

1 *Supplementary Note 1: Organization of the macaque pulvinar*

2 The primate pulvinar is anatomically and functionally heterogeneous. It is sensitive to a variety of visual
3 features^{1, 2, 3} and cognitive states^{4, 5, 6, 7, 8, 9, 10}. Traditionally, the pulvinar has been anatomically divided into
4 lateral (PL), inferior (PI), medial (PM), and anterior (oral) regions in non-human primates¹¹, although more
5 recent studies have identified finer segmentations within lateral and inferior regions^{12, 13, 14, 15}. Inferior, lateral,
6 and medial subdivisions of the pulvinar are interconnected with cortical regions involved in visual processing.
7 The lateral pulvinar and lateral subdivisions of the inferior pulvinar are interconnected with occipital cortex^{12,}
8^{16, 17}. Medial subdivisions of the inferior pulvinar are interconnected with several middle temporal areas
9 including MT, MST, and FST^{18, 19, 20, 21}. The medial pulvinar and dorsal sections of the lateral pulvinar are
0 anatomically connected with parietal, frontal, and cingulate cortex^{18, 22, 23}.

1
2 *Supplementary Note 2: Organization of cortical coupling in motion-sensitive cortex*

3 Functional coupling of motion-sensitive cortical areas TO1/2 was localized to the ventral pulvinar
4 (Figure 6b). While anatomical subregions could not be resolved within the human ventral pulvinar, the foci of
5 these correlations were medial to the correlations of area V1 and anterior to ventral temporal areas, consistent
6 with the location of medial subdivisions within the inferior pulvinar (PIcm, PIm, and Pip) that are anatomically
7 interconnected with motion sensitive areas (MT complex) in monkeys^{19, 24}. Interestingly, TO1/2 (possible
8 homologue to monkey MT complex) were clustered with human occipital and temporal areas based on the
9 network-level analyses of pulvino-cortical connectivity (Figure 2). The MT complex is traditionally associated
0 with the dorsal stream^{18, 25, 26}. However, comparable network-level analyses have not been performed based on
1 pulvino-cortical connectivity in monkeys. A similar analysis based solely on cortico-cortical anatomical
2 connectivity in macaques found a close link between MT and dorsal areas V3A and V3²⁷ whereas an analysis
3 of cortico-cortical functional coupling in humans found a closer link between TO1/2 and ventral stream areas
4 LO1/2²⁸. Future work will be needed to resolve the relationship of MT to TO1/2 and their connectivity with the
5 pulvinar across species.

6 The functional coupling between the pulvinar and TO1/2 appears to be situated within a broader
7 topography linking lateral temporal regions and the ventral medial pulvinar. The foci of functional coupling for
8 lateral temporal cortical regions, EBA and pSTS, were also found within medial portions of the ventral
9 pulvinar, proximal to the TO foci. Though monkey homologues of these regions remain to be resolved, cortical
0 regions surrounding MT in monkeys (e.g., FST and STP) are interconnected with parts of the pulvinar proximal
1 to MT connections (i.e., adjacent to PIm)¹⁸. These data suggest that discrete pulvinocortical connections (such
2 as between MT and PIm^{19, 20, 21}) are embedded within a larger framework that preserves cortical topography²³.

3
4 *Supplementary Note 3: - V1 cortical distance*

5 To evaluate the influence of individual areas on the relationship between cortical distance and pulvino-cortical
6 functional coupling, comparisons were made relative to a single reference area. V1 as the reference area (i.e.,
7 the distances between each area and V1) yielded the strongest correlation between cortical distance and the
8 peaks of functional connectivity (Supplementary Figure 3a). To illustrate this relationship, we plotted the
9 distances of peak correlations for all occipital-temporal areas (Supplementary Figure 3b) and for the subset of
0 occipital, face-, and scene-selective ventral temporal areas (Supplementary Figure 3c) relative to V1. The
1 distances for occipital-temporal areas fell close to a line between V1 and the maximally distant temporal area,
2 AT.

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4
5 *Supplementary Methods:*

6
7 *Retinotopic Mapping.* All subjects participated in a single scan session in which polar angle and eccentricity
8 representations were measured across cortex using a standard traveling wave paradigm consisting of a wedge or
9 annulus, respectively²⁹. A subset of these subjects participated in two additional scan sessions in which polar

0 angle and eccentricity representations were measured within the pulvinar using a similar paradigm, but scanning
1 protocols optimized for subcortical structures³⁰. Stimuli mapped the central 15° of the visual field. Due to
2 limitations of the scanner bore size and viewing angle, peripheral representations beyond 15° were not mapped
3 nor included in any analyses. Each run consisted of eight 40s cycles. For each subject, 2-5 runs were collected
4 for cortical mapping and 8-10 runs were collected for pulvinar mapping. Fourier analysis^{31, 32, 33} was used to
5 identify voxels that were sensitive to the spatial position (i.e., polar angle) of a peripheral cue during the task.
6 Early visual and extrastriate areas V1, V2, V3, hV4, V3A–B, VO1–2, PHC1-2, LO1-2, TO1-2 were defined
7 using standard criteria reported previously^{32, 34, 35, 36, 37}. Pulvinar visual field maps, vPul1 and vPul2, and other
8 subcortical visual field maps were defined using standard criteria previously published^{30, 38, 39}.

9 All subjects participated in a single scan session in which a memory-guided saccade task was used to
0 localize topographically organized areas in parietal and frontal cortex^{40, 41}. This task incorporates covert shifts
1 of attention, spatial working memory, and saccadic eye movements in a traveling wave paradigm. The detailed
2 description of the design and scanning parameters is provided in^{40, 41}. Briefly, subjects had to remember and
3 attend to the location of a peripheral cue over a delay period while maintaining central fixation. After the delay
4 period, subjects had to execute a saccade to the remembered location and then immediately back to central
5 fixation. The target cue was systematically moved on subsequent trials either clockwise or counterclockwise
6 among eight equally spaced locations. Each run was composed of eight 40 s cycles of the eight target position
7 sequence. A total of eight runs were collected in a single scan session for each subject. Fourier analysis^{31, 32, 33}
8 was used to identify voxels that were sensitive to the spatial position (i.e., polar angle) of a peripheral cue
9 during the task. Parietal and frontal areas IPS0-5, SPL, FEF, and IFS were defined using criteria previously
0 published^{41, 42}.

1
2 *Object localizer.* Sixteen subjects participated in a single scan session in which a standard object category
3 localizer was used to define the occipital face area OFA;⁴³ fusiform face area FFA;^{44, 45} anterior temporal
4 face-selective area AT;⁴⁶ the posterior superior temporal face area pSTS⁴⁶; extrastriate body area EBA;⁴⁷
5 fusiform body area FBA;⁴⁸ parahippocampal place area PPA;^{49, 50} transverse occipital sulcus TOS;⁵¹ and
6 retrosplenial cortex RSC;⁵² and lateral occipital complex LOC⁵³. Briefly, grayscale pictures of images (~12° x
7 12°) from five different categories (faces, headless bodies, inanimate objects, scrambled images, and scenes)
8 were presented in 15s blocks, each containing 20 stimuli (350ms duration, 400ms interstimulus interval).
9 Subjects viewed 12 blocks per stimulus category over the course of 4 runs. During stimulus presentation,
0 subjects maintained central fixation and performed a one-back task indicating the repeated presentation of an
1 object. Stimuli for each block were drawn from one of five categories: faces, scenes, headless bodies, intact
2 generic objects, and scrambled pictures of generic objects. The OFA was defined as a region within the
3 occipitotemporal sulcus that showed significantly stronger activity during the presentation of faces compared
4 with intact object stimuli ($p < 0.0001$). The FFA was defined as a region within the lateral fusiform sulcus based
5 on the same statistical criteria. For many subjects, this region included two distinct sub-regions in close
6 anatomical proximity FFA-1/2;⁴⁶ pFus/mFus;⁵⁴. AT was defined as a region within anterior temporal cortex
7 based on the same contrast, though with a slightly lower threshold ($p < 0.01$). The pSTS was defined as a region
8 within the posterior superior temporal sulcus that showed significantly stronger activity during the presentation
9 of faces compared with intact object stimuli ($p < 0.0001$). The EBA was defined as a region within the lateral
0 occipitotemporal cortex that showed significantly stronger activity during the presentation of headless bodies
1 compared with intact object stimuli ($p < 0.0001$). The EBA partially overlapped retinotopic areas LO2 and TO1.
2 The FBA was defined as a region within the fusiform sulcus based on the same statistical criteria. In several
3 subjects, the FBA partially overlapped the FFA. Overlapping voxels were assigned to either the FFA or FBA
4 based on contrasting activity during face and headless body presentations. The PPA was defined as a region
5 within the posterior parahippocampal cortex within the collateral sulcus and along the medial fusiform sulcus
6 that showed significantly stronger activity during the presentation of scenes compared with intact object stimuli

($p < 0.0001$). The PPA largely overlapped with retinotopic areas PHC1-2. Since the PPA was localized using a different experiment and may represent functional dissociations within this part of cortex, voxels were not restricted to non-overlapping portions. The TOS was defined as a region within the transverse occipital sulcus based on the same statistical criteria as the PPA. TOS partially overlapped with retinotopic areas V3B, IPS0, and LO1. The RSC was defined as a region within retrosplenial cortex based on the same statistical criteria as the PPA. LOC was defined as a region within the posterior superior temporal sulcus that showed significantly stronger activity during the presentation of intact objects compared with scrambled stimuli ($p < 0.0001$). Since the areas EBA, PPA, LOC, and TOS were localized separately from retinotopic mapping and may represent functional dissociations, voxels were not restricted to portions of cortex non-overlapping with retinotopic areas. Group-level regions were identified using a mixed effects meta-analysis (AFNI's 3dMEMA).

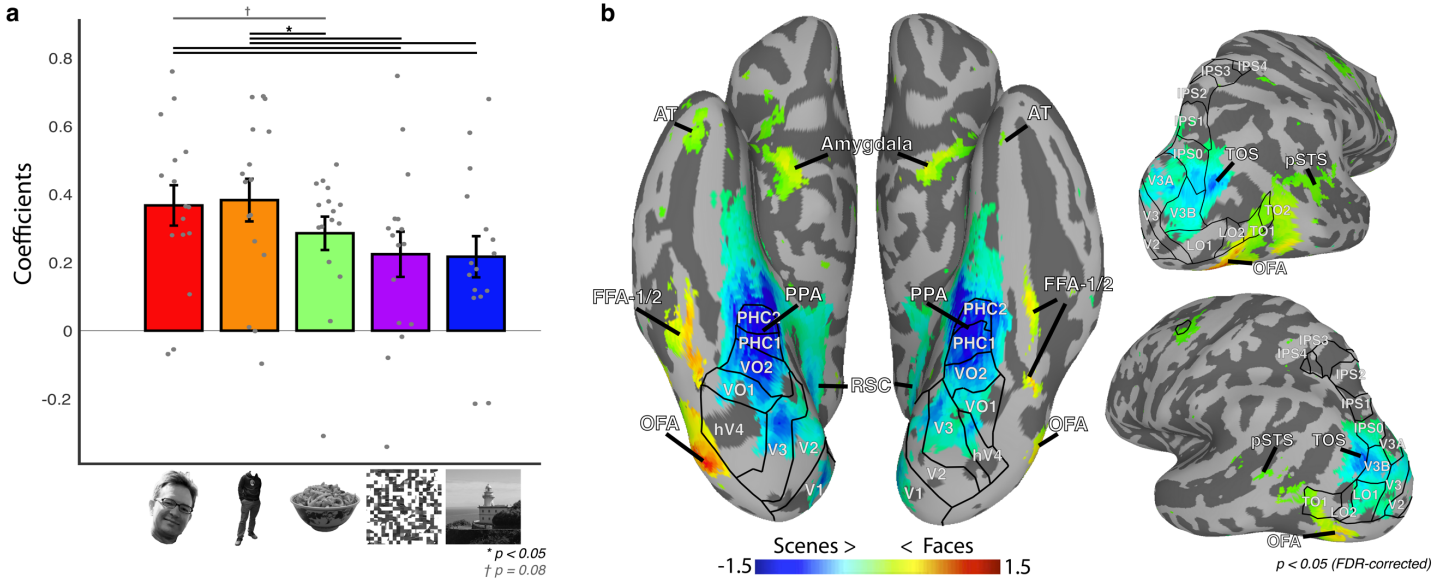
1. Maior RS, Hori E, Tomaz C, Ono T, Nishijo H. The monkey pulvinar neurons differentially respond to emotional expressions of human faces. *Behav Brain Res* **215**, 129-135 (2010).
2. Robinson DL, McClurkin JW, Kertzman C, Petersen SE. Visual responses of pulvinar and collicular neurons during eye movements of awake, trained macaques. *J Neurophysiol* **66**, 485-496 (1991).
3. Bender DB. Receptive-field properties of neurons in the macaque inferior pulvinar. *J Neurophysiol* **48**, 1-17 (1982).
4. Fischer J, Whitney D. Attention gates visual coding in the human pulvinar. *Nat Commun* **3**, 1051 (2012).
5. Hakamata Y, *et al.* The functional activity and effective connectivity of pulvinar are modulated by individual differences in threat-related attentional bias. *Sci Rep* **6**, 34777 (2016).
6. Komura Y, Nikkuni A, Hirashima N, Uetake T, Miyamoto A. Responses of pulvinar neurons reflect a subject's confidence in visual categorization. *Nat Neurosci* **16**, 749-755 (2013).
7. Saalman YB, Pinsk MA, Wang L, Li X, Kastner S. The pulvinar regulates information transmission between cortical areas based on attention demands. *Science* **337**, 753-756 (2012).
8. Smith AT, Cotton PL, Bruno A, Moutsiana C. Dissociating vision and visual attention in the human pulvinar. *J Neurophysiol* **101**, 917-925 (2009).
9. Strumpf H, *et al.* The role of the pulvinar in distractor processing and visual search. *Hum Brain Mapp* **34**, 1115-1132 (2013).
10. Zhou H, Schafer RJ, Desimone R. Pulvinar-Cortex Interactions in Vision and Attention. *Neuron* **89**, 209-220 (2016).
11. Olszewski J. *The thalamus of the Macaca, mulatta: an atlas for use with the stereotaxic instrument.* Karger Publishers (1952).
12. Adams MM, Hof PR, Gattass R, Webster MJ, Ungerleider LG. Visual cortical projections and chemoarchitecture of macaque monkey pulvinar. *J Comp Neurol* **419**, 377-393 (2000).

- 3
- 4 13. Cola MG, Seltzer B, Preuss TM, Cusick CG. Neurochemical organization of chimpanzee inferior pulvinar
5 complex. *J Comp Neurol* **484**, 299-312 (2005).
- 6
- 7 14. Gutierrez C, Yaun A, Cusick CG. Neurochemical subdivisions of the inferior pulvinar in macaque
8 monkeys. *J Comp Neurol* **363**, 545-562 (1995).
- 9
- 0 15. Stepniewska I, Kaas JH. Architectonic subdivisions of the inferior pulvinar in New World and Old World
1 monkeys. *Vis Neurosci* **14**, 1043-1060 (1997).
- 2
- 3 16. Gutierrez C, Cusick CG. Area V1 in macaque monkeys projects to multiple histochemically defined
4 subdivisions of the inferior pulvinar complex. *Brain Res* **765**, 349-356 (1997).
- 5
- 6 17. Benevento LA, Davis B. Topographical projections of the prestriate cortex to the pulvinar nuclei in the
7 macaque monkey: an autoradiographic study. *Exp Brain Res* **30**, 405-424 (1977).
- 8
- 9 18. Kaas JH, Lyon DC. Pulvinar contributions to the dorsal and ventral streams of visual processing in
0 primates. *Brain Res Rev* **55**, 285-296 (2007).
- 1
- 2 19. Lin CS, Kaas JH. Projections from the medial nucleus of the inferior pulvinar complex to the middle
3 temporal area of the visual cortex. *Neuroscience* **5**, 2219-2228 (1980).
- 4
- 5 20. Ungerleider LG, Desimone R, Galkin TW, Mishkin M. Subcortical projections of area MT in the
6 macaque. *J Comp Neurol* **223**, 368-386 (1984).
- 7
- 8 21. Standage GP, Benevento LA. The organization of connections between the pulvinar and visual area MT
9 in the macaque monkey. *Brain Res* **262**, 288-294 (1983).
- 0
- 1 22. Schmahmann JD, Pandya DN. Disconnection syndromes of basal ganglia, thalamus, and
2 cerebrotocerebellar systems. *Cortex* **44**, 1037-1066 (2008).
- 3
- 4 23. Shipp S. The functional logic of cortico-pulvinar connections. *Philos Trans R Soc Lond B Biol Sci* **358**,
5 1605-1624 (2003).
- 6
- 7 24. Kaas JH, Morel A. Connections of visual areas of the upper temporal lobe of owl monkeys: the MT
8 crescent and dorsal and ventral subdivisions of FST. *J Neurosci* **13**, 534-546 (1993).
- 9
- 0 25. Ungerleider LG, Mishkin M. Two cortical visual systems. In: *Analysis of Visual Behavior* (ed[^](eds Ingle
1 DJ, Goodale MA, Mansfield RJW). MIT press (1982).
- 2
- 3 26. Goodale MA, Milner AD. Separate visual pathways for perception and action. *Trends Neurosci* **15**, 20-25
4 (1992).
- 5
- 6 27. Young MP. Objective analysis of the topological organization of the primate cortical visual system.
7 *Nature* **358**, 152-155 (1992).
- 8

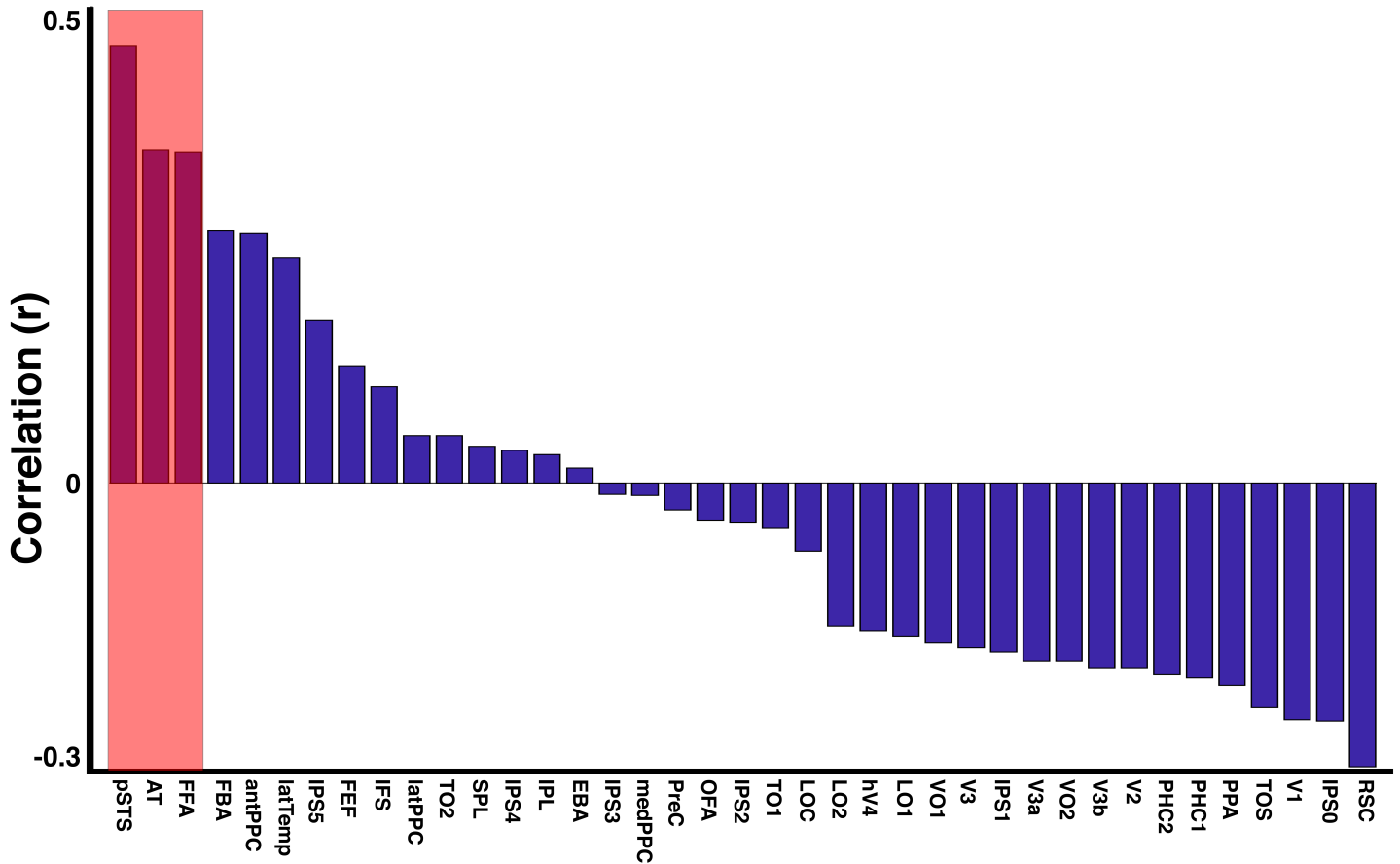
- 9 28. Haak KV, Beckmann CF. Objective analysis of the topological organization of the human cortical visual
0 connectome suggests three visual pathways. *Cortex* **98**, 73-83 (2018).
- 1
- 2 29. Wang L, Mruczek RE, Arcaro MJ, Kastner S. Probabilistic Maps of Visual Topography in Human Cortex.
3 *Cereb Cortex*, (2014).
- 4
- 5 30. Arcaro MJ, Pinsk MA, Kastner S. The Anatomical and Functional Organization of the Human Visual
6 Pulvinar. *J Neurosci* **35**, 9848-9871 (2015).
- 7
- 8 31. Bandettini PA, Jesmanowicz A, Wong EC, Hyde JS. Processing strategies for time-course data sets in
9 functional MRI of the human brain. *Magn Reson Med* **30**, 161-173 (1993).
- 0
- 1 32. Engel SA, Glover GH, Wandell BA. Retinotopic organization in human visual cortex and the spatial
2 precision of functional MRI. *Cereb Cortex* **7**, 181-192 (1997).
- 3
- 4 33. Sereno MI, Pitzalis S, Martinez A. Mapping of contralateral space in retinotopic coordinates by a
5 parietal cortical area in humans. *Science* **294**, 1350-1354 (2001).
- 6
- 7 34. Arcaro MJ, McMains SA, Singer BD, Kastner S. Retinotopic organization of human ventral visual cortex.
8 *J Neurosci* **29**, 10638-10652 (2009).
- 9
- 0 35. Brewer AA, Liu J, Wade AR, Wandell BA. Visual field maps and stimulus selectivity in human ventral
1 occipital cortex. *Nat Neurosci* **8**, 1102-1109 (2005).
- 2
- 3 36. DeYoe EA, *et al.* Mapping striate and extrastriate visual areas in human cerebral cortex. *Proc Natl Acad*
4 *Sci U S A* **93**, 2382-2386 (1996).
- 5
- 6 37. Sereno MI, *et al.* Borders of multiple visual areas in humans revealed by functional magnetic resonance
7 imaging. *Science* **268**, 889-893 (1995).
- 8
- 9 38. Schneider KA, Kastner S. Visual responses of the human superior colliculus: a high-resolution functional
0 magnetic resonance imaging study. *Journal of neurophysiology* **94**, 2491-2503 (2005).
- 1
- 2 39. Schneider KA, Richter MC, Kastner S. Retinotopic organization and functional subdivisions of the
3 human lateral geniculate nucleus: a high-resolution functional magnetic resonance imaging study. *J*
4 *Neurosci* **24**, 8975-8985 (2004).
- 5
- 6 40. Konen CS, Kastner S. Representation of eye movements and stimulus motion in topographically
7 organized areas of human posterior parietal cortex. *The Journal of neuroscience : the official journal of*
8 *the Society for Neuroscience* **28**, 8361-8375 (2008).
- 9
- 0 41. Kastner S, DeSimone K, Konen CS, Szczepanski SM, Weiner KS, Schneider KA. Topographic maps in
1 human frontal cortex revealed in memory-guided saccade and spatial working-memory tasks. *Journal*
2 *of neurophysiology* **97**, 3494-3507 (2007).
- 3

- 4 42. Swisher JD, Halko MA, Merabet LB, McMains SA, Somers DC. Visual topography of human intraparietal
5 sulcus. *The Journal of neuroscience : the official journal of the Society for Neuroscience* **27**, 5326-5337
6 (2007).
7
- 8 43. Puce A, Allison T, Asgari M, Gore JC, McCarthy G. Differential sensitivity of human visual cortex to
9 faces, letterstrings, and textures: a functional magnetic resonance imaging study. *J Neurosci* **16**, 5205-
0 5215 (1996).
1
- 2 44. Kanwisher N, McDermott J, Chun MM. The fusiform face area: a module in human extrastriate cortex
3 specialized for face perception. *J Neurosci* **17**, 4302-4311 (1997).
4
- 5 45. McCarthy G, Puce A, Gore JC, Allison T. Face-specific processing in the human fusiform gyrus. *J Cogn
6 Neurosci* **9**, 605-610 (1997).
7
- 8 46. Pinsk MA, *et al.* Neural representations of faces and body parts in macaque and human cortex: a
9 comparative fMRI study. *J Neurophysiol* **101**, 2581-2600 (2009).
0
- 1 47. Downing PE, Jiang Y, Shuman M, Kanwisher N. A cortical area selective for visual processing of the
2 human body. *Science* **293**, 2470-2473 (2001).
3
- 4 48. Peelen MV, Downing PE. Selectivity for the human body in the fusiform gyrus. *J Neurophysiol* **93**, 603-
5 608 (2005).
6
- 7 49. Epstein R, Kanwisher N. A cortical representation of the local visual environment. *Nature* **392**, 598-601
8 (1998).
9
- 0 50. Aguirre GK, Detre JA, Alsop DC, D'Esposito M. The parahippocampus subserves topographical learning
1 in man. *Cereb Cortex* **6**, 823-829 (1996).
2
- 3 51. Grill-Spector K. The neural basis of object perception. *Curr Opin Neurobiol* **13**, 159-166 (2003).
4
- 5 52. Maguire EA. The retrosplenial contribution to human navigation: a review of lesion and neuroimaging
6 findings. *Scand J Psychol* **42**, 225-238 (2001).
7
- 8 53. Grill-Spector K, Kourtzi Z, Kanwisher N. The lateral occipital complex and its role in object recognition.
9 *Vision Res* **41**, 1409-1422 (2001).
0
- 1 54. Grill-Spector K, Weiner KS. The functional architecture of the ventral temporal cortex and its role in
2 categorization. *Nature reviews Neuroscience* **15**, 536-548 (2014).
3
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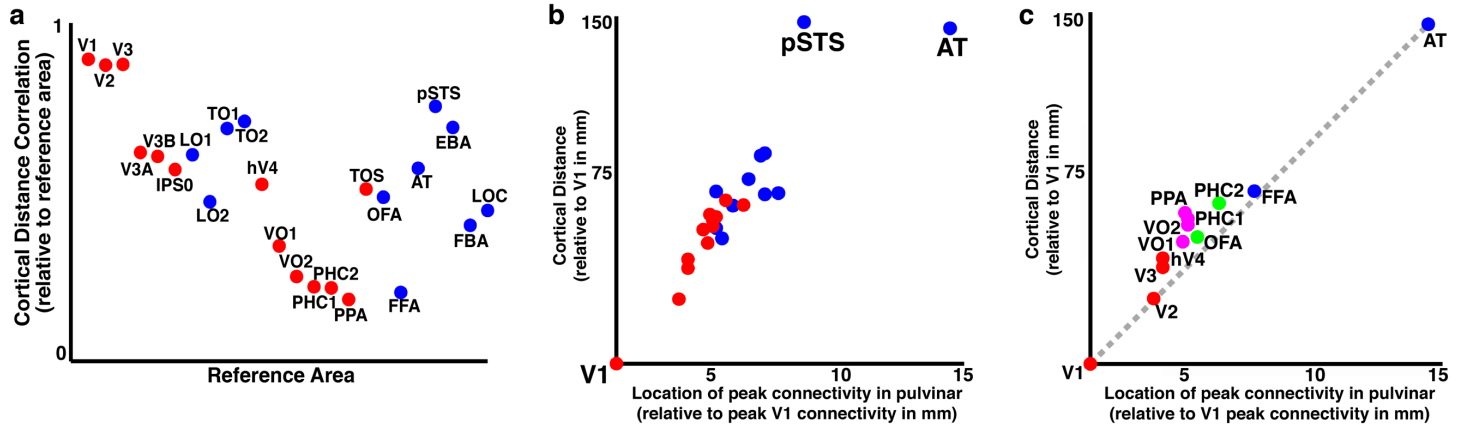
6 Supplementary Figures



7
8 Supplemental Figure 1. Category localizer responses in the pulvinar and cortex. (a) Individual subject and group mean
9 betas for face, headless body, object, scrambled, and scene categories in the posterior pulvinar. (b) Cortical activity for
0 face vs. scene stimuli ($p < 0.05$, FDR-corrected, $n = 16$). Bar graphs show the group average and S.E.M for each
1 category. Grey circles illustrate individual subjects.
2



4 *Supplementary Figure 2. Resting state pulvino-cortical coupling predicts functional tuning within the pulvinar.*
 5 *Correlation between the spatial pattern of face-minus-scene betas and each cortical areas functional coupling within the*
 6 *pulvinar. The functional coupling at rest for face-selective cortical areas pSTS, AT, and FFA were most predictive of the*
 7 *face-minus-scene contrast within the pulvinar.*



0 *Supplementary Figure 3. Pulvino-cortical coupling reflects cortical distance from V1. (a) Graph shows the cortical*
 1 *distance correlation relative to each of the ventral areas. (b) A plot of the cortical distance relative to V1 vs. distance of*
 2 *peak location relative to V1 in the pulvinar for all 24 areas in Figure 6c. (c) Same plot as in (b), but for the subset of*
 3 *areas reported in Figure 6d.*