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Eccentric grouping by proximity in multistable dot lattices

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Abstract

The Pure Distance Law predicts grouping by proximity in dot lattices that can be organised in four ways by grouping dots along parallel lines. It specifies a quantitative relationship between the relative probability of perceiving an organisation and the relative distance between the grouped dots. The current study was set up to investigate whether this principle holds both for centrally and for eccentrically displayed dot lattices. To this end, dot lattices were displayed either in central vision, or to the right of fixation with their closest border at 3° or 15°. We found that the Pure Distance Law adequately predicted grouping of centrally displayed dot lattices but did not capture the eccentric data well, even when the eccentric dot lattices were scaled. Specifically, a better fit was obtained when we included the possibility in the model that in some trials participants could not report an organisation and consequently responded randomly. A plausible interpretation for the occurrence of random responses in the eccentric conditions is that under these circumstances an attention shift is required from the locus of fixation towards the dot lattice, which occasionally fails to take place. When grouping could be reported, scale and eccentricity appeared to interact. The effect of the relative interdot distances on the perceptual organisation of the dot lattices was estimated to be stronger in peripheral vision than in central vision at the two largest scales, but this difference disappeared when the smallest scale was applied.

Keywords: Central vision; Peripheral vision; Grouping; Proximity; Gestalt

1. Introduction

The legacy of early Gestalt psychologists remains of considerable value to vision scientists and visual neuroscientists today (Rock & Palmer, 1990; Spillmann, 1999; Westheimer, 1999). One particularly important Gestalt contribution is the definition of grouping principles governing perceptual organisation. A group of researchers has taken up the challenge of specifying these principles quantitatively so that concrete predictions can be derived from them (e.g., Kubovy, Holcombe, & Wagemans, 1998; Quinlan & Wilton, 1998). Among these principles, the 'Pure Distance Law' (Claessens & Wagemans, 2005; Kubovy & Wagemans, 1995; Kubovy et al., 1998) has been proposed as an objective quantification of the Gestalt law of proximity, which states that units that are close together tend to be grouped together. The model has been shown to predict grouping by proximity in dot lattices, a class of multistable dot lattices that can be organised in four ways (**a**, **b**, **c** and **d**; see Fig. 1A and B) as a collection of parallel lines (Kubovy, 1994).

Central to the model description of the Pure Distance Law is the assumption that the probability of making a particular organisation depends purely on the distance between the dots that are grouped together (|v|) relative to the shortest possible interdot distance (|a|) in the dot lattice. The exact function is given in Eq. (1). The model parameter α expresses the strength of this relationship. The higher this value, the more grouping will depend on the relative interdot distance. Note that in this equation and throughout the article an organisation is indicated by a boldface letter (e.g., **a**) and the corresponding interdot distance is indicated by the || markers (e.g., |a|).

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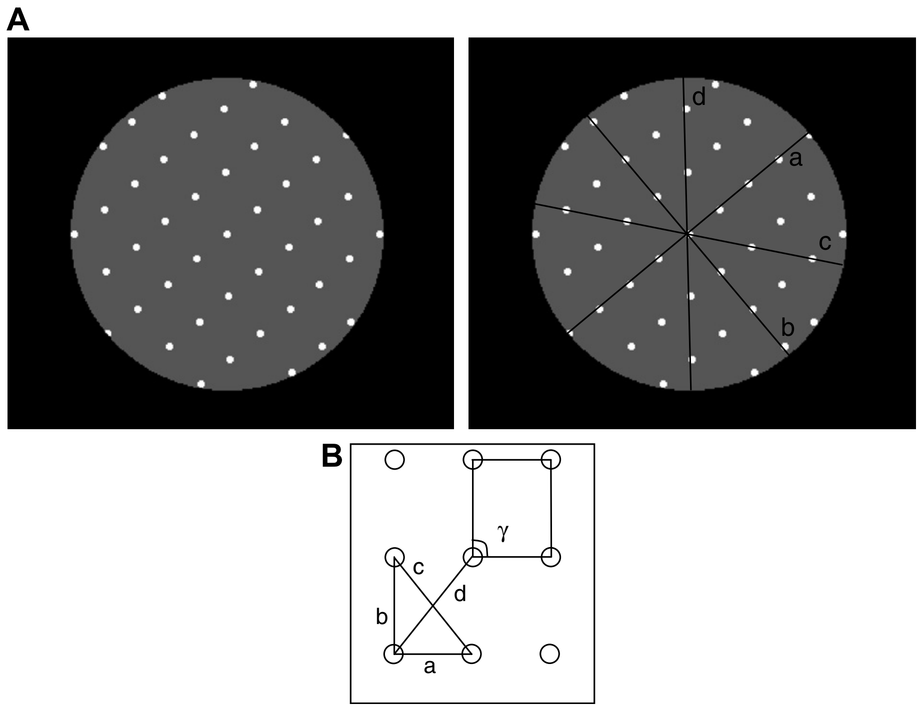

Fig. 1. (A) Illustration of a dot lattice. Note that there are four possible organisations in the dot lattice on the left, each illustrated on the right by a line indicating the orientation of the grouping. Organisations **a** and **b** tend to be seen more frequently. (B) Basic parallelogram of a dot lattice. The basic parallelogram characterises the dot lattice and is determined by the length of two vectors **a** and **b**, that correspond to the sides of the parallelogram, and the angle described by the two vectors (γ). Vectors **a** and **b** correspond to the shortest and the second shortest interdot distance. The **c**- and **d**-vectors correspond to the diagonals of the base parallelogram. In the case of rectangular dot lattices, the basic parallelogram is a rectangle. The four vectors indicate the four possible organisations of a dot lattice (adapted from Kubovy et al., 1998).

$$f(\mathbf{v}) = \frac{p(\mathbf{v})}{p(\mathbf{a})} = e^{-\alpha\left(\frac{|v|}{|a|}-1\right)} \quad (1)$$

The relationship expressed in Eq. (1) is exponential. A linear equation is more convenient for modelling and displaying the results. Such an equation is obtained by taking the natural logarithm of $f(\mathbf{v})$ in the above formula. The result is called the logit value of perceiving organisation **v** (see Eq. (2)).

$$\ln\left(\frac{p(\mathbf{v})}{p(\mathbf{a})}\right) = -\alpha\left(\frac{|v|}{|a|} - 1\right) \quad (2)$$

It is assumed that the four possible organisations of the dot lattices (**a**, **b**, **c** and **d**) are exhaustive and mutually exclusive, which is expressed in the following equation:

$$p(\mathbf{a}) + p(\mathbf{b}) + p(\mathbf{c}) + p(\mathbf{d}) = 1 \quad (3)$$

From Eqs. (1) and (3), we can derive the predicted probabilities for each organisation:

$$p(\mathbf{a}) = \frac{1}{1 + e^{-\alpha\left(\frac{|b|}{|a|}-1\right)} + e^{-\alpha\left(\frac{|c|}{|a|}-1\right)} + e^{-\alpha\left(\frac{|d|}{|a|}-1\right)}}$$

$$p(\mathbf{b}) = \frac{e^{-\alpha\left(\frac{|b|}{|a|}-1\right)}}{1 + e^{-\alpha\left(\frac{|b|}{|a|}-1\right)} + e^{-\alpha\left(\frac{|c|}{|a|}-1\right)} + e^{-\alpha\left(\frac{|d|}{|a|}-1\right)}}$$

$$p(\mathbf{c}) = \frac{e^{-\alpha\left(\frac{|c|}{|a|}-1\right)}}{1 + e^{-\alpha\left(\frac{|b|}{|a|}-1\right)} + e^{-\alpha\left(\frac{|c|}{|a|}-1\right)} + e^{-\alpha\left(\frac{|d|}{|a|}-1\right)}}$$

$$p(\mathbf{d}) = \frac{e^{-\alpha\left(\frac{|d|}{|a|}-1\right)}}{1 + e^{-\alpha\left(\frac{|b|}{|a|}-1\right)} + e^{-\alpha\left(\frac{|c|}{|a|}-1\right)} + e^{-\alpha\left(\frac{|d|}{|a|}-1\right)}}$$

The Pure Distance Law has been tested and confirmed for large dot lattices (aperture radius of 12.6°) shown centrally. This means that both central and peripheral information was available. In the current study we examined grouping of dot lattices either shown centrally or at eccentric locations. We investigated whether the model still holds in the latter conditions in which only peripheral information is available.

Peripheral visual input is undersampled and underrepresented relative to central vision, due to anatomical differences already apparent at the retinal level and continuing up the visual pathways (Wilson, Levi, Maffei, Rovamo, &