Enhancing visual working memory performance using statistical regularities requires explicit awareness

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What is visual working memory?

- The system responsible for actively storing visual information essential for cognitive tasks
  - Reading this sentence requires a store for the letters and words
  - Tracking multiple objects in the visual scene
  - Predicting the motion of objects

Visual working memory capacity

- The amount of information this active store can retain is limited!
  - On average, 3-4 objects worth of information
- It is different between individuals
  - Gradually increases during adolescence into adulthood
- A reliable predictor of cognitive performance
  - High correlations with fluid intelligence, academic performance and control of attention

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Measuring VWM capacity

- Using a change-detection task

Can visual working memory capacity be increased?

- How does experience and learning influence visual working memory processes?
- Can we augment the visual working memory system with training?
- Do capacity increases lead to changes in cognition?

Mixed results in the literature…

Psychological Research
DOI 10.1007/s00426-015-0648-y

ORIGINAL ARTICLE

Working memory training improves visual short-term memory capacity

Hillary Schwarb · Jayde Nail · Eric H. Schumacher

Memory & Cognition
2004, 32 (8), 1326-1332

Visual short-term memory is not improved by training

INGRID R. OLSON
University of Pennsylvania, Philadelphia, Pennsylvania
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Harvard University, Cambridge, Massachusetts

Training Improves the Capacity of Visual Working Memory When It Is Adaptive, Individualized, and Targeted

Eunsam Shin, Hunjae Lee, Sang-Ah Yoo, Sang Chul Chong

Brady, Konkle, & Alvarez (2009)

Journal of Experimental Psychology: General
2009, Vol. 138, No. 4, 487–502

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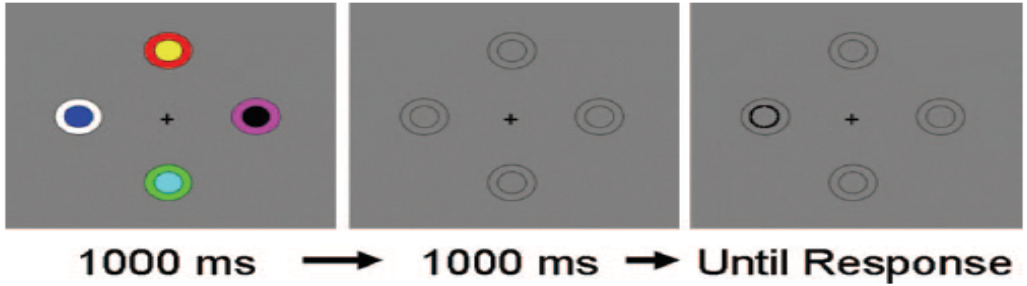
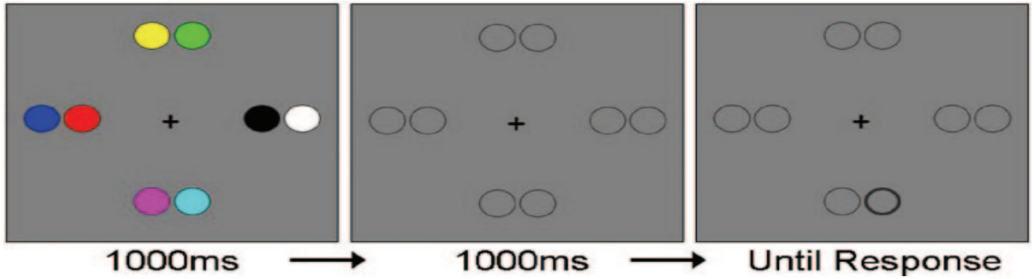
Compression in Visual Working Memory: Using Statistical Regularities to Form More Efficient Memory Representations

Timothy F. Brady and Talia Konkle
Massachusetts Institute of Technology

George A. Alvarez
Harvard University

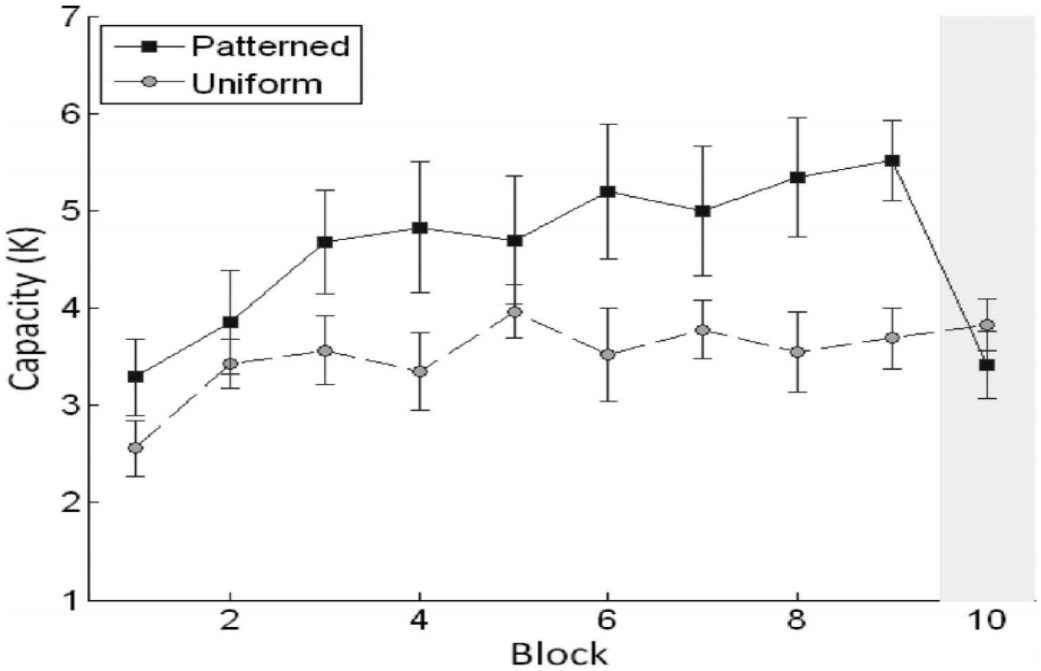
Brady, Konkle, & Alvarez (2009)





- 10 blocks of 60 trials
- Two conditions:
  - *Patterned* – Four pairs with high-probability (p = .2151) and all others with low-probability (p = .0027).
    - Approximately 80% of the pairs shown were the high-probability pairs
    - The regularities were removed from the displays in the last block
  - *Uniform* – All pairs with equal probability
- Between-subjects, n = 20

Brady, Konkle, & Alvarez (2009)



- Recall performance improves in the *patterned* condition but not in the *uniform* condition
  - Observers benefit from the statistical regularity in the displays
  - A product of visual statistical learning

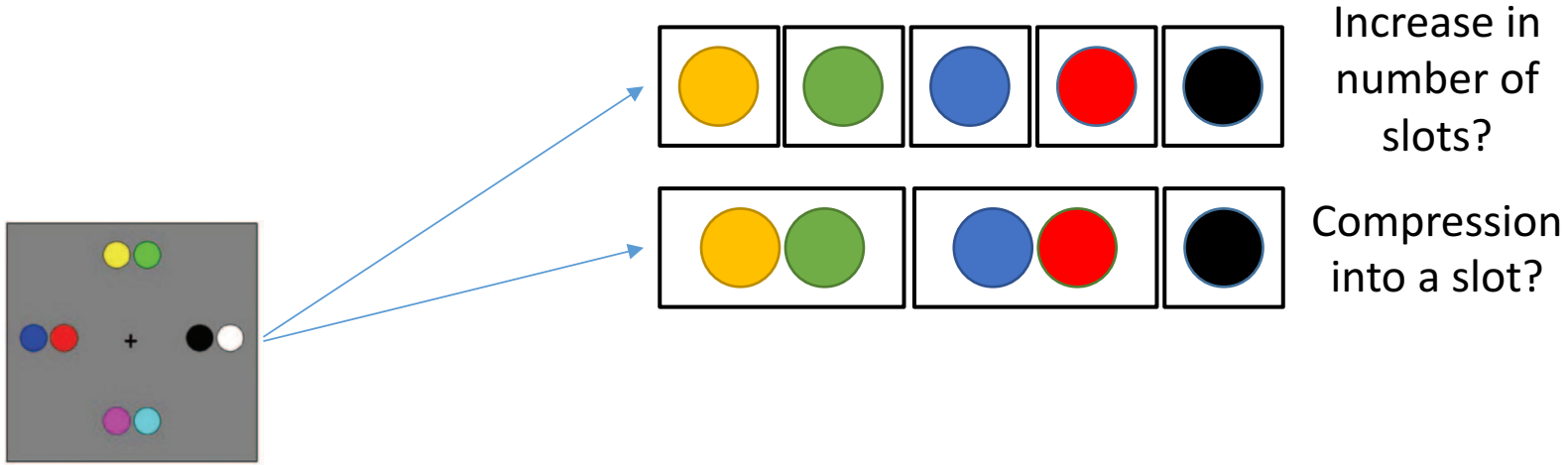
Visual Statistical Learning

- *The ability for observers to learn subtle statistical relationships automatically **without awareness** of those regularities*
  - Thought to involve unconscious statistical computations, forming the required associations between elements for the efficient **chunking** of information
  - An automatic underlying perceptual process, rather than a higher-level intentional learning strategy
  - Thought to proceed "automatically", "incidentally", "spontaneou[illegible] of mere exposure"

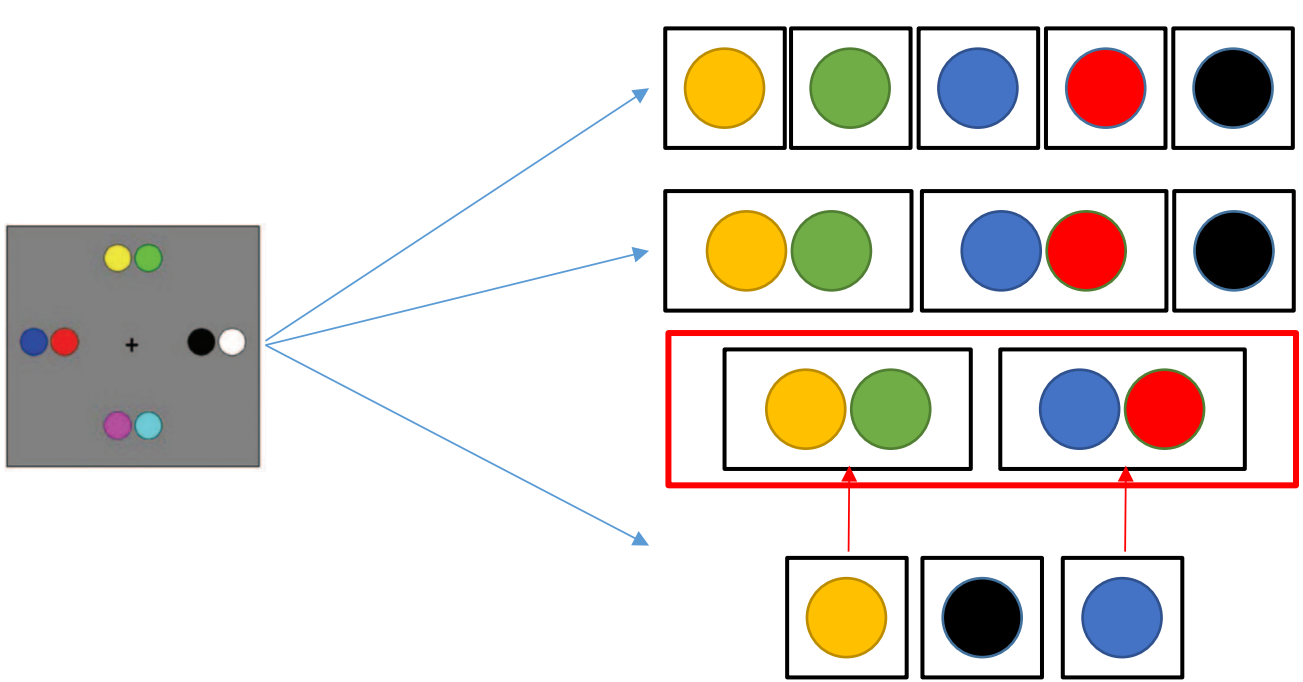
The Automaticity of Visual Statistical Learning

Nicholas B. Turk-Browne, Justin A. Jungé, and Brian J. Scholl
Yale University

How does this increase occur in VWM?



But is there an alternative?

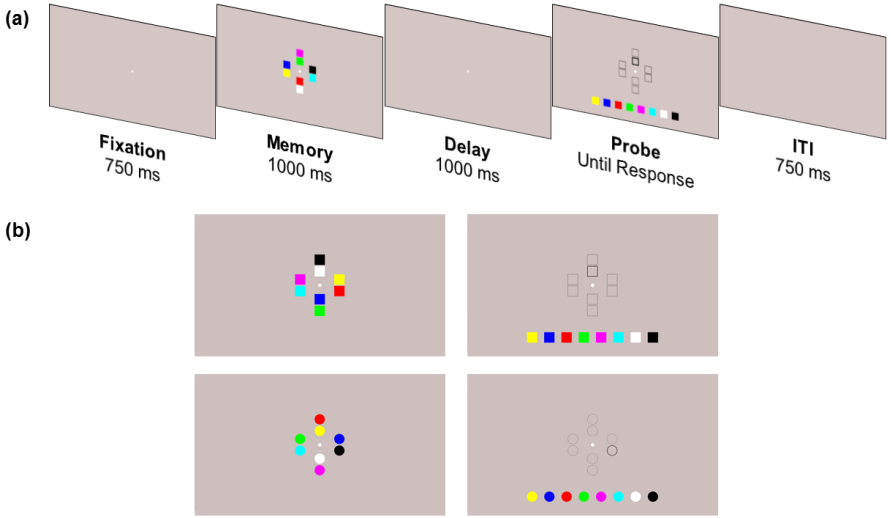


Increase in number of slots?

Compression into a slot?

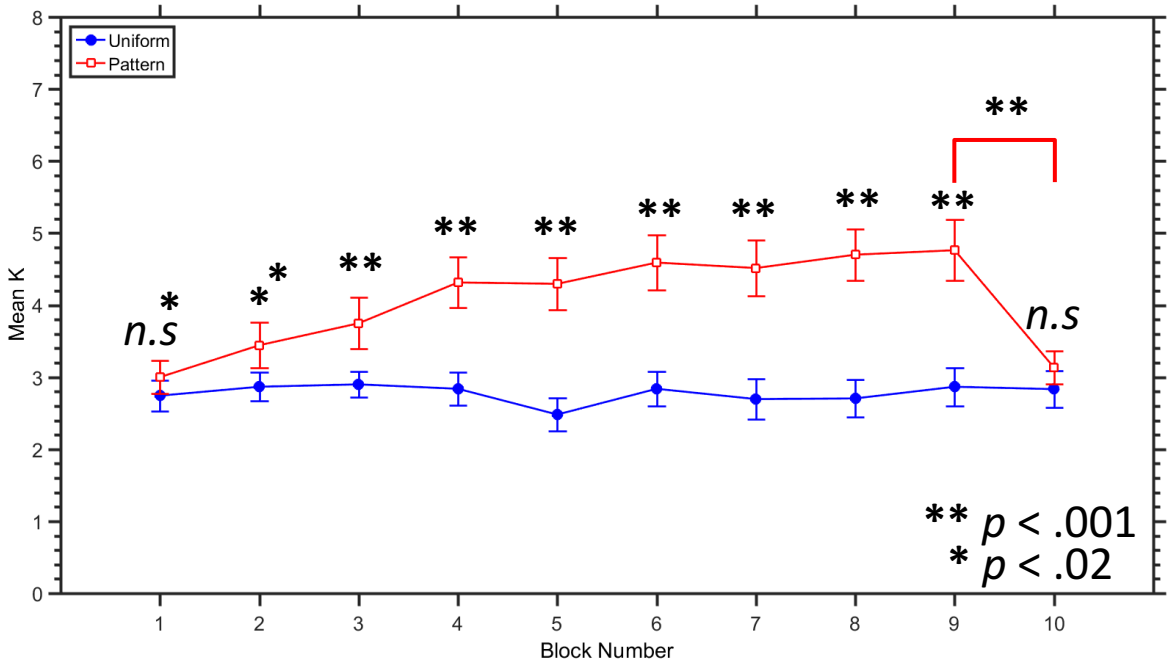
Pointers to chunks in LTM?

Experiment 1



- No explicit instruction about pairs or statistical regularities
- Blocked design – All subjects ($n = 32$) completed 10 blocks in the *patterned* condition and 10 blocks in the *uniform* condition
- *Tested on awareness at the end*

Did people get better with statistical regularities?



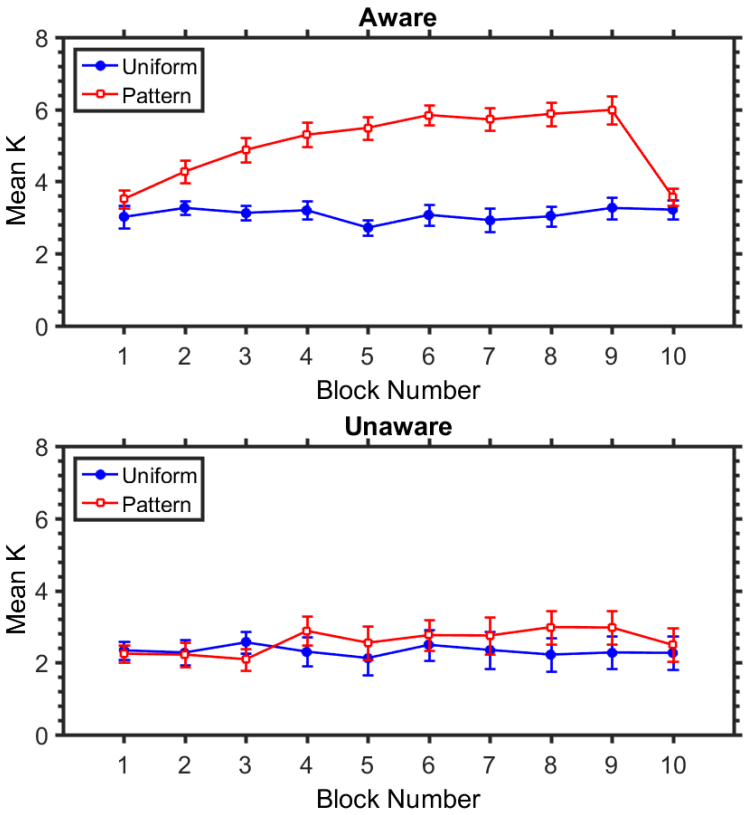
- Significant effect of condition, block and interaction between condition and block

Did participants become aware of the statistical regularities?

- Aware = Correctly identified **all** the colors paired in the high-probability pair with each of the **eight** colors.

	Patterned First	Uniform First	Total
Aware	**14**	5	19
Unaware	2	**11**	13
Total	16	16	32

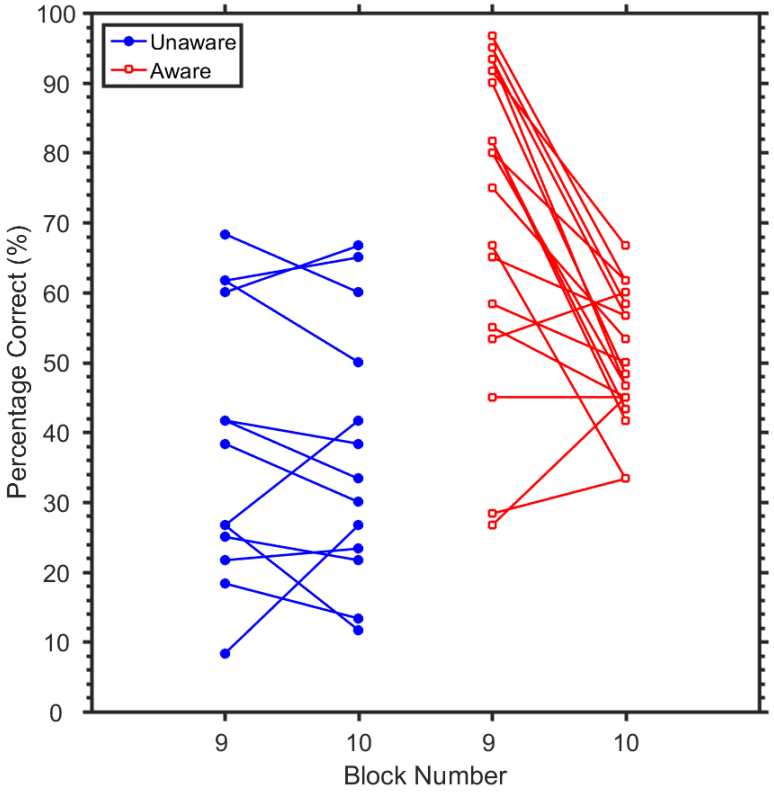
Did awareness of the statistical regularities help?

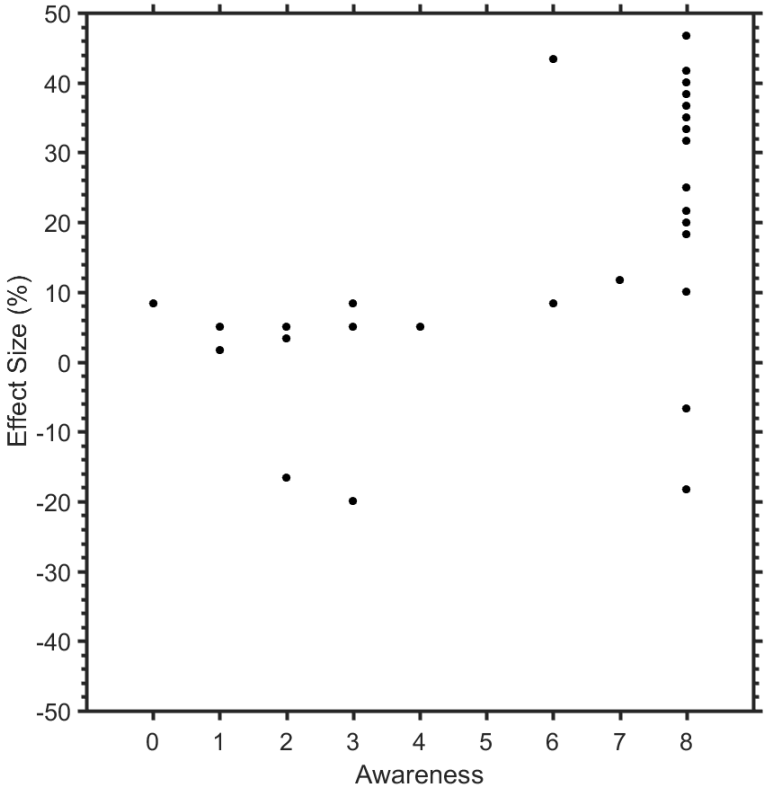


- Analysis with awareness as a factor
  - Main effect of awareness - $p < .001$
  - Significant three-way interaction - $p < .05$
- Among aware participants only, significant interaction between block and condition – $p = .001$
- Among unaware participants only, interaction between blocks and condition was not significant – $p = .35$

p	Condition	Block	Two-way Interaction
Aware	< .001	< .001	< .001
Unaware	*n.s*	*n.s*	*n.s*

What effect did awareness have?

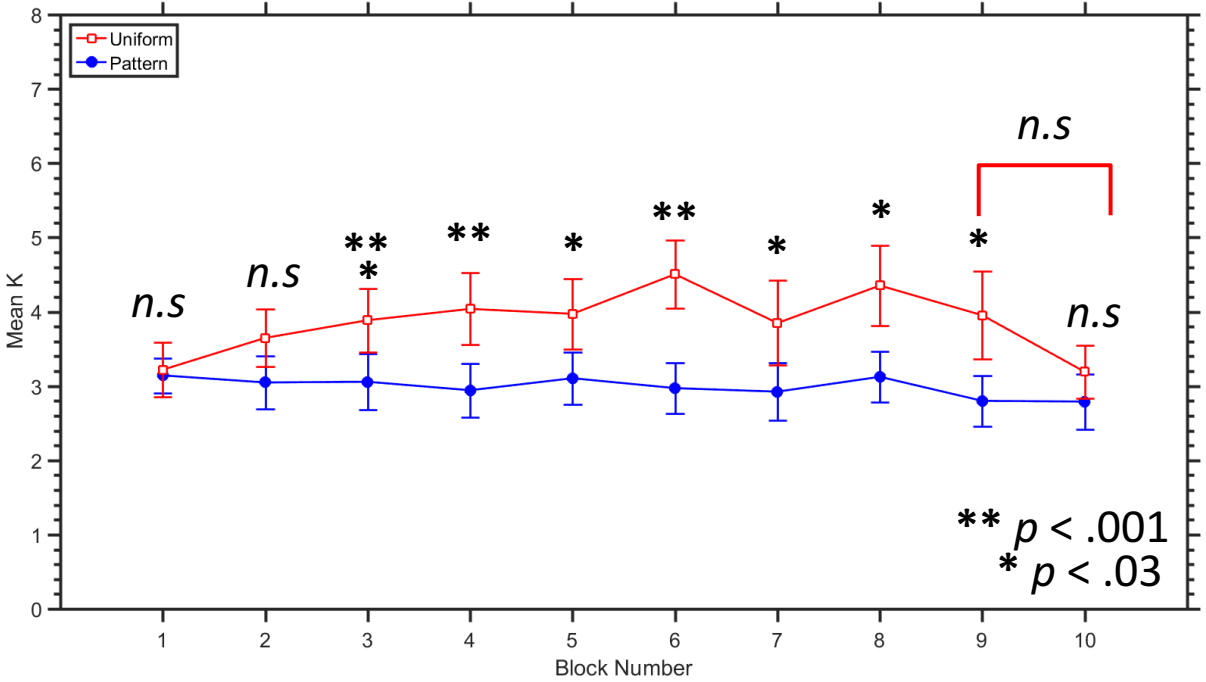




Experiment 2

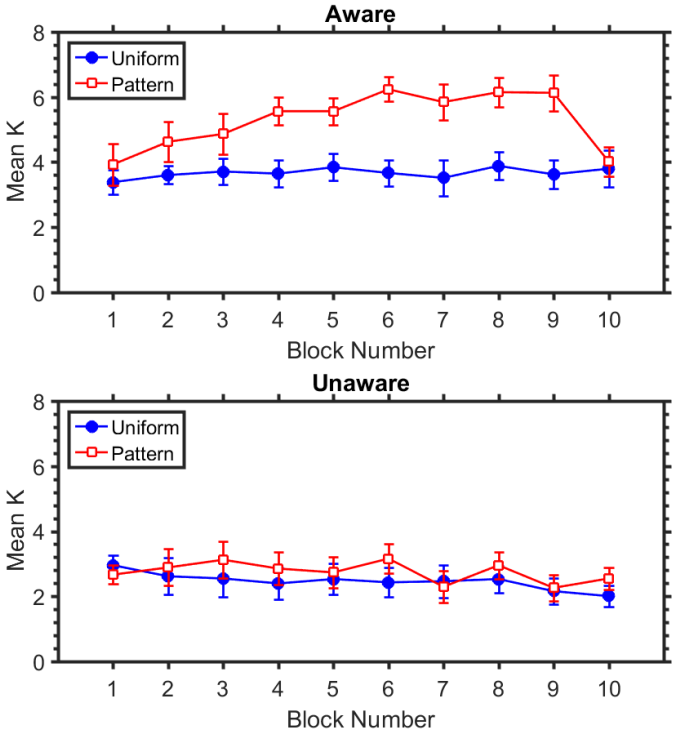
- It seems clear that explicit awareness seems to produce this “memory compression” effect…
- But we did have a primacy effect – Participants who completed the patterned blocks first were more likely to be aware.
- Alternating conditions
  - *Patterned* block followed by a *uniform* block or vice versa

Did we replicate observers improving with statistical regularities?



- Main effect of condition, no effect of block but significant interaction
- No primacy effects this time

Did we replicate the effect of awareness?



- 7 of the 16 observers were 'aware'
- Three-way ANOVA (awareness, block, condition)
  - Main effect of awareness - $p < .01$
  - Significant three-way interaction - $p < .05$

p	Condition	Block	Two-way Interaction
Aware	< .001	< .001	< .001
Unaware	*< .02*	*n.s*	*n.s*

Conclusions

- Memory compression requires explicit awareness of statistical regularities
  - This suggests that the memory compression effect is not produced by implicit visual statistical learning
- Observers may use chunks held in LTM to improve recall performance
  - VWM does not need to be augmented to hold chunks of feature values
  - Using objects stored in VWM as pointers, they can retrieve the chunk and recall more items in the display

Thank you

Edward Awh

Edward Vogel

Alex Holcombe

Patrick Goodbourn

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