# The role of global layout in visual short-term memory

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Among the most fundamental questions we can address in visual cognition research is what the basic unit of analysis is for a particular visual function. Work on visual memory has contrasted three candidate units: objects, spatial locations, and feature dimensions. An implicit assumption in this search for the basic units of memory is that the units are independent: whether objects, locations, or features are the basic unit of analysis, presumably each unit is encoded and stored in memory independently of the others.

Although some earlier research suggested that visual short-term memory operates over discrete objects (Lee & Chun, 2001; Luck & Vogel, 1997), more recent work suggests that the independence assumption may be false. Specifically, it appears that the spatial relationship between objects plays a role in memory for both spatial and featural information about objects. For example, disrupting the spatial layout of a display between the study display and the test display interferes with retrieval of both the location and the identity of objects (e.g., Jiang, Olson, & Chun, 2000).

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While it appears that spatial configuration may play an important role in visual memory, it is less clear how we should characterize the spatial configuration of a collection of objects. Exactly what constitutes the spatial configuration of a collection of objects, and which dimensions of this configuration are important for memory? In the present study we attempt to quantify the spatial layout of objects and to determine which aspects of spatial layout are represented in memory.

## QUANTIFYING SPATIAL LAYOUT

The first step for this study was to develop a formal method to quantify the spatial relationship between objects with a psychologically relevant measure. Gestalt psychology suggests many candidate features, and we began with what we call "spatial regularity", which represents the degree of regularity in the spacing between objects.

To quantify spatial regularity, we begin by reducing each object to a set of $\{x,y\}$ coordinates corresponding to the object's centre of gravity. An index of spatial variability was computed by measuring the distance between each pair of objects, then taking the standard deviation of these distances and dividing it by the mean (variability index = std/mean). Dividing by the mean makes this measure a scale invariant index of the variability in the spacing between objects. Finally, an index of *spatial regularity* was taken as 1/(variability index). Displays with higher values on this regularity index tend to look more organized and structured (see Figure 1a).

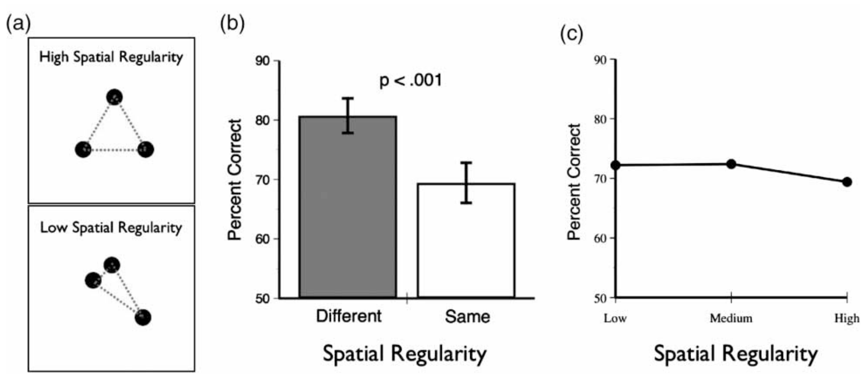


**Figure 1.** (a) Quantifying spatial regularity. (b) Percent correct on the change detection task was higher when the change altered spatial regularity (different) than when it left the spatial regularity unchanged (same). (c) Overall level of spatial regularity did not affect change detection accuracy.

## REPRESENTATION OF SPATIAL REGULARITY IN MEMORY

We investigated the extent to which our measure of spatial regularity captures the representation of the spatial relationship between objects in memory. We had observers remember the location of a set of briefly presented objects, followed by a blank interval, and then a test display in which one item changed location. Two items in the test display were highlighted (the one that changed, and one that did not), and the task was to indicate which of the two items had changed location.

The distance of the location change was always 4 degrees visual angle. However, in the spatial regularity–same condition, the change resulted in the same spatial regularity between items, whereas in the spatial regularity–different condition the change altered the spatial regularity between items. The results showed that a location change that disrupts the spatial regularity was identified more accurately than one that did not alter the spatial regularity (Figure 1b). Critically, the local change in terms of pixel distance was identical for these two conditions, so it must be the magnitude of change in the spatial layout that distinguished between them.

It appears that the spatial relationship between objects is an important component of the memory representation, and our spatial regularity measure captures an important component of this representation. While previous work has suggested that spatial layout is encoded in memory (Jiang et al., 2000), to our knowledge the spatial regularity measure is the first formal representation that has been shown to capture a psychologically relevant component of spatial layout.

## EFFECTS OF SPATIAL REGULARITY ON MEMORY CAPACITY

Although it appears that spatial regularity measures a critical component of relational encoding in visual memory, it does not appear to be a factor in determining the amount of information that can be stored in short term memory. Our results suggest that is just as easy to remember the layout of objects with low spatial regularity, as it is to remember the layout of objects with high spatial regularity (Figure 1c). Thus, while these regularities are part of the memory representation (as described above), they do not impact the fidelity of memory storage.

This indicates that the spatial relationships between objects are not encoded for the purposes of "saving memory space" by forming a more compact code for memory storage. Instead, these spatial relationships must play a different role. One possibility is that the degree of spatial regularity is an informative feature in real-world contexts. If this were the case, then the ability to detect and maintain this information in memory could be important for learning and could lead to faster more efficient processing of information in real world displays. Further research exploring spatial regularity in real-world scenes is necessary to test this possibility.

## REFERENCES

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# An information processing investigation of hierarchical form perception: Evidence for parallel processing

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Studies of hierarchical form perception (e.g., large letter composed of individual letters) have explored many experimental conditions supporting findings of global advantage, i.e., global reaction times (RTs) are faster than local RTs, and global interference, where incongruent global information slows local processing; such studies have pursued general underlying processing mechanisms for these findings (for review, see Kimchi, 1992). There exists a powerful set of models and methodologies developed by Townsend and colleagues (Townsend, 1974; Townsend & Schweickert, 1989) designed to establish more detailed mechanisms involved in cognitive processing and perception.

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