## Persistence of visual memory for scenes

## A medium-term memory may help us to keep track of objects during visual tasks.

uilding a complete representation of a visual scene requires information to be remembered across separate glances and over time<sup>1,2</sup>, but it has been suggested that visual details are forgotten soon after they are viewed<sup>3-6</sup>. Here I show that cumulative memory build-up allows the same number of objects to be recalled, irrespective of whether these were seen in a series of short, separate presentations several minutes apart, or as one continuous presentation of the same total duration. I find that the build-up of visual memory over time is much better than has been widely thought and may underlie the successful performance of real-world visual and cognitive tasks that require people to keep track of objects in the immediate environment.

Scenes were computer-generated 'rooms' containing 12 unrelated objects (Fig. 1). They were presented for a cumulative viewing duration of 1, 2, 3 or 4 seconds, either all at once (continuous-presentation trials) or as brief views of 0.25, 1 or 2 seconds in duration and separated by as many as eight other trials (re-test trials). Participants (n=6;vision was normal or corrected to normal) did not know whether, or when, a particular scene would be re-tested, or whether a trial would contain an old or a new scene. The long intervals between re-tests (0.5-4.0 min), the presence of intervening presentations, and the random occurrence of re-tests precluded effective rehearsal.

Memory improved with re-testing. The number of items recalled after a series of separate brief views was almost identical to the number recalled after a single continuous

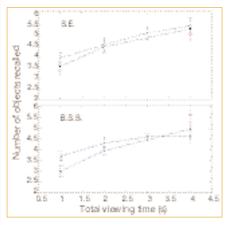
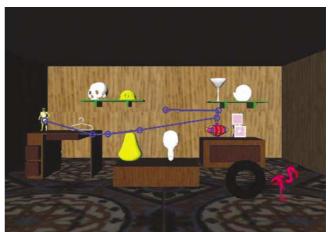


Figure 2 Number of items recalled as a function of total viewing time by two representative participants (S.E. and B.S.S.). Solid lines, continuous trials of 1, 2 or 4 s; dashed lines, performance after 1, 2, 3 or 4 re-test trials of 1 s each; squares, 4 trials of 250 ms each; triangles, 2 trials of 2 s each. Error bars represent standard error. Four other participants generated similar results (data not shown).

Figure 1 Visual memory for objects in a scene. Representative computer-generated display of 12 objects  $(1-2^{\circ} \text{ of visual angle})$  in a room  $(10 \times 8^{\circ} \text{ of visual angle})$ . The blue line shows the scanning path followed by one subject. Objects were presented for a cumulative viewing duration either as a continuous presentation or as brief separate views summing to the same duration. The number of items recalled was similar in both cases



view of the same total duration (Fig. 2). For example, the number of items recalled after the last of four separate 1-second trials was equal to the number of items recalled after 4 seconds of continuous presentation. Memory of each scene continued to accumulate over repeated viewings as though the scene had never been out of sight.

I investigated the nature of memory accumulation by presenting new objects on previously viewed backgrounds. If the entire scene (objects plus background) is encoded in the memory, then a familiar background should bring to mind the memory of the original set of objects and interfere with memory for the new set of objects<sup>7</sup>, which I found to be the case.

Memory was poorer for new objects seen against old backgrounds than for completely new scenes (P < 0.05; 6 subjects). When object names, such as 'apple', were presented in place of a picture of the object, the memory accumulation and the effect of repeating previously viewed backgrounds were both virtually abolished. These results suggest that a visuo-spatial representation of the whole scene was remembered across re-tests, rather than simply a verbal list of object names.

Earlier studies of visual memory produced diverse estimates of capacity<sup>4-6</sup>, with memory being either inferred from performance of a concurrent task or assessed using displays containing semantic cues that may have influenced encoding<sup>8-10</sup> or guessing<sup>11</sup> strategies. The experiments I describe here remove semantic cues and evaluate memory capacity by using measures of recall rather than by a secondary task.

The visual memory reported here is unusual in that it does not resemble traditional short- or long-term memory. Shortterm memory is not involved because the time between re-tests of the same display exceeded the temporal limits of information summation<sup>12</sup> and short-term memory<sup>13</sup>. Also, the presence of intervening scenes during the intervals between re-tests precluded rehearsal as a means of retaining the items in short-term storage. Traditional long-term memory was not involved either, because there was no build-up across days. The memory studied here may therefore be best described as 'medium-term' or 'disposable'.

Medium-term memory may underlie the ability to keep in mind the identity and location of objects while performing visuomotor tasks that last for a few minutes within an unchanging visual environment<sup>2,14,15</sup>. A medium-term visual memory could be instrumental in quickly directing the eye or arm to selected objects without the continual need for expensive or timeconsuming visual searching.

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