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Supplemental information

Joint representation of working memory and uncertainty in human cortex

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Supplementary Figures

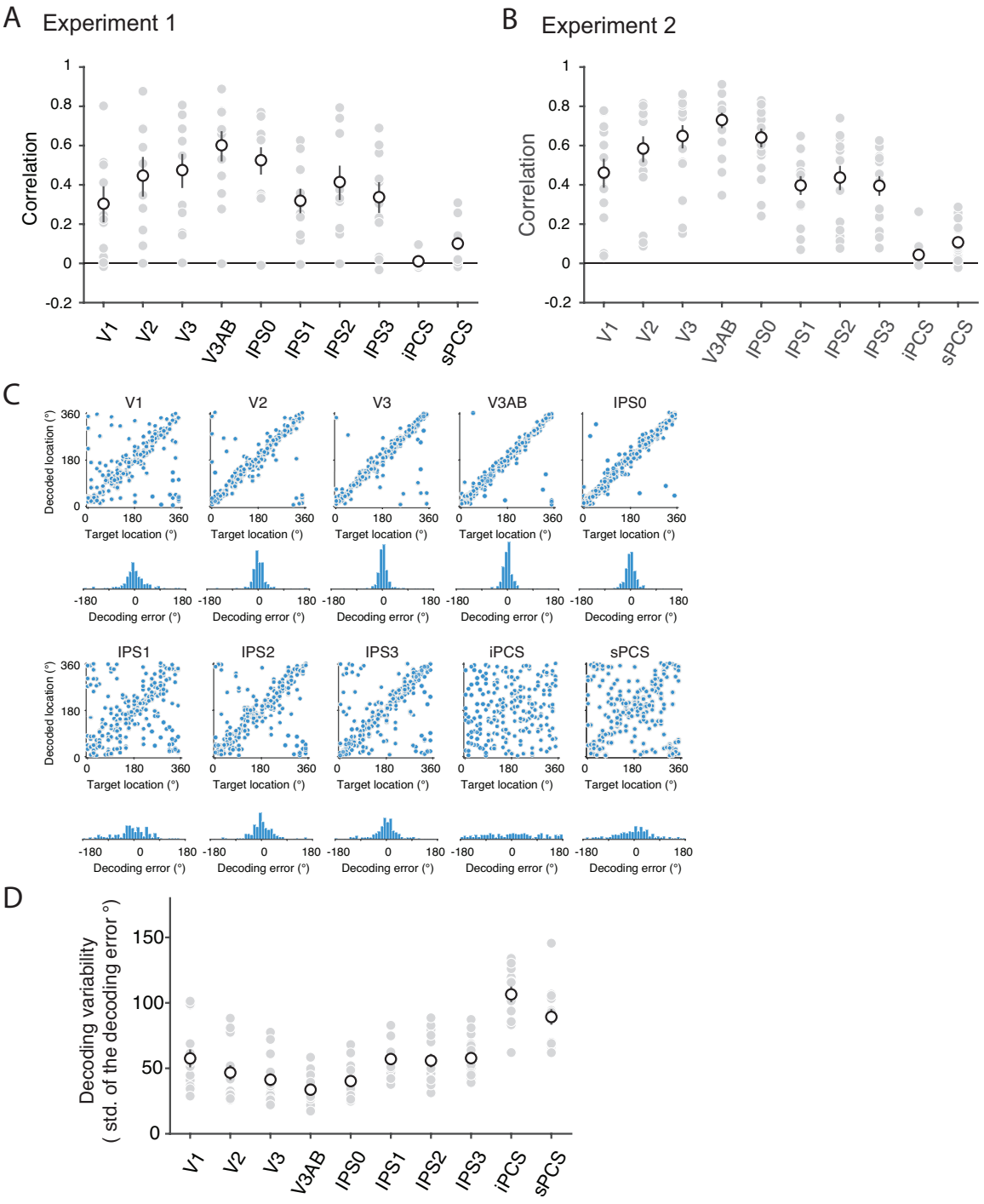

Figure S1. Decoded location correlates with target location, related to Figure 3. (A) Experiment 1. The circular correlation between decoded location and target location. All ROIs showed above chance correlations (p<0.001 for all ROIs, permutation test). (B) Experiment 2. All ROIs showed above chance correlations (p<0.001 for all ROIs, permutation test). Decoding performance varied significantly across ROIs in both

experiments (permutation one-way repeated-measures ANOVA, $F(9, 90) = 19.10$, $p < 0.001$, $\eta_p^2 = 0.66$ for Experiment 1; $F(9, 117) = 48.22$, $p < 0.001$, $\eta_p^2 = 0.79$ for Experiment 2). (C) Working memory content can be precisely decoded in Experiment 2. Decoding performance of an example participant. For each ROI, the top figure represents the decoded location as a function of target location. The bottom figure is the distribution of decoding error (decoded location minus the target location). (D) Decoding performance quantified as decoding variability, the standard deviation of the decoding error distribution. The filled gray dots represent individual participants. The empty white dots represent group average. The error bars represent ±SEM. Decoding performance varied significantly across ROIs (permutation one-way repeated-measures ANOVA, $p < 0.001$, $\eta_p^2 = 0.82$).

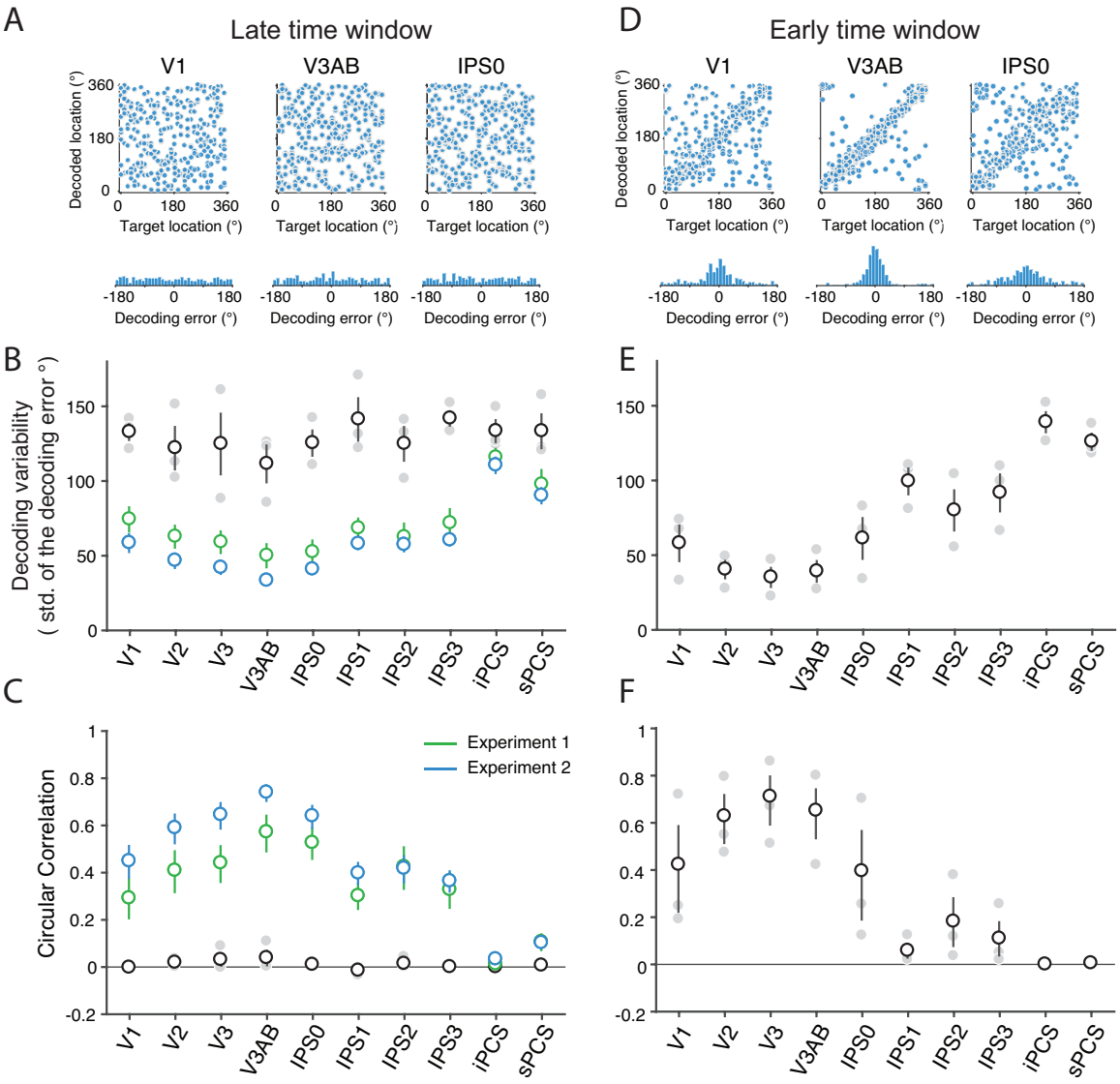

Figure S2. Decoding performance is low in the late time window in the passive viewing experiment, related to Figure 3. In a control experiment, a subset of participants (n = 3) performed a demanding task at fixation throughout each trial. During the same interval of the trial during which the WM target was presented in Experiment 1 and 2, we presented a high-contrast flickering checkerboard stimulus to drive strong sensory responses. (A) - (C) are the decoding results from a late time window (5.25 to 12 seconds from the delay period onset), same as the time window used for VWM analyses in Figs. 3-4 and Fig. 6-8. (A) Decoding performance of an exemplar participant, as in Fig. 3A. The top row, decoded location plotted against target location. The bottom row, the distributions of decoding error (decoded location minus the target location). (B) Decoding variability, quantified as the standard deviation of the decoding error distribution. (C) Circular correlation between the decoded location and the target location. In (B) and (C), the filled gray dots represent individual participants. The empty white dots represent group average. The error bars represent ±SEM. For comparison, the blue and the green data points represent the results of Experiment 1 and 2 using the same late time window. (D) - (F)

represent the decoding results from an early time window (0.75 to 5.25 seconds from the delay period onset). Decoding performance was high for early, but not late, time periods. See Supplementary Table 1 and 2 for statistical tests on the decoding variability and circular correlation. For the late time window, decoding performance was higher in VWM experiments (Experiment 1 and 2) than in the passive viewing experiment.

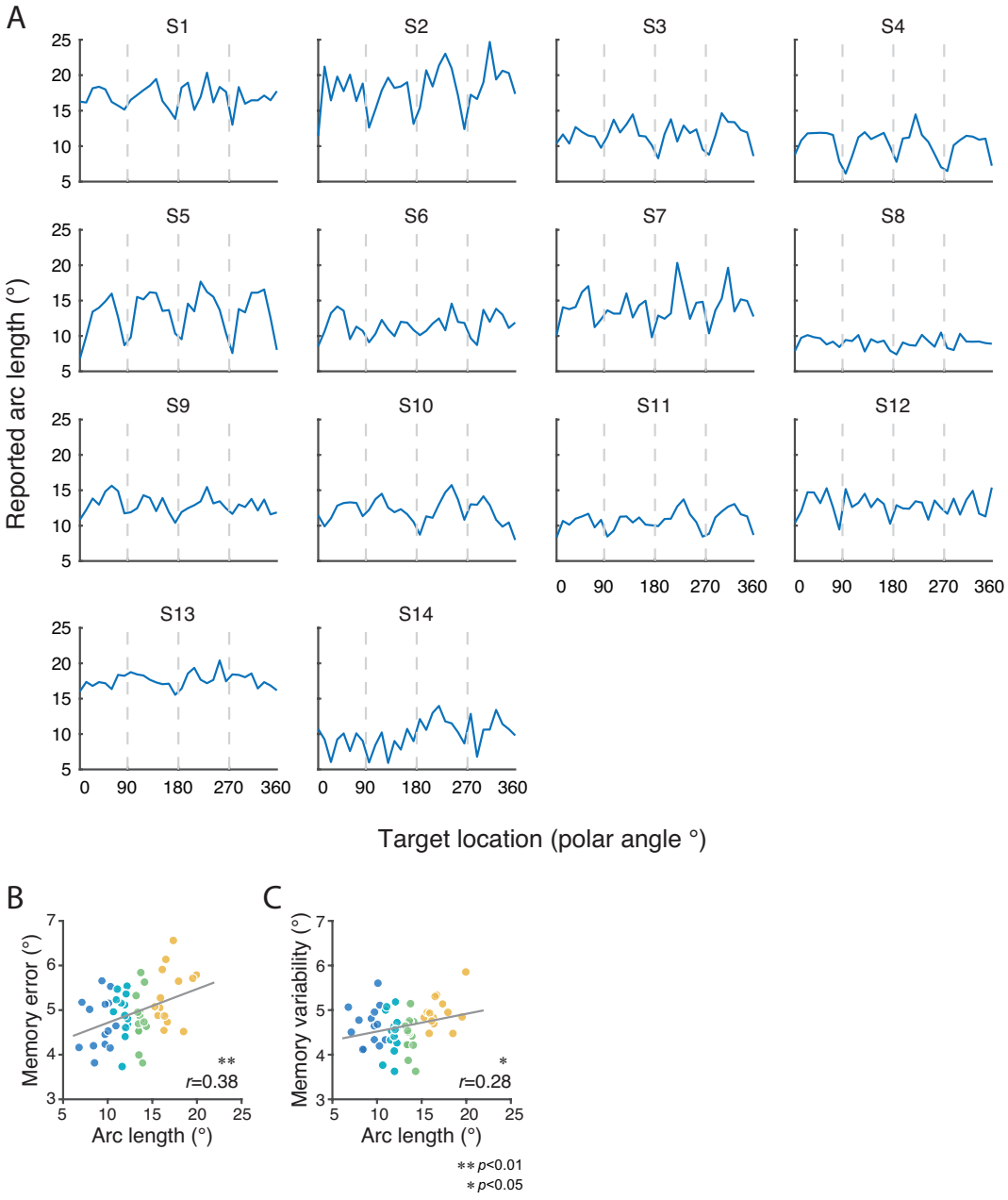

Figure S3. Arc length reports, related to Figure 5. (A) Arc length as a function of target location for individual participants. Here 90° corresponds to the top of the vertical meridian and 180° represents the left of the horizontal meridian. (B-C) Memory error and memory variability increase with reported arc length. The data here are similar to those reported in Fig. 5D and 5E, except that the effect of target location was regressed out from the arc length. (B) Behavioral error as a function of reported arc length. Four colors represent four bins (within each of 14 participants) with increasing arc length. (C) Behavioral variability as a function of reported arc length. On trials where participants report longer arc lengths, behavioral recall of remembered positions has greater error magnitude (permutation test, $p < 0.05$) and is more variable (permutation test, $p < 0.01$).

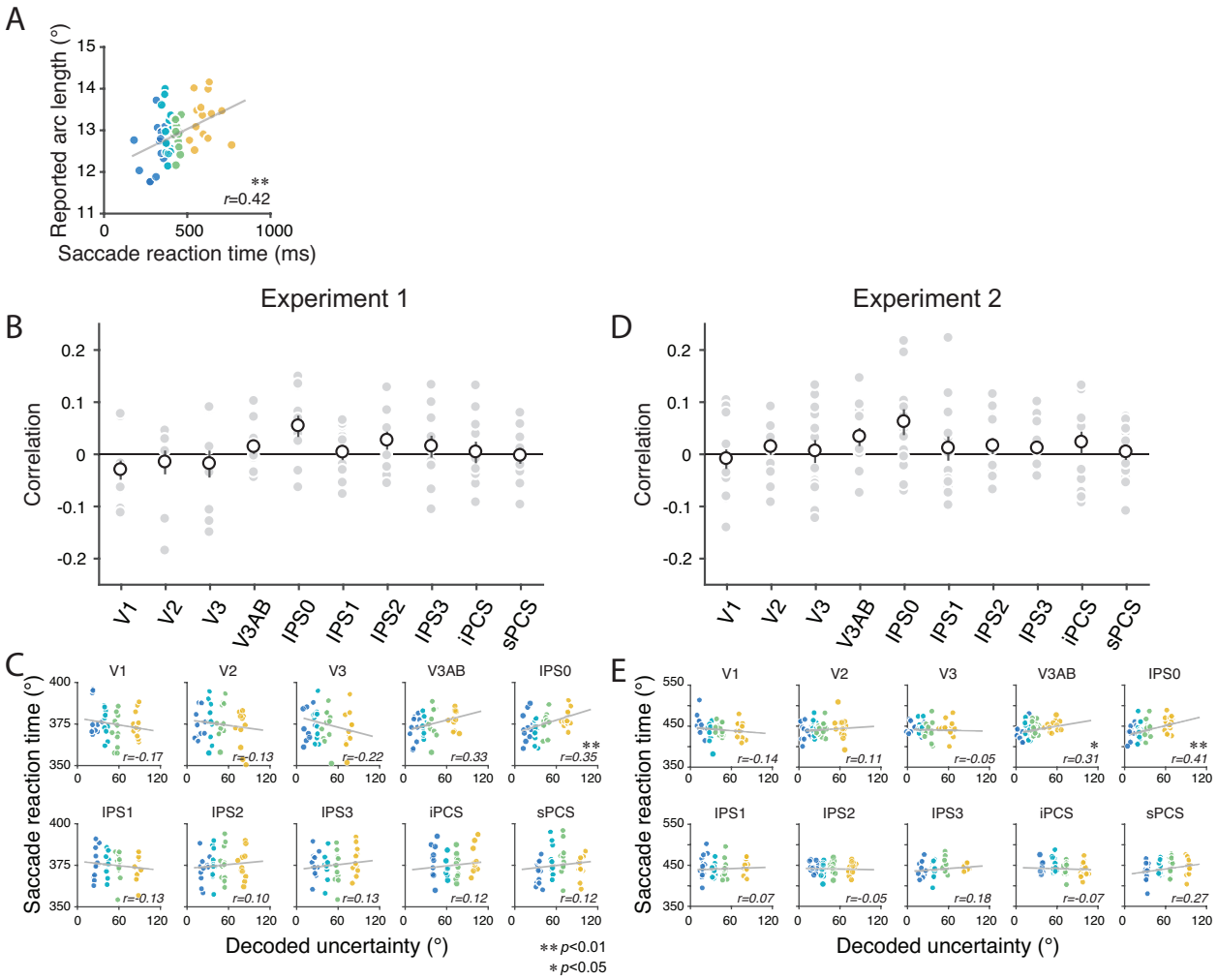

Figure S4. Saccade reaction time, related to Figure 6. (A) Reported arc length increased with saccade reaction time. Four colors represent four bins (within each of 14 participants) with increasing saccade reaction time. (B) Correlations between saccade reaction time and decoded uncertainty in Experiment 1. The filled gray dots represent individual participants. The empty white dots represent the group average. The error bars represent ±SEM. (C) Saccade reaction time plotted against decoded uncertainty in Experiment 1. The four colors indicate four bins (within each of 14 participants) with increasing decoded uncertainty. The gray line in each panel represents the best linear fit. The value at the lower right of each panel is the Pearson correlation coefficient. (D-E) Same analysis for Experiment 2, corresponding to (B) and (C).

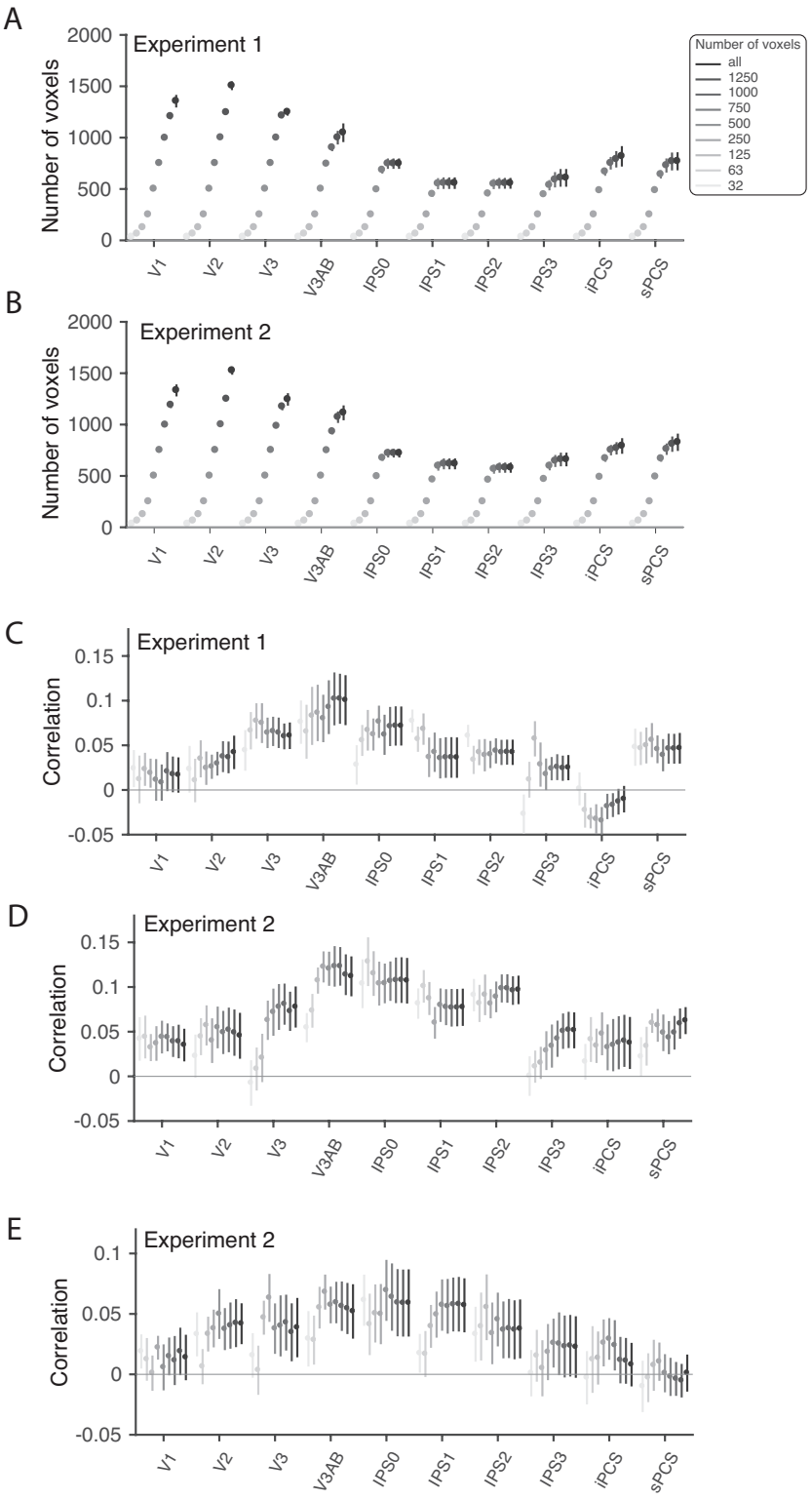

Figure S5. The effect of the number of voxels, related to Figure 6 - 7. (A) Number of voxels analyzed under different selection criteria in Experiment 1. To investigate whether our results depend on the number of voxels in each ROI, we selected different numbers of voxels (ranging from 32 to 1250 voxels) and conducted the same analyses. Here, the actual

number of voxels included in the analyses are illustrated. For ROIs with fewer voxels, the number of voxels included in the analyses saturated at a smaller value. For example, an ROI with 550 voxels will have 550 voxels even when we tried to select 1000 voxels. The dots represent the group average. The error bars represent ±SEM. We also conducted analyses without voxel selections by including all the voxels in each ROI (labeled as 'all' in the figure legend). (B) Number of voxels analyzed under different selection criteria in Experiment 2. (C-E) Correlations between the outputs of the decoder and behaviors. (C) Correlations between decoding error and memory error in Experiment 1, corresponding to the analyses presented in Fig. 4B. (D) Same as (C) but for Experiment 2, corresponding to the analyses presented in Fig. 7B. (E) Correlations between memory uncertainty (reported arc length) and decoded uncertainty in Experiment 2, corresponding to the analyses presented in Fig. 6B.

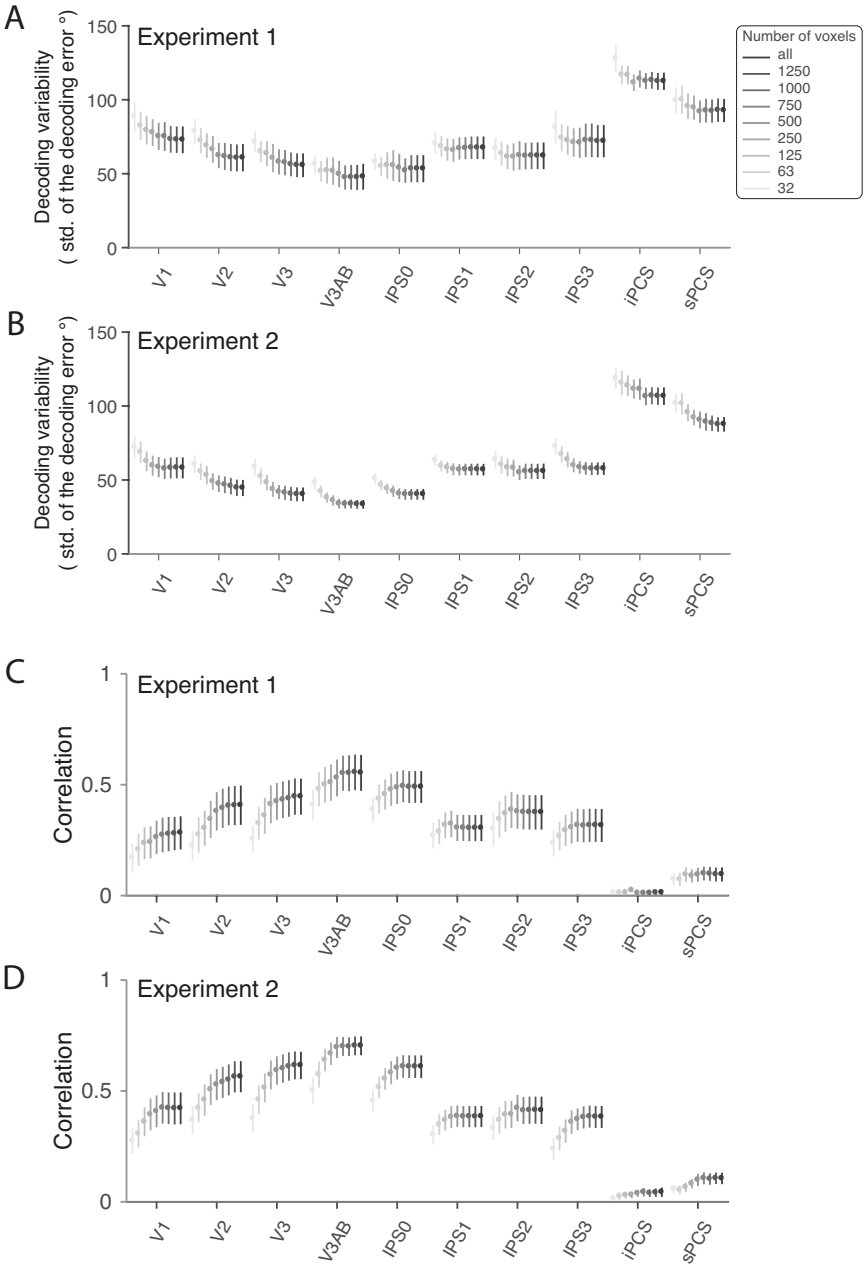

Figure S6. Decoding performance as a function of the number of voxels, related to Figure 3. (A) Decoding performance quantified as decoding variability, the standard deviation of the decoding error distribution, for Experiment 1, corresponding to the analysis in Fig. 3B. (B) Same as (A), but for Experiment 2, corresponding to the analyses in Supplementary Fig. 6B. (C) Decoding performance, quantified as the circular correlation between decoded location and target location, in Experiment 1, corresponding to the analysis in Supplementary Fig. 1A. (D) Same as (C), but for Experiment 2, corresponding to the analyses in Supplementary Fig. 1B.

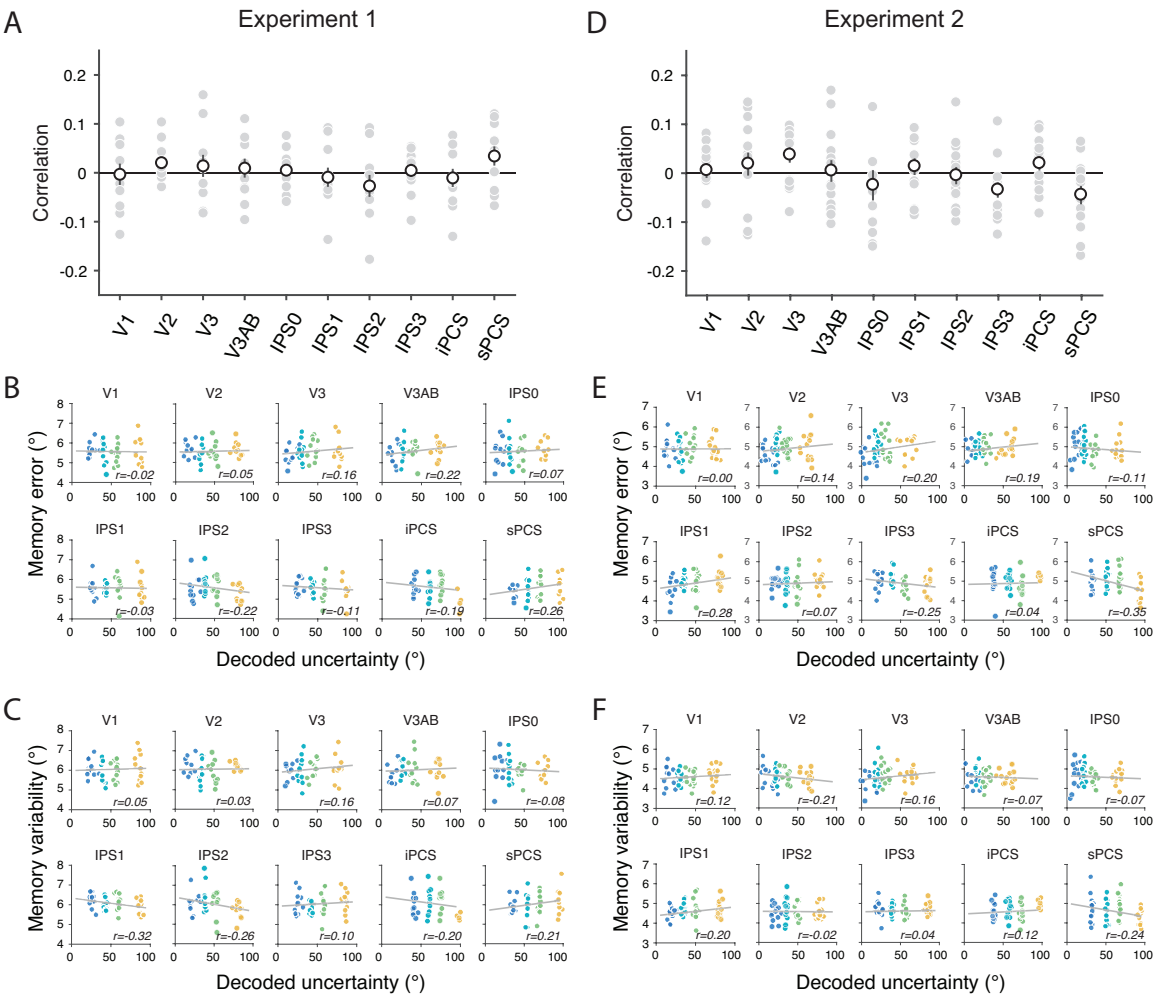

Figure S7. Correlations between the decoded uncertainty, memory error and memory variability, related to Figure 6. (A) Correlations are computed between decoded uncertainty and the magnitude of memory error for Experiment 1. The filled gray dots represent individual participants. The empty white dots represent the group average. The error bars represent ±SEM. (B) The magnitude of memory error plotted against decoded uncertainty. The four colors indicate four bins (within each of 14 participants) sorted by decoded uncertainty. The gray line in each panel represents the best linear fit. The value at the lower right of each panel is the Pearson correlation coefficient. (C) Similar to (B), but for each bin, the variability of memory recalls is plotted for the y-axis instead of the magnitude of error. (D-F) Correspond to (A-C) but for Experiment 2. Across (A-F) no ROI shows significant correlations between decoded uncertainty and memory error (or variability).

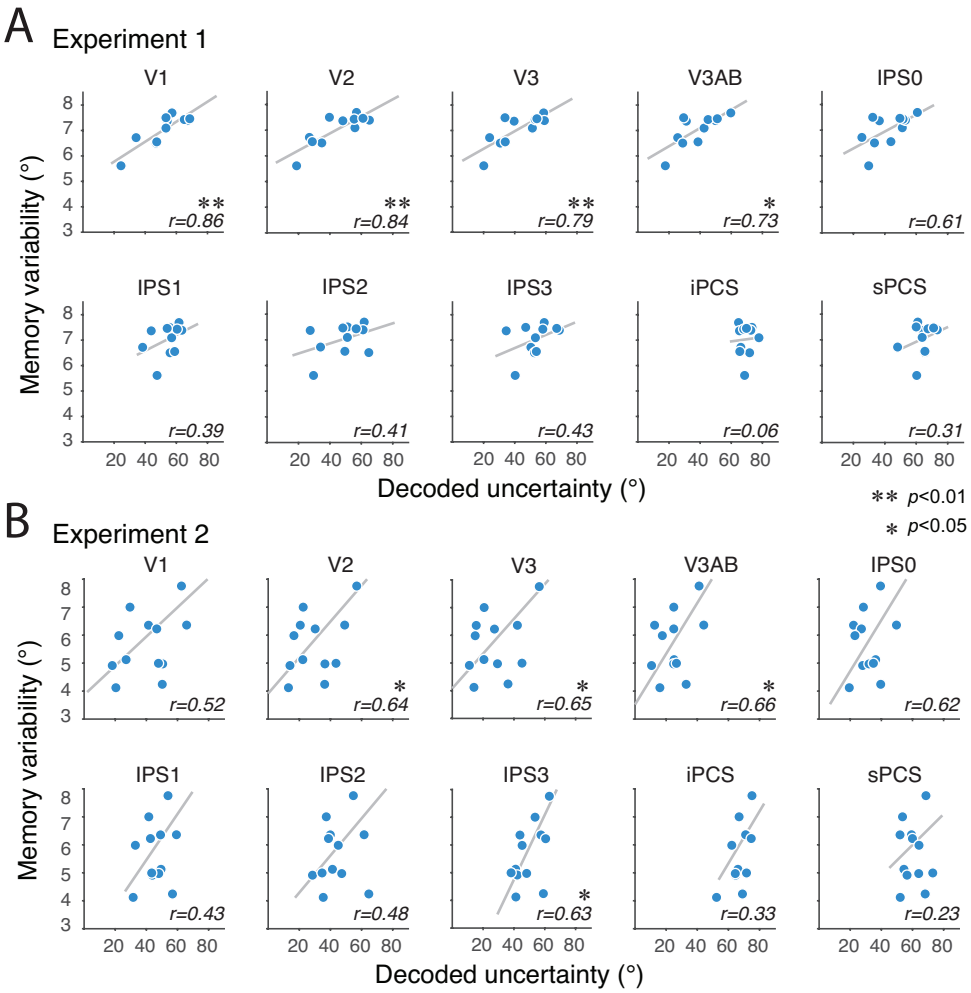

Figure S8. Participants with higher decoded uncertainty exhibit larger variability in memory report, related to Figure 8. (A) Experiment 1. Each dot represents one participant. The decoded uncertainty (x-axis) was averaged across trials per participant. Memory variability (y-axis) is the standard deviation of behavioral error distribution of each participant. The gray lines represent the best linear fit. (B) Experiment 2.

Supplementary Tables

	V1	V2	V3	V3AB	IPS0	IPS1	IPS2	IPS3	iPCS	sPCS
S1	201 (<.001)	232 (<.001)	243 (<.001)	246 (<.001)	245 (<.001)	221 (<.001)	227 (<.001)	209 (<.001)	79 (<.001)	168 (<.001)
S2	16 (0.120)	20 (0.051)	20 (0.053)	20 (0.039)	18 (0.075)	16 (0.125)	12 (0.249)	3 (0.738)	-10 (0.326)	-1 (0.936)
S3	299 (<.001)	313 (<.001)	300 (<.001)	315 (<.001)	289 (<.001)	256 (<.001)	288 (<.001)	259 (<.001)	78 (<.001)	175 (<.001)
S4	144 (<.001)	187 (<.001)	219 (<.001)	262 (<.001)	253 (<.001)	222 (<.001)	282 (<.001)	264 (<.001)	100 (<.001)	126 (<.001)
S5	139 (<.001)	195 (<.001)	204 (<.001)	223 (<.001)	217 (<.001)	139 (<.001)	179 (<.001)	176 (<.001)	35 (0.005)	104 (<.001)
S6	174 (<.001)	193 (<.001)	201 (<.001)	266 (<.001)	220 (<.001)	190 (<.001)	223 (<.001)	204 (<.001)	42 (<.001)	142 (<.001)
S7	38 (<.001)	63 (<.001)	83 (<.001)	128 (<.001)	126 (<.001)	72 (<.001)	83 (<.001)	38 (<.001)	22 (0.032)	21 (0.030)
S8	63 (<.001)	92 (<.001)	116 (<.001)	150 (<.001)	132 (<.001)	87 (<.001)	102 (<.001)	108 (<.001)	45 (0.001)	67 (<.001)
S9	198 (<.001)	237 (<.001)	255 (<.001)	270 (<.001)	250 (<.001)	171 (<.001)	132 (<.001)	203 (<.001)	29 (0.023)	96 (<.001)
S10	195 (<.001)	228 (<.001)	218 (<.001)	228 (<.001)	219 (<.001)	167 (<.001)	166 (<.001)	136 (<.001)	52 (<.001)	58 (<.001)
S11	27 (0.008)	71 (<.001)	90 (<.001)	124 (<.001)	137 (<.001)	115 (<.001)	136 (<.001)	33 (0.006)	-6 (0.610)	33 (0.002)

Table S1. Statistical test for the uniformity of the decoding error distributions in Experiment 1. For each participant and ROI, we reported a V statistics and the (uncorrected) *p*-value obtained by permutations (see Methods). A *p*-value smaller than 0.05 indicates that the error distribution is not uniform and favors the alternative hypothesis that the error distribution has a mean centered at zero degree (polar angle). The *p*-values smaller than 0.05 are highlighted by red color.

	V1	V2	V3	V3AB	IPS0	IPS1	IPS2	IPS3	iPCS	sPCS
Experiment 1										
S1	47 (<.001)	35 (<.001)	30 (<.001)	29 (<.001)	29 (<.001)	39 (<.001)	37 (<.001)	43 (<.001)	91 (<.001)	58 (<.001)
S2	129 (0.538)	123 (0.272)	123 (0.272)	119 (0.125)	127 (0.412)	129 (0.539)	136 (0.975)	158 (0.174)	140 (0.831)	149 (0.428)
S3	27 (<.001)	21 (<.001)	27 (<.001)	20 (<.001)	31 (<.001)	42 (<.001)	31 (<.001)	41 (<.001)	97 (<.001)	65 (<.001)
S4	72 (<.001)	59 (<.001)	49 (<.001)	35 (<.001)	38 (<.001)	48 (<.001)	28 (<.001)	35 (<.001)	87 (<.001)	78 (<.001)
S5	67 (<.001)	47 (<.001)	44 (<.001)	37 (<.001)	39 (<.001)	67 (<.001)	53 (<.001)	54 (<.001)	114 (0.013)	80 (<.001)
S6	69 (<.001)	64 (<.001)	62 (<.001)	46 (<.001)	58 (<.001)	65 (<.001)	57 (<.001)	62 (<.001)	119 (0.016)	78 (<.001)
S7	105 (0.001)	88 (<.001)	77 (<.001)	56 (<.001)	57 (<.001)	83 (<.001)	77 (<.001)	104 (<.001)	120 (0.175)	122 (0.191)
S8	91 (<.001)	76 (<.001)	66 (<.001)	52 (<.001)	59 (<.001)	79 (<.001)	72 (<.001)	69 (<.001)	103 (0.001)	89 (<.001)
S9	54 (<.001)	42 (<.001)	35 (<.001)	29 (<.001)	37 (<.001)	62 (<.001)	74 (<.001)	52 (<.001)	124 (0.125)	87 (<.001)
S10	47 (<.001)	35 (<.001)	39 (<.001)	35 (<.001)	39 (<.001)	57 (<.001)	57 (<.001)	68 (<.001)	104 (<.001)	101 (<.001)
S11	119 (0.095)	88 (<.001)	79 (<.001)	65 (<.001)	59 (<.001)	68 (<.001)	60 (<.001)	113 (0.026)	139 (0.984)	113 (0.013)
Passive viewing experiment										
S3	142 (1.000)	151 (0.539)	126 (0.156)	126 (0.143)	142 (0.977)	171 (0.080)	132 (0.431)	140 (0.894)	149 (0.596)	122 (0.073)
S4	121 (0.057)	102 (<.001)	88 (<.001)	85 (<.001)	123 (0.089)	131 (0.367)	101 (<.001)	133 (0.456)	124 (0.093)	120 (0.052)
S6	135 (0.456)	113 (<.001)	161 (0.281)	123 (0.051)	111 (0.001)	122 (0.041)	141 (0.831)	152 (0.568)	127 (0.118)	157 (0.349)

Table S2. The variability of decoding error in Experiment 1 and the passive viewing experiment. For each participant and ROI, we report the standard deviation of the decoding error distribution (in unit of degree polar angle). The values in the parenthesis are uncorrected *p*-values computed by comparing the variability of the data with a null distribution obtained by a permutation procedure. The *p*-values smaller than 0.05 are highlighted by red color.

	V1	V2	V3	V3AB	IPS0	IPS1	IPS2	IPS3	iPCS	sPCS
Experiment 1										
S1	0.51 (<.001)	0.69 (<.001)	0.76 (<.001)	0.78 (<.001)	0.77 (<.001)	0.63 (<.001)	0.66 (<.001)	0.56 (<.001)	-0.01 (0.068)	0.31 (<.001)
S2	-0.02 (0.039)	0.00 (0.968)	0.00 (0.581)	-0.00 (0.697)	-0.01 (0.125)	-0.01 (0.341)	-0.00 (0.657)	0.03 (0.001)	-0.02 (0.017)	-0.02 (0.025)
S3	0.80 (<.001)	0.88 (<.001)	0.81 (<.001)	0.89 (<.001)	0.75 (<.001)	0.58 (<.001)	0.74 (<.001)	0.60 (<.001)	0.02 (0.001)	0.26 (<.001)
S4	0.21 (<.001)	0.35 (<.001)	0.48 (<.001)	0.69 (<.001)	0.64 (<.001)	0.48 (<.001)	0.79 (<.001)	0.69 (<.001)	0.10 (<.001)	0.10 (<.001)
S5	0.25 (<.001)	0.51 (<.001)	0.55 (<.001)	0.66 (<.001)	0.63 (<.001)	0.26 (<.001)	0.42 (<.001)	0.41 (<.001)	0.02 (0.006)	0.09 (<.001)
S6	0.22 (<.001)	0.28 (<.001)	0.30 (<.001)	0.53 (<.001)	0.35 (<.001)	0.25 (<.001)	0.38 (<.001)	0.30 (<.001)	0.00 (0.204)	0.14 (<.001)
S7	0.03 (<.001)	0.09 (<.001)	0.16 (<.001)	0.36 (<.001)	0.34 (<.001)	0.12 (<.001)	0.15 (<.001)	0.03 (0.002)	0.01 (0.079)	0.01 (0.186)
S8	0.08 (<.001)	0.17 (<.001)	0.26 (<.001)	0.45 (<.001)	0.34 (<.001)	0.15 (<.001)	0.18 (<.001)	0.23 (<.001)	-0.01 (0.102)	0.09 (<.001)
S9	0.41 (<.001)	0.59 (<.001)	0.69 (<.001)	0.77 (<.001)	0.66 (<.001)	0.30 (<.001)	0.18 (<.001)	0.43 (<.001)	0.00 (0.366)	0.10 (<.001)
S10	0.50 (<.001)	0.68 (<.001)	0.62 (<.001)	0.68 (<.001)	0.63 (<.001)	0.36 (<.001)	0.31 (<.001)	0.21 (<.001)	0.01 (0.064)	0.01 (0.149)
S11	0.00 (0.405)	0.09 (<.001)	0.14 (<.001)	0.28 (<.001)	0.33 (<.001)	0.24 (<.001)	0.33 (<.001)	0.02 (0.011)	-0.00 (0.478)	0.02 (0.013)
Passive viewing experiment										
S3	-0.00 (0.603)	0.00 (0.878)	0.01 (0.163)	0.00 (0.266)	0.00 (0.971)	-0.01 (0.080)	-0.00 (0.583)	0.00 (0.579)	-0.01 (0.054)	0.01 (0.060)
S4	-0.01 (0.065)	0.03 (<.001)	0.09 (<.001)	0.11 (<.001)	0.01 (0.070)	-0.04 (<.001)	0.04 (<.001)	-0.00 (0.833)	0.01 (0.076)	0.01 (0.033)
S6	0.00 (0.422)	0.02 (<.001)	-0.00 (0.237)	0.00 (0.576)	0.02 (<.001)	-0.00 (0.278)	-0.00 (0.927)	-0.00 (0.386)	-0.00 (0.779)	-0.00 (0.572)

Table S3. Circular correlation between the decoded location and the target location in Experiment 1 and the passive viewing experiment. For each participant and ROI, we report the circular correlation and the values in the parenthesis are uncorrected *p*-values computed by comparing the correlation with a null distribution obtained by a permutation procedure. The *p*-values smaller than 0.05 are highlighted by red color.

	V1	V2	V3	V3AB	IPS0	IPS1	IPS2	IPS3	iPCS	sPCS
S1	45 (<.001)	60 (<.001)	79 (<.001)	119 (<.001)	99 (<.001)	70 (<.001)	76 (<.001)	62 (<.001)	42 (<.001)	52 (<.001)
S2	160 (<.001)	175 (<.001)	178 (<.001)	179 (<.001)	179 (<.001)	142 (<.001)	151 (<.001)	140 (<.001)	72 (<.001)	98 (<.001)
S3	179 (<.001)	190 (<.001)	192 (<.001)	190 (<.001)	163 (<.001)	121 (<.001)	159 (<.001)	163 (<.001)	40 (<.001)	111 (<.001)
S4	158 (<.001)	158 (<.001)	161 (<.001)	167 (<.001)	154 (<.001)	128 (<.001)	155 (<.001)	138 (<.001)	47 (<.001)	88 (<.001)
S5	173 (<.001)	211 (<.001)	216 (<.001)	224 (<.001)	213 (<.001)	130 (<.001)	180 (<.001)	169 (<.001)	23 (0.045)	113 (<.001)
S6	51 (<.001)	92 (<.001)	130 (<.001)	157 (<.001)	129 (<.001)	98 (<.001)	80 (<.001)	95 (<.001)	11 (0.295)	64 (<.001)
S7	45 (<.001)	80 (<.001)	98 (<.001)	160 (<.001)	165 (<.001)	120 (<.001)	102 (<.001)	80 (<.001)	-27 (0.010)	4 (0.714)
S8	105 (<.001)	149 (<.001)	177 (<.001)	191 (<.001)	181 (<.001)	143 (<.001)	136 (<.001)	142 (<.001)	76 (<.001)	42 (<.001)
S9	99 (<.001)	127 (<.001)	128 (<.001)	146 (<.001)	117 (<.001)	62 (<.001)	53 (<.001)	86 (<.001)	-13 (0.118)	27 (0.006)
S10	200 (<.001)	209 (<.001)	216 (<.001)	215 (<.001)	211 (<.001)	193 (<.001)	191 (<.001)	173 (<.001)	133 (<.001)	133 (<.001)
S11	126 (<.001)	143 (<.001)	144 (<.001)	161 (<.001)	147 (<.001)	129 (<.001)	152 (<.001)	149 (<.001)	18 (0.058)	50 (<.001)
S12	138 (<.001)	168 (<.001)	175 (<.001)	194 (<.001)	192 (<.001)	167 (<.001)	169 (<.001)	109 (<.001)	14 (0.195)	69 (<.001)
S13	146 (<.001)	158 (<.001)	169 (<.001)	188 (<.001)	166 (<.001)	160 (<.001)	100 (<.001)	128 (<.001)	18 (0.111)	44 (<.001)
S14	183 (<.001)	186 (<.001)	193 (<.001)	184 (<.001)	187 (<.001)	159 (<.001)	142 (<.001)	153 (<.001)	68 (<.001)	62 (<.001)

Table S4. Statistical test for the uniformity of the decoding error distributions in Experiment 2. For each participant and ROI, we reported a V statistics and the (uncorrected) *p*-value obtained by permutations (see Methods). A *p*-value smaller than 0.05 indicates that the error distribution is not uniform and favors the alternative hypothesis that the error distribution has a mean centered at zero degree (polar angle). The *p*-values smaller than 0.05 are highlighted by red color.

	V1	V2	V3	V3AB	IPS0	IPS1	IPS2	IPS3	iPCS	sPCS
S1	98 (<.001)	88 (<.001)	78 (<.001)	58 (<.001)	68 (<.001)	83 (<.001)	79 (<.001)	87 (<.001)	102 (0.001)	94 (<.001)
S2	41 (<.001)	33 (<.001)	31 (<.001)	30 (<.001)	30 (<.001)	49 (<.001)	45 (<.001)	50 (<.001)	83 (<.001)	70 (<.001)
S3	36 (<.001)	30 (<.001)	29 (<.001)	30 (<.001)	44 (<.001)	63 (<.001)	46 (<.001)	44 (<.001)	105 (0.001)	67 (<.001)
S4	29 (<.001)	29 (<.001)	27 (<.001)	22 (<.001)	32 (<.001)	47 (<.001)	31 (<.001)	42 (<.001)	94 (<.001)	68 (<.001)
S5	45 (<.001)	26 (<.001)	23 (<.001)	17 (<.001)	25 (<.001)	62 (<.001)	42 (<.001)	46 (<.001)	119 (0.097)	69 (<.001)
S6	99 (<.001)	78 (<.001)	61 (<.001)	50 (<.001)	62 (<.001)	75 (<.001)	83 (<.001)	76 (<.001)	134 (0.799)	90 (<.001)
S7	101 (<.001)	81 (<.001)	72 (<.001)	45 (<.001)	42 (<.001)	62 (<.001)	70 (<.001)	81 (<.001)	116 (0.045)	146 (0.572)
S8	69 (<.001)	50 (<.001)	37 (<.001)	29 (<.001)	34 (<.001)	52 (<.001)	55 (<.001)	53 (<.001)	83 (<.001)	103 (<.001)
S9	62 (<.001)	46 (<.001)	46 (<.001)	36 (<.001)	52 (<.001)	83 (<.001)	89 (<.001)	69 (<.001)	126 (0.497)	107 (0.003)
S10	34 (<.001)	30 (<.001)	26 (<.001)	27 (<.001)	29 (<.001)	38 (<.001)	38 (<.001)	46 (<.001)	62 (<.001)	62 (<.001)
S11	51 (<.001)	43 (<.001)	42 (<.001)	32 (<.001)	40 (<.001)	50 (<.001)	37 (<.001)	39 (<.001)	116 (0.080)	93 (<.001)
S12	55 (<.001)	42 (<.001)	38 (<.001)	28 (<.001)	29 (<.001)	42 (<.001)	41 (<.001)	67 (<.001)	134 (0.813)	87 (<.001)
S13	56 (<.001)	52 (<.001)	47 (<.001)	39 (<.001)	49 (<.001)	51 (<.001)	75 (<.001)	64 (<.001)	130 (0.510)	106 (<.001)
S14	29 (<.001)	27 (<.001)	22 (<.001)	28 (<.001)	26 (<.001)	42 (<.001)	50 (<.001)	45 (<.001)	86 (<.001)	89 (<.001)

Table S5. The variability of decoding error in Experiment 2. For each participant and ROI, we report the standard deviation of the decoding error distribution (in unit of degree polar angle). The values in the parenthesis are uncorrected *p*-values computed by comparing the variability of the data with a null distribution obtained by a permutation procedure. The *p*-values smaller than 0.05 are highlighted by red color.

	V1	V2	V3	V3AB	IPS0	IPS1	IPS2	IPS3	iPCS	sPCS
S1	0.05 (<.001)	0.09 (<.001)	0.15 (<.001)	0.35 (<.001)	0.24 (<.001)	0.12 (<.001)	0.14 (<.001)	0.08 (<.001)	0.01 (0.142)	0.04 (<.001)
S2	0.60 (<.001)	0.72 (<.001)	0.75 (<.001)	0.76 (<.001)	0.76 (<.001)	0.46 (<.001)	0.53 (<.001)	0.46 (<.001)	0.09 (<.001)	0.17 (<.001)
S3	0.67 (<.001)	0.75 (<.001)	0.77 (<.001)	0.75 (<.001)	0.55 (<.001)	0.29 (<.001)	0.52 (<.001)	0.54 (<.001)	0.01 (0.064)	0.26 (<.001)
S4	0.77 (<.001)	0.77 (<.001)	0.81 (<.001)	0.86 (<.001)	0.73 (<.001)	0.51 (<.001)	0.74 (<.001)	0.59 (<.001)	0.05 (<.001)	0.23 (<.001)
S5	0.54 (<.001)	0.82 (<.001)	0.85 (<.001)	0.91 (<.001)	0.83 (<.001)	0.30 (<.001)	0.58 (<.001)	0.52 (<.001)	0.00 (0.605)	0.18 (<.001)
S6	0.03 (<.001)	0.14 (<.001)	0.32 (<.001)	0.46 (<.001)	0.30 (<.001)	0.18 (<.001)	0.11 (<.001)	0.16 (<.001)	0.00 (0.432)	0.06 (<.001)
S7	0.04 (0.001)	0.11 (<.001)	0.18 (<.001)	0.53 (<.001)	0.57 (<.001)	0.30 (<.001)	0.21 (<.001)	0.13 (<.001)	0.02 (0.034)	0.00 (0.468)
S8	0.23 (<.001)	0.47 (<.001)	0.66 (<.001)	0.77 (<.001)	0.69 (<.001)	0.42 (<.001)	0.37 (<.001)	0.42 (<.001)	0.09 (<.001)	-0.02 (0.010)
S9	0.31 (<.001)	0.51 (<.001)	0.52 (<.001)	0.68 (<.001)	0.43 (<.001)	0.07 (<.001)	0.08 (<.001)	0.23 (<.001)	-0.01 (0.111)	0.03 (0.008)
S10	0.70 (<.001)	0.76 (<.001)	0.82 (<.001)	0.81 (<.001)	0.78 (<.001)	0.65 (<.001)	0.64 (<.001)	0.52 (<.001)	0.26 (<.001)	0.29 (<.001)
S11	0.45 (<.001)	0.57 (<.001)	0.58 (<.001)	0.73 (<.001)	0.60 (<.001)	0.47 (<.001)	0.65 (<.001)	0.63 (<.001)	0.01 (0.074)	0.07 (<.001)
S12	0.39 (<.001)	0.59 (<.001)	0.64 (<.001)	0.78 (<.001)	0.77 (<.001)	0.58 (<.001)	0.59 (<.001)	0.24 (<.001)	0.00 (0.629)	0.08 (<.001)
S13	0.38 (<.001)	0.44 (<.001)	0.51 (<.001)	0.62 (<.001)	0.49 (<.001)	0.45 (<.001)	0.17 (<.001)	0.28 (<.001)	-0.01 (0.093)	0.01 (0.035)
S14	0.78 (<.001)	0.80 (<.001)	0.86 (<.001)	0.78 (<.001)	0.81 (<.001)	0.58 (<.001)	0.43 (<.001)	0.54 (<.001)	0.09 (<.001)	0.09 (<.001)

Table S6. Circular correlation between the decoded location and the target location in Experiment 2. For each participant and ROI, we report the circular correlation and the values in the parenthesis are uncorrected p-values computed by comparing the correlation with a null distribution obtained by a permutation procedure. The *p*-values smaller than 0.05 are highlighted by red color.