant that is subtracted from each X value. In this experiment, the experimenter estimated α to be 0.375 seconds since no subject ever made a response to an inverted word faster than that--α may be considered as a correction factor for a constant lag in the system. m and σ were computed for the logarithm of the response times:

$$m = \frac{\sum \ln (x - \alpha)}{n}$$

$$\sigma^2 = \frac{\sum [\text{deviations of } \ln (x - \alpha) \text{ from } m]^2}{n}$$

where m and σ^2 are the mean and variance, x is an observed response time, α is a correction factor of 0.375, and n is the number of responses.

Graph G shows how the logarithmico-normal curve, derived by inserting m and σ of the <u>logarithms</u> of the response times into the logarithmico-normal curve formula, fits the frequency curve of the pooled response times of T-2, T-3, T-4 and I.T.

Now let us consider why the logarithms of the response times should be more appropriate for statistical analysis than the response times themselves. The reason is simple: with the response time plotted along a logarithmic X-axis, equal distances along the X-axis represent equal difficulties; e.g., the distance between 2 seconds and 3 seconds is less than the distance between 1 second and 2 seconds, because it is much easier to improve slow responses by 1 second than it is to improve fast ones by 1 second.

Table III shows the results of various comparisons of mean of the logarithms of the response times for different test sessions. T-1 is not included because it had a different shaped distribution. That its mean response time is significantly longer than that for T-2 can hardly be questioned, however, if one looks at Graph A and Graph B.

TABLE II

MEAN RESPONSE TIMES AND STANDARD DEVIATIONS

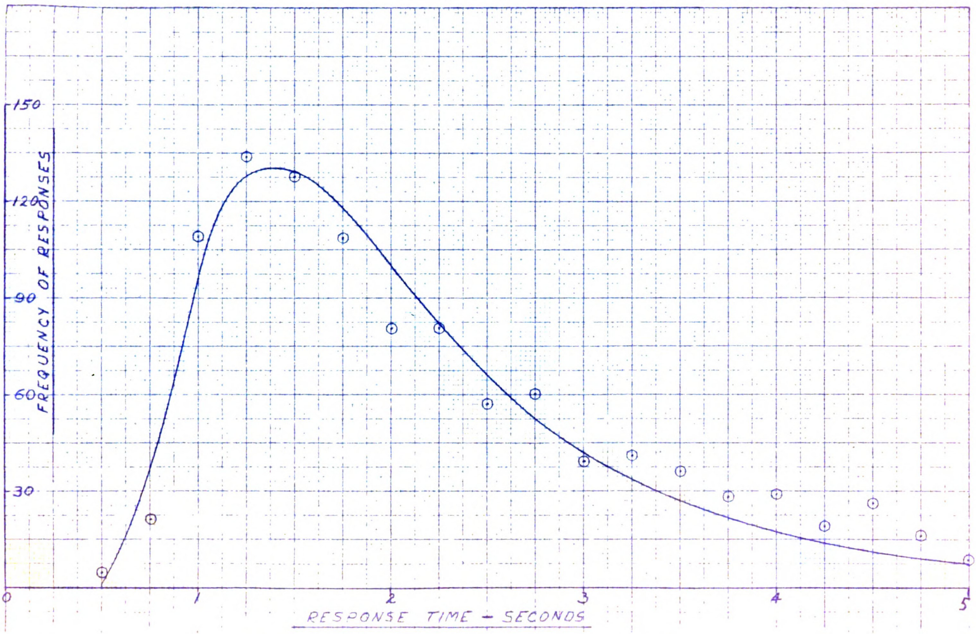
Test	Mean Response Times	Standard Deviations
T-2	0.4918	0.599
T-3	0.4410	0.637
T-4	0.3394	0.637
I.T.	0.3943	0.613

TABLE III

COMPARISON OF MEAN RESPONSE TIMES

Comparisons	Value of "t" for difference of means	Probability that the difference is due to chance*
T-2 and T-3	0.91	0.18
T-2 and T-4	2.88	0.002
T-3 and T-4	1.78	0.04
T-4 and I.T.	1.04	0.15

* These probabilities are for obtained differences, taking into consideration the direction of the differences. This is valid practice, since in this experiment the hypothesis tested is not simply about the difference of means, but also about the direction of the difference.



Graph G: Logarithmico-normal response frequency curve.

Qualitative Results

The subjects experienced considerable difficulty in recognizing an inverted word even when they could spell out the word. In one practice session the word "apes" appeared as an inverted word on the screen. Several of the subjects had difficulty figuring out what it was, even though they had little difficulty with longer words. One subject said, "I can spell it out, but it doesn't make sense: a - p - e - s . . . . "uhpez?" 'Appies?'"

Often, when a subject had difficulty with a word after spelling it, he would look away from the screen or shut his eyes. His explanation was that he could concentrate on the spelling better in that way. Several subjects reported this.

CONCLUSIONS

1. Since the shape of T-1 distribution is not like that of the other tests, there was no appropriate statistical test for comparing it with the others, but it appears obvious from Graphs A and B that there was improvement in speeding up responses from T-1 to T-2, indicating that the practice sessions between T-1 and T-2 were effective in helping the subjects to respond faster to inverted words.

2. The subjects were not significantly faster or slower on T-3 than on T-2. There was no significant difference of means for these two test sessions, which occurred on successive days with no intervening practice session. So, there is no reason to believe that the factor of having test sessions on successive days with no intervening practice is in any way influential in producing a difference in response times for the two test sessions.

3. The subjects were significantly faster on T-4 than on either T-2 or T-3. This shows that the practice sessions between T-3 and T-4 were probably effective in helping the subjects to respond faster to inverted words.

4. The results were inconclusive. Therefore, the hypothesis that eye movement is unnecessary for interocular transfer can not be rejected.

The purpose of this experiment and the second experiment of this thesis was to get information that might lead to the demonstration that conjugate eye movement is necessary and sufficient for interocular transfer to occur: "sufficient" meaning sufficient without common pathways being formed in the brain.

It was not until the data for these experiments had been gathered and analyzed that the experimenter received from Dr. Chow a description of experimental results that would seem to indicate that conjugate eye movement is not a sufficient condition for interocular transfer. The chimpanzee experiments which gave these results are discussed in the introduction. The fact that there was incomplete transfer from the former test eye back to the former trained eye on a second task showed that although the eye to which the task was transferred had previous experience in tracing outlines, there was not complete transfer; the tested eye although experienced at tracing contours did not reinstate an "approach" pattern (to which the animal responded) in the opposite eye through conjugate eye movement.

This evidence of Dr. Chow's that conjugate eye movement is not sufficient when there has been no opportunity for building up common neural pathways in the brain, together with the lack of evidence in the present experiment for conjugate eye movement being a necessary condition for interocular transfer, point strongly against conjugate eye movement being necessary and sufficient (sufficient without common neural pathways) for interocular transfer.

In ruling out conjugate eye movement, how can the concept of neural pathways common to the two eyes be compatible with those phenomena such as stereoscopic vision, which apparently require a discrimination between the impulses from the two eyes? One explanation might be this: the region in the nervous system where the impulses from the two eyes arouse a common pattern may be beyond the region involved in stereoscopic perception and other phenomena that apparently necessitate a distinction between the impulses from the two eyes; i.e., certain perceptual processes may occur while the impulses from the two eyes are still distinct, whereas the paths may later converge into a common pattern of excitation.

SUMMARY

1. The existence of such phenomena as stereoscopic vision and binocular rivalry in animals with binocular experience seems to be inconsistent with Hebb's idea that binocular vision tends to build up a common visual pathway in the brain such that a thing seen by either eye tends to arouse the same pattern of excitation in the brain. Stereoscopic vision is not a simple superposition of two images: the effect is different if the stimuli for the two eyes are exchanged. Why should this exchange of stimuli make any difference if there is a simple fusion through a common path in the brain without respect to which eye originated the visual impulse?

2. Since one of Hebb's main arguments for common neural pathways is interocular transfer, consideration should be given to the problem of interocular transfer to see if it might be explained without recourse to the concept of common visual paths.

3. One such explanation might be that the interocular transfer is carried out by means of conjugate eye movement: through conjugate eye movement, an "approach pattern" of eye movement is reinstated in the original trained eye, even when it is covered. No common visual pathways would be needed. Conjugate eye movement might be necessary and sufficient for interocular transfer to occur in the absence of common visual pathways.

4. The hypothesis tested in this experiment was that conjugate eye movement is not necessary for interocular transfer.

5. The hypothesis was tested by training one eye of adult human subjects on a task where opportunity for transfer through conjugate eye movement was minimized and checking for transfer to the opposite eye. The task was learning to read inverted words. Six subjects were used. The criterion for proficiency was the time to give the correct response to an inverted word projected on a screen.

6. The hypothesis that conjugate eye movement is not necessary for interocular transfer could not be rejected. There was no significant increase in response times from the test sessions immediately before to those immediately following exposure of the test eye to inverted words.

7. This lack of evidence for the necessity of conjugate eye movement for interocular transfer, in conjunction with results obtained by Dr. Chow (still unpublished at the time of this writing) indicating that conjugate eye movement in the absence of binocular vision, is not sufficient for interocular transfer, leaves unsettled the problem of incompatibility of stereoscopic vision (and other manifestations of independence of visual impulses from the two eyes) with the concept of common visual pathways in the brain.

8. An alternative answer to this problem: the region in the nervous system where the impulses from the two eyes arouse a common pattern may

be beyond the region involved in stereoscopic perception and other phenomena that apparently necessitate a distinction between the impulses from the two eyes; i.e., certain perceptual processes may occur while the impulses from the two eyes are still distinct, whereas the paths may later converge into a common pattern of excitation.

INTRODUCTION: EXPERIMENT II

A second type of interocular transfer experiment was carried out upon completion of the experiment with inverted words. The second experiment dealt with interocular transfer of an eye-hand coordination task. The objective of the second experiment was to determine whether there is interocular transfer of an eye-hand coordination task, in binocularly experienced humans when the opportunity for transfer through conjugate eye movement is minimized. In order to proceed toward this objective it was necessary to develop a new technique for controlling for conjugate eye movement and a new technique for measuring errors in mirror-tracing.

METHODS AND MATERIALS

Fundamentally, in the eye-hand coordination experiment, the technique used in controlling for interocular transfer through conjugate eye movement was that of training subjects on one task and testing them on a different task which had a certain known relationship to the first task. The first task, the learning task, involved head movement without eye movement, whereas the second task, the testing task, involved eye movement without head movement. A control group was used to determine the nature of the relationship between the performance on the two tasks.

It was desired that a new visual-motor coordination be built up to see if it would transfer to the other eye. The visual-motor task selected was mirror-tracing. In mirror-tracing a subject observes his hand movements in a mirror while tracing a pattern. His hand appears to move in the proper direction for horizontal movements but appears to be going opposite for vertical movements.

Two groups of subjects were used for this experiment. They were male college students between 20 and 30 years of age. None of them wore glasses or was aware of any deficiency of vision in either eye. A screening test was administered by requiring each subject to read a paragraph of fine print with either eye, although most of the subjects were known to have 20-20 vision.

The control group was trained with the right eye on a mirror-tracing task, wearing the eye tube shown in Figure 2, with the apparatus shown in Figure 3 (with the exclusion of (c), the headrest). They were tested with the same eye, using the headrest, instead of the eye tube. The experimental group followed the same procedure except that it was tested on the opposite eye from which it was trained. Thus, the only difference between the experimental and control groups was that the experimental group was tested with a different eye from which it was trained.

The figure to be traced is shown to scale in Figure 4A. The way the pattern appeared in the mirror is Figure 4B. The subjects were allowed 45 seconds to trace the entire pattern. The experimenter started the stop watch, said "now" when it read five seconds, "now" again in ten seconds, "start" at fifteen seconds, and said "one", "two", "three", and so on at five second intervals for the next 45 seconds to let the subject know where he should be at each moment.

The apparatus is shown in Figure 2. For the training sessions the subjects wore the eyetube shown in Figure 4, instead of using the headrest. They leaned over the apparatus shown in Figure 2 until the end of the eye tube was about four inches from the mirror (a). The pattern to be traced was A in Figure 3 which was positioned on the apparatus at (b) in Figure 2. During the test sessions, the subject removed the eye tube and sat at the apparatus with his head against the headrest (c). The pencils used by the subjects for tracing were kept sharp and were about 5 inches long to allow easy handling. The subjects were told to hold the pencils near the tip.

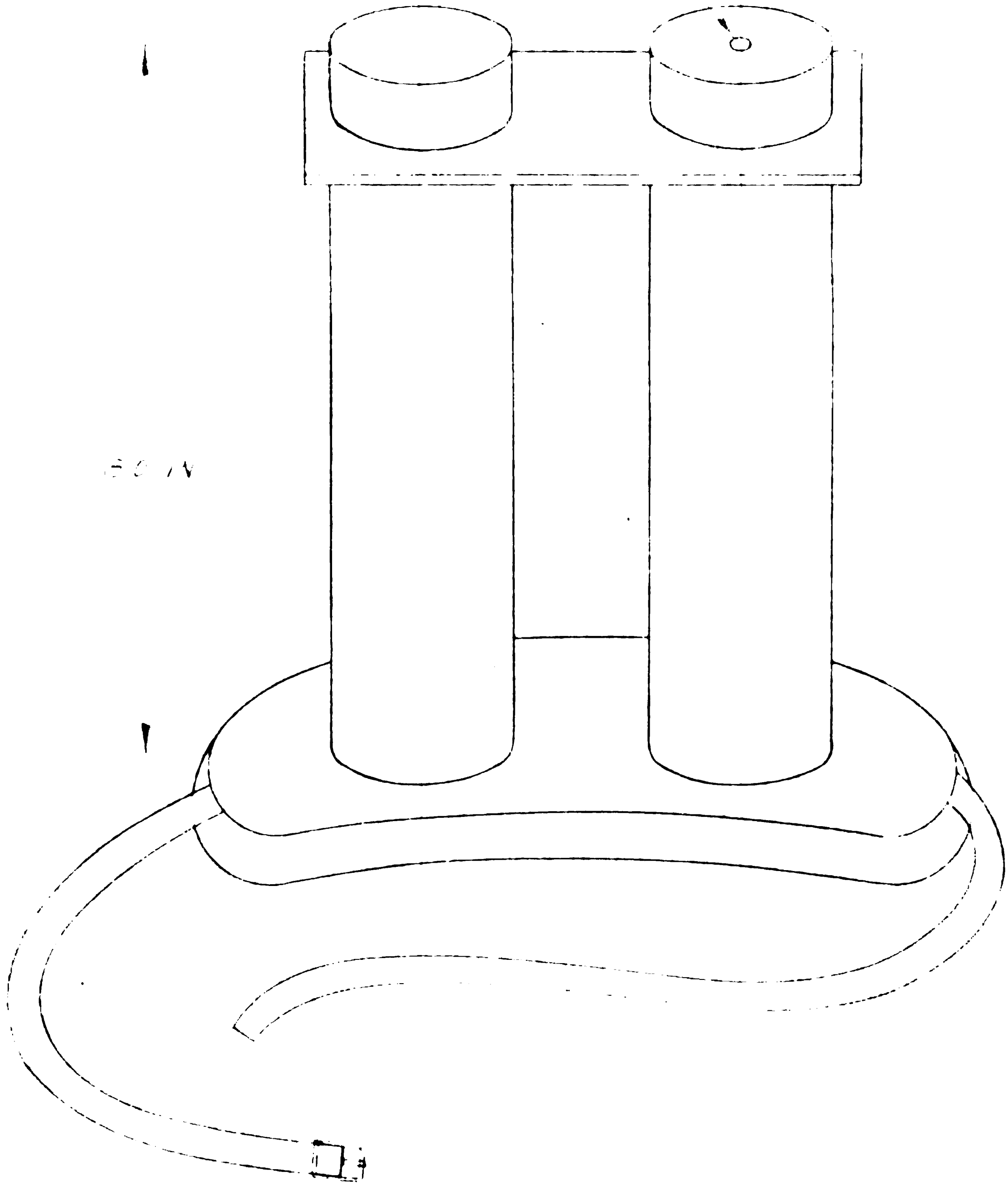


Figure 2. Eye tube.

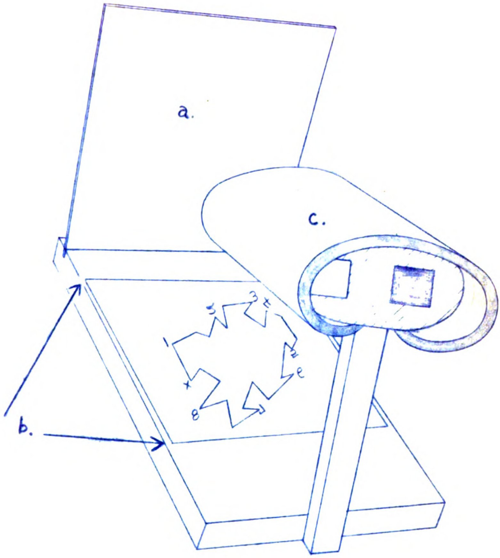


Figure 3. Mirror-tracing apparatus (with head rest).

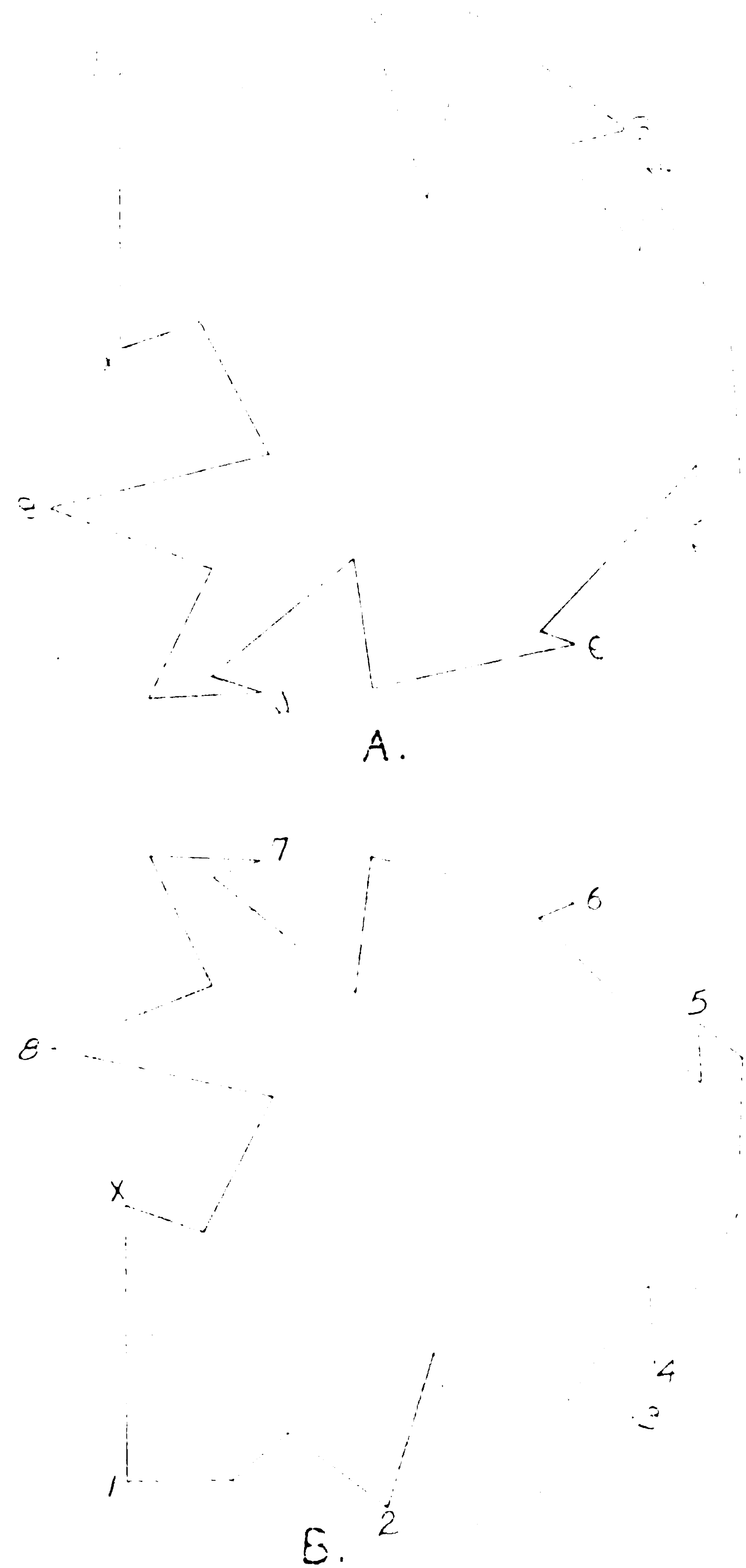


Figure 4. Mirror-tracing pattern.

Schedule for subjects: 4 consecutive days.

Day 1: (morning) Subjects were told that this was an eye-hand coordination experiment in which only one eye would be used. They were fitted with the eyetube. For the first tracing trial the subject was told to go completely around the pattern no matter how far off the pattern he may be. It was explained to him that he would learn faster this way. Eight tracings (wearing eyetube).
(afternoon) Eight more tracings, wearing the eyetube.

Day 2: Eight tracings in the morning and eight tracings in the afternoon, all with the eyetube.

Day 3: (morning) The subjects were told that this would be another experiment similar to the one for the previous two days. Each subject was told to hold his head against the headrest and only move his eye. There were eight tracings, using the headrest and eyetube alternately.
(afternoon) Eight more tracings using the headrest and eye tube alternately.

Day 4: Eight tracings in the morning and eight tracings in the afternoon, using the headrest and eyetube alternately in both sessions.

RESULTS

The only difference in treatment of the control and experimental groups was that the experimental group changed eyes from practise to test sessions. So a comparison of the data for the two groups should indicate any differences caused by changing from one eye to the other.

Method of Analysis

Various techniques have been used in mirror-tracing studies to measure the proficiency of the subject on the task. Difficulty in counting errors led G. M. Whipple (1910) to devise the concentric double star. The subject was instructed to keep the line he drew between the printed lines. The error score was the number of times the subject's line strayed from between the lines, or the total distance over which the subject deviated from keeping the line between the printed lines. In 1918 G. R. Wells used Whipple's concentric stars, making the stars from metal so that when the stylus touched the edges it completed an electrical circuit and rang up an error. The error score was thus the number of times the stylus hit the inner or outer star. In 1933 C. E. Lauterback used a star with the contour formed of small circles. He suggested a scoring method in terms of the number of circles drawn through per minute, giving a single score, rather than the two, a time and an error score, traditionally used. Jean Weidensall (1916) suggested a precision scoring technique. She measured the tracings of three mm. or more that did not cross the pattern-outline or vary more than one mm. on either side of it. The total distance thus obtained was considered the precision score.

H. W. Isreal (1925) designed transparent stencils for specific six-pointed star patterns. By fitting a cross-sectioned stencil over a traced test-pattern, the tracing may be scored according to the extent and duration of tracing errors.

Norma Scheidemann (1950) suggested that a plastic ruler could serve as a cross-sectioned scale for scoring both extent and duration of tracing errors by means of uniform units, applicable with any mirror-tracing test pattern comprised of straight lines.

Believing that it is difficult to evaluate precision in mirror-tracing when both time and errors are variables, the experimenter set time up as a constant. As mentioned in the "Methods and Materials" section, the subjects were paced around the pattern, so that each trial was completed in about 45 seconds. None of the trials took longer than 47 seconds or less than 43 seconds, and most of the trials were in between 44 and 46 seconds. In measuring the errors, it was considered by the experimenter that a proper measure should involve both extent and duration of error. But extent and duration of error should not be separate measures. Consideration will show that the area between the figure to be traced and the line drawn by the subject represents the extent and duration of the deviations from the pattern contour. In her approximation of this area, Scheidemann, using the cross-sectioned plastic ruler, did not compute the deviation from the pattern for every point in the drawn line, but for each cross-section used a single representative deviation for that segment of the drawn line falling within that cross-section. In the present experiment the experimenter measured the area between the pattern and the drawn line by using a planimeter, thereby considering deviations along the full extent of the drawn line. The area between the pattern and the drawn line was determined by subtracting the area enclosed by the innermost line from that enclosed by the outermost line.

Data

Table IV shows the error scores for both the control and experimental groups. These are the error scores for days 3 and 4. The first 2 days were practice sessions. E signifies eye movement condition (using headrest), and H signifies head movement condition (wearing eyetube).

The results of the control group show that the eye movement condition was easier for every subject. Although a pattern traced by eye movement shows only 0.2 square inches less error on the average than a pattern traced by head movement, it is apparent that eye movement is more accurate than head movement. Seventeen of the twenty subject-session blocks show eye movement being more accurate than head movement.

For the experimental group, the pattern for the left eye (eye movement) shows 0.3 square inches less error on the average than a pattern traced by the right eye (with head movement). Nineteen of the twenty subject-session blocks show eye movement being better than head movement.

TABLE IV

MIRROR-TRACING ERRORS (IN SQUARE INCHES)

Subject		Session				Total Errors
		Day 3		Day 4		
		Morning	Afternoon	Morning	Afternoon	
		Control Group				
Ed	E	2.6	2.6	2.0	2.2	9.4
	H	3.2	2.8	3.4	2.4	11.8
Tom	E	4.2	4.0	3.0	2.8	14.0
	H	4.0	4.2	3.8	3.8	15.8
Jack	E	2.8	2.6	2.0	2.4	9.8
	H	3.0	3.2	2.6	2.4	11.2
George	E	2.8	2.6	3.0	2.2	10.6
	H	3.0	3.0	2.8	2.6	11.4
Pat	E	3.8	3.4	3.4	3.2	13.8
	H	4.6	4.2	3.6	3.4	15.8
		Experimental Group				
Rod	E	2.6	2.0	2.0	2.0	8.6
	H	3.4	3.0	2.4	2.4	11.2
Dick	E	2.8	2.6	2.2	2.4	10.0
	H	3.4	3.4	3.6	2.6	13.0
Bob	E	5.0	3.2	3.8	3.4	15.4
	H	3.8	4.1	5.2	4.4	17.6
Earl	E	3.2	3.4	2.8	2.8	12.2
	H	3.6	3.8	3.8	3.2	14.4
Aaron	E	2.6	2.6	2.8	2.8	10.8
	H	2.8	3.0	3.0	2.8	11.6

Evidence of incomplete interocular transfer would be that H minus E for the experimental group must be <u>less</u> than H minus E for the control group. There was no such tendency in this experiment, so there is no evidence against complete interocular transfer of a mirror-tracing habit when transfer through conjugate eye movement is eliminated.

CONCLUSIONS

This experiment showed that area measured by a planimeter can be used as a measure of error in a mirror-tracing task. Furthermore, it is shown that for all subjects the eye movement condition yielded fewer errors than the head movement condition. It is concluded that the methods and materials used would be useful in testing for interocular transfer of mirror-tracing tasks, if the eye movement and head movement conditions were equated (by increasing the difficulty of the eye movement condition or decreasing the difficulty of the head movement condition).

As was pointed out in the "Conclusions" section of Experiment I, the results of that experiment, in conjunction with the results of Dr. Chow's chimpanzee experiment, make it unlikely that conjugate eye movement is the medium for interocular transfer in the absence of common visual pathways. Furthermore, there was no observable lack of transfer in this experiment. So, it probably will be more profitable to investigate other factors in interocular transfer than conjugate eye movement in trying to determine if common visual pathways need be in the brain for interocular transfer to occur.

SUMMARY

1. The hypothesis that led to this experiment is the same as that for the first experiment, which dealt with interocular transfer of the ability to read inverted words. This hypothesis is that conjugate eye movement is not necessary for interocular transfer.

2. Five control and five experimental subjects were used in this experiment. The control subjects were trained with one eye on a mirror-tracing task, moving their head but holding their eyes still and they were tested on the same mirror-tracing problem with the same eye, but on the test, the subjects moved their eyes and held their head still. The experimental group was trained and tested identically, except for one condition: the test eye was not the training eye; instead, it was the opposite eye which had been shielded during the training period.

3. The errors in mirror-tracing were measured with a planimeter. The planimeter proved to be capable of detecting small differences in mirror-tracing ability and the fact that both duration and extent of error are considered over the entire line traced provides a logical basis for preferring it over a technique which only took extent or duration of error, alone, into consideration.

4. There was no evidence of lack of interocular transfer, although the opportunity for transfer through conjugate eye movement was

eliminated. The negative results of this experiment and the preceding one, in view of Dr. Chow's evidence for conjugate eye movement not being sufficient for interocular transfer, suggest that other factors than conjugate eye movement will probably be more profitable for study to determine whether conditions other than common visual pathways in the brain might explain interocular transfer.

FREQ

Subject	0.25	0.50	0.7	4.25	4.50	4.75	5.00
George	0	0	0	0	0	3	3
Kwong	0	0	2	0	1	2	0
Harry	0	0	0	1	1	0	1
Herb	0	0	1	0	2	6	1
Don	0	0	0	1	1	1	2
Ed	0	0	0	2	1	2	0
George	0	0	0	0	1	1	0
Kwong	0	0	0	0	2	0	1
Harry	0	1	1	0	0	0	0
Herb	0	1	0	1	3	0	0
Don	0	0	0	2	2	2	1
Ed	0	0	0	3	2	0	1
George	0	0	0	1	3	2	0
Kwong	0	0	3	0	2	0	1
Harry	0	0	2	0	0	0	0
Herb	0	1	2	0	0	0	1
Don	0	0	0	0	0	0	0
Ed	0	0	1	1	1	2	1
George	0	0	0	1	2	0	1
Kwong	0	0	1	1	0	1	0
Harry	0	1	2	0	0	0	0
Herb	0	1	4	0	0	0	0
Don	0	0	0	1	1	2	0
Ed	0	0	0	2	2	2	1
George	0	0	0	1	1	1	0
Kwong	0	0	0	2	1	0	0
Harry	0	0	2	0	1	0	0
Herb	0	1	1	0	0	0	0
Don	0	0	1	1	2	2	1
Ed	0	0	1	2	0	1	1

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APPENDIX B

INVERTED VISION

This appendix is not an attempt at a comprehensive coverage of the topic of inverted vision. Rather it is an attempt to bring forth a few notions on inverted vision which might be of interest or use to the readers of this thesis.

Definition of inverted vision. For the purposes of this report, inverted vision is that vision which results when an optical apparatus outside the eye causes the images on the retina to be inverted with respect to the same images on the retina without the external optical apparatus. This inversion may be in the horizontal or the vertical dimension, or both. In the historical section of this appendix, the experimenters to be mentioned used lenses that produced inversion in the horizontal and vertical relationships at the same time. However, other experimenters have used inversion prisms to invert only one dimension at a time.

The relationship of inverted vision experiments to psychology. There are several ways in which inverted vision experimentation may yield information of psychological significance. In the first place, inverted vision may serve as a means of studying the development of visual perception. Also, it may serve as a method by which the visual-motor coordinations may be studied, thereby adding to our knowledge of sensory-motor processes. Closely related to the visual-motor coordinations are the visual-sensory associations: the associations between vision and the other senses. The use of inverted vision to study visual perception was mentioned, and it might be pointed out that the concept of perceptual organization is especially susceptible to study; for example, could a person wear inversion lenses so long that things would start looking right-side-up? Several investigators have carried out research on inverted vision, but as a source of psychological data, it has been barely tapped.

<u>History of inverted vision experimentation</u>. Stratton (1897) is often considered the pioneer of research on inverted vision. He used a monocular system of two double-convex lenses, which he wore for several consecutive days. He obtained qualitative data concerning the adaptations he made to the new visual world (which was inverted in both the horizontal and vertical dimensions).

Ewert (1931) used a three-lens system which, like Stratton's apparatus, rotated the visual field 180 degrees. Besides qualitative data like Stratton's, Ewert also obtained quantitative data by utilizing such tasks as card-sorting, to obtain time or error scores. He traced the development of visual-motor coordination in the performance of the tasks.

Foley (1940) studied a monkey that wore inversion goggles for eight days. Upon removal of the goggles, slight disturbances in behavior were noted, but most of these quickly disappeared. There was a slight but definite motor incoordination, especially in climbing and jumping. When jumping from a platform to the floor, the animal showed errors in spatial estimation, hitting the floor too soon. This error and the resulting hesitancy in jumping persisted for approximately three days.

Snyder and Pronko (1952) jointly conducted an experiment in which the subject wore a binocular lens system for inverting the visual field. The subject wore the lens system for 30 consecutive days. They tested the visual-motor coordination during the inversion period by means of several tests: a card-sorting task; the Minnesota Rate of Manipulation Test (in which 60 cylindrical blocks are fitted into holes in a wooden base); the Purdue pegboard test; and a mirror-tracing task.

The ambiguity of the expression "seeing things right-side-up". What does it mean when a subject with inverted vision reports that things do or do not appear right-side-up? Four possible interpretations are given below:

1. The person is reporting on impressions aroused when he directed his attention inward; i.e. when he consciously introspects.
2. He is reporting on impressions aroused when he was attending to external things, instead of his introspections.
3. He is reporting on the similarity or difference (as he remembers it) between his visual experience while wearing the inversion apparatus and his visual experience before the inversion apparatus.
4. He is reporting on the relative vividness in his memory of the inversion apparatus type of images and the pre-inversion type of images.

The examples which follow will show how the above interpretations may lead to ambiguous reports by investigators.

First, let us consider the interpretations dealing with introspection: interpretations 1 and 2. It is here proposed that there has been confusion among reviewers of Stratton's writings primarily because Stratton shifted from introspective to non-introspective reports. Some writers claim that Stratton, after wearing inversion lenses for a while, began to see things right-side-up again, and they quote Stratton to verify that point. Other writers also quote Stratton to show that Stratton never arrived at the state of seeing things right-side-up while he wore the inversion lenses.

Stratton, in the course of his reports, mentioned that he became so adept in his visual-motor coordination that often <u>he was not aware that he was using inverted vision</u>. But he also pointed out that at all times when he introspected to see if things looked right-side-up that <u>he was aware that they looked unfamiliar and not right-side-up</u>. These statements of Stratton are not contradictory. One statement refers to his impressions while he was introspecting, the other to his impressions while he was not introspecting. Often he was not aware that he was using inverted vision because he had acquired new visual-motor coordination sufficiently to be able to carry out certain tasks more or less unconsciously, without much concentration. On the other hand, when he consciously considered how things looked to see if they looked right-side-up, they didn't. This phenomenon is similar to what occurs repeatedly in everyday life: a person is not even aware of a multitude of sounds until he directs his attention to them, at which time he can hear and identify them quite easily.

To clarify the distinction between the third and fourth numbered interpretations, an hypothetical situation will be used. Let us assume that a subject has worn a visual inversion apparatus continually from five years of age until he was 30 years old. Now he is asked whether things look right-side-up. Since the person asking the question is not wearing a visual inversion apparatus, the subject assumes that the interrogator means by right-side-up appearance that appearance which is obtained without inversion apparatus. So he concentrates on the visual experience he had before he wore the apparatus, and recalls that it was different from the experience he had after donning the apparatus, although it is vague in his memory since it was so long ago. So, because his interpretation of right-side-up is that given in number 3 above, he replies that things do not look right-side-up. Clearly, using this interpretation of right-side-up appearance, things could never appear right-side-up so long as the subject had any memory of the difference between the type of visual impressions he has with the inversion apparatus and the type of visual impressions he had before wearing the apparatus. Now, let's assume that the subject used number 4 interpretation of right-side-up appearance. Using this interpretation, he would interpret the question as being an inquiry into the comparative vividness of the memory of the type of visual experience before the wearing of the inversion apparatus and the memory of his visual experience since wearing the apparatus. Through the use of number 4 interpretation of right-side-up appearance, the subject would reply that things certainly do look right-side-up; he would mean that inversion apparatus type images are more vivid in his memory than pre-inversion type images.

Cues that tell a person his vision has been inverted. Suppose a person were to wake up some morning and find that he had on a pair of spectacles with some kind of lenses. Without removing the spectacles, how could he tell whether his vision was inverted? The cues that he could use to tell him that his vision has been inverted might be broken into two categories:

1. Intrasensory conflict. This refers to the inverted arrangement of visually familiar objects on the retina. This is the most obvious cue, and many people are not aware that there are other cues. It is called intrasensory conflict, since no other senses than vision are required for this to serve as a cue.

2. Intersensory and sensory-motor conflict. For intersensory conflict to serve as a cue, naturally other senses than vision must come into play. It is the conflict between vision and the other senses such as hearing and the kinesthetic sense that serves as a cue. For example, a person sees his hand move up, but feels it move down. Another example of intersensory conflict is the conflict between sensations from the neck muscles and visual sensations during movements of the head: when the head is felt to be lifted, the upper part of the visual field vanishes (instead of the lower part vanishing, as with ordinary vision).

An example of sensory-motor conflict would be the difficulty encountered in reaching and grasping a seen object; it might be called visual-motor conflict, since the visual-motor coordination is disrupted.

<u>The question of the innateness of right-side-up vision</u>. The problem of the extent to which right-side-up vision is innate has been speculated on, but never subjected to experiment. Right-side-up vision might be operationally defined as that vision which accompanies behavior which is indistinguishable from the type of behavior exhibited by a normal animal. Through the use of this definition, it can be determined whether it would make any difference in an animal's behavior if it were raised from birth with inversion goggles.

Perhaps what has led many people to assume right-side-up vision, and any behavior dependent on vision, to be entirely learned is their belief that the intrasensory conflict (the inverted arrangement of visually familiar objects on the retina) is <u>the</u> cue for inverted vision. Their question is: how can you recognize the inverted arrangement of visually familiar objects unless you have had a chance to become visually familiar with some objects? With no previous arrangement of the objects on the retina, where is the basis for comparison to say if this arrangement is inverted?

Such reasoning neglects an important aspect of inverted vision: intersensory conflict, which may not require visually familiar objects. There may be a conflict with innate associations between the visual sensations and those arising from the kinesthetic or other senses.

That there may be such innate associations is suggested by the observations of investigators that animals turn their head or eyes toward a flash of light when they first open their eyes, apparently with no learning required. What seems to be another unlearned response is the turning of the head in the direction of a sharp sound.

If inverted vision can produce a conflict between vision and the other senses in animals with no visual experience, then such a conflict should be demonstrable in an experimental situation. One such experimental situation is as follows:

<u>Subjects</u>: Three groups of kittens.

<u>Materials</u>: Dark room for raising kittens; right angle "inversion prisms" on spectacle frames; clear optical glass.

<u>Procedure</u>: Kittens are born in the darkness, raised from birth wearing the spectacles.

Group I: spectacles with inversion prisms for both right and left eye.

Group II: spectacles with inversion prism for one eye and optical glass for the other eye (to restrict the size of the visual field and the amount of entering light to the same extent as the prism eye).

Group III: spectacles with optical glass for both eyes.

Thus, Group I will have inverted vision in both eyes; Group II will have inverted vision in one eye and normal vision in the other; and Group III will have normal vision in both eyes.

Visual-motor tasks could be set up on which the animals could be tested and the performance of the groups could be compared. Since it would be possible for an animal in Group II to suppress vision in either the normal or inverted eye, the animals in this group should also be tested with each eye separately and the performance of one eye compared with that of the other.

The role of equilibrium in right-side-up vision. Some relationship between vision and the sense of balance has been observed by most people. Watching things spin around or rock from side to side often makes people dizzy. And conversely, when a person has had his vestibular sense thrown into confusion by spinning or the like, it sometimes appears that things change their spatial orientation by tilting from side to side, or spinning around. It would be necessary to assume extreme cyclotorsional movements (rotary movements of the eye in its socket) if one were to explain this apparent tilt on the basis of eye movement causing a change in the angle at which the image strikes the retina. An alternative explanation could be that the uprightness of vision is dependent on vestibular and kinesthetic sensations being in harmony with the visual sensations. Whether these associations between vision and kinesthetic-vestibular sensations are primarily innate or acquired might be determined through experiment.

Such a relationship could account for certain disturbances of equilibrium due to vision, as well as certain disturbances of vision due to disturbances of equilibrium. Would there be any right-side-up vision in the absence of kinesthetic and vestibular sensations?

BIBLIOGRAPHY

1. Carr, Harvey A. An Introduction to Space Perception. Longmans, Green & Co., New York 1935, 413 p.

2. Chow, K. L. and Nissen, H. W. Personal communication from Dr. Chow, dated Oct. 25, 1954.

3. Cramer, Harald. Mathematical Methods of Statistics. Princeton: Princeton University Press. 1946, 120 p.

4. Ewert, P. Harry. A Study of the effect of retinal stimulation upon spatially coordinated behavior. Genetic psychol. Monog. 7, 1930, 177-363 pp.

5. Foley, John P., Jr. An experimental investigation of the effect of prolonged inversion of the visual field in the rhesus monkey (macaca mulatta), J. genet. Psychol. 1940, 56, 21-51.

6. Hebb, D. O. The innate organization of visual activity. Perception of figures by rats reared in total darkness. J. gen. Psychol., 1937, 51, 101-126 pp.

7. Hebb, D. O. The Organization of Behavior. New York: Wiley. 1949, 335 p.

8. Isreal, H. W. Scoring Stencil for mirror-tracing, J. educ. Psychol. 16, 1925, 537 f.

9. Lashley, K. S. Brain Mechanisms and Intelligence: A Quantitative Study of Injuries to the Brain. Chicago: Univ. Chic. Press. 1929, 186 pp.

10. Lauterbach, C. E. An improved technique in the mirror-tracing experiment, J. exp. Psychol., 1933, 16, 451-453 pp.

11. Levine, Jacob. Studies in the interrelations of central nervous structures in binocular vision: II. The conditions under which interocular transfer of discriminative habits takes place in the pigeon. J. genet. Psychol., 1945, 67, 131-142 pp.

12. Riesen, Austin H., et al. Interocular Transfer of habits learned monocularly in visually naive and visually experienced cats. J. comp. physiol. Psychol. June, 1953, v. 46, no. 3, 166-171 pp.

13. Scheidemann, Norma V. A ruler for scoring mirror-tracing errors. Am. J. Psychol., 1950, 63, 445-446 pp.

14. Siegel, Arthur I. Deprivation of visual form definition in the ring dove: II. Perceptual-motor transfer. J. comp. physiol. Psychol. Aug. 1953, v. 46, no. 4, 249-252 pp.

15. Snyder, F. W. and Pronko, N. H. Vision with Spatial Inversion. Wichita: University of Wichita Press, 1952, 144 pp.

16. Stratton, G. M. Vision without inversion of the retinal image. Psychol. Rev. 1897, 4, 341-360; 463-481 pp.

17. Weidensall, Jean, The mentality of the criminal woman, Educ. Psychol. Monog. 14, 1916, 1-332 pp.

18. Wells, G. R., An apparatus for mirror-drawing test, J. Educ. Psychol. 1918, 9, 99-101 pp.

19. Whipple, G. M. Manual of mental and physical tests. Baltimore: Warwick & York, 1910.

20. Woodworth, Robert S. Experimental Psychology. New York: Henry Holt and Co., 1938, 573 pp.