THE LAW OF THE "FIELD" IN VISUAL FORM PERCEPTION (I)

— A THEORETICAL FORMULA TO SEEK THE FIELD STRENGTH OF THE FORM AND ITS EXPERIMENTAL PROOF.—

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PROBLEM

If Köhler's idea of "Isomorphism" that a visual form corresponds to self-distribution by mutual action of physico-chemical forces in the cerebrum is true, it can be said that a form perceived by us constitutes a certain field around an electric charge in physics. Consequently, we can reasonably think that there must be differences in strength or in direction around both inside and outside of a contour figure. To prove this experimentally, I placed a minute light point at various places around a contour figure and tried to study the differences of stimulus threshold of this light point. By doing so, I aimed at measuring placial differences in volume of the potentiality of the various fields of the figure.

Experimental procedures.— Stimulus figures were cut out of a card board in the dark-room. They were then lighted by a light coming from the other side of a clouded-glass. A spot of light was thrown on the figure by a spot light apparatus in the adjoining room. Position and light strength of the spot could be changed freely by a resistance. A volt-meter was connected to make the measurement of lumen exactly. Dark-room was used. Dark-adaptation for 15 minutes before beginning the experiment.

Stimulus threshold was measured at various places on the figure by gradually weakening the volt-meter and light from a point where the light spot could be seen clearly. Repeated each experiment 5 times. Subjects were 3. Observation distance 50 cm.

Results.— 1) The light stimulus threshold was weakened as the distance between the spot-light and the figure became greater. Consequently the strength of field (M) is in functional relationship with the distance (D) from the figure.

2) Then, the light stimulus threshold was strengthened with the figure. Consequently M is in functional relationship with the clearness (H) of the figure.

3) Other conditions being equal, the light stimulus threshold varies according to the nature of the figure. Therefore, M is affected by the particular figure structure (E).

From above experimental facts \( M = f(D, H, E) \) can be inferred. Then upon seeking the functional relation of
these based upon the experimental measurement value, the result on the outside of a figure was

\[ M = f \left( E \frac{H}{D_a} \right) \]

**M** = Strength of field
**E** = The figure particular structure.
**H** = Degree of clearness (Contrast of Figure and Ground)
**D** = Distance from the figure
**a** & **b** = constant.

**Considerations of results.**—Now, the field forces in physical "Gestalt" have been based decidedly on the experimental facts that they are proportional to the amount of electricity, and in inverse proportion to the distance squared.

And, but when we study the results of our experiments, that is, the strength of the psychological field measured by the light stimulus threshold, we find that the two are very much similar even in their functional relations.

But the experimental formula above is still incomplete, like Corte's law, and cannot yet be used in calculation as it is. It has not yet reached that stage of a complete theoretical estimation of a phenomenon by means of functional formula. However, the writer was able to confirm by experiments that our visual process corresponds to the electrical phenomena in the field of human brain. Thus by applying Biot Savart's law of electromagnetism by which to seek the strength of magnetic field, the writer succeeded in obtaining a theoretical formula to seek the field strength or the potentical at various points around a figure. It is as the following.

**THEORETICAL FORMULA**

Take a segmental line a, b, and imagine it to be electrified (currentactive). Then place an optional point P. First, the potential of point P can be thought to be the amount of influence of the unit area of line a, b on point P, integrated in relation to a, b. Accordingly, as is shown in Fig. 1, draw a vertical line PO from point P to line a, b, and then also join P with the two ends of the line.

Now, \( aP = A_1 \), \( bP = A_2 \), \( PO = D \), \( aO = S_1 \), \( bO = S_2 \), \( LaPO = \theta_1 \) and \( LbPO = \theta_2 \) Let \( H \) represent the degree of clarity on line a, b. Then \( M_p \), which stands for the potential at point P, will be

\[ M_p = k \frac{H}{D} \int_{-\theta_2}^{\theta_1} \cos \theta d\theta \]

\[ M_p = k \frac{H}{D} (\sin\theta_1 - \sin\theta_2) \]

\( k \) represents the difference arising from individual differences in vision or attitude of the subjects.

When the above formula is developed and simplified, it will be

\[ M_p = k \frac{H}{D} (\sin\theta_1 + \sin\theta_2) \]

\( k \) and \( H \) in the above are left out because they have no direct relation with the question of form. Thus, it may be written as

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Fig. 1
\[ M_p = \frac{\sin \theta_1 + \sin \theta_2}{D} \quad \text{(I)} \]

Since, however, \( \sin_1 = \frac{S_1}{A_1} \)

and \( \sin_2 = \frac{S_2}{A_2} \)

according to trigonometrical function, if the segment line and point \( P \) are given, it is possible to get the potential of \( P \) from formula (I).

In case the vertical line from \( P \) falls above line \( a, b \), then \( \text{LOP}_b = \theta_2 \), \( \text{LOP}_a = \theta_2 \), \( \text{Ob} = S_1 \), and \( \text{Oa} = S_2 \) as is shown in Fig. 2. The potential of point \( P \) will be

\[ M_p = \frac{\sin \theta_1 + \sin \theta_2}{D_1} \quad \text{and} \quad \frac{\sin \theta_3 + \sin \theta_4}{D_2} \quad \text{(II)} \]

Thus with (I) and (II) above as the fundamental formulas, the potential of an optional point outside the angle in Fig. 3 can be obtained. That of an optional point of a triangle, square or any polyangular figure can likewise be obtained.

\[ \text{LAPO}_1 = \theta_1 \quad \text{LbPO}_1 = \theta_2 \quad \text{LbPO}_2 = \theta_3 \]

\[ \text{LcPO}_2 = \theta_4 \quad \text{PO}_1 = D_1 \quad \text{and} \quad \text{PO}_2 = D_2 \]

The potential of point \( P \) will be

\[ M_p = \frac{\sin \theta_1 + \sin \theta_2}{D_1} \quad \text{and} \quad \frac{\sin \theta_3 + \sin \theta_4}{D_2} \]

On the same principle, the potential of the field around a circle can be obtained, i.e. in Fig. 4.

\[ R = \text{radius}, \quad a \text{p} = D, \quad \text{then} \ \text{OP} = R + D. \]

If \( b \text{p} = \text{a tangent line from} \ P \) to circle \( O \), \( \text{Lbpa} = \theta_1 \quad \text{Lb'pa} = \theta_2 \) then
\[ \sin \theta_1 = \sin \theta_2 = \frac{R}{R + D} \]

Hence \( M_p \), the potential of any optional point around the circle, will be

\[ M_p = \frac{2R}{R + D} \frac{1}{D} \]

\[ M_p = \frac{2R}{D(R + D)} \] \( \cdots \cdots \) (IV)

Based on the above fundamental formula, it is possible to obtain, by calculation the numerical values of the theoretical formula, the field potential of any optional points around various kinds of figure.

**EQUIPOTENTIAL LINES FOR VARIOUS CONFIGURATIONS DERIVED FROM FUNDAMENTAL FORMULAS**

Taking up several lengths of straight segmental lines, I examined what variations would be caused in the field strength when the distance was gradually extended along the central line of a segmental line as shown in Fig. 5. The calculation was made on the basis of the fundamental formula I and the result is shown in Fig. 5. On the horizontal axis, the distance from the central part of the segmental line is denoted by \( \log \), and, on the vertical axis, the field strength by \( \log \). The result tells us that the mode of the field strength reduction relative to the change of distance differs according to the length of a segmental line.

As the length (\( S \)) of a segmental line grows extremely short and draws close to the point the mode of its reduction is in an inverse proportion to the distance squared. In proportion as the length of a segmental line increases the degree of reduction becomes gradually moderate, moreover, the difference

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*Fig. 5*

*Fig. 6*
in the field strength becomes similar as the length of a segmental line increases. Therefore, the difference in the functional length in the psychophysical sphere never is identical with a geometrical scale. As in an exceptional case, in the immediate neighborhood of the segmental line, the difference in the field strength is not great even though some considerable difference exists in the length of segmental lines, but the difference will become more conspicuous as the distance extends far from the segmental line.

It is a matter of course that if the distance extends too far from the segmental line the difference in the field strength relative to the length of the segmental line will become smaller again because the diminishing degree of the field strength becomes greater.

Next, speaking of the distance from a segmental line, there is some difference between one measured from the central part of the segmental line and the other measured from the end part of it and I must say the field strength reacts differently in each case even though the distance is equal as measured by scales on a rule. Here, I will show you the results derived from the fundamental formulas I and II in Fig. 6, which indicate various field strengths—(a of Fig. 6) at various distances from the central part of a segmental line (20mm in length), (b of Fig. 6) from a point ¼ from the end, (c of Fig. 6) from the extreme end, and so on, ranging in order from a to f. Look at their values and you will see that of all field strengths at equi-distant points, as shown by scales on a rule, the one directing vertically to the central part is the greatest, and that the field strength weakens gradually as the point moves farther toward the end of the segmental line. Depending on Fig. 6, if you connect the points which have the same field strength value and draw an equal strength line or equi-potential line, you will get a chart similar to Fig. 7.

This chart will help you see at a glance the condition of distribution of energy in the field around the segmental line. The numerals put on the equipotential line in Fig. 7 indicate the field strength on that line. Through a process similar to above, we can draw equi-potential lines for various configurations. For instance, if we want to know the distribution of field strengths around two parallel segmental lines, we have only, as stated above, to add the integral influence of one segmental line to that of the other, therefore, we can make its calculation with the fundamental formula II. Fig. 8 indicates its equipotential lines. By the way, I will show you some charts on bloc in Fig. 9, listing equi-potential lines for various configurations.

**Experimental Proof of Theoretical Formula**

By means of the theoretical formula stated above, not only were we enabled
to estimate the field strength at an optional point in various configurations by mere mathematical calculations, but also thus to seize an idea of the distribution of field strength of any contour figure by drawing an equi-potential line for its inside and outside fields. And we knew that these equi-potential lines could produce a chart quite similar to the equi-threshold line chart which was drawn from our experimental results of the method of light spot stimulus threshold \(^5\) or to the equi-induction line chart drawn from the experimental results of Motokawa’s purely physiological stand point \(^3\). I believe, however, this sort of summary coincidence is unsatisfactory and farther discussion will have to be made minutely. Let us go still further positively. The question of field strengths raises various possibilities according to the conditional value given to each factor by this theoretical formula. Since it is possible to foresee these possibilities through calculations we should try out experiments on them and prove whether they are applicable to the actual field. Next, I will confirm this point.

**Experiment 1**—As already deducible in Fig. 6, the field strength differs according to which part a configuration it is distanced from a segmental line. Take a segmental line for example, it can easily be induced that the distance will differ according to whether it is measured from the central part or the end-part of it.

Well, then, can this sort of phenomenon be possible in reality? Let me try to prove this point by experiment.

**Condition of experiment**—Regarding a segmental line (30 mm in length and 2 mm in diameter), we examined the light spot stimulus threshold at various distances vertical to the segmental line, namely, at the central part (a in Fig. 10) and the points of 5 mm (b in Fig. 10) and 1 mm (c in Fig. 10) from the end respectively.

**Result of experiment**—The results are shown in Fig. 10 under the title of the experimental value at the right. On the horizontal axis were listed by log the distances from the segmental line (in mm) and on the vertical axis by log the light spot threshold (in radlux). The graph titled as theoretical value at the left shows the values

![Fig. 9](image-url)
of field strengths (Mp) calculated by the fundamental formula I.

Considerations of result—As expected, the result of the experiment has revealed that the field strength is the strongest at the central part and weakened gradually as the field moves sideways toward the end of the segmental line. Moreover, we could confirm the fact that the curve of the theoretical value derived from the calculation is extremely identical with that of experimental value*.

Experiment 2—As a means of calculating the field strength around two segmental lines, the segmental formula III gives us an idea that the integral influence from the one configuration should be added to that from the other. The question is whether this new idea is coincident with a fact in reality. To prove this the following experiment was carried out.

Condition of experiment—As a stimulus configuration we adopted two parallel lines each 30m.m., in length. The distance between the two segmental lines was set in three ways, namely, 4m.m., 6m.m., and 8m.m. We experimented to obtain stimulus threshold of light spot at various points in the direction from the center of the two segmental lines as indicated with an arrowed dashed line in Fig. 11.

Result of experiment—The result is shown in Fig. 11 under the title of experimental value at the right. On the horizontal axis, the central point of the two segmental lines is marked with 0m.m. and the distance from it is indicated by m.m. unit. Therefore, the point marked 15m.m. falls on the line

* The field strength value Mp. is a theoretical value and merely represents a relative value because the degree of clarity (H) of the configuration was taken as a constant and omitted from the calculation. Speaking of the experimental value, its absolute value is little worth consideration because the light spot stimulus threshold is indicated by radlux unit. The only point which should be taken into account is its relativity, that is, the similarity in the incline of the curve.
connecting the ends of both segmental lines. The confirmation I obtained thus is that the stimulus threshold value begins to diminish suddenly at a point a little inside of this line. The variations of the field strength were also calculated by the fundamental formula III and its values were listed in Fig. 11 under the title of the theoretical value at the left. Compare the theoretical value with the experimental value and you will see the extreme resemblance of both curves. It may be said that this gives full proof of the correctness of the fundamental formula III, which shows that the field strength around two configurations is the sum of both field strengths.

Experiment 3—Next, let us make a close inquiry into the fundamental formula IV, which deals with an instance in case of circles.

Condition of experiment—I take two circles as a stimulus configuration. Both circles are 10m.m. in radius. The distance of both circles is set in three kinds of 6m.m., 8m.m. and 10m.m. I will try to obtain the stimulus threshold of light spot at various points on the line connecting the centers of both circles, that is, in the direction shown by an arrowed dashed line in Fig. 12.

Result of experiment—The result is shown in Fig. 12 under the title of the experimental value at the right. The distance from the circle is denoted by m.m. unit on the horizontal axis. The value of the stimulus threshold is entered by radlux unit on the vertical axis. A curve at the left in Fig. 12 shows the theoretical value of field strengths, which were calculated by the fundamental formula IV. Compare the experimental value with the theoretical value we could recognize that there was also an extreme similarity existed between the two curves. Thus, we could prove the correctness of the fundamental formula IV.

Through the experiments mentioned above, I could confirm the fact that various possibilities naturally presupposed from my theoretical formula are sure to occur in actual reality. Moreover, I could prove the exact
coincidence between the curve of anticipated values derived from the theoretical formula and that of experimental values obtained through actual experiments.

**Verification by Other Psychological Facts.**

The foregoing is a research respecting experiments based on the method of the light spot stimulus threshold at our laboratory. In addition, I should like to add that this theoretical formula I originated leads you to foresee any of the known results of psychological experiments which, I presume, concerns "Field strength of the form." Now, I will show you a couple of examples. First, a lot of experimental facts about the field strength of the form were discovers by Motokawa 3), making a study of the field of retinal induction by electric excitation. I may say that these experimental facts are foreseeable in detail with the aid of my theoretical formula. The fact is, by measuring the induced field strength concerning Hering squares he discovered the sudden decline of the field gradient at the end of the parallel lines. This experimental fact may also be properly foreseen by the estimated figures bases on my fundamental formula II. As seen clearly in fig. 11, the field strength in the neighborhood of the end of the parallel segmental lines begins to weaken suddenly at a point a little inside of the line connecting the ends of both segmental lines. Moreover, the degree of its diminishing steepness corresponds to a function of the space between the parallel lines. The wider the space grows the weaker will the steepness of a curve become. Again this fact is foreseeable by the theoretical values derived from my formula.

Next, I will talk about what we call
an experiment on perception of forms, 
which is conducted under the condition 
of stimulus reduction such as the short 
time of exposure, the low intensity or 
the indirect vision and so forth. Of 
this experiment, lots of data have been 
provided for a research to define what 
sort configuration can be recognized 
comparatively quicker and more cor-
rect than any other configuration. Sum-
mring up these results, I know it is a 
generally admitted fact that of com-
paratively simple giometrical figures 
each with aneual area a triangle can 
be recognized quickest, being followed 
by a square and a hexagon in point of 
hard recognition. It may seem a ques-
tion how this sort of difference occurs 
according to its form. But I maintain 
that this fact can also be explained 
easily from the point of the difference 
in field strength formed by each con-
figuration. Now, I will use my theore-
tical formula for estmating the field str-
ngth in the inside sphere of these con-
figuration. I think, for the immediate 
purpose, the comparison between field 
strength at the central part of each 
configuration may be sufficient because 
these configuration have each equal 
area in spite of its different form. 
Taking each area as 400 m.m.², I will 
calculate the field strength at the center 
of each configuration. The results are 
0.592 for the triangle, 0.566 for the 
square 0.544 for the hexagon. The 
difference may not so conspicuous, and 
yet I realize the field strength is most 
strong in case of a triangle, growing 
weaker in case of a square, still weak-
er in hexagon. It is natural enough 
that the stronger a configuration is 
the quicker and correcter it can be 
recognized.

CONCLUSION
As I have stated in the foregoing, 
I can confirm the fact that by the the-
oretical formula on the field strength 
of forms which was originated by me, 
the experimental results obtained at our 
laboratory under the light spot stimu-
lus threshold method can not only 
be foreseen on numerical value culcu-
lations, but also lots of experimental 
results hitherto carried out by a number 
of persons and seemingly concerning 
the so-called "Field strength forms" be 
easily explained as well as foreseen.

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