Supplementary Methods

Subjects. Twelve naïve subjects participated in each of the three experiments (ages 18-45; normal or corrected-to-normal vision, 9 male, 27 female), and provided informed consent in accordance with the MIT Committee on the Use of Humans as Experimental Subjects.

Stimuli. The objects used in this experiment were modified versions of the publicly available "greeble" stimuli[1]. Object images were approximately 2.5° wide by 4° high and were presented on a gray background on a 21" Trinitron CRT (viewing distance of approximately 65 cm), using custom software that also handled saccade detection, swapping of stimuli in mid-saccade, response collection and all other aspects of the experiment. The same three pairs of objects were used in all three experiments, with subtle differences between members of each pair, and qualitatively greater differences between pairs (**Fig. 1b**). Relatively similar objects were used for each pair under the logic it might not be possible to induce radical shifts in object representations within the time constraints of an experimental session.

Eye Tracking. Subjects' eye positions were tracked using an EyeLink II head-mounted infrared video eye tracking system (SR Research Ltd., Mississauga, ON, Canada) running at a rate of 250 Hz, with built in head-tracking. Subjects were required to fixate within 1.5° of the central fixation point, and trials were aborted if the subject's eye position deviated from this window. The endpoints of saccades to objects were repeatedly estimated in mid-saccade, and trials were aborted (i.e. the object was removed) on trials where saccades were estimated to be headed to land outside of the target object.

Exposure Phase (Experiments 1 & 2). During the exposure phase, an object appeared 6° to the left or right of the fixation point (randomly, see **Fig. 1a**). Subjects had been instructed to feel free to look at any object and, to ensure that they attended to the objects, decide if it was the same object that had appeared in the previous trial. Unknown to subjects, some objects were replaced by the other member of their pair while the subject was making this saccade (see **Fig. 1a**). Thus, Object A might appear to the left of fixation, eliciting a saccade to the object, but be replaced by Object A' by the time the subject's eyes landed. Each subject experienced i) one of the three pairs of objects swapped in mid-saccade on the left, but behaving normally on the right, ii) another pair swapped on the right but not on the left, and iii) the third pair not swapped in either position (control pair, see **Fig. 1c**). Each subject experienced each of the six objects equally often in each position (see **Fig. 1c**), and object pairs were counterbalanced across subjects such that each of the three object pairs was equally often swapped on the left, swapped on the right, or not swapped at all. None of the subjects reported being aware that objects were being swapped, despite being asked in a post-session debriefing whether they had seen objects change or appear otherwise unusual. Subjects did not take longer to saccade to the to-be-swapped objects ($P > 0.4$, mean: 200.7 ms), nor did they did look at swapped objects for a significantly different amount of time ($P > 0.8$, mean: 354.5 ms).

"Replay" Exposure Phase (Experiment 3). Twelve subjects in Experiment 3 were each paired with one of the twelve subjects in Experiment 1 and received retinal exposure that was matched, trial for trial, to their counterpart in Experiment 1. Subjects in this experiment were instructed to fixate the central fixation point while objects appeared first in the periphery, and then at the center of gaze with timing generated from the saccades made by their counterpart subject in Experiment 1. The screen was left blank during the time that the Experiment 1 subjects' eyes had been in flight, simulating the lack of appreciable form vision while the eyes are moving at high velocity. Failures to maintain fixation resulted in the trial being aborted and re-run. Subjects performed an analogous 1-back task as in Experiment 1, in which they reported whether the object was the same or different than the object presented on the previous trial. The instructions implied that the same object would appear in the periphery and at the center of gaze, even though different objects would in fact appear on the "swapped" trials.

Testing Phase (Experiments 1, 2 & 3). During the testing phase, designed to probe object representations across retinal positions, subjects fixated while an object appeared briefly in the periphery (6°; 150 ms), followed by a 300 ms delay, and then either the same object or the other member of its pair at the center of gaze (150 ms). Subjects indicated whether the two objects were the same or different. No feedback was given regarding accuracy of their responses. Each testing block contained an equal number of all combinations of within-object-pair comparisons, and peripheral positions (right and left). Blocks where subjects did not perform significantly above chance with control objects ($P > 0.2$; less than 5% of all data) were excluded from further analysis.

Experimental Sessions. Experiment 1 was conducted across two days, with subjects receiving exposure on both days (720-1200 total exposure trials, of which 240-400 were swapped) and completing four testing blocks (120 trials each) at the end of the second day. Experiment 2 was conducted in a single session, with subjects receiving 360-540 exposure trials (120-180 swapped exposures), and completing three testing blocks (120 trials each) at the end of the same session. In Experiment 3, the number of sessions, training blocks, and testing blocks was exactly matched to Experiment 1.

1. Gauthier, I. & Tarr, M. J. Becoming a "Greeble" expert: exploring mechanisms for face recognition. *Vision Res* **37**, 1673-82 (1997).