Supporting Information

Kaiser et al. 10.1073/pnas.1400559111

SI Text

Functional MRI Results

Face-Selective Control Regions. To further test the specificity of the results to parahippocampal place area (PPA), we also analyzed activation profiles in fusiform face area (FFA) (1) and occipital face area (OFA) (2). We defined the peaks of activation for FFA [average Montreal Neurological Institute (MNI) coordinates: left: $x = -40.3$ (0.7), $y = -50.0$ (1.1), $z = -20.8$ (0.6); right: $x =$ 41.9 (0.9), $y = -49.7$ (1.1), $z = -21.9$ (0.6); SEs in parentheses] and OFA [left: $x = -42.1$ (0.9), $y = -78.0$ (1.1), $z = -13.1$ (0.8); right: $x = 43.3$ (0.9), $y = -76.9$ (1.1), $z = -13.8$ (0.8)] using the face > object contrast from the functional localizer runs, thresholded at $P < 0.01$ (uncorrected). As in the main experiment, all analyses were carried out on 4-mm spheres around the peak voxel (see *Methods* for details). A repeated measures ANOVA with the factors presentation order (simultaneous vs. sequential) and configuration (regular vs. irregular), revealed a main effect of presentation order, with higher responses in the sequential condition, in both FFA ($F[1,22] = 9.89$, $P = 0.0047$; Fig. S1*A*) and OFA ($F[1,22] = 22.67$, $P < 0.001$; Fig. S1*B*). However, there was neither a main effect of configuration nor an interaction of the two factors in the two regions (all $F < 1.68$, $P > 0.20$). These results match the activation profile of object-selective LO.

PPA Defined by a House > Face Contrast. In the primary analysis reported in the main text, we defined PPA on the basis of the house > object contrast from the functional localizer runs. This conventional way of defining the region could in principle make it possible that the effects observed in PPA are not linked to its house selectivity per se, but rather to its "antiselectivity" for objects. To exclude this possibility, we repeated the analysis for a new region (PPA*) defined on the basis of the house > face localizer contrast. Using again a threshold of $P < 0.01$ uncorrected, we were able to define bilateral PPA* in 21 participants [average MNI coordinates: $x = -25.1$ (1.3), $y = -43.8$ (1.4), $z = -8.2$ (1.1); right: $x = 26.7$ (1.3), $y = -45.1$ (1.8), $z = -8.6$ (0.9); SEs in parentheses]. A repeated measures ANOVA with the factors of presentation order (simultaneous vs. sequential) and configuration (regular vs. irregular) was carried out on the data from 4-mm spheres around the peak voxel. Importantly, this analysis revealed a significant interaction ($F[1,20] =$ 4.94, $P = 0.038$; Fig. S2*A*), with no significant difference between regular and irregular object pairs in the sequential condition ($t[20] = 0.39$, $P = 0.70$), but a trend toward significantly higher responses for the regular than the irregular pairs in the simultaneous condition ($t[20] = 1.86$, $P = 0.078$). This pattern of results closely resembles the pattern of results obtained from conventionally defined PPA, and thus indicates that house selectivity—rather than object antiselectivity—is the key property that accounts for the results in PPA. Additional evidence for this stems from the data obtained from the face-selective regions of interest (ROIs): If object antiselectivity were the cause for the interaction observed in PPA, we should also observe such an interaction in FFA and/or OFA, as these ROIs were also defined against objects as a control condition.

PPA Response Profile Based on Peak Voxel Activation. PPA in the main analysis was defined by taking a spherical ROI (containing 33 voxels) around the peak voxel. To ensure that results were not specific to this particular ROI definition, we also analyzed results in PPA restricted to the peak voxel only. A repeated measures ANOVA with the factors of presentation order (simultaneous vs. sequential) and configuration (regular vs. irregular) showed a significant interaction ($F[1,20] = 5.94$, $P = 0.023$; Fig. S2*B*). Similar to the spherical PPA ROI, the PPA peak voxel showed higher responses for the regular than the irregular condition in the simultaneous ($t[20] = 2.26$, $P = 0.034$), but not in the sequential condition ($t[20] = 0.86$, $P = 0.40$).

Event-Related Time Courses. We also replicated the results of the ROI analysis using event-related time courses of the blood-oxygen-level–dependent (BOLD) signal (Fig. S3). To do so, we extracted the mean intensity values from the smoothed functional images for every condition, for both PPA and LO (using the same spherical ROIs as for the analysis reported in the main text). We computed these values for the eight repetition times (TRs) following the onset of the trial (rounded down to the nearest TR). Then, separately for each run, we subtracted the time course obtained for the fixation trials. To assess differences between conditions, we performed a repeated-measures ANOVA with the factors presentation order (simultaneous vs. sequential) and configuration (regular vs. irregular) on the mean value of the third and fourth TR after trial onset (representing the peak of the time course). In PPA, we found a significant interaction ($F[1,22] = 22.89$, $P < 0.001$), with higher responses for the regular than the irregular condition in the simultaneous ($t[22] = 4.31$, $P < 0.001$), but not in the sequential condition ($t[22] = 1.53$, $P = 0.14$). By contrast, there was no significant interaction in LO ($F[1,22] = 1.04$, $P = 0.32$; interaction including ROI: $F[1,22] = 6.60$, $P = 0.018$). These results confirm the pattern of results obtained in the other analyses.

Whole-Brain Analysis. To investigate whether brain regions outside our visual cortex ROIs showed activity modulations, we conducted whole-brain analyses. Similar to the ROI analyses, we tested for the main effects of presentation order (simultaneous vs. sequential) and pair configuration (regular vs. irregular), and their interaction. For the main effect of presentation order, i.e., the contrast between the simultaneous and the sequential condition ($P < 0.05$, corrected for false discovery rate), large clusters in visual cortex showed reduced responses in the simultaneous compared with the sequential condition, replicating earlier work (3). These clusters spanned bilateral ventral and lateral occipital cortex, fusiform gyrus, and parts of the parahippocampal gyrus (Fig. S4). No regions showed a significant main effect of pair configuration or an interaction between presentation order and pair configuration, even at an uncorrected threshold of $P < 0.001$.

Response-Time Variant of Visual Search Experiment

In our visual search experiments, we used an accuracy measure to quantify the efficiency of search among regular and irregular distracters. Similar approaches have been used in numerous previous studies (e.g., 4–6). These studies have revealed important insights about visual search in the absence of overt attention (7) and have informed models of parallel attentional allocation (8, 9). However, another major branch of the visual search literature quantifies search efficiency as the search time to set size relation (10–12). Here, the longer the additional search time when adding an item to a display (i.e., the steeper the search slope), the less efficient the search process is considered. In an additional visual search experiment, we aimed to demonstrate that the benefit of real-world object regularities is not only visible in higher search accuracy, but can also be observed in shallower search slopes in a response-time–based variant of the task.

SI Methods

Participants. Eleven participants (one male, mean age 22.3 y, SD = 2.0) volunteered for the experiment.

Stimuli. The stimuli were identical to the ones used in the accuracy-based search experiments.

Procedure. We used a similar design as in visual search experiment 1 reported in the main text (Fig. 2*A*), but made a number of changes that allowed us to estimate search efficiency based on response times. Again, each trial started with a word cue indicating the target object. However, the task was now changed to a present/absent judgment: On 50% of trials, the cued target was present, whereas on the other 50% of trials it was absent. The search display stayed on the screen until a response was given and participants were instructed to respond as fast as possible on every trial (responses were nonspeeded in the accuracy-based experiments reported in the main text). Importantly, to be able to estimate search slopes, we also manipulated set size: We either presented two pairs and one single object (either the target or a distracter) on one side of fixation (i.e., a total of five objects, set size 5 condition; see Fig. S5*A*), or we doubled the number of objects and presented two pairs and a single object (either the target and a distracter or two distracters) on either side of fixation (i.e., 10 objects, set size 10 condition; see Fig. S5*B*). This was done to equate the level of crowding across the two set sizes. The spatial arrangement of the stimuli differed slightly from the accuracy-based experiments to make the potential target locations less predictable: The target could now appear in any position of the search display and for the larger set size condition, the stimulus positions could differ between hemifields. The experiment was divided into 16 blocks of 36 trials, in which the distracter pairs always appeared either in regular or irregular configurations. The two set sizes and target absent/present trials were randomly intermixed.

SI Results

We analyzed response times in a three-factorial ANOVA with the factors of pair configuration (regular vs. irregular), set size (5 vs. 10 objects), and target presence (present vs. absent). There were significant main effects of target presence ($F[1,10] = 62.7$, $P < 0.001$) and set size ($F[1,10] = 42.7$, $P < 0.001$), indicating slower responses for the larger set size and in target absent trials, with a larger response time difference between target absent and target present trials in the set size 10 condition (interaction between set size and target presence: $F[1,10] = 38.98$, $P < 0.001$, Fig. S5*C*). There was also a significant main effect of pair configuration ($F[1,10] = 21.08$, $P < 0.001$), reflecting faster responses for regular than for irregular pairs. Importantly, if regular distracter pairs led to higher search efficiency, we would expect an interaction of pair configuration and set size, indicating an influence of pair configuration on the steepness of the search slopes. This interaction was significant ($F[1,10] = 5.81$, $P = 0.037$), with an effect of pair configuration in both set sizes (both $t[10] > 6.67$, $P < 0.001$), but a larger benefit for regular pairs in the set size 10 condition, indicating steeper slopes for irregular than for regular distracters (Fig. S5*D*). When we analyzed target detection accuracy for this speeded version of the visual search experiment, we found no main effect of, or interaction with, pair configuration (all $F[1,10] < 0.51$, $P > 0.49$). In sum, these findings demonstrate the beneficial effect of real-world distracter regularities on search efficiency as measured by response time to set size slopes in a speeded search task and thus confirm and substantiate the results of our accuracy-based experiments.

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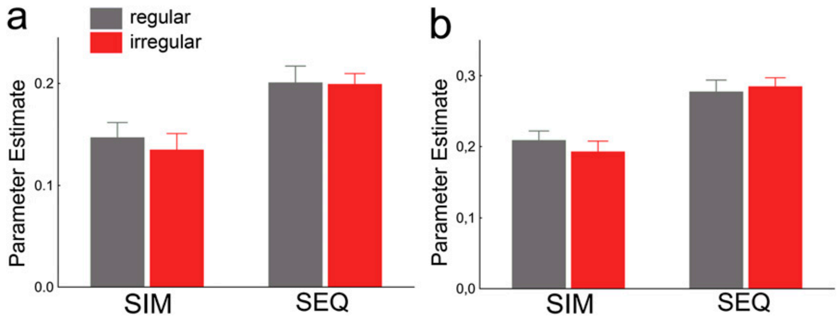

Fig. S1. Data from face-selective FFA (*A*) and OFA (*B*). Both face-selective regions showed reduced responses in the simultaneous condition, but no interaction between presentation order and pair configuration.

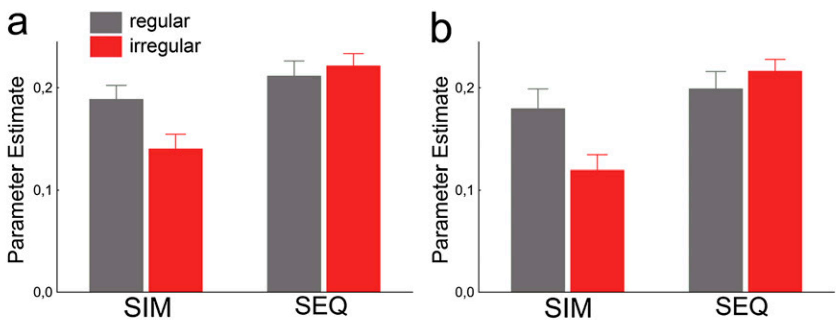

Fig. S2. The results from PPA are not due to object antiselectivity: The PPA response profile is preserved also if the region is defined on the basis of a house > face contrast (*A*). The response profile is also maintained if, instead of a spherical ROI, only the peak voxel activation is used for the analysis (*B*).

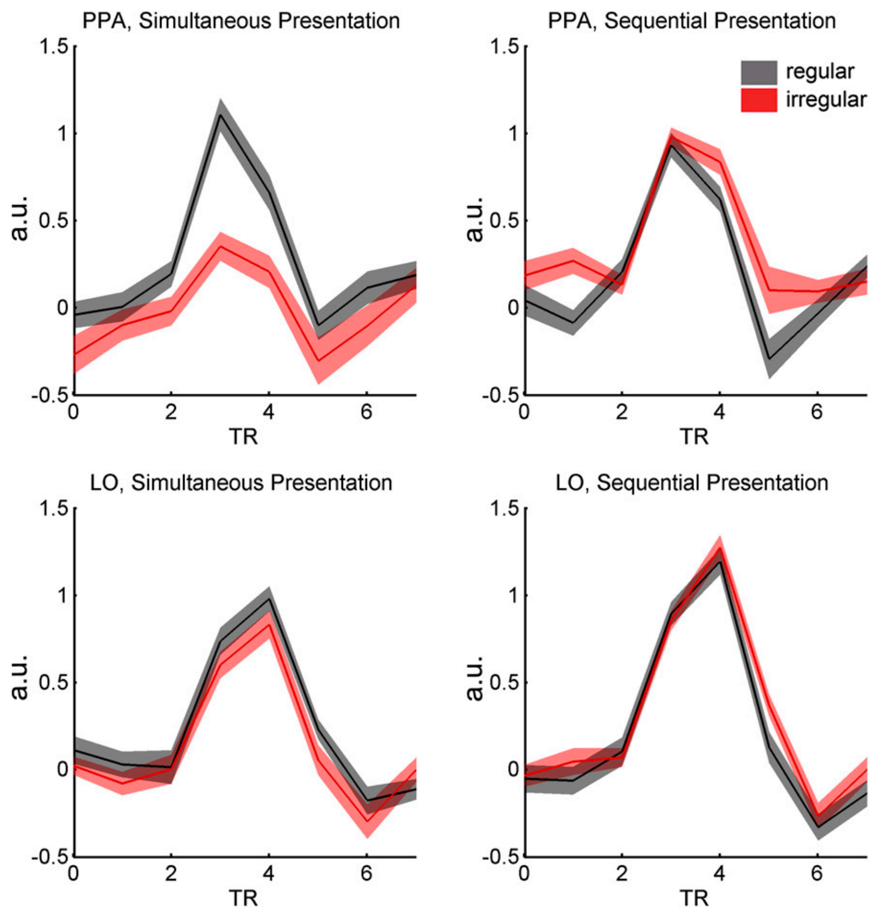

Fig. S3. Event-related time courses of activation in PPA and LO. The pattern of results confirms the interaction of presentation order and pair configuration in PPA, with a marked difference between the regular and irregular configurations in the simultaneous condition. By contrast, LO activity did not show an interaction between presentation order and pair configuration.

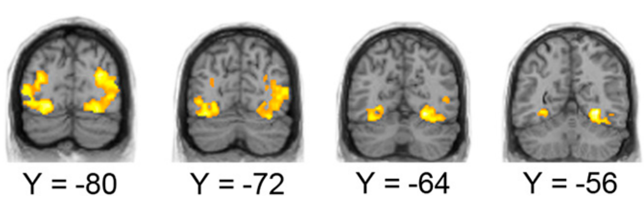

Fig. S4. Bilateral visual areas showed reduced activity to simultaneously compared with sequentially presented displays (whole brain analysis, $P < 0.05$, corrected for false discovery rate).

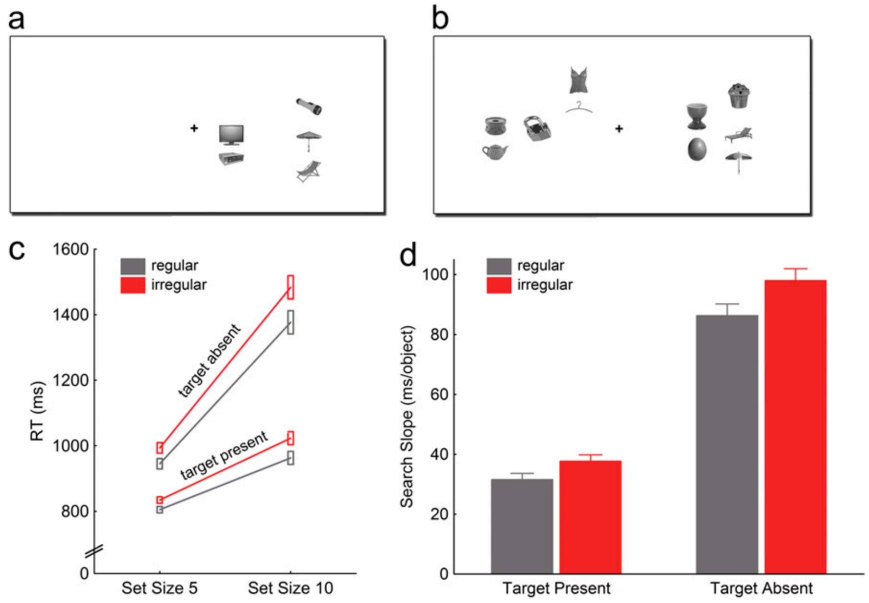

Fig. S5. Real-world distractor regularities increase efficiency also in speeded visual search. (*A*) Example display for the set size 5 condition with regular pair configurations. (*B*) Example display for the set size 10 condition with irregular pair configurations. (*C*) Response times were generally lower in the regular condition than in the irregular condition, both in target absent and target present trials, with a more pronounced effect in the set size 10 condition. (*D*) Search slopes were significantly shallower when the distracters were presented in regular compared with irregular configurations.