The Capacity of Visual Short-term Memory Is Set Both by Visual Information Load and by Number of Objects
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APPENDIX

Two methods were used to estimate capacity in terms of the number of objects stored for each stimulus material. The first method is based on change detection accuracy averaged over change and no-change trials. The second method, based on Pashler (1988), takes both hits (accurately detecting a change) and false alarms (reporting a change when there was no change) into account. Both models are admittedly simplified, but nevertheless allow us to interpret memory capacity in terms of the number of objects stored.

Method 1: 75% Threshold Divided by 2

Dividing the 75%-correct threshold by 2 can provide a rough estimate of capacity in these experiments (see Table A1). Subjects were instructed to indicate "different" only when they saw an object change, and "same" otherwise. Thus, to obtain 75% correct for, say, eight objects in the display, subjects could store half of these in memory and answer "different" correctly when one of them changed (i.e., on half of the change trials) and then answer "no change" incorrectly when one of the other objects changed (the other half of the change trials). Assuming that subjects always indicated "same" on no-change trials, performance would be 100% correct on no-change trials and 50% correct on change trials, or 75% correct overall, if half of the objects were stored in memory. This rough estimate, however, does not take into account the probability that subjects guessed that there was a change even when they did not see the change. Method 2 addresses this concern.

Method 2: Probability of Hits and False Alarms

Pashler (1998) proposed a model for estimating the number of objects stored in a change detection task:

$H = m/n + (n - m)/ n * g$,

where H is the probability of a hit (correctly indicating there was a change), m is the number of objects stored in memory, n is the total number of items presented, and g is the probability of guessing there was a change. The model assumes that when one of the items in memory changes (m/n of the change trials), the subject accurately detects the change. When an item that is not stored in memory changes ($(n - m)/n$ of the change trials), the subject will guess correctly on some portion of the trials (g). This guessing rate can be estimated from the proportion of trials on which the subject guesses there was a change on no-change trials (false alarms). Thus, given the hit rate and false alarm rate for a particular set size, it is possible to solve this equation for the number of objects stored.

In the current experiments, change detection was tested at eight different set sizes, providing eight hit rates and eight false alarm rates for each stimulus class. Thus, we obtained an estimate of capacity for each stimulus material at each set size individually for each subject. The average of the eight individual estimates was taken as each subject's capacity for a given material. Note, however, that set sizes less than the capacity or much higher than the capacity do not provide appropriate estimates. For example, perfect performance at set size 1 can yield a maximum capacity estimate of 1 object, even if the true capacity is 4 objects. At larger set sizes, such as set size 15, subjects appear to change their strategy. Realizing that they have little chance to detect actual changes, they guess more freely (higher rates of false alarms) and appear not to put much effort into storing the stimuli. As a result, the frequency of hits minus the frequency of false alarms becomes very small or negative. Therefore, after taking the average estimate over all set sizes, we dropped set sizes smaller than this first average or greater than twice this first average, and took the average estimate from the remaining set sizes as the capacity estimate. This process was iterated until the estimate no longer changed. This procedure limited the set sizes included in the estimate to a few set sizes near, but always greater than, the capacity estimate.

The results provide capacity estimates very similar to those obtained from Method 1 (see Table A1). Note that this model fails to provide an adequate account for performance when false alarm rates are higher than the hit rate. This happened rarely (less than 5% of the cases), and these cases were not included in the analysis.

Table A1.

Mean capacity estimate and standard error of the mean for each stimulus material in Experiment 1.

	Method 1		**Method 2**	
Material	***M***	***SEM***	***M***	***SEM***
Drawings	3.25	0.53	2.63	0.47
Cubes	1.74	0.43	1.57	0.38
Polygons	2.31	0.48	2.04	0.29
Characters	2.82	0.33	2.76	0.14
Letters	3.06	0.21	3.65	0.44
Color	3.58	0.28	4.43	0.40