BINOCULAR RIVALRY, PERCEPTUAL CLOSURE, AND INTELLIGENCE TEST PERFORMANCE

DISSERTATION

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By

Kenneth Jones Crain, B.A., M.A.

The Ohio State University

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Approved by:

[Signature]

Adviser
Department of Psychology
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CHAPTER I
INTRODUCTION

When the eyes are presented with different fields of view, as when slides of different colors are viewed through a stereoscope, one observes not a fusion of the two fields, but a rivalry—first one and then the other is seen. It is even possible, as some have suggested, that this process goes on continually in normal, everyday vision, but that one is not conscious of its occurrence (12, 41, 42).

This phenomenon of binocular rivalry has been studied extensively in an effort to determine its nature. In addition, it has been studied as a "visual skill," that is, as a process influential in affecting other perceptual performances or processes. But as Chenoweth (11) has concluded: "The role of rivalry in a general theory of perception is not clear. Its relationship to other visual skills in not known" (p. 7).

Selzer (34), on a priori grounds, sees rivalry as detrimental to efficient reading. The conditions of eye-muscle imbalance and alternation of the eyes, in addition to a lack of fusion, are held to account for that reading disability not accounted for by general mental disability. Upon rivalry he lays the blame for reversals in reading
(e.g., seeing \( b \) as \( d \)), reversals in the order of letters, and the addition or omission of letters. Thus, when rivalry takes place with individuals who have eye-muscle imbalance, they are unable to maintain their point of fixation on the page. And as functioning shifts from one eye to the other, the point of fixation may move backward or forward, resulting in a reversal in the order of letters or the omission of letters, respectively. Since Selzer makes no reference to the influence of rivalry on the reading of those persons with normal eye-muscle balance, it is difficult to determine whether he conceives of rivalry per se as being detrimental or rivalry only as it occurs in conjunction with the diplopia accompanying eye-muscle imbalance. His discussion in general indicates clearly, however, that he sees the process of rivalry as unfavorable.

That rivalry is related to reading ability in any manner, positively or negatively, finds no experimental support. Clark (13), in a study on college students with normal eye-muscle balance, induced rivalry while the subject was reading by placing a vertical bar in the subject's median plane between the eyes and the material to be read. The effect of the rod was to divide the lines of reading material into four sections. The first and fourth sections were seen binocularly, while the second section could be seen only by the left eye and the third only by the right.
The effect was that the subject read first with both eyes, then with the left only, then with the right only, and finally again with both eyes. The rivalry thus induced did not alter reading efficiency as measured by eye-movement photography. In addition, none of the subjects reported difficulty in reading the material, and six of the ten subjects were unaware that there was any change in the use of their eyes during the reading process.

Crain (15), in a study of college students unselected with respect to any visual criterion, used the Robinson-Hall Reading Test, which yields separate scores of reading speed and comprehension. No relation was found between these indices of reading ability and binocular rivalry.

The only other study in the literature relating reading ability and rivalry rate, so far as the writer has been able to determine, is that of Armistead and Dannenberg (5), in which members of a remedial reading clinic were tested before and after one semester of remedial training. These authors found an "extremely low" rivalry rate in all of their subjects, no subject exhibiting an "adequate performance" at the beginning of training and only 4 per cent after training. The criterion (25 to 30 cycles per minute) used by these authors to gauge "adequate performance" is so extremely high, however, that it is unlikely that even excellent readers could have reached it did a relationship actually exist.
Most investigators of the rivalry phenomenon have postulated an influence of this phenomenon opposite to that held by Selzer. Washburn (42) suggested that rivalry plays an important part in the perception of solidity and is a contributing factor to stereopsis. Clark (12) arrived at a similar conclusion on the basis of his investigations. Several other investigators have placed even more emphasis on rivalry, holding that without its presence stereoscopic perception is impossible (28).

So far as the writer has been able to determine, only one study directly concerned with the relation of rivalry to stereopsis is reported in the literature. Murroughs and Ball (28), in a study of 57 adults with normal binocular vision, found no correlation between stereopsis, as measured by the Betts D. C. airplane series, and binocular rivalry. Until further research is forthcoming, any relationship which exists between rivalry and stereopsis will remain theoretical.

Perhaps because the phenomenon is different from most, or perhaps because it has defied physiological and anatomical analysis, or perhaps simply because there would seem to be some reason for its existence, researchers have tenaciously held that rivalry is related to reading and/or stereopsis and is thus to be considered not only as a phenomenon but
also as a visual skill. Yet it is perhaps not without some basis that such a view is held. Renshaw (32) points out that the rivalry phenomenon is susceptible to practice effects. One of his subjects, trained in 18 practice sessions of two two-minute periods each, increased her rate from 17 to 39 cycles per minute. Further research has confirmed the effect of such training on rate of rivalry (29). And as Renshaw (32) states: "Since the rivalry function can be changed by training the question arises as to whether this does not or should not have a place in orthoptic procedures." With reference to illusions of reversible perspective such as the Necker Cube, which have been shown to be related to binocular rivalry (19, 37), Renshaw (31) states:

It should be noted that in simple illusions of reversible perspective of this type we are dealing with one of the most elementary considerations in seen movement, namely, change of position in space resulting in change of point of regard in a bi-dimensional figure which does not move. Further, it should be noted that we are dealing with one of the simplest and most fundamental considerations in stereoscopic vision. The two dimensional figure takes on third dimensional or depth properties when the observer himself does something, and this change occurs equally well whether the figure is viewed binocularly or monocularly.

Boring (9) concludes similarly: "The problem of the geometrical illusion is not a special problem of space

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1The suggestion of McDougall, later confirmed in a study by George (19), that rivalry is related to performance on scales of introversion-extroversion is an interesting one, but not one to be considered in terms of rivalry as a "visual skill."
perception. When the general laws are known, the illusions will also be understood" (p. 345).

It was in a study of binocular rivalry as a visual skill that the writer first became aware of the possibility of rivalry as something more than a "skill." In this study (15), 40 unselected undergraduate male students of the Ohio State University were tested with respect to several visual skills, these in turn being studied as to their relationship to the student's raw score on the Ohio State Psychological Examination (OSPE) and his point-hour ratio. The relationships obtained between binocular rivalry, on the one hand, and OSPE score and point-hour ratio on the other were as follows: (1) Using the eta coefficient and its corresponding epsilon value as the index of correlation, the regression of OSPE score on rivalry rate yielded an epsilon of .64, which was significant at the .01 level; and (2) the t-ratio of the difference between the mean rivalry rates of the highest and lowest thirds of the subjects (13 in each group) with respect to point-hour ratio was 2.88, which was significant at the .01 level. The mean rivalry rate for the entire group of 40 subjects was 12.7 cycles per minute, that for the highest third of the subjects with respect to point-hour ratio was 15.4, while that for the lowest third with respect to point-hour ratio was 9.2. The mean rivalry rate of the middle third of the subjects (not used in the t-test) was 13.5.
It was the writer's preference not to interpret these results, but rather to formulate an hypothesis which was suggested by the data and which would require separate, more critical investigation. The hypothesis is this: that level of intellectual functioning and rate of binocular rivalry are related, higher intelligence being associated with higher rate of rivalry and lower intelligence being associated with lower rate of rivalry.

In an attempt to test this hypothesis, 41 undergraduate students at the Ohio State University were tested on Raven's Progressive Matrices Test, after which each subject was tested individually with respect to binocular rivalry rate. The correlation (Pearson r) between intelligence test scores and rivalry rate was .42, which was significant past the .01 level.

As an even more critical test of the hypothesis, 40 undergraduate students at Ohio State were tested individually with the Wechsler-Bellevue Intelligence Scale for Adults, Form I. After the test was completely scored and his IQ derived, each subject was tested individually with respect to binocular rivalry rate. Most of the subjects were enrolled in the beginning psychology course at the University, but, as in the previous studies, no criterion for selection of subjects was used, visual or otherwise. Measurement of rivalry was accomplished in a manner identical to that used
by the investigator in the previous studies (and as described in Chapter III).

The correlation (Pearson r) obtained between the Full Scale IQ score and rate of rivalry was .24, which was not significant. However, a test of the significance of the difference between the mean binocular rivalry rates of the high and low IQ groups (the Full Scale IQ distribution having been divided into halves) was significant at the .05 level ($t = 2.08$). The mean rivalry rate of the high IQ group was 14.3 and that of the low IQ group 10.9 cycles per minute. Further analysis revealed that the relation between the Full Scale IQ and rivalry was primarily a reflection of that between the Performance Scale IQ and rivalry. The t-test of the difference between the mean rivalry rates of the high and low Performance IQ groups (the distribution being divided into halves) was significant past the .01 level ($t = 3.13$). The mean rivalry rate of the high IQ group was 14.9 and that of the low IQ group 10.1 cycles per minute. Although the difference between the mean rivalry rates of the high and low Verbal Scale IQ groups was in the predicted direction, it was not large enough to be significant.

Binocular rivalry and intelligence are related. This much is evident. What the nature of this relationship poses quite another problem. Spearman (35), in a discussion of the phenomenon of "oscillation in cognitive efficiency," felt that the available evidence indicated that this
phenomenon (including binocular rivalry) constitutes a unitary function and has a central origin. Statistical analysis led him to conclude, however, that it was not $g$ which made the different oscillations correlate with one another. Perserveration was likewise rejected as a possible origin of the correlations displayed by the oscillations. He concluded that oscillation represents a new single and universal factor, a third in addition to $g$ and perserveration.

Since there was no evidence to the contrary, Spearman had assumed that the measures of oscillation in efficiency with which he was dealing in the tetrad analysis were related to measures of such phenomena as binocular rivalry and reversible perspective. Later research in his own laboratory, however, clearly indicated that that assumption could not be made (36). Thus, while there is ample evidence to indicate that the phenomena of reversible perspective and binocular rivalry are related (19, 37), there is additional evidence that these phenomena are unrelated to those which Spearman refers to as "oscillations in cognitive efficiency."

Thurstone (37), in a factorial study of numerous perceptual tests, identified twelve factors, three of which have relevance to the present discussion. Factor A was interpreted as representing the ability to form and/or to hold a perceptual closure against distraction. Highest saturations on factor D were identified with tests of alternation effects in perception. Factor E was
interpreted as representing the ability to eliminate one set in order to take a new one, or "flexibility in manipulating several more or less conflicting gestalts." One of the perceptual tests which had a moderate saturation (.35) on factor A, the Street Gestalt Completion Test, also had a low saturation on factor D. Thurstone states that this saturation may or may not be significant. "If it is significant, then we should conclude that those subjects who have a high rate of alternation of ambiguous presentations tend to find a meaningful closure in a relatively short time." (36, p. 109).

Although this last finding is suggestive only, it becomes the more interesting under further consideration of the results of the study. The tests which had the highest saturations on factor A also had appreciable saturations on factor E, the most notable of these being the Gottschaldt Figures Test and the Block Design Test. And concerning the factor E, Thurstone states: "Since the reasoning tests of the primary mental abilities have significant loadings on the factor E, one might wonder whether this factor represents one important aspect of intelligence" (p. 111). Along this line, it will be recalled that the Block Design Test, which gave saturations on both factors A and E, is also one of the subtests of the Performance Scale of the Wechsler-Bellevue.
In the light of Thurstone's findings, the hypothesis presents itself that, if rivalry is related to the ability to form a closure out of an unorganized presentation or to hold a closure against distraction, then rivalry may be related to intelligence through the mediation of performance on such tests as involve this factor of closure. At least one test (Block Design) of the Wechsler-Bellevue is heavily saturated with factor A, and it appears likely that others, especially the Object Assembly Test, may be also (39). That the relationship between intelligence and rivalry was found to be primarily a reflection of that between the Performance Scale IQ and rivalry lends support to this point of view. And it would seem that the study involving the Progressive Matrices Test should certainly be in accord with this approach. Wechsler (40), in a review of the latter, characterizes the "themes" of certain subtests as "progressive alteration of patterns," "permutations of figures," and "resolution of figures into constituent parts."

2In the study by the writer reported above, the distribution of raw scores of the Block Design subtest was divided into halves and a test of significance of difference was computed between the mean rates of binocular rivalry of the high and low groups, to determine if some relation existed with rivalry. The difference was small and not significant. Since the closure factor may be represented in several of the subtests of the Performance Scale, however, rivalry might still quite possibly be related to performance on that scale as a whole as a function of a more primary relation to the closure factor.
If rivalry were found to be related to performance on tests of this type (involving the factor of closure), one would be inclined to conclude, as a first hypothesis, that rivalry was related not to intelligence in the abstract, but intelligence as it is measured. Further, as a first hypothesis, one would conclude that rivalry was related not to intelligence in a general manner, but rather in some specific aspect. Thus, rivalry would be seen as related to the Performance Scale IQ of the Wechsler-Bellevue, for example, not because of some general relationship transcending the various subtests, but because of a stronger specific relation to such subtests which involve the factor of closure. One might then conclude, again as a first hypothesis, that (a) rivalry functioned as a direct influence on these perceptual tasks or that (b) rivalry was correlated with other visual functions which in and of themselves alone had a direct influence on those tasks involved in intelligence testing. If the former of these were the case, then it should follow that rivalry would be functioning as a visual skill, and increasing the rate of rivalry should effect improvement in performance on such tasks. It was with such an approach to the problem that the present experiment was designed.
CHAPTER II

THE PROBLEM

In the 1860's Francis Galton, desiring to study the effects of heredity and environment upon the development of mental abilities, made an attempt to measure intelligence, the tests used by him being largely those of sensory discrimination. Delicacy of weight discrimination was one such test and a test measuring susceptibility to high tones was another. Although it is now known that elementary sensory and motor processes bear little relationship to intelligence, the influence of Galton was felt until the time of Alfred Binet (18).

Binet shifted the emphasis away from elementary sensory and motor processes and onto tasks which were predominately verbal in nature, and this trend was continued in the several revisions of this scale. However, there are many for whom these tests cannot be used (for example, the deaf and the illiterate). A type of test which placed no emphasis upon language was thus devised as a substitute for or a supplement to the Binet scales. The use of these "nonverbal" or performance tests has since been extended, and they are now employed not only for those with special
disabilities but also, at least in the case of certain
tests, for everyone tested. The Wechsler-Bellevue, for
example, the most commonly used intelligence test for adults,
yields a separate Performance Scale IQ (18).

However, it is clear that certain performance tests
also cannot be used in testing everyone. The color blind
person might be penalized on such a test as Block Design
and the illiterate on such tests as Digit Symbol, both of
which are contained in the Wechsler-Bellevue Test.

One may wonder, then, just what the influence is of
such visual functions as the "visual skills" (stereopsis,
eye-muscle balance, binocular rivalry, and the like) on
performance tests of intelligence. None, one would think, None of the visual skills have been shown to be very
strongly related to reading ability, much less to intelli-
gence. Yet, one visual skill, binocular rivalry, has been
found to bear a relation to intelligence. Could it be
possible, then, that binocular rivalry functions in its
relation to intelligence through its function as a visual
skill? Just as the color blind person might be penalized
on certain performance tests, could the person possessing
a low rate of rivalry be similarly penalized?

Thurstone (37) had obtained a finding suggesting of
a relation between binocular rivalry and performance on
tests of perceptual closure. Since several of the
performance subtests of the Wechsler-Bellevue also appear to involve the closure factor, it would seem pertinent to study more fully the suggestion of Thurstone.

Accordingly, the problem of the present investigation is that of determining whether binocular rivalry actually bears a relationship to performance on tests of perceptual closure. If a relation is found, the problem is that of determining whether rivalry functions as a visual skill, influential in and of itself, in effecting improvement in performance on such tests of closure when an increase in its rate is achieved through training.
The subjects of the experiment were 70 undergraduate students, ranging in age from 17 to 47, all of whom were enrolled in the beginning psychology course at the Ohio State University. Selection of each subject for inclusion in the experiment was based on rate of binocular rivalry, only those persons being included whose rates were below 11 or above 14 cycles per minute. Exclusion of persons whose rates fell between these limits was intended simply to provide for a clearer division between groups. No other criterion for selection of subjects was used.

The binocular rivalry measurements were made with the aid of a Renshaw Stereo-Disparator. This instrument is a mechanism for presenting to the eyes pairs of half-stereograms in order that optically correct positioning for stereoscopic fusion may be obtained. Although the instrument has several specialized uses, its use in the present experiment was limited to that of any ordinary stereoscope, and it will hence be referred to simply as "stereoscope" throughout the following discussion.

Conditions under which measurement of rivalry was accomplished were constant for all subjects; the room in which the measurements were made was lighted by a 100-watt
bulb situated approximately two feet above the head of the observer. The slides used are described by alternating black and white stripes which run diagonally, in the case of the right-eye slide, up to the right and, in the case of the left-eye slide, up to the left. These slides differed somewhat from those used by the writer in previous investigations in that the black stripes were 3 mm. and the white stripes 6 mm. wide, whereas both the black and the white stripes on slides used previously were 3 mm. wide. Preliminary investigation by the writer on a separate group of subjects, however, revealed no effect on rivalry rate as a function of this difference between the slides. These slides were mounted in the stereoscope at far point (focal distance of 200 mm.) such that, when viewed through the instrument, they fused to form a single slide approximately four inches in width. No part of a slide designated to be viewed by one eye was seen by the other.

The subject was seated before the stereoscope and instructed as follows:

Closing your left eye and looking through with your right, you see some black lines on a white background and that they run from the lower left up to the upper right-hand corner.

Now close your right eye and look through with your left. You see the lines going from the lower right to the upper left.

Now with both eyes open, you will see the lines cross, forming a lattice. As you continue looking, you will notice a fluctuation of the lines; sometimes you will see them going up to the right and sometimes up
up to the left. When most of the lines go up to the right, call out "Right"; and when most of them go up to the left, call out "Left." Do not try to force the alternations, but simply assume a passive attitude.

Two trials of one minute each were given, with an interval of one-half minute being allowed between trials for the subject to rest. A stopwatch was used to time these periods. After the subject had called out "Right" once or twice, the watch was started, on a response of "Right." After the first minute the watch was stopped and the number of cycles recorded (a cycle being defined by a response of "Right" followed by a response of "Left," regardless of time interval). Only such complete cycles were recorded, except where the one-minute period ended on a response of "Right," in which case a complete cycle was counted. Although the rivalry rate was recorded for both of the one-minute periods, only that of the second minute was used in the computations.

The subjects were divided into three groups on the basis of their rivalry rates. One group (hereafter designated the High Rivalry group) consisted of 24 subjects whose rates were 15 cycles per minute or above. The other two groups consisted of subjects whose rates were 10 cycles per minute or less, the subjects being arbitrarily placed in the one or the other group. One of these groups (22 subjects) will hereafter be designated the Low Control
group and the other (21 subjects) the Low Training group.

All subjects, irrespective of which group in which they were placed on the basis of binocular rivalry rate, were tested initially on eight of the figures from Thurstone's modification of the Gottschaldt Figures Test (38). Only eight of these figures were used, since the remaining eight were contained in the original Gottschaldt Figures Test, which was to be used as part of the post-test. Whereas Thurstone's test simply requires the subject to indicate in which of the complex figures the sample figure is to be found, in the present case the subject had to trace that part of the complex figure which was the same as the sample figure. This latter modification was designed to make this pre-test somewhat more comparable to the original Gottschaldt Figures Test (used by Thurstone in his factorial study and in the post-test of the present experiment). The subjects were told that the sample figure of a given row was to be found in one or more of the more complex figures of that row, the figure to be traced being the same size and in the same position as the sample figure. They were further instructed that, since this was a speed test, neat tracings were not necessary but that they were to trace as accurately as they could. The test was administered in group form. A sample of the test used is contained in Appendix A.
The scoring for this pre-test (hereafter called Gottschaldt Pre-Test) was \( \frac{C}{T} \), computed to the nearest tenth of a point, where \( C \) was the number of designs in which the sample figure was correctly traced (one point each) minus one point for a design skipped and one-half point for a design in which the sample figure was partially but not completely traced correctly, and \( T \) was the time taken to complete the test in minutes.

Following the administration of Gottschaldt Pre-Test, a period of about one week was allowed to intervene before any subsequent testing. Subjects of both the High Rivalry and the Low Control groups were then tested individually a second time on binocular rivalry and on the Street Gestalt Completion Test and on a test of reversible perspective.

The task confronting the subject in the Street test is the identification of the pictures presented. Twenty-seven pictures, the same as those used by Thurstone in his factorial study, were used in the present experiment and are shown in Figure 1. The pictures themselves measured \( 3 \times 2 \) inches and were mounted on gray cardboard measuring \( 3 \times 5 \) inches.

The subject was instructed as follows:

I am going to show you some pictures which I want you to name as quickly as you can. (Showing Picture 1, "Sailboat") This is a sailboat. Not all of the pictures will be so clear as this one, since many of them will have more parts missing.
FIGURE 1

THE STREET GESTALT COMPLETION TEST
Before each picture is presented, I will have you close your eyes. When I say "Open," open your eyes and try to name the picture as quickly as you can. If your response is correct, I will stop the stopwatch; that will be your sign to automatically close your eyes again and wait for the next picture. If your response is not correct, or if it is not quite specific enough, I will let the stopwatch run and you are to continue trying to name the picture. You are allowed to guess as many times as you wish in this test, since wrong guesses will not count against you. By being as specific as you can I mean, for example, rather than simply calling this a "boat," you would call it a "sailboat."

The picture in each case was rested on a table about a foot and a half from the subject and perpendicular to his line of regard. This method of presentation differed from Thurstone's primarily in that in the latter the pictures were projected on a screen situated fifteen feet from the subject.

Maximum time allowed the subject on any one picture was 30 seconds. Table 1 contains the accepted response or responses for each picture. Responses which are not marked by asterisk correspond to those which Thurstone had accepted as correct in his study; those so marked were also accepted as correct in the present investigation. These latter responses were accepted since it was apparent that a stricter scoring was tapping something other than simple perceptual "closure." Thus, while one would look for a response more definitive than "Bird" to Picture 18, one would also be hard put to say just why the correct response should be "Eagle," and not "Hawk" or "Falcon." In the case
<table>
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<th>Table 1 Correct Responses for the Street Gestalt Completion Test</th>
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| (a) 1. Sailboat (Demonstration Item)  
2. Boy, Man*  
3. Soldier, Oriental  
4. Airplane  
5. Dog  
6. Baby, Child*  
7. Geese, Ducks*, Birds in Flight**  
8. Couple Dancing  
9. Rabbit |
| (b) 10. Woman at Washtub  
11. Dog  
12. Tennis Player, Man Hitting Ball*  
13. Baseball Player  
14. Man on Horse  
15. Stove  
16. Horse and Buggy  
17. Automobile  
18. Eagle, Falcon*, Hawk* |
| (c) 19. Runner, Football Player*  
20. Table  
21. Man on Horse  
22. Horses and Plow  
23. Locomotive  
24. Man and Girl  
25. Boy on Tricycle  
26. Man's Face (General Grant)  
27. Photographer Kneeling, Man Bending Down Catching Something** |

* Designates response also accepted as correct  
** Designates response given partial credit (see Text)
of pictures 7 ("Geese") and 27 ("Photographer"), partial credit was given if the subject said "Birds in flight" or "Man bending down, catching something," respectively, or if some such similar ideas were conveyed. These responses were given some weight since it would be clear that closure had occurred at least to the extent that a generally correct identification had been made. It is evident, for example, that a greater difference in terms of closure exists between the responses of "Fish" and "Birds in flight" to picture 7 than between the latter and that of "Geese."

The score on this test was the total number of seconds taken to identify all the pictures. If the response was correct, the time recorded was the time taken to begin the response. Where the subject did not identify a picture within the time allowed, he was given a score of 30 seconds on that picture. In the case of pictures 7 and 27, if the response for either was as indicated above, the time taken to give that response was recorded but the stopwatch allowed to continue running; this score was then averaged with the time taken to give the "correct" response or with the maximum time (30 seconds) if that response was not forthcoming.

Measurement of rate of reversal of perspective was used as a control condition and was accomplished with the use of the Necker Cube illusion. The cube was drawn on white cardboard which was then mounted on a block of wood
so as to maintain as constant as possible the angle at which the drawing was presented. A picture of the cube is presented in Figure 2. The sides of each square measured 25 1/2 mm. and the diagonal lines 18 1/2 mm. A fixation point was placed in the center of the drawing.

The drawing was placed approximately one foot from the subject and the following instructions presented.

Look at this cube. It can be seen in two ways. Sometimes this point (Pointing to the corner marked "A" in Figure 2) appears to be forward, one of the front edges of the cube, and sometimes it appears to be in back of the cube, one of the back edges.

Try to concentrate your attention on the dot in the center of the cube. Avoid looking at the corners or letting your eyes wander over the drawing. When this edge (Pointing to corner "A") appears to be out near you, one of the forward edges of the cube, say "Out." When it appears to be away from you, in back of the cube, say "In." Do not try to force the alternations, but simply assume a passive attitude.

This test was scored in the same manner as that of binocular rivalry. Two trials of one minute each were given, with an interval of one-half minute between trials to allow the subject to rest. Only complete cycles were recorded ("out" followed by "in," or vice-versa), except where the minute ended on a half-cycle, in which case a complete cycle was recorded. The alternation rate of only the second minute was used in the computations.

Approximately one week following the administration of the above individual tests, the subjects of the High
FIGURE 2
THE NECKER CUBE
(Original Size)
Rivalry and Low Control groups were tested in groups on the original Gottschaldt Figures Test. Following Thurstone's lead (37), the test was divided into two sections, the designs of Parts I and II comprising "Gottschaldt A" and those of Parts III, IV, and V comprising "Gottschaldt B." A sample of the test is contained in Appendix B.

For Gottschaldt A, Part I, the subjects were instructed to trace in each of the designs that part of the second design which was the same as the first; for Gottschaldt A, Part II, to find the sample figure in each design below it and to trace it, tracing only one figure in each design; and for Gottschaldt B (Parts III, IV, and V), to trace that part of each design which was the same as one of the sample figures at the top of the page, tracing only one figure in each design. The subjects were told that in each case the sample figure was reproduced in the more complex design in the same position as in the sample and that it was of the same size as in the sample. As with the Gottschaldt Pre-Test, the subject were told that since this was a speed test neat tracings were not necessary but that they should be as accurate as possible. They were instructed, finally, not to spend too much time on any one design.

Gottschaldt A was administered first and then Gottschaldt B, instructions and illustrations for each being given separately just prior to administration. The time
limit specified for Gottschaldt A was 2 minutes, while that for Gottschaldt B was 8 minutes. This allowed 10 minutes for the combined test, in contrast to Thurstone's allowance of 14 minutes. Scoring for both Gottschaldt A and Gottschaldt B was C/T, where C was the number of designs correctly traced and T was the time allowed (2 and 8 minutes for Gottschaldt A and Gottschaldt B, respectively). Where a subject finished either test in less than the allotted time, his time for that test was recorded and was used as the denominator. This scoring differed from that of Thurstone primarily in that in the latter Gottschaldt A was scored simply in terms of the number of designs correctly completed within the time allowed. Scoring of Gottschaldt B, on the other hand, corresponded to Thurstone's.

The subjects of the Low Training group were tested in a manner similar to that employed with the High Rivalry and Low Control groups, with the exception that intervening between the pre-test (comprising the first binocular rivalry measurement and the Gottschaldt Pre-Test) and post-test (Necker Cube illusion, final binocular rivalry measurement, and Gottschaldt A and B) were five days of training on binocular rivalry.¹

¹Since no difference was found between the High Rivalry and Low Control groups in performance on the Street Gestalt Completion Test, this test was not administered to the Low Training group. The statistical analysis of the results on this test are presented in Chapter IV.
Training was accomplished with the aid of Slide #9 of the PV series (Three Dimensional Company). This slide is composed of two polaroid films each of which is polarized on a different plane. The films are diagonally lined in opposite directions, in a manner similar to the slides described above used in the measurement of the phenomenon. By inserting a polarizing filter in front of the lens of a projector and projecting the slide onto a screen, the direction of the lines on the screen, when viewed through polaroid glasses, can be controlled. The subject was equipped with polaroid glasses, and conditions were thus set up so that stimulation to each eye could be controlled and, when the filter was shifted through a 90° angle, artificial rivalry induced.

On the first day of training a metronome was set for 24 beats per minute and the filter shifted in time with each beat. A complete phase (right- and left-eye stimulation) being accomplished with every two beats, rate of rivalry thus induced was 12 cycles per minute. On the second day the metronome was set for 30 beats per minute, allowing for an induced rivalry rate of 15 cycles per minute. On the next day the metronome was set for 48 beats and rivalry speeded to 24 cycles per minute. On the remaining two days, rivalry was induced at 30 cycles per minute (metronome set at 60 beats per minute).
On the day following the last training session, each subject of the Low Training group was tested individually with respect to binocular rivalry rate and rate of reversible perspective on the Necker Cube and in groups on the Gottschaldt tests. Testing was so arranged that the subjects of the training group were administered the Gottschaldt tests on the same day as were those of the High Rivalry and Low Control groups.
CHAPTER IV
RESULTS AND DISCUSSION

A measure of the reliability of rivalry rate was computed (measurements made one week apart) for the subjects of the High Rivalry and Low Control groups (N = 46) and was found to be .89. The indicated degree of correlation is somewhat spuriously high as a function of the exclusion of part of the middle of the distribution, however, and hence should not be taken at face value. The reliability of rivalry rate computed for the High Rivalry and Low Control groups separately was .73 and .47, respectively. These correlations, in contrast to that computed for the groups combined, are spuriously low due to the restriction in range of rivalry rate of each group taken separately. These latter indices, nevertheless, are probably somewhat more meaningful in terms of the present investigation than is that computed for the groups in combination.

Table 2 presents, for each of the groups separately, the means and standard deviations of all measures taken and the standard errors of the means of the binocular rivalry and reversible perspective measures. For the binocular rivalry and Necker Cube measures, the means are stated in terms of the number of cycles per minute; that of the
### TABLE 2
MEANS AND STANDARD DEVIATIONS OF ALL TESTS USED, AND STANDARD ERRORS OF THE MEANS OF THE BINOCULAR RIVALRY AND NECKER CUBE MEASUREMENTS

<table>
<thead>
<tr>
<th></th>
<th>Binocular Rivalry</th>
<th>Gottschaldt Pre-Test</th>
<th>Street Completion Test</th>
<th>Necker Cube</th>
<th>Gottschaldt Figures Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>II</td>
<td></td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>High Rivalry group</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(N = 24)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>20.0</td>
<td>21.8</td>
<td>3.08</td>
<td>299.7</td>
<td>10.9</td>
</tr>
<tr>
<td>( \sigma )</td>
<td>4.13</td>
<td>5.55</td>
<td>0.82</td>
<td>85.21</td>
<td>4.13</td>
</tr>
<tr>
<td>( \sigma_m )</td>
<td>0.86</td>
<td>1.16</td>
<td>--</td>
<td>--</td>
<td>0.88</td>
</tr>
<tr>
<td>Low Control group</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(N = 22)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>7.7</td>
<td>9.0</td>
<td>2.66</td>
<td>316.1</td>
<td>5.9</td>
</tr>
<tr>
<td>( \sigma )</td>
<td>2.30</td>
<td>3.60</td>
<td>0.78</td>
<td>79.20</td>
<td>2.16</td>
</tr>
<tr>
<td>( \sigma_m )</td>
<td>0.50</td>
<td>0.79</td>
<td>--</td>
<td>--</td>
<td>0.47</td>
</tr>
<tr>
<td>Low Training group</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(N = 21)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>6.5</td>
<td>9.9</td>
<td>2.91</td>
<td>--</td>
<td>8.1</td>
</tr>
<tr>
<td>( \sigma )</td>
<td>2.72</td>
<td>4.19</td>
<td>0.91</td>
<td>--</td>
<td>4.48</td>
</tr>
<tr>
<td>( \sigma_m )</td>
<td>0.68</td>
<td>1.05</td>
<td>--</td>
<td>--</td>
<td>1.12</td>
</tr>
</tbody>
</table>
Gottschaldt Pre-Test in terms of the ratio of number of designs correct to time taken to complete the test; that of the Street Gestalt Completion Test in terms of the total number of seconds required; and those of Gottschaldt A and Gottschaldt B in terms of the ratio of number of designs correct to the time allowed on either test. Gottschaldt "Total" represents the mean score of both A and B combined.

The mean binocular rivalry rates of the High Rivalry and Low Control groups are seen to be 20.0 and 7.7 cycles per minute, respectively (measure I). This difference is so large that we may very confidently conclude that these groups were reliably different with respect to rate of rivalry. This is not surprising, of course, since the groups were so selected. On the other hand, the mean rivalry rate of the Low Training group is 6.5 cycles per minute, which is not significantly different from that of the Low Control group. The assumption may be made for these latter groups, then, that there was no selective factor, at least with respect to the variable in question, underlying the placement of subjects in the one or the other group.

It will be noted, further, that the mean rate of rivalry of each of the three groups increased on the second measurement over that of the first. Only one of these differences is significant, however. The difference between the mean rates of the first and second measurements of the
Low Training group is 3.4 cycles per minute (t = 3.78, correlated samples, significant past the .01 level). Since the Training group differed from the Low Control group only in the training obtained, we may conclude that the training was the factor underlying the significant increase in mean rivalry rate of the trained group. On the other hand, it is clear that the rivalry rate of this group after training did not even nearly approach the mean rate of the High Rivalry group and was not even high enough to be significantly different from that of the Low Control group. This is not taken to be evidence against the efficacy of training on rate of rivalry, but as rather quite possibly a function of the short period of time spent in training.

As can be readily seen from Table 2, there were no significant differences between the groups on the Gottschaldt Pre-Test, Street Gestalt Completion Test, or on Gottschaldt A or B or a combination of the two. As was stated earlier, the Street test was not administered to the Low Training group, since a significant difference between the mean performances of the High Rivalry and Low Control groups did not exist (a test of significance of difference yielding a t of practically zero). The mean performances of all three rivalry groups on Gottschaldt A, Gottschaldt B, and a combination of both A and B were all so similar as to be judged by inspection not to be significantly different from one another. Had the differences between the means on the
Gottschaldt tests been significant, it would have been necessary, in order to determine the influence of rivalry per se, to have selected another Low Training group and to have continued training in an effort to make their mean rate of rivalry equal that of the High Rivalry group. Since performance on the Gottschaldt tests were so nearly identical for all groups, this continuation of the experiment was unnecessary.

The results of the present investigation indicate that binocular rivalry is not related to tests of closure such as the Gottschaldt Figures Test and the Street Gestalt Completion Test. The Gottschaldt tests were chosen for the present study since they were not only highly saturated on factor A (closure) but were also, of the tests of closure, most highly saturated on factor E, which Thurstone felt might represent one important aspect of intelligence. The Street test was used since this was the only test associated with factor A which was found to have at least some saturation on factor D, on which rivalry had high loadings. Had there been some relationship, it should have been observed, especially with the use of groups with such large differences with respect to rivalry rate.

Since others have obtained a relation between rate of fluctuations in binocular rivalry and that in tests of reversible perspective, the Necker Cube Test was used as a control condition. A test of significance of difference
between the mean rate of reversal of perspective of the High Rivalry group (10.9 cycles per minute) and that of the Low Control group (5.9 cycles) yielded a t of 4.84, which was significant past the .01 level. The mean performance of the Low Training group (8.1 cycles), on the other hand, was not significantly different from that of either the High Rivalry or Low Control groups. Why there should be no reliable difference between the means of the High Rivalry and Low Training groups is somewhat problematical considering the great difference between these groups with respect to rivalry rate. The finding of George (19) that males tend to score higher than females on tests of reversible perspective would not appear to account for the difference obtained in the present case between the High Rivalry and Low Control groups, on the one hand, and on the other the lack of difference between the High Rivalry and Low Training groups, since the relative number of males and females was approximately constant for all three groups.

A second possible answer to the problem is suggested by the finding that voluntary control of rate of fluctuation in tests of reversible perspective are about twice as effective as that in tests of binocular rivalry (19). It may have been, then, that the subjects of the Training group were influenced by suggestion and unknowingly influenced their rate of fluctuation. Of course, the same thing could be said for their increase in rivalry rate, except
that one would hardly expect significant differences in the latter and not in the former (over that of the Control group) when it is the former of these which is more susceptible to voluntary influences. Again, of course, both of these tests were administered under a passive set on the part of the subject.
CHAPTER V
GENERAL DISCUSSION

It was stated earlier that no relationship was found between the Block Design Test of the Wechsler-Bellevue and rivalry in a previous investigation of the writer. It appeared pertinent, then, as a result of that finding and those of the present investigation to analyze further the data of that previous study, the question being: Is rivalry related to any of the subtests, individually considered, of the Performance Scale of the Wechsler-Bellevue? That is, if rivalry is not related to tests of closure in general, and to the Block Design Test in specific, could it be related to any other subtest or subtests in so strong a manner that at least its obtained relation to the Performance Scale IQ could be explained as primarily a reflection of such a relationship? The answer is that this is not the case. The subjects' raw scores on each subtest of the Performance Scale were tallied and the distribution divided
into halves.¹ Tests were made of the significance of the difference between the mean binocular rivalry rates of the high and low groups with respect to performance on each subtest. In Table 3 are shown the mean rivalry rates of the high and low groups with respect to subtest performance, with the corresponding values of the tests of significance of difference. It will be noted that, while four of the five differences are in the predicted direction, not one of them is large enough to be significant.

The conclusion can be made that binocular rivalry is not related to the Performance Scale IQ through the mediation of some stronger relationship to certain specific subtests, but that it is related, rather, to performance on the total scale as a unit. As a further check that distortion of the results was not introduced as a function of the use of the

¹In the original study in which the relationship was obtained between rivalry and Performance Scale IQ, the 40 subjects were not divided into two groups of exactly 20 each on the basis of IQ, since the cut-off point would have fallen between scores of the same value. Hence, the distribution was divided at that point which would provide for as equal a grouping as possible and yet not place subjects with equal IQ scores in both groups. The division thus made resulted in the high IQ group containing 22 subjects and the low group 18 subjects. The same result obtained for all three IQ distributions (Full Scale, Verbal, and Performance), the most natural division placing 22 and 18 subjects in the high and low groups, respectively. This exact division was not possible in the case of most of the subtest distributions, but size of groups was kept as constant as possible throughout. Table 3 shows the number of subjects in the high and low groups for each subtest. One subject was color blind, and was hence not administered the Block Design Test. For the analysis of the sums of the raw scores of the Performance Scale, the division of 22 to 18 was again possible.
TABLE 3
MEAN BINOCULAR RIVALRY RATES OF THE HIGH AND LOW HALVES OF THE DISTRIBUTION WITH RESPECT TO PERFORMANCE ON EACH OF THE SUBTESTS OF THE PERFORMANCE SCALE OF THE WECHSLER-BELLEVUE INTELLIGENCE TEST

<table>
<thead>
<tr>
<th>Subtests</th>
<th>Mean Rivalry Rate of High Group</th>
<th>Mean Rivalry Rate of Low Group</th>
<th>t-ratio of Difference Between Mean Rivalry Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Picture Arrangement</td>
<td>14.1 (N=21)</td>
<td>11.4 (N=19)</td>
<td>1.62</td>
</tr>
<tr>
<td>Picture Completion</td>
<td>13.8 (N=21)</td>
<td>11.6 (N=19)</td>
<td>1.31</td>
</tr>
<tr>
<td>Block Design</td>
<td>13.2 (N=20)</td>
<td>12.7 (N=19)</td>
<td>0.29</td>
</tr>
<tr>
<td>Object Assembly</td>
<td>12.2 (N=22)</td>
<td>13.7 (N=18)</td>
<td>1.00</td>
</tr>
<tr>
<td>Digit Symbol</td>
<td>13.6 (N=21)</td>
<td>11.8 (N=19)</td>
<td>1.06</td>
</tr>
</tbody>
</table>
subtest raw scores in this analysis (whereas the Performance Scale IQ incorporates the use of weighted scores), a test of significance of difference between the mean rivalry rates of the high and low groups with respect to performance on the Performance Scale was again computed, but this time, instead of using IQ scores or even weighted scores, the sums of the raw scores were used. The mean rivalry rate of the high group was 14.5 and that of the low group 11.1 cycles per minute, respectively. The t-test value was 2.09, significant at the .05 level.

How can one reconcile the relationships obtained--its relation to point-hour ratio, to the Ohio State Psychological Examination (a verbal test), to a visual test of intelligence (Progressive Matrices Test), and to the total score on the Performance Scale of the Wechsler-Bellevue but not in any reliable manner to any of the subtests of this scale? The conclusion appears inescapable: Binocular rivalry is a phenomenon which, in its relation to intelligence, is of general scope. And it could hardly function in this regard as a visual "skill."

Almost every investigator of the phenomenon of rivalry has concluded that it is of central origin. Just why it should be or how it could be of central origin no one, with the exception of McDougall (27), has attempted to make explicit. It is the writer's feeling, however, that the findings presented above demand an explanation of the rivalry
phenomenon in terms of brain dynamics, at least in part. It is with this goal in view that the following analysis of the conditions necessary for the occurrence of rivalry is made and the following general theory of its nature and physiological correlates is presented.

**Conditions Necessary for the Occurrence of Rivalry**

One gets the impression from the writings of certain investigators that a necessary condition for the occurrence of rivalry between non-homogeneous fields is the interaction between the contours of the different figures presented to the eyes (11). That interaction between contours influences the process is undoubtedly true, but this is not the same as saying that a causal relation exists. When a white slide with black stripes is presented to one eye and a plain white slide to the other eye, rivalry is observed—contrary to Alexander's (4) statement that the figure will be seen continuously—, the stripes appearing to blot out and reappear partially or totally. This would appear to be conclusive enough evidence that the occurrence of rivalry between non-homogeneous fields is not dependent upon the interaction between the contours of the figures in the fields.

---

2Rivalry between homogeneous fields, such as that obtained between slides of different colors, can be conceived, of course, as dependent upon factors different from those functioning for non-homogeneous fields.
The point could be raised, however, that the texture of the plain white slide produces enough "figure" to result in rivalry. Thus, while the process may not require interaction of contours, it could still be a "figural alternation" process. To test this point, the writer stimulated one eye with a homogeneous light field, thus avoiding any possibility of texture (the "figure") being perceived, while the other eye viewed the black- and white-striped slide through the stereoscope. The homogeneous light field was produced by placing a half of a ping-pong ball over the eye and adjusting a daylight bulb directly in front of the eye-piece of the instrument. Three graduate students in addition to the writer served as observers; these students were quite familiar with the rivalry phenomenon but were naive as to the purpose of the experiment. The black lines of the one slide were seen to fade out (at least partially) and reappear, and in the place of that portion of the striped slide which faded out the bright-light field was seen. Three of the four observers reported this result and stated that the rivalry which occurred did not appear to differ from that observed under the more usual conditions of measurement. The subject who did not obtain rivalry reported that she experienced difficulty in obtaining rivalry under any conditions.

It is of perhaps even greater significance to report the results of another experiment, identical to the one
above with the exception that a homogeneous black field was used in place of the homogeneous light field. The black field in this case was obtained by having the subject look into an eyecup which was painted black: since the eyecup fit snugly around the eye, absolutely no light was admitted. Rivalry was observed in this case by the subjects just as it had been observed in the case above, with the exception that what rivaled now was an area of the striped slide with a black field rather than with a bright-light field. This finding is of the utmost significance, for it means that rivalry can occur between the two eyes even when one of them is not stimulated at all. It should be noted, however, that the fields still differ from each other: in the case of the non-stimulated eye, the visual field is one of total blackness. If one would argue that the obtained results can be accounted for on the basis of adaptation of the stimulated eye, he must also be prepared to account for the fact that, in the case of the light-field experiment, the stripes were replaced with a bright field, whereas in the case of the black-field experiment they were replaced with a black field.\(^3\)

That differences between the visual fields provide one necessary condition for the occurrence of rivalry is

\(^3\)Even when the subject simply closes one eye and looks at the striped slide through the instrument with the other, a partial blotting-out is observed, although this blotting is not so extensive as under the conditions outlined above.
not a new hypothesis, having been first emphasized by Helmholtz and by investigators ever since. It would appear to the writer that this is the single characteristic common to all cases in which rivalry is seen to occur: the existence of a sufficient difference between the visual fields (in the case of binocular rivalry) or within a single visual field (in the case of rivalry between parts of a field presented monocularly). In common with other investigators of the rivalry phenomenon, the writer makes no attempt to delineate exactly what "sufficiently different" encompasses, if indeed the task be possible.

In certain cases, even though there would seem to be a "sufficient" difference between the fields, rivalry is not observed. In such cases a concept such as "compatibility between the visual fields" might be introduced (20). It should be reasonable, then, to have the inverse concept "incompatibility between the visual fields" replace that of "sufficient difference." Since, however, in the vast majority of cases of rivalry, one has difficulty in determining just why the fields should be "incompatible" but little trouble in seeing the difference between them, the latter concept is to be preferred. The compatibility concept would seem to be useful only in the case where it appears that the difference between the fields is sufficient to result in rivalry, but where only superposition is observed instead. In a word, a sufficient difference between
the fields would appear a necessary, but not always a sufficient, condition for rivalry; on the other hand, incompatibility is not a necessary condition, and it would be meaningless to talk of it as a sufficient condition, since some difference between the fields would be presupposed.

An Hypothesized Locus for Binocular Rivalry

To say that binocular rivalry is a retinal process would imply that the image of the figure projected on each retina adapts out (or is otherwise inhibited) in a cyclical manner, the suppression of the perceived image being followed by recovery from its state of suppression. This suppression and recovery must be an intra-retinal process, since in no way do the two retinal processes interact in such a manner at the peripheral level. Yet this process would remain unexplained, since the receptors in the "recovering" eye are continuously stimulated. Add to this the facts that no change in rate of rivalry occurs under conditions of cocainized cornea (thus eliminating blinking) or under conditions in which blink is allowed (6), and that eye movements are uncorrelated with rivalry rate (30), and we have good basis for disclaiming a peripheral locus for binocular rivalry.

Let us bypass sub-cortical centers and assume that rivalry has its locus in the visual cortex. Since fusion of the binocular images appears to occur only at this level (14), it would not seem too brash an assumption to
suppose that rivalry of the binocular images also occurs here. The question which is crucial is again to be asked: How does the perceived image "recover" from its state of suppression when the applied stimulus continues to excite the cells involved (both retinal and cortical) in the formation of the image? We may either assume (1) that the striate cortices of the two hemispheres reciprocally inhibit each other or (2) that this inhibitory-excitatory mechanism resides within each hemisphere itself. With regard to the first assumption, we are faced with the fact that "strychnine applied to area 17 never fires into the contralateral hemisphere, not even into the contralateral area 17" (7), and must thus conclude that reciprocal inhibition between the striate cortices of the two hemispheres is a highly improbable phenomenon.

With regard to assumption (2), we face the same difficulty encountered above: What mechanism underlies the "recovery" of the perceived image, once suppressed, when both suppression and recovery occur under conditions in which the stimulus applied is neither removed nor changed? One might postulate eye movements as a possible explanation: that, through gross eye movements, fresh cortical cells are excited and hence the figure which disappeared through adaptation of one group of cells now reappears as a function of the different cells stimulated. Several considerations argue against such an explanation for binocular rivalry,
however. (1) Since the eyes move together, it should be obvious that fresh cells in both eyes are being stimulated simultaneously, and hence the images on both retinas (and in the corresponding areas of the brain) should reappear together, not alternately; (2) The eye-movement explanation cannot possibly account for Breese's (10) finding of the rivalry between two fields whose light rays (by means of prisms) are made to fall at the same time upon the same area of a single retina; (3) This explanation will not account for the rivalry between homogeneously colored slides; and (4) Peckham (30) found no correlation between eye movements and rivalry.

McDougall (27) has been the only investigator to explicitly state a theory of the physiological correlates of the rivalry phenomenon. His theory incorporates the concepts of nervous fatigue and reciprocal inhibition and is capable, theoretically, of answering the critical question posed above. However, there is no physiological evidence available at the present time to support the hypotheses he makes (of reciprocal inhibition, either between or within the visual cortices). In addition, Flugel (17), in a study designed to test a direct postulate of McDougall's theory, found no evidence in support of a concept such as "fatigue." McDougall himself, on the other hand, presents some evidence in favor of such a concept (27).
Proposed Physiological Correlates of Binocular Rivalry

Alpha waves are moderately large rhythmic waves with a frequency ranging between 8 and 14 cycles per second. Termed "spontaneous" because their origin is not known, they are recordable over all regions of the cortex but are strongest and most persistent over the occipito-parietal regions (25). The alpha rhythm may be observed in the occipital region under conditions of relaxation and when the eyes are closed, but it is blocked or abolished under conditions of excitement, auditory and visual perception, performance on complex motor tasks and "thought problems" (e.g., mental arithmetic), and under certain other conditions (22, 24, 25).

Although the alpha rhythm blocks when the eyes are open, visual stimulation is not the necessary nor the sufficient condition in this case for the blockage. According to Adrian (1),

If the eyes are opened in a completely dark room the alpha rhythm is usually abolished, although there can have been no change in the illumination of the retina. But the subject has only to learn the trick of not trying to see anything, of not looking, when he opens his eyes, and then the waves will persist. Similarly when the eyes are kept closed the alpha rhythm can be made to disappear by trying to see something through the closed lids (pp. 196-197).

Adrian (1) has interpreted these results as indicating that

... the act of looking, the focusing of attention on the visual field, somehow prevents the alpha
excitation from reaching the cortex, by blocking the pathways through which it is conducted there, or by inhibiting some essential part of the neural mechanism. Or possibly it is the blocking of the alpha rhythm which is the first stage in visual attention, for when it has gone the unoccupied cortex should be more precisely responsive to signals from the striate area (p. 205).

Now although there is alpha rhythm blockage under conditions of visual stimulation, there is usually a return of the alpha rhythm periodically, sometimes at one- or two-second intervals (23). Lindsley (25), summarizing the results of studies reporting this sporadic return of the alpha rhythm, concludes that it is "... apparently dependent upon fluctuations of attention" (p. 1056).

There appears to be no particular need in postulating that return of the alpha rhythm represents necessarily a loss of awareness on the part of the subject. Certainly, however, one would predict at least a diminished awareness in most cases (if for no other reason than that return of the rhythm is associated with withdrawal of attention from the visual field), and in certain cases awareness may be so diminished that for all practical purposes it may be said to be "lost". A person whose thoughts are a million miles away may "look through" you, for example, hardly aware of your presence.

Now binocular rivalry, as stated earlier, is observed under those conditions in which the two visual fields differ
sufficiently. Since each field is different from the other, each should exert its own "demand" upon the perceiver's attention, and hence we should expect attention to be divided between the two fields. This division of attention and consequent fluctuation which most investigators assume occurs in binocular rivalry does not appear for the most part an active process on the part of the subject, but rather a passive one determined, as stated above, primarily by the differential demand exerted by the different visual fields. There is no doubt that a loud noise sounded near one's ear exerts a "demand" on one's attention, and it is just such a phenomenon which exemplifies the meaning of the term as it is used here. Of two fields which are different, the one which enjoys the greater contrast, intensity of stimulation, or whatever, will exert the greater attention demand of the two, but both fields will exert a demand so long as they are different. Thus is "attention demand" operationally defined.

While it is undoubtedly true that binocular rivalry is dependent to some degree upon active, determined modifications of attention (one can increase somewhat the rate of alternation of the fields by conscious effort), the effect

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4 The term "visual field" refers throughout the remainder of this discussion to the "external monocular visual field."
on rivalry of such attentional factors is not marked (10). Moreover, since rivalry is measured under a passive set on the part of the subject, any such conscious modifications of attention are minimized.

Now if it is true, as postulated, that the visual fields themselves exert the primary demand for attention, then it should follow that, when attention is being directed toward one of the fields, the process of blockage of the alpha rhythm will be reflected in the cortical areas to which the nerves from the hemiretinas of that eye lead. Correspondingly, the other visual field, having temporarily "released" its demand for attention, should be reflected in its hemiretinal cortical areas by the return of the alpha rhythm. Even though the hemiretinas of each eye contribute fibers to different occipital lobes, there is no difficulty in accounting for the alternate appearance and disappearance of the left- or right-eye field as a totality (rather than in the manner, for example, of an alternating bitemporal and binasal hemianopsia), since it is the peripheral stimulus

Although the rate of rivalry may be somewhat affected by active effort, Breese (10) presents evidence contradictory to the finding of St. Witasek's that rivalry can be prevented with practice such that the binocular views remain superimposed. Breese states that St. Witasek's finding is "... very remarkable. No one has reported such a result before ... . One of my problems during these two years has been just this attempt to control the rivalry, but I have gained absolutely nothing in my ability to do so; nor have any of my subjects been able to prevent the rivalry" (p. 20).
and not the occipital lobe which is presumed in the case of binocular rivalry to exert the primary influence upon attention. Thus, when either visual field is dominant, its dominance will be reflected in blockage of alpha rhythm in both occipital lobes as a result of the fact that the hemiretinas of the eye whose field is dominant sent fibers to both lobes. Similarly, the return of the alpha rhythm corresponding to the visual field from which attention is withdrawn will also occur in both occipital lobes.

That this is not the whole story is reflected in the fact that not only may the total fields rival, but also only portions of the fields can rival while the remaining portions superimpose. This would suggest that, while the visual fields may exert the primary influence on the fluctuation of attention, there is also a central (but not voluntary) influence exerted on (or reflected in) the rivalry process by the nature of the cortical and subcortical cellular activity underlying the abolition and return of the alpha rhythm. Thus, the coming and going of the alpha

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6 If the slides are designed in a certain manner, such that the temporal half of the right-eye slide forms a better "gestalt" with the temporal half of the left-eye slide than either does with the nasal halves (and correspondingly for the nasal halves), then rivalry can be easily obtained in the manner of an alternating bitemporal and binasal hemianopsia. However, what is impossible to obtain in the testing situation is rivalry in the manner of an alternating right and left lateral homonymous hemianopsia.
alpha rhythm corresponding to the going and coming of the perceived image in binocular rivalry would be influenced primarily by two processes, the one an external and the other a central, which mutually influence each other in both positive and negative fashion.

The view that alpha activity may not only be affected by perception but may itself affect perception was suggested some years ago by Adrian (1; quotation earlier) and appears to be now gaining some acceptance. In a later paper, Adrian (2) suggests more explicitly that the alpha rhythm may function as a causal factor in the cessation of perception, functioning to block the passage of afferent impulses. Darrow (16) also points out that, to a certain extent, a strong alpha rhythm may not be simply a consequence of "an accompanying state of mental relaxation," but a cause. It is in the manner in which cortical and subcortical processes, whatever they may be, influence the alpha rhythm that they are conceived in the present theory to influence binocular rivalry. Furthermore, it is postulated that the central involuntary processes determine the major part of the variance in rate of rivalry. The "primary" influence of the visual fields in binocular rivalry, then, is primary only in the sense that (1) rivalry does not occur unless there is a sufficient difference existing between the fields and (2) when there is such a difference, rivalry cannot be prevented such that the fields remain superposed. Thus, the visual
fields are the important variable in the occurrence of rivalry in the first place. However, since the visual fields may be so modified such that rivalry is correspondingly affected (e.g., see Footnote 5), they are also conceived to determine some of the variance in rate of rivalry, although a relatively minor portion as compared with that determined by central processes. This is based on the presumption that measurement of rivalry is made under a passive set on the part of the subject.

Since great weight is placed in the present theory on cortical and subcortical processes in the determination of variance in rate of rivalry, some attempt should be made to make explicit just what these processes are. This the writer cannot do, nor does the state of knowledge at the present time allow of such an explication. A relationship which is suggestive, however, as a first step, is that between alpha activity, visual stimulation, and cerebral blood flow.

That alpha rhythm is affected by visual stimulation is clearly evident from countless studies, and the major results pertinent to the present discussion have already been presented. With respect to the relationship between visual stimulation and blood flow, Schmidt (33) reports the finding (of Schmidt and Hendrix) that a gentle and specific light stimulus to the eye resulted in an increase in blood flow which could be detected in only a sharply demarcated area.
indicating the specific nature of the phenomenon. Schmidt entertains two possible explanations for the obtained effect. The first involves activation of the vasodilator nerves in the brain by the impulses resulting from retinal stimulation. The alternative proposal is that the vasodilatation is brought about by an increased concentration of vasodilator metabolic products, as a result of increased activity of the cortical cells receiving the nerve impulses generated by the illumination of the retina. He states:

Increased metabolic activity associated with an increase in the specialized function of these nerve cells (i.e., perception of visual impulses) is reasonably to be expected. The effect on blood flow would be limited to the region in which the increased functional activity took place. Thus the entire phenomenon might be explained without calling upon any mechanism except the ability of metabolic products to dilate cerebral blood vessels, which is about the best known and most firmly established of their physiological attributes (33, pp. 40-41).

(Note should be made especially of the phrases "perception of visual impulses" and "functional activity" in the above quotation, although these may be somewhat misleading on the basis of the experimental data on hand.) The actual dilatation of the cerebral blood vessels could occur either through a direct effect on the vessel walls of the products of cellular metabolism or through activation of vasodilator innervation by chemoreceptors which are located in the
active tissue and which are affected by local concentration of metabolic products (33).\footnote{The relationship suggested finds an interesting parallel in McDougall's concept of nervous fatigue and rivalry. Especially to be read are pages 346 and 347 of McDougall's (27) article.}

With respect to the relationship between alpha activity and cerebral blood flow, the results of several pertinent studies are summarized by Darrow (16), and these studies are in accord in finding an increase in frequency of alpha to be associated with an increase in blood flow. Increase in the frequency of the alpha rhythm has also been found to be related to an increase in the blood pressure (Traube-Hering waves), which, of course, need not necessarily be related to increase in cerebral blood flow, but which is pertinent in the light of the studies to be reported on binocular rivalry.

Finally, with respect to the relationship between binocular rivalry and blood pressure, the results are conflicting. Bonser (8) found that the appearance and disappearance of a perceived figure in binocular rivalry corresponded with the undulations of the Traube-Hering waves: when the figure was perceived, the Traube-Hering wave was at its crest; when the figure disappeared, the trough of the wave was present. For the very short portion of tracings which he presents (5 cycles), the correspondence was perfect. Griffitts and Gordon (21), on the other hand,
found no correlation at all between the lengths of the Traube-Hering waves and those of alternation in rivalry.

**An Experimental Test of the Theory**

Because of the makeup of the optic system, a clear test of the theory proposed would appear to be very difficult to make. One cannot stimulate only one occipital lobe at a time. And since both lobes are always receiving impulses from both eyes, rivalry, even if complete, will always be reflected (according to the theory) in both lobes.

The writer conducted an experiment in an attempt to test the hypothesized relation between alpha activity and rivalry. The assumption was made that when most of the lines on the slide were seen going up one way, either to the right or to the left, the occipital lobes would not be as fully activated as when the lines were seen to cross. Thus, in the former case there would be presumed to be more admixture of high- and low-amplitude alpha activity than in the latter case, where more definite blockage of the alpha activity should occur.

A subject was chosen who had a "responsive" alpha, that is, an alpha activity which was of high amplitude when the subject's eyes were closed and he was mentally relaxed and which blocked only momentarily, returning, somewhat sporadically, for varying lengths of time, when the eyes were opened and fixated upon a wall in a dimly lighted room. Vertex
electrodes were used, placed over the occipital lobes. The subject was seated in a chair and the stereoscope so situated that he could look into it without inducing much muscular strain. The lighting of the room was quite dim, just enough light being allowed to enter to allow for the seeing of the slides.

The subject was instructed that the sequence of testing would be as follows: On the signal "Close," he was to close his eyes until the examiner spoke again (this constituted a one-minute rest); on the signal "One Way," he was to open his eyes and press a button whenever most of the lines were seen going up either to the right-hand or to the left-hand corner, and to hold the button down as long as most of the lines continued in one direction (two-minute test); on the signal "Close," he was again to close his eyes and rest (one minute); on the signal "Crossed," he was to open his eyes and press the button whenever most of the lines were seen to crosshatch, and to hold the button down as long as most of the lines continued crosshatched (two-minute test).

The sequence continued in this manner (close, one way, close, crossed, close, one way, etc.) throughout a testing period of approximately one-half hour. The subject had been pre-trained for a few minutes each day for several days so as to make him accustomed to pressing the button without expending much muscular effort or devoting much attention to
the task. The button, which when pressed resulted in a tracing being recorded on the encephalograph paper, was pressed throughout by the first finger of the right hand. The subject was completely naive with respect to the theory under test.

The experimenter analyzed the tracings in an attempt to find any consistent pattern of alpha activity associated with the "One Way" responses as opposed to that associated with the "Crosshatch" responses. A fairly consistent pattern was found, the criteria being empirically established as follows: (1) two or more cycles in succession, measured in terms of downward slope, the first slope being over 42µV (5mm.) and the second slope equal to 42µV or more; (2) The response must be coincident with the beginning of high voltage or must be followed by high voltage within one second, "high voltage" being as defined in criterion #1. If high voltage preceded the response's beginning and did not change in any manner when the response was made, it was called "Indeterminate."

A few days later the same subject was again tested in a manner identical to that described above, with the exception that testing continued this time for almost an hour. The electroencephalograph paper was immediately cut in two, separating the tracing of the alpha rhythm from that of the subject's responses. Adhering precisely to the criteria established on the basis of the previous record, and without
reference to the subject's responses, the experimenter then analyzed the alpha record, marking each "return" of the alpha according to the criteria. The experimenter, moreover, had no way of knowing whether a particular section of the alpha record was associated with a one-way or a crosshatch period of testing, since all identification of the record was obscured.

After the alpha record was completely analyzed, it was fitted together again with the tracing of the subject's responses and the relationships tallied. Where return of the alpha rhythm occurred in the tracings of either or both occipital lobes according to criterion, a tally was entered under the heading of "Both." Where return of the alpha did not occur, a tally was entered under "Neither." Where the alpha returned but no response was made, no tally was made. Where the response of pressing the button did not last one full second (and if return of alpha did not occur while that response did last), a tally was entered under "Indeterminate."

A test of significance (chi-square) was computed involving the frequency of return and non-return of alpha ("Both" and "Neither" frequencies, respectively) in association with the one-way and crosshatched responses. The chi-square was 13.52, which was significant past the .01 level. The frequencies of each cell are shown in Table 4, "A."
TABLE 4
FREQUENCIES OF RETURN AND NON-RETURN OF ALPHA RHYTHM IN ASSOCIATION WITH ONE-WAY AND CROSSHATCH RESPONSES UNDER FOUR CONDITIONS OF ANALYSIS

<table>
<thead>
<tr>
<th></th>
<th>A Both</th>
<th>A Neither</th>
<th>B Both</th>
<th>B Neither</th>
<th>C Both</th>
<th>C Neither</th>
<th>D Both</th>
<th>D Neither</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross-hatch</td>
<td>18</td>
<td>35</td>
<td>11</td>
<td>48</td>
<td>32</td>
<td>26</td>
<td>20</td>
<td>61</td>
</tr>
<tr>
<td>One-way</td>
<td>87</td>
<td>50</td>
<td>50</td>
<td>76</td>
<td>62</td>
<td>70</td>
<td>49</td>
<td>99</td>
</tr>
</tbody>
</table>
A second chi-square was computed on the frequency of return of alpha within two-fifths of a second after the beginning of a response, rather than one second as before, in relation to the same categories used in the previous test. Chi-square was 8.09, significant past the .01 level. These frequencies are shown in Table 4, "B."

As a check on the data to determine whether there was some factor at work other than the one presumed, a page of the response record was displaced and the return of alpha tallied as above with the one-second response. No part of the response record was associated with its original mate in the alpha record. Chi-square, computed as before, was 1.04 and was not significant. Table 4, "C," shows the frequencies involved.

A final test was computed, with the return of alpha being tallied if it fell within one second before a response was made. The Chi-square in this case was 1.76, which again was not significant. Table 4, "D," shows the frequencies involved.

Attempts to repeat the above findings on two other subjects have met with failure, no consistent patterns of relationship being apparent. Time did not permit study of additional subjects. It is the feeling of the writer that the findings on the first subject, however, while not proving the relation hypothesized, do lend strong support to it.
Application of the Theory to Data on Binocular Rivalry

Alexander (4), using figures of different "figure strength" (measured in terms of brightness contrast between figure and ground and continuity of figure-contour), found that fields which include "strong" figures alternated at a greater rate than fields with "weak" figures. In the terms of the theory, the "stronger" figures exert a stronger demand for attention than the "weaker" figures, and on this basis alone would be predicted to alternate at a somewhat faster rate. In addition, the stronger figures, being the more integrated, would be more likely to result in better coordinated activity of the cortical projection areas associated with the hemiretinas of the eyes stimulated by those figures; hence, less partial blotting out of the figures will occur and a corresponding increase in the reported rate of alternation would follow.

Breese (10) found that rivalry occurs between the after-images of stereoscopic impressions when they differ from each other. And Jasper and Cruikshank (23), while not concerned with the rivalry of after-images, measured the alpha rhythms of subjects in which after-images appeared following a single light stimulus. They state:

In the subjects who experienced a rather continuous waxing and waning in intensity of the after-image rather than clean-cut disappearance and appearance of successive images, there appeared a rather constant low level of rhythmic activity rather than periodic rises in activity as for the subjects who reported definite intervals between images. The presence of
rhythmic brain potentials is therefore a remarkably reliable objective indication of a formerly entirely subjective phenomena, that of the visual after-image (p. 38).

Although the visual fields may blot out and reappear in any number of different ways, it is commonly observed that disappearance and reappearance occur in a wavelike manner. Thus, the blotting out of a field may begin at the lower left-hand corner and progress upward to the upper right-hand corner, the other field then beginning to reappear in one corner and progressing in its reappearance to the opposite corner. In would appear that Adrian and Matthew's hypothesis of a shift in the focus of activity for the alpha rhythm may be related to the phenomenon. Adrian and Yamagiwa (3) state of this focus:

The shift often taken place suddenly, the potential distribution changing in the course of a single beat and showing no sign of a gradual movement from the old position to the new . . . . But most records of the Berger rhythm will show regions of periodic increase and decrease in the size of the waves, and during these there is often a gradual movement of the focus (p. 342).

And according to Marshall and Talbot (26):

. . . Brain-waves sweep over the centrum with various characteristic periodicities of various origins . . . to produce temporal and spacial changes in excitation by virtue of the Berger activity at any

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6 This is an additional argument in favor of the influence of involuntary central factors in the rivalry process, since neither voluntary attentional factors nor attentional factors influenced solely by the applied stimulus would be likely to be reflected in a wavelike appearance and disappearance of the perceived image.
point and instant, and also because of the excitability cycle which follows it (p. 151).

Relation of Rivalry to Intelligence

It is not assumed that rivalry is related to intelligence in any causal manner. Rivalry is seen, rather, as related to intellectual functioning in that both are reflections of the same brain processes. When the brain dynamics underlying the phenomenon of rivalry are known, it may be that our understanding of those underlying intelligence will have finally come of age.
CHAPTER VI
SUMMARY AND CONCLUSIONS

In several previous studies by the writer, rate of binocular rivalry was found to be directly related to point-hour ratio, performance on the Ohio State Psychological Examination, performance on the Progressive Matrices Intelligence Test, and performance on the Wechsler-Bellevue Intelligence Scale for Adults. The latter two relationships were obtained in a test of the hypothesis that rate of rivalry is directly related to level of intellectual functioning.

The problem of the present investigation was that of determining whether binocular rivalry bears a relationship to performance on tests of perceptual closure. On the basis of Thurstone's (37) suggestion that this might be the case, and since the Performance Scale of the Wechsler-Bellevue contains tests involving the closure factor, the hypothesis presented itself that rivalry may be related to intelligence through the mediation of performance on such tests as involve this factor of closure. If a relationship was obtained between binocular rivalry and perceptual closure, the problem was then that of determining whether rivalry functions as a visual skill, influential in and of
itself, in effecting improvement in performance on tests of closure when an increase in its rate is achieved through training.

Seventy undergraduate college students were selected whose rivalry rates were below 11 or above 14 cycles per minute. The subjects were divided into three groups on the basis of their rivalry rates. One group (High Rivalry group) consisted of subjects whose rates were 15 cycles per minute or above. The other two groups (Low Control and Low Training groups) consisted of subjects whose rates were 10 cycles per minute or less, the subjects being arbitrarily placed in the one or the other group. The Low Training subjects were given special training in an attempt to increase their rates of rivalry. The tests of perceptual closure administered were the Gottschaldt Figures Test and the Street Gestalt Completion Test.

No relationship whatever was found between binocular rivalry and performance on the tests of perceptual closure. As a result of this finding, it was felt that further analysis of the results of the previous investigation of the writer involving binocular rivalry and performance on the Wechsler-Bellevue Intelligence Test might prove fruitful. In that study, it was found that the relation between the Full Scale IQ and rivalry was primarily a reflection of that between the Performance Scale IQ and rivalry. The t-test of the difference between the mean rivalry rates of the high
and low Performance IQ groups (the distribution being divided into halves) was significant past the .01 level ($t = 3.13$). The question now was: If rivalry is not related to tests of closure in general, could it be related to any subtest or subtests in so strong a manner that at least its obtained relation to the Performance Scale IQ could be explained as primarily a reflection of such a relationship? It was found that this was not the case. Tests were made of the significance of difference between the mean rivalry rates of the high and low halves of the distribution with respect to performance on each subtest, and not one of the differences was large enough to be significant. It was concluded that binocular rivalry was not related to the Performance Scale IQ through the mediation of some stronger relationship to certain specific subtests, but that it was related, rather, to performance on the total scale as a unit.

On the basis of all of the research presented, it was concluded that rivalry is a phenomenon which, in its relation to intelligence, is of general scope, and that it could hardly function in this regard as a visual "skill." A thorough analysis of the rivalry phenomenon was then made and a general theory of its nature and physiological correlates was presented. The suggestion was made that binocular rivalry and intelligence are related in that both are reflections of the same brain processes.
APPENDIX A

GOTTSCHALDT-PRE TEST
APPENDIX B

GOTTSCALDT FIGURES TEST (A and B)
BIBLIOGRAPHY


