Spatial Clustering and Its Effect on Perceived Numerosity and Dispersion

Michele Zito[1], Nick Scott-Samuel[2], and Marco Bertamini[3]

1. Department of Computer Science, University of Liverpool, UK
2. Department of Psychology, University of Bristol, UK
3. Department of Psychological Sciences, University of Liverpool, UK

Perception of numerosity

Human observers are able to estimate the numerosity of large sets of visual elements. The occupancy model of perceived numerosity in intermediate numerical ranges is based on the overlap of regions of influence around each element. The key idea is that when items are within a certain range they start to count for less than their actual numerical value, and more so the closer they are to their neighbours.

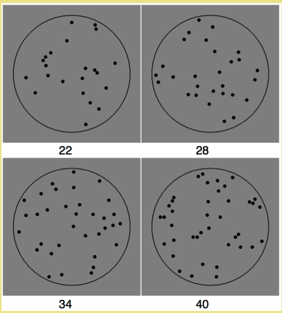
The study

We tested perceived numerosity using elements placed at random within a circular region. Observers saw two patterns (presented in two intervals) and chose the one that appeared as more **numerous**. The same observers performed two other separated tasks in which they judged which pattern appeared more **dispersed**, or more **clustered**. In each pair of images the number was always the same because we were interested in which "appeared" more numerous. We computed the following spatial properties: **area of convex hull**, **occupancy area**, **total degree** of connectivity, and **local clustering**.

The results suggest that estimates of numerosity, dispersion and clustering are based on different spatial information, that there are alternative approaches to quantifying clustering, and that in all cases clustering is linked to a decrease in perceived numerosity. The alternative measures have different properties and different practical and computational advantages.

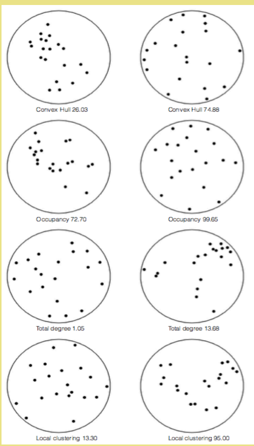
Stimuli

Elements (between 22 and 40) were placed at random within a circular region. Observers performed three separated tasks in which they judged which pattern appeared more numerous, more dispersed, or more clustered. In each pair the number was the same (22, 28, 34, or 40 items).



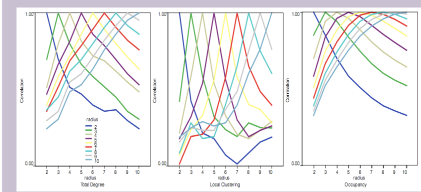
Examples of stimuli with 22, 28, 34 and 40 elements within a circular contour. The only constraint on position was that the elements could not overlap.

Examples of extreme values for each of the four indices. To illustrate, 20 dots are shown in each example and the parameter r is always four times the radius of the dot. The configurations are those with minimum (left) and maximum (right) values from 10000 random configurations. For ease of comparison values are expressed as percentages. For example for convex hull the area is divided by the area of the circle. For occupancy the area is divided by the maximum value (the sum of areas without any overlap). Note a similarity in the comparison between the left and right columns (with a reversed pattern in the top two and in the bottom two).

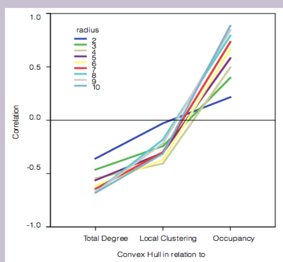


Indices

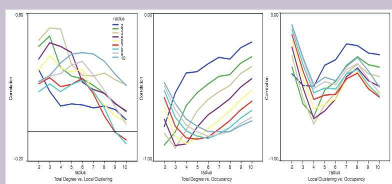
We computed the following spatial properties: area of convex hull, occupancy area, total degree of connectivity, and local clustering. For all indices apart from convex hull we varied a parameter for the radius of the area that defined neighbours.



Correlations between values computed with different radii. The peak in the lines is the point where correlation is 1. For all indices the correlation drops quickly on either side, showing that radius is indeed an important parameter.

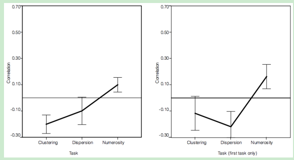


Convex Hull in relation to the other three indices. The relationship is positive with Occupancy and negative for the other two.

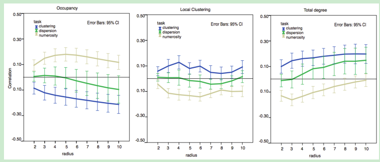


Relationship between each pair of indices as a function of radius. Note how correlations range from some high values (close to 1) to values close to zero in other cases. Total degree and local clustering tend to be positively correlated, and both are negatively correlated to occupancy. This is because as area increases clustering decreases.

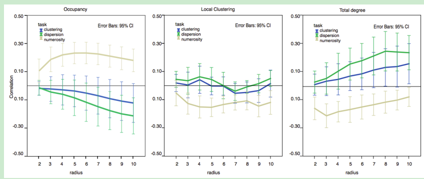
Results



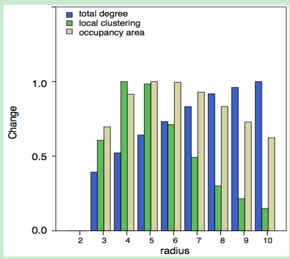
Mean correlation values for the difference score of the convex hull (difference in area) and responses. The first panel shows the data for all participants on all three tasks: a correlation between tasks performed by the same person. The second panel shows only the first task performed: three different groups.



Mean correlation values for the difference score of the local clustering, total degree and occupancy area and the observer's response.



Mean correlation values for the difference score of the local clustering, total degree and occupancy area and the observer's response. Only one third of the data is included with respect to the graph in Figure 7, because this graph shows how observers responded on the first task only.



References

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