

The Functional Units of Visual Working Memory- Objects or Locations?



Verena-Cathérine Niederhöfer, Erik Blaser

Human Vision Laboratory, Psychology Department, University of Massachusetts Boston



Background

Visual Working Memory (VWM)

Interacting with and navigating in a complex environment requires remembering crucial visual information.

A solution is **short-lived storage** that can maintain a **limited number of visual items** (~ 4).

This Visual Working Memory (VWM) system allows for recognition, interpretation and manipulation, orchestrating interaction with the environment.

The Question

What is the organizing principle of VWM?

- single **features** (color, shape, texture etc.)?
- integrated **objects** (constellations of features)?
- all information at particular **locations**?
- Hybrid models?

The Answer ?

The answer is controversial.

→ Luck and Vogel found that observers remember two or more features about one object just as easily as any one single feature.



They concluded that

VWM is object-based

Luck and Vogel, 1997

→ But Delvenne and Bruyer (2004) were unable to replicate Luck and Vogel's results in which features within the same dimension did not compete for resources. Instead they supported the "dual storage mechanism" proposed by Wheeler and Treisman (2002).

→ **In general, the consensus is that there is some object benefit, and that VWM is to some extent or at some level object-based.**

But there's a problem...

A Problem and a Solution

The Confound

In previous studies of VWM, each object occupied a unique location. Thus the number of *locations* instead of the number of *objects* could have limited the capacity of VWM in these studies.

→ VWM could, in fact, be **location-based**.

The Solution: *Superimposed Objects*

Two objects transparently overlapped, two different patterns within the same boundary.



→ **two objects at one location**

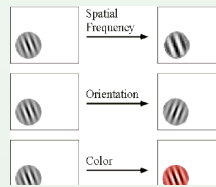
Blaser et al. (2000) showed that one can allocate attention to either one of 2 such objects and track changes over time.

'Gabor' Objects

Circular patches with colored sine-wave grating patterns defined by independent features (orientation, color, spatial frequency)

Advantages :

- Quantitative, independent feature-manipulation
- Unfamiliarity



A previous attempt

Lee and Chun (2001) also addressed this confound by testing memory on stimuli with superimposed rectangles and lines. Their results supported object-based memory.

Weaknesses

Variations: Not all feature dimensions were continuous

Familiarity: rectangles/lines are very easy to remember due to experience – potential long term memory contamination.

Incomplete Superimposition: Objects could not be completely overlapped; there was considerable white-space between objects.

Our Experiment

Methods

Procedure: Sequence of memory displays (2 sec exposure) followed by test displays on a computer screen, after a 800 ms retention interval

- 2 tasks:**
- Did the color change? ("C")
 - Did the orientation change? ("O")

2 conditions:

Within-object: both questions asked about same gabor

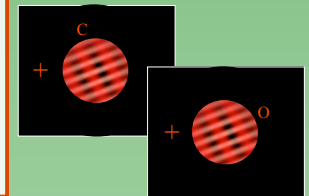
Between-objects: one question asked about each gabor

Memory display

1 deg



Test display (between-objects)



Predictions

If VWM is object-based, observers should be able to remember all features of a particular object, without significant competition for resources

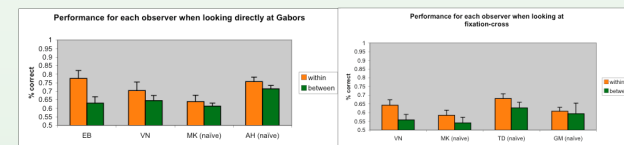
→ Performance for the *Within-object* condition should be better than performance in the *Between-objects* condition. **Within-object > Between-objects**

If VWM is location-based, observers should be able to remember all features at a particular location without significant competition for resources

→ Performance for the *Within-object* condition should be equal to performance in the *Between-objects* condition. **Within = Between**

Results

• Overall performance better for 'within-object' judgments than 'between-objects' judgments



Conclusion

When properly tested with superimposed objects (*two objects at one location*), thereby removing location-based confounds...

the units of VWM are best described as entire objects.

VWM is 'object-based'.

References

- Blaser, E., Pylyshyn, Z. W., & Holcombe, A. O. (2000). Tracking an object through feature space. *Nature*, 408(6809), 196-199.
- Delvenne, J. L., & Bruyer, R. I. (2004). Does visual short-term memory store bound features? *Visual Cognition*, 11(1), 1.
- Lee, D., & Chun, M. M. (2001). What are the units of visual short-term memory, objects or spatial locations? *Perception & Psychophysics*, 63(2), 253-257.
- Luck, S. J., & Vogel, E. K. (1997). The capacity of visual working memory for features and conjunctions. *Nature*, 390(6657), 279-281.
- Wheeler, M. E., & Treisman, A. M. (2002). Binding in short-term visual memory. *Journal of Experimental Psychology: General*, 131, 48-64.