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The effect of the context on the anisotropy of the visual field

RICCARDO LUCCIO and GRAZIA CAPORUSSO

The phenomenal (visual) field is not homogeneous (anisotropic). Clear examples of this are given by Bartlett's "replication experiments" and Blum's "firegrass model". In 1991, Stadler, Kruse, Richter and Pfaff attempted to develop a vector field model of the visual field, and on this basis, Kruse, Luccio, Pfaff and Stadler (1996) demonstrated relevant context effects introducing different directionally oriented shapes in the field. In this paper, we propose some methodological modifications, aimed to improve the consistency of the results.

Key words: Perceptual field, anisotropy, vector field, context

The dynamics of the anisotropy of the visual field

The phenomenal (visual) field is not homogeneous (anisotropic). We have many clear examples of this anisotropy. First of all, we can point to a number of phenomena which indicate that the simple position of the stimuli in the field induces different functional effects. A classic example is the vertical-horizontal illusion, with the well-known overestimation of the length of the vertical line over the horizontal one; or the rod and frame effect, etc.

As in many cognitive processes, the dynamics of phenomena which evolve in time clearly shows this anisotropy. In 1951, Bartlett gave a formidable experimental demonstration of this, however neglected by most scholars (but indeed very difficult to replicate, as many Bartlett's reproduction experiments were; Bartlett, 1932; Bergman and Roediger, 1999).

He presented his participants with a white sheet of paper with a point near to the centre. After a while, the participant had to draw down a point on another sheet, in the same position he remembered to have seen previously. This point was after shown to a second participant, his point to a third, and so on. These points in succession evolved more or less as in Figure 1.

In the '60s Blum developed the "grassfire" model of the structure of shapes. According to Blum (1973), the "skeleton" of a shape could be represented similarly to the pattern of the cinder resting on a field of grass after the burning from the periphery of the field towards its centre. On this basis, Blum proposed the so-called Symmetry Axis Transform (SAT), that is considered yet a milestone for the study of the visual processing of the figural geometry. On the Ba-

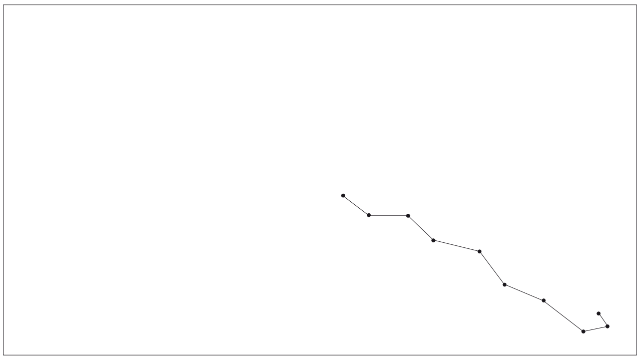


Figure 1. The "migration" of the points in Bartlett's replication experiment.

Riccardo Luccio: Department of Psychology "Gaetano Kanizsa", University of Trieste, Italy, E-mail luccio@psico.units.it (the address for correspondence).

Grazia Caporusso: Department of Psychology "Gaetano Kanizsa", University of Trieste, Italy.

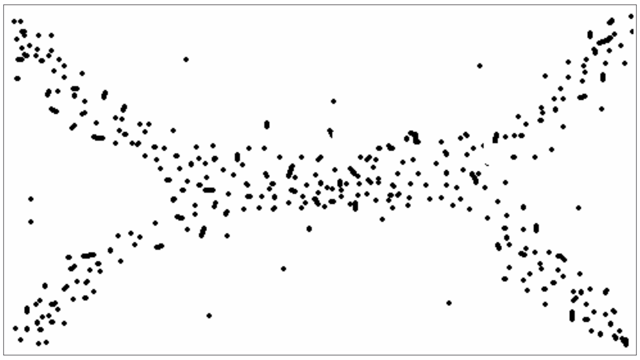


Figure 2. The result of the overlapping of single points put at random by several participants on a blank sheet of paper. Each participant drew only one point.

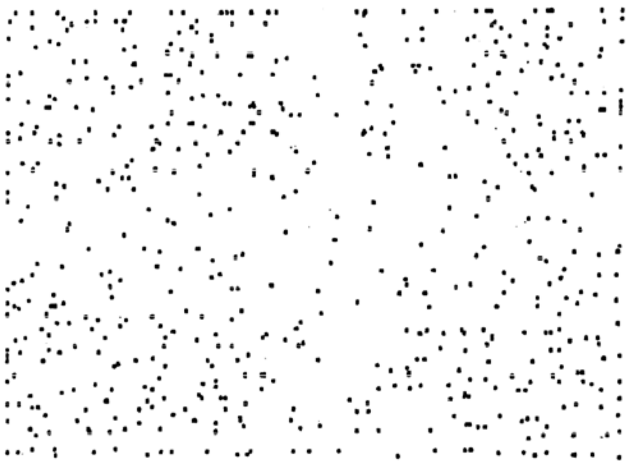


Figure 3. A pattern of a participant in Stadler, Richter, Pfaff and Kruse's experiment.

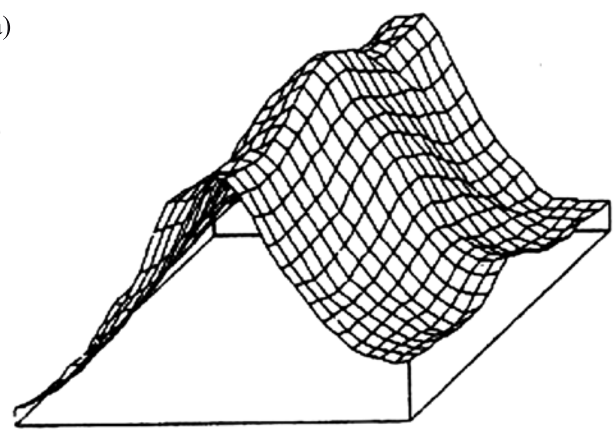
sis of Blum's model, Psotka (1978) asked to his participants to draw down each one only one point on a white sheet in a position at will. Overlapping the points he had a pattern similar to the one shown in Figure 2. This pattern was obtained by one of us with a group of students in an introductory course of Psychology.

In 1991, Stadler, Kruse, Richter and Pfaff attempted to develop a vector field model of the visual field. This model too refers to the anisotropy of the perceptual field. The experiments at the basis of this model required that the Ss, presented with a sheet on which there was one dot chosen at random between 1218 equally spaced positions, to reproduce the position of the dot on a pressure pad with a stylus. They attempted from the displacement of the reproduced dots to calculate the vectors of translation and torsion for each position on the field. The resulting vector field was amazingly similar to Blum's grass fire field, and in some sense to the path shown by Bartlett in the reproduction experiments. In this model, the dynamics of each point in the field was decomposed to two components, a *gradient field* and a *circulation field* (see below). According to this representation, one can describe the field in terms of a landscape, with hills (high potential) and valleys (low potential). (For the formal description of the model, see next section.)

A typical pattern of a participant is shown in Figure 3. Notice that, at difference with Blum's pattern, there is a rarefaction of the points towards the center of the figure. We will discuss this issue later.

If we calculate the distance and the direction of each displacement of the reproduced points from the original ones, we are able to decompose it in terms of gradient and circulation. The average representation for all participants of the gradient potential (left) and of the circulation potential (right) is given in Figure 4.

a)



b)

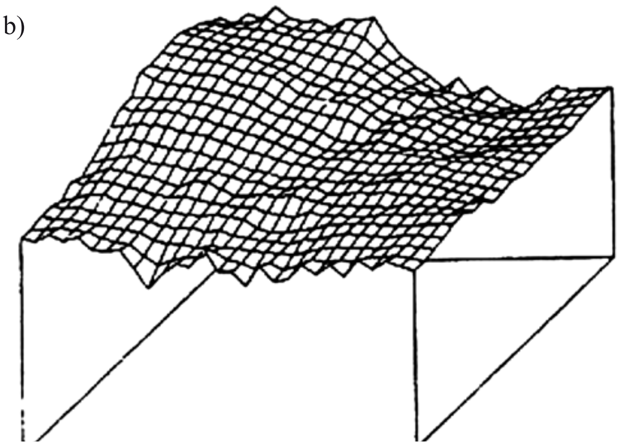


Figure 4. (left, a) The average gradient potential for all the participants in Stadler and coll. experiment; (right, b) the corresponding circulation potential.

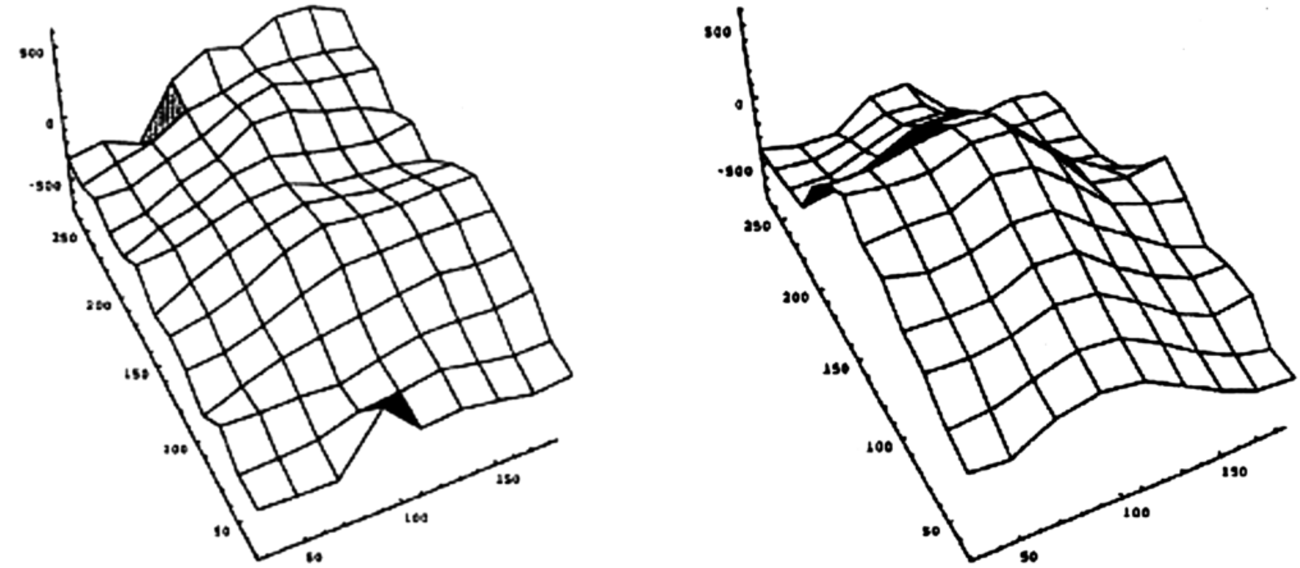


Figure 5. Vector field and gradient potential in Kruse, Luccio, Pfaff and Stadler's experiment, introducing isosceles triangles pointing the center (left) or the corners (right).

Following the same general methodology of the previous experiment, Kruse, Luccio, Pfaff and Stadler (1996) introduced different directionally oriented shapes in the field. For example, introducing isosceles triangles with the vertex "pointing" the center or the corners they obtained quite different vector fields and gradient potential (Figure 5).

They studied also the effects of the introduction of anomalous figures and of circular field, instead of rectangular ones. They were so able to demonstrate that the vector field modified itself according to the directionality of the introduced figures.

But let us give a short illustration of what a vector field is, and in which terms we can consider the visual field a vector field.

The visual field as a vector field

According to the representation of the vector field, one can describe the field $A(r)$ decomposing it into two subfields, a gradient field $G(r)$ and a circulation field $C(r)$:

$$A = G + C = -gradV + curlW \qquad (1)$$

The minus sign indicates that the vector G points down the hill, in direction of a lowering of the potential with hills (high potential) and valleys (low potential).

Before proceeding, let's introduce some concepts. We have a point in a space defined by a system of coordinates:

$$\mathbf{x} = (x, y, z) \qquad (2)$$

Suppose, now, that some property (the "value") of the point is function of the position of the point. We can write down this function so:

$$f = F(\mathbf{x}) = F(x, y, z) \qquad (3)$$

f is a scalar, and this space is a *field*: more precisely, a *scalar field*.

Suppose, now, that the result of the application of our function is not a scalar, but a vector:

$$\mathbf{v} = \mathbf{v}(\mathbf{x}) \qquad (4)$$

For example, the function **v** could indicate the different velocity of a point in function of its position. In this case, the length of the vector **v**, v, is its speed). Our field is now a *vector field*. Similarly, we can define *tensor fields*, and so on.

We are now interested in calculating the change of the value of f if we move along one coordinate (for instance, x), holding constant the other two other coordinates.

In other words, we work out the *partial derivative* of f with respect of x. The three directional derivatives along the base vectors can be seen as three components of a vector. We call this vector the *gradient* of the scalar field f, and we denote this as *grad* (f).

$$grad(f) = \nabla f = \mathbf{i}\frac{\partial f}{\partial x} + \mathbf{j}\frac{\partial f}{\partial y} + \mathbf{k}\frac{\partial f}{\partial z} \qquad (5)$$

Over a scalar field f, the gradient ∇f will form a vector field. Suppose we want to figure out the flow of strength, or flux, of something at a point. An approximation of this would to measure over some small area and divide by the area.

If we would like to measure the rotational strength at a point, could we then do something similar? The physical significance of the curl of a vector field is the amount of "rotation" or angular momentum of the contents of given region of space. Given three coordinates, for each couple of coordinates we can figure out this rotational components; that is,

$$\text{curl}\,\mathbf{f} = \mathbf{i}\left(\frac{\partial f_3}{\partial x_2} - \frac{\partial f_2}{\partial x_3}\right) + \mathbf{j}\left(\frac{\partial f_1}{\partial x_3} - \frac{\partial f_3}{\partial x_1}\right) + \mathbf{k}\left(\frac{\partial f_2}{\partial x_1} - \frac{\partial f_1}{\partial x_2}\right) \qquad (6)$$

Notice that any continuous function with continuous derivative (at a point $\mathbf{x}$) can be approximated by a linear function at the point. So, we get

$$\tilde{\mathbf{n}}\ \text{curl}\,\mathbf{f} = \lim_{\Delta A \to 0} \frac{\oint_C \mathbf{f} \cdot d\mathbf{r}}{\Delta A} = \left(\nabla \times \mathbf{f}\right) \cdot \tilde{\mathbf{n}} \qquad (7)$$

$\tilde{\mathbf{n}}$ is the unit normal vector to $\nabla \times \mathbf{f}$. The second part is a *line integral* over an infinitesimal region *A* that is allowed to shrink to zero via a limiting process.

Now, notice that *div curl* as well as *curl grad* is equal to 0. This means that

$$V(\mathbf{r}) = -Q(\mathbf{r}), \qquad (8)$$

and

$$W(\mathbf{r}) = -R(\mathbf{r}). \qquad (9)$$

In other words, the sources $Q(\mathbf{r})$ of the vector field are equal to the gradient potential $V(\mathbf{r})$ with the minus sign. The computational procedures are not simple, and here we have not the space to velop them. The interested reader is referred to Stadler et all. (1991, p. 107-109). Notice that to manage such procedures we must discretize sour field.

The replication experiments

In more recent years, we introduced several methodological innovations (first proposed by Luccio, Mancini and Salvadori, 2005). Our aim was to further investigate the dynamics of the visual field as a vector field, improving the consistency of the obtained results. At this aim, the participant was presented with a screen on which there was a dot randomly chosen in a virtual matrix of 744 × 522 points. After a 1 sec masking, the participant had to draw with the mouse on the screen a point in the same position in which he had seen the previous point. The participant was unaware of the fact that after the first four points, the new points that appeared on the screen were the same that he/she himself/herself had drawn four points before. In this way we were able to follow the sequences of the points.

Figure 6. A typical pattern of one participant.

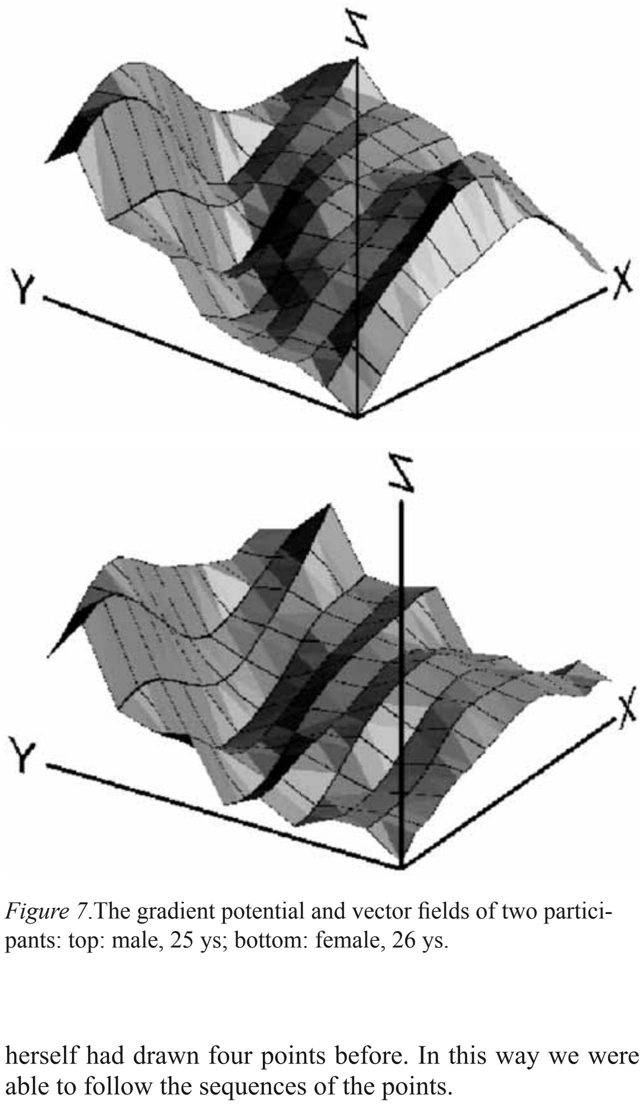


Figure 7. The gradient potential and vector fields of two participants: top: male, 25 ys; bottom: female, 26 ys.

Each participant had to perform 3,200 determinations in 40 sessions, with an interval from one session to the other that could last from 15 minutes to one day. The analysis of data was to be done individually for each participant. All the patterns obtained by the participants were quite similar. A Typical one is shown in Figure 6.

We computed the decomposition of the displacement of each point in the two components of gradient and curl, and calculated the field vector and gradient potential, using the same computational procedures of the previous experiments. On this basis, we were able to map the different levels of potential on a landscape, which we can show here. For sake of brevity, I present only the patterns of two participants (male, 25 years, and female, 26 years). The data are averaged from the four quadrants of the field only in one quadrant, with a second order smoothing.

The pictures can appear at first sight similar to the ones obtained by Stadler and collaborators and Pfaff and collaborators, and as in all previous research, the valleys (low potential) are along the main diagonals, which act as attractors. However, notice that in the center of the field (at the intersection of the axes, given that we have here only a quarter of the field) there is a very low potential, as in Blum's patterns, but differently from the ones obtained with the replication experiments. This difference can be explained only in terms of difference in method.

We must stress that in no participant was apparent some clear effect of sequence, but that they were also unaware of the fact that they had to reproduce the points that they themselves had drawn earlier.

In conclusion, this technique appears a reliable way to assess the dynamics of the visual field as a vector field. Of course, a great amount of research is again needed, given the great individual differences and the high sensitivity of the method to minimal changes.

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