Supplementary Information

Behavioral experiment for the estimation of encoding duration for face and color stimuli.

1. Introduction

The time required to encode two colors and two faces were separately estimated by identifying when performance reached asymptote along a range of memory array durations, ranging from 30 ms to over 1,500 ms. In this experiment, the critical manipulation was the presentation duration of the stimuli. The encoding duration for each stimulus condition (color and face) was estimated as the presentation duration after which no further information could be stored in visual working memory (VWM) (Luck & Vogel, 1997). The methods in this experiment are very similar to those for the fMRI experiment's behavioral task, to which the reader is referred for comprehensive methodological details.

2. Methods

2.1. Participants. Thirty-nine volunteers (27 females, 2 left-handed) from the Vanderbilt and the local Nashville community provided informed consent and participated in this 1-hour long experiment for paid compensation. Twenty-four subjects performed both color and face conditions, and 15 subjects performed only the face condition, discussed in detail below. All subjects reported normal color vision.

2.2. Stimuli. In each trial, two grayscale faces were selected randomly without replacement from the sample set of twenty faces, which were modified in the same manner as in the neuroimaging experiment (e.g., control for mean contrast, differences in facial features, stimulus size). Two

colors were also selected randomly without replacement from a set of seven distinct colors (green, magenta, violet, yellow, cyan, light blue, and red).

2.3. Trial design. At the onset of each session, the subject was reminded of the task (remember color or face features). Trial onset was cued by a fixation cross appearing at the center of a computer display. At this point, the subject began an articulatory suppression task: rehearse "the" aloud at a fast but comfortable rate (2–3 times/second) (Baddeley, 1992). The experimenter monitored the subject's rehearsal in a separate room via an audio baby monitoring system. After 500 ms, the fixation cross was replaced by a small dot for 500 ms, then the memory array was presented. Because encoding takes longer for faces than colors, 15 of the 39 subjects performed only the face condition. This allowed for presentation durations that lie comfortably outside estimates for color encoding (Vogel et al., 2006) to be tested in the face condition. Thus, the total set of durations used for the face condition were 30, 50, 100, 300, 600, 900, 1,200, 1,500, 1,800, 2,100, 2,700, and 3,400 ms. The color condition used durations of 30, 50, 100, 300, 600, 900, 1,200, 1,500, and 1,800 ms. Each duration occurred four times in each block of trials, with the total number of trials dependent upon the experiment version (ranging from 32 to 72 trials/block), and subjects performed 8–14 blocks per session (number of blocks was inversely related to the number of trials per block). Immediately following the offset of the memory array, two masks were presented in the same positions as the memory array stimuli, for 500 ms. A 1,500-ms retention period ensued, during which only the fixation dot was presented. The probe stimulus was subsequently presented at fixation until the subject indicated whether the probe's target-relevant feature was present or absent in either of the two memory array stimuli. Subjects made button presses on a standard keyboard using the index and middle fingers of their dominant

hand to report whether the target feature was respectively present or absent in the memory array. Subjects were explicitly instructed to ignore the irrelevant feature, because its presence in the memory array was not related to the occurrence of the task-relevant probe feature. Subjects were instructed to emphasize accuracy, but to still respond in a timely manner. After responding to the probe, they could stop rehearsing "the". The intertrial interval was 500-ms.

Every thirty trials, a screen appeared that reminded the subject of the task, and the subject could take a break at that time, To motivate subjects to perform as accurately as possible, subjects were given the opportunity to win up to $10 in bonus pay for responding accurately. As in the neuroimaging experiment, the reward amount of money was prorated as a fraction of the total number of experimental trials. The subject was compensated for each correct response, and the "rest-break screen" reported his or her total bonus reward. Finally, twenty practice trials were administered before each session.

3. Results and discussion

Performance in the memory task was converted to Cowan (2001) *k* values (Todd & Marois, 2004). Within each condition, pair-wise comparisons were made between durations to determine when performance reached asymptote. The onset of performance asymptote for a condition was defined as the duration whose *k* value is not significantly different from three subsequent durations. In the color condition, the amount of information encoded into VWM increased between consecutive increases in duration, from 30 to 300 ms (ts > 2.6, ps < 0.01, 2-tailed paired *t* tests) and leveled off with further increases in presentation duration between 300 and 1,500 ms (all ts < 1.2, ps > 0.28, 2-tailed; blue line in Figure S1). These results are interpreted as evidence for subjects needing approximately 300 ms to encode the two stimuli's

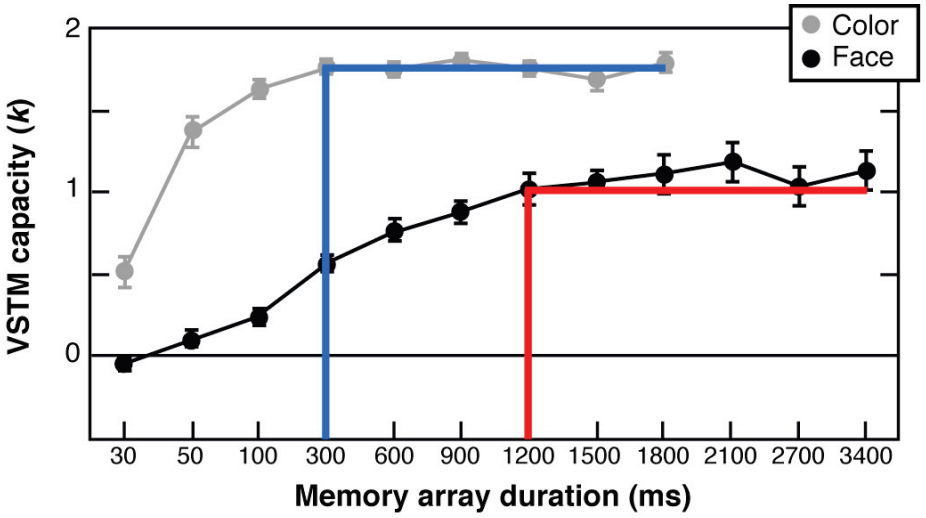

Figure S1. Encoding duration estimates of two color (gray) and two face (black) stimuli reached asymptote at different memory array durations, defined as when VWM capacity estimates (*k*) reached asymptote. Color encoding took less time (300 ms, blue line marking when performance reached asymptote) than faces (1,200 ms, red line). Error bars represent standard error of the mean.

colors. This estimate of encoding duration is somewhat larger than that estimated by others, possibly owing to the stimuli used in the present experiment being more complex (colored faces) than the stimuli used in experiments testing only color encoding, which were composed of a homogenous hue of a particular color (Vogel, Woodman, & Luck, 2006). Regardless, the important point is that is the current encoding estimate is much shorter than those for more complex stimuli, such as faces, as demonstrated next.

Subjects spent considerably more time encoding faces into VWM before their performance reached asymptote (red line in Figure S1). Performance increased up to 1,200 ms, at which point it stabilized with further increases in presentation duration (all pair-wise comparisons from 1,200 to 3,400 ms, ts < 2, ps > 0.06). Thus, performance reached asymptote when the memory array is presented for about 1,200 ms. Half of this estimate would represent the encoding duration of a single face (600 ms), and it is consistent with Curby and Gauthier's (2007) work showing that WM capacity for a single face doesn't change when it's presentation

duration is increased from 1,500 ms to 2,500 ms.

Taken together, the encoding time courses for colors and faces show that, on average, WM capacity is filled much sooner for colors than for faces, as evidenced by a shorter encoding duration for two colors (approximately 300 ms) than for two faces (about 1,200 ms). Functional MRI is capable of resolving this difference (900 ms) within a given brain region (e.g., Dux, Ivanoff, Asplund, & Marois, 2006). Thus, these stimuli were used the neuroimaging experiment, in order to isolate regions sensitive to VWM encoding duration.

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