Supporting Information

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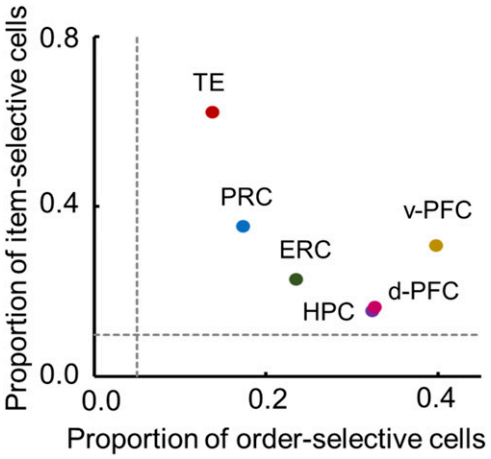

Fig. S1. Two-dimensional scatter plots between proportions of item cells and order-selective cells for the recording areas. Dashed gray lines indicate chance levels of item cells (horizontal, $P = 0.0975$) and order-selective cells (vertical, $P = 0.05$).

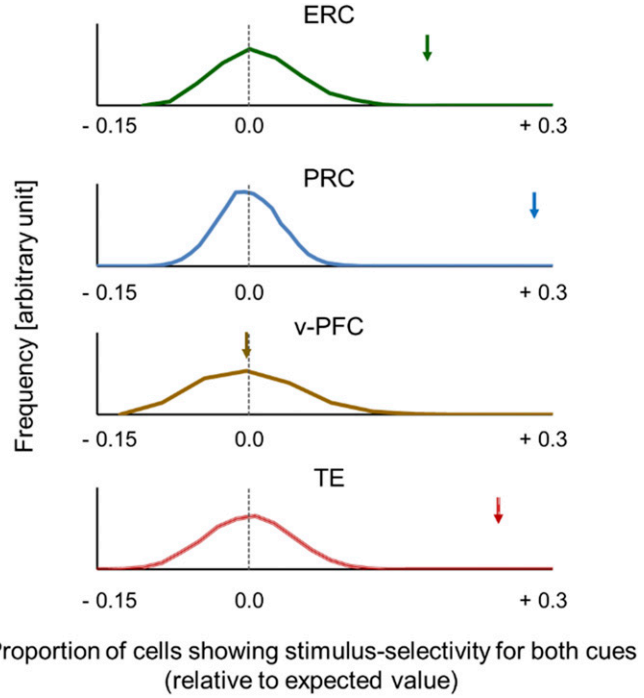

Fig. S2. Distribution of simulated number of conjunctive-item cells. We conducted 10,000 simulations for the number of conjunctive-item cells with the numbers of cue 1-selective cells, cue 2-selective cells, and total recorded cells fixed in each area, which were taken from the experiment (Table S1). In each simulation, cue 1-selective cells and cue 2-selective cells were randomly (independently) chosen from the total cells. If a cell was chosen as both cue-1 selective and cue-2 selective, it was regarded as a conjunctive-item cell. We counted the number of conjunctive-item cells in each simulation and determined a distribution of the numbers of conjunctive-item cells in each area. The distributions were aligned to the expected numbers of cells showing stimulus selectivity for both cue 1 and cue 2, which were theoretically given [(cue 1-selective cells) × (cue 2-selective cells)/(total cells)] and displayed as proportions from item cells. Real values are indicated by arrows. These values situated beyond the distributions for PRC and TE and at the rank of 2nd–6th in 10,000 for ERC and at the rank of 3,407th–6,544th for v-PFC. We estimated P values as $P < 1/5{,}000$ for PRC and TE, $P < 6/5{,}000$ for ERC, and $P > 3{,}407/5{,}000$ for v-PFC.

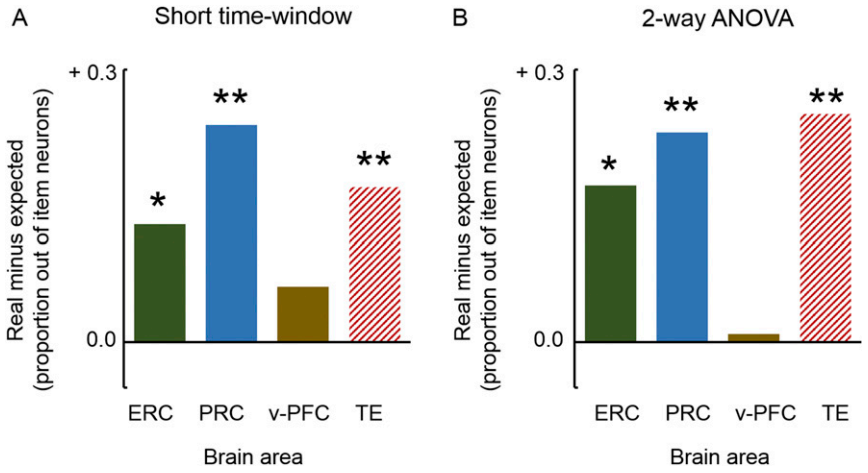

Fig. S3. (*A*) Proportions of conjunctive-item cells that were defined using a short time-window (80–400 ms after cue onset). The proportions were significantly larger than the expected values in ERC ($P = 0.011$, permutation test), PRC ($P < 0.0001$), and TE ($P < 0.0001$) but not in v-PFC ($P > 0.13$). The values subtracted by theoretically determined expected values were plotted. (*B*) Proportions of conjunctive-item cells that were defined using two-way ANOVA with cue 1 stimulus and cue 2 stimulus identities as two main factors. The proportions were significantly larger than the expected values in ERC ($P < 0.0008$), PRC ($P < 0.0001$), and TE ($P < 0.0001$) but not in v-PFC ($P > 0.51$). *$P < 0.05$; **$P < 0.0001$.

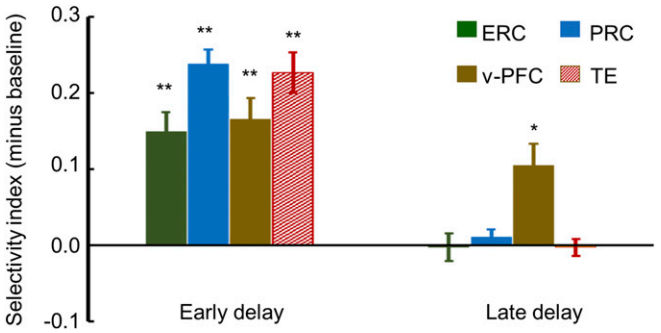

Fig. S4. Stimulus selectivity during the delay period following the cue 1 stimulus. The selectivity index during the early delay period (400 ms after cue 1 offset) and the late delay period (400 ms before the cue 2 onset) was compared with that during the base line period (400 ms before the cue 1 onset) for item cells with stimulus selectivity for the cue 1 in each area. During the late delay period, the selectivity index was significantly larger than baseline only in v-PFC ($t = 3.45$, df = 15, $P = 0.0036$, two-tailed paired t test). *$P < 0.005$; **$P < 0.0001$.

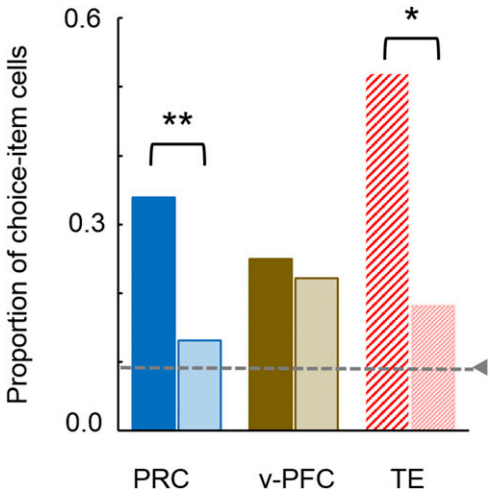

Fig. S5. Proportions of stimulus-selective cells (choice-item cells) in the response phase out of item cells (dark bars, *Left*) and nonitem cells (light bars, *Right*) in the encoding phase. The choice-item cells showed significant stimulus-selective activity 1 s after the onset of choice stimuli, which was explained by either cue 1 stimulus or cue 2 stimulus ($P < 0.05$ for each cue stimulus, two-way ANOVA). Dashed line and arrowhead indicate a chance level ($P = 0.0975$). The presence or absence of stimulus selectivity of individual neurons during the choice period was dependent on that during the cue period in PRC ($\chi^2 = 19.1$, df = 1, $P < 0.0001$, χ^2 test) and TE ($\chi^2 = 9.8$, df = 1, $P = 0.0018$) but not in v-PFC ($\chi^2 = 0.072$, df = 1, $P = 0.79$). *$P < 0.005$; **$P < 0.0001$.

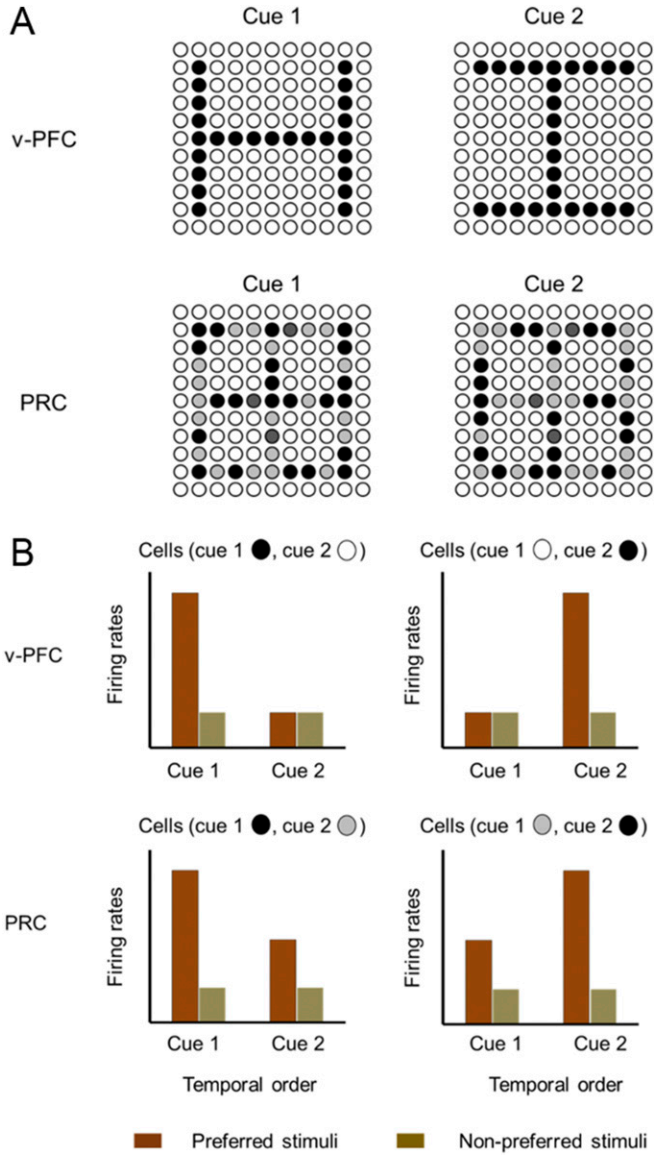

Fig. S6. Different integrated representations of item and temporal-order information between PFC and MTL. (*A*) Schematic distributions of stimulus-selective responses to a particular stimulus set in v-PFC and PRC at different temporal orders. Circles at the same position in cue 1 (*Left*) and cue 2 (*Right*) indicate degrees of stimulus-selective responses (sharpness of tuning) of the same neuron at corresponding temporal orders in each area. Black-filled circles indicate strongly or sharply tuned stimulus-selective responses, while open circles indicate no stimulus-selective responses. Gray-filled circles indicate weakly tuned stimulus-selective responses. In v-PFC, independent groups of neurons show stimulus-selective responses to cue 1 and cue 2 (i.e., exclusive-or-item cells). In contrast, the same group of neurons tend to show stimulus-selective responses to both cues in PRC (i.e., conjunctive-item cells) although some neurons show strongly or sharply tuned responses to cue 1 compared with cue 2, while other neurons show the opposite pattern. (*B*) Schematic firing patterns to preferred stimuli and nonpreferred stimuli at different temporal orders in v-PFC and PRC. In v-PFC, one group of exclusive-or-item cells (*Left*) responded selectively to their preferred stimuli for cue 1, but they responded to neither the preferred nor the nonpreferred stimuli for cue 2. Another group of exclusive-or-item cells (*Right*) showed an activation to their preferred stimuli only for cue 2. In PRC, one group of conjunctive-item cells responded to their preferred stimuli more strongly for cue 1 than cue 2 although their activation levels to nonpreferred stimuli did not change across the two cue presentations. Another group of conjunctive-item cells showed stronger responses for cue 2 than for cue 1 only when their preferred stimuli were presented.

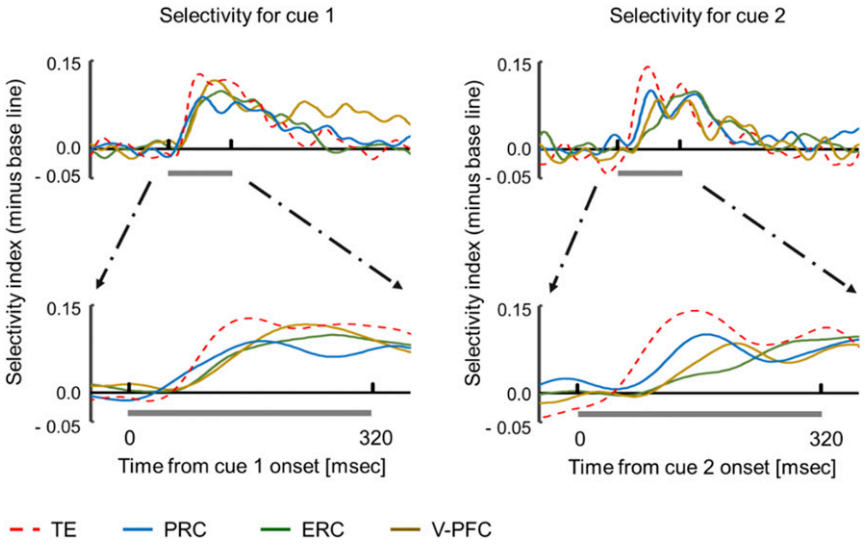

Fig. S7. Time courses of magnitude-adjusted population-averaged stimulus selectivity to cue 1 (*Left*) and to cue 2 (*Right*). We first examined a peak amplitude of selectivity index defined by the 200-ms time window for each item cell. The first and the third quartile points of the peak selective index of v-PFC item-selective cells were 0.31 and 0.48 for cue 1 and 0.33 and 0.44 for cue 2. To adjust the magnitude of the selectivity index for the comparison of time courses, we collected PRC item cells and TE item cells, the peak selectivity index of which was between the first and the third quartiles of the v-PFC item cells. Mean values of the selectivity index for cue 1 and cue 2 were 0.40 ($n = 16$) and 0.41 ($n = 10$) in v-PFC, 0.40 ($n = 30$) and 0.39 ($n = 16$) in PRC, and 0.40 ($n = 10$) and 0.42 ($n = 9$) in TE. We used all of the item cells showing stimulus selectivity for cue 1 ($n = 29$) and cue 2 ($n = 19$) in ERC, and their mean values were 0.45 and 0.42, respectively. The time course of the population-averaged selectivity index is displayed as values subtracted by mean values of the selectivity index during the baseline (400 ms before cue 1 onset) for both cue 1 and cue 2. TE (93 ms and 86 ms for half peak time from cue 1 onset and cue 2 onset) and PRC (89 ms and 113 ms) started to show selective activity earlier than v-PFC (146 ms and 136 ms) and ERC (121 ms and 206 ms) for both cue 1 and cue 2.

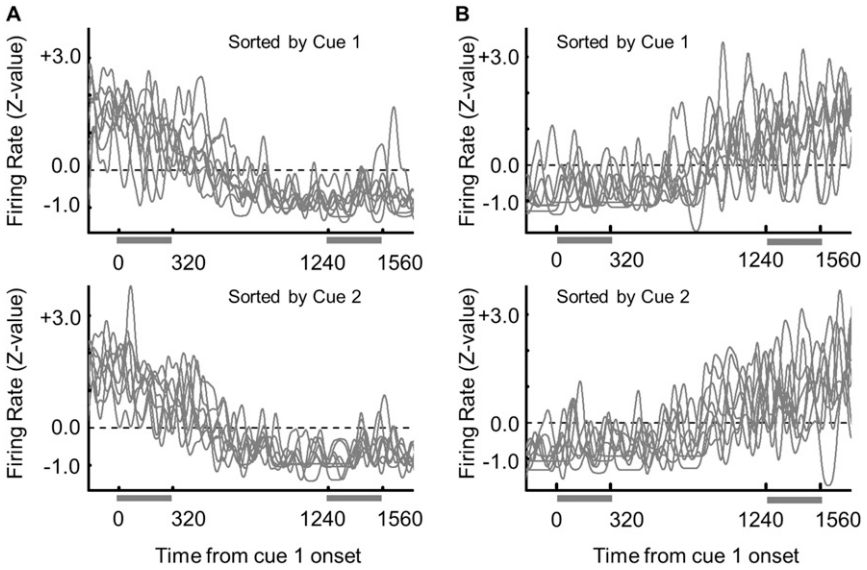

Fig. S8. Time courses of firing rates of the PFC order-selective neurons. (*A*) The d-PFC order-selective cell shown in Fig. 4*A*. Average SDFs ($\sigma = 50$ ms) across trials with the same cue 1 stimuli (sorted by cue 1) and with the same cue 2 stimuli (sorted by cue 2) were standardized (*z*-score) from the period from 200 ms before cue 1 onset to 200 ms after cue 2 offset, respectively. (*B*) The v-PFC order-selective neuron shown in Fig. 4*B*.

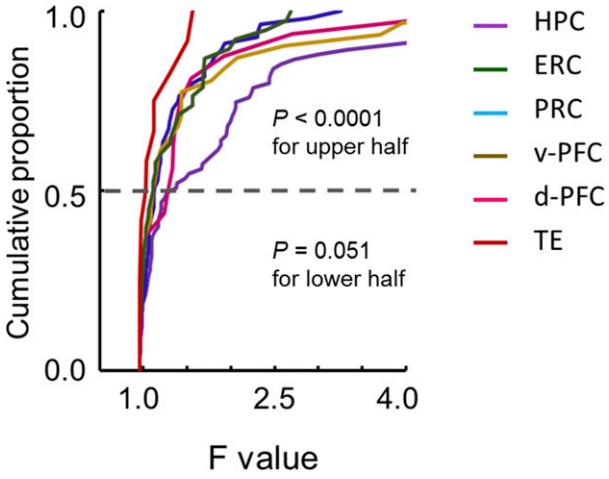

Fig. S9. Cumulative frequency histograms of *F*-values comparing a first-order polynomial fitting with a zero-order polynomial for order-selective cells in HPC ($n = 75$), ERC ($n = 39$), PRC ($n = 55$), TE ($n = 12$), d-PFC ($n = 16$), and v-PFC ($n = 31$). Dashed gray line, middle of the total distributions. There was a large difference in the cumulative curves for the order-selective cells among HPC, ERC, PRC, and both parts of PFC within the upper half of the *F*-values ($\chi^2 = 26.0$, df = 4, $P < 0.00001$, Kruskal–Wallis test), while the difference was marginal within the lower half ($\chi^2 = 9.4$, df = 4, $P = 0.0051$). In the upper half, the order-selective cells in HPC had the largest *F*-values of those in any other area including both d-PFC ($ks = 0.52$, $P = 0.035$, Kolmogorov–Smirnov test) and v-PFC ($ks = 0.51$, $P = 0.0033$).

Table S1. Number of neurons showing stimulus selectivity for encoding in MTL and PFC

Cell group	HPC	ERC	PRC	d-PFC	v-PFC	TE
Total	232	166	317	49	78	87
Selective for cue 1	19 (8)	29 (17)	85 (27)	3 (6)	16 (21)	49 (56)
Selective for cue 2	19 (8)	19 (11)	80 (25)	5 (10)	10 (13)	42 (48)
Selective for either cue 1 or cue 2	36 (16)	38 (23)	112 (35)	8 (16)	24 (31)	54 (62)
Selective for both cue 1 and cue 2	2 (1)	10 (6)	53 (17)	0 (0)	2 (3)	37 (43)

Stimulus selectivity was examined using the time window 80–840 ms from cue onset ($P < 0.05$ for each cue, one-way ANOVA). Numbers in parentheses indicate percentage of total cells in each area.