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Supplemental information

VIP interneurons regulate cortical size tuning and visual perception

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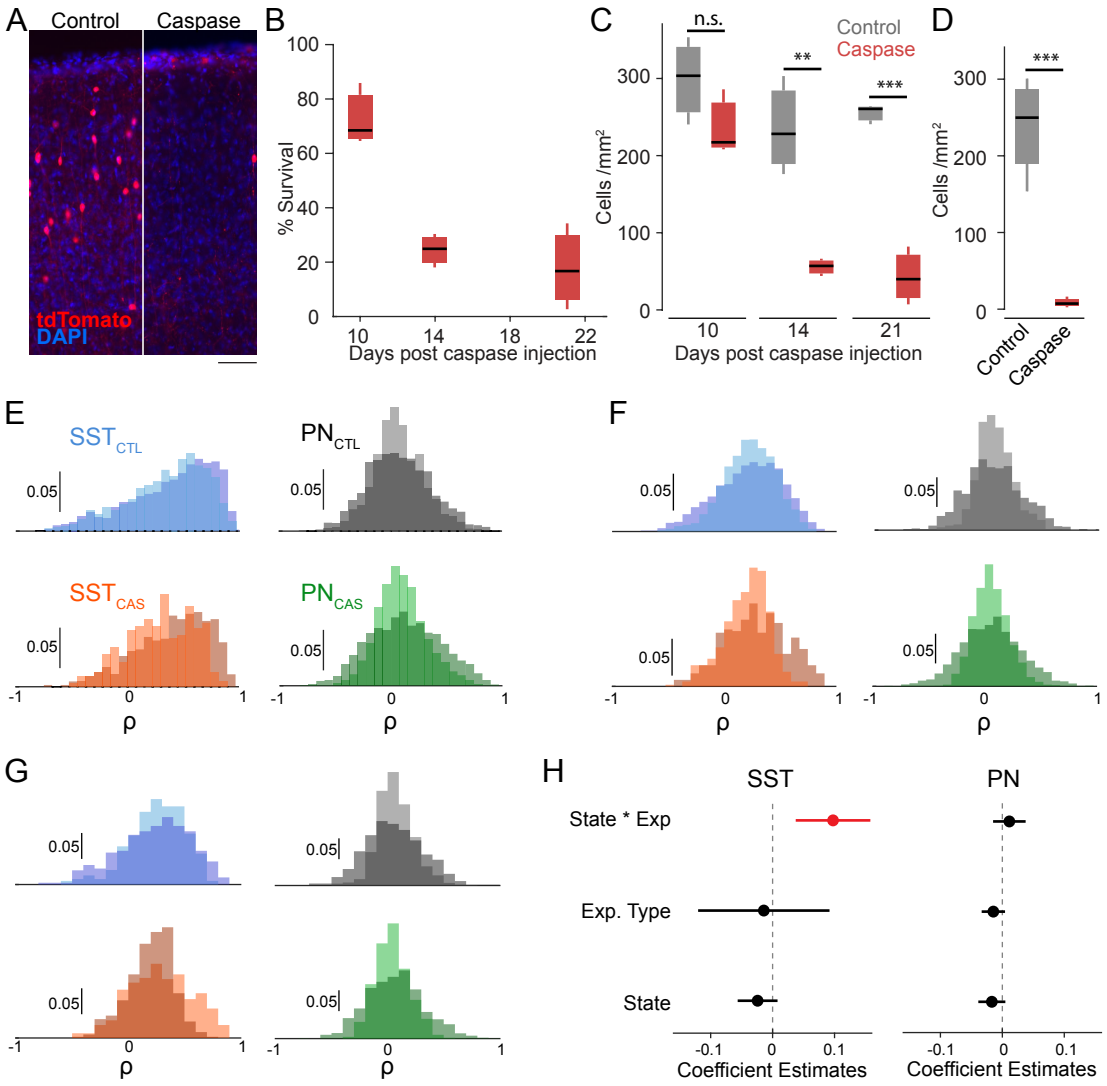
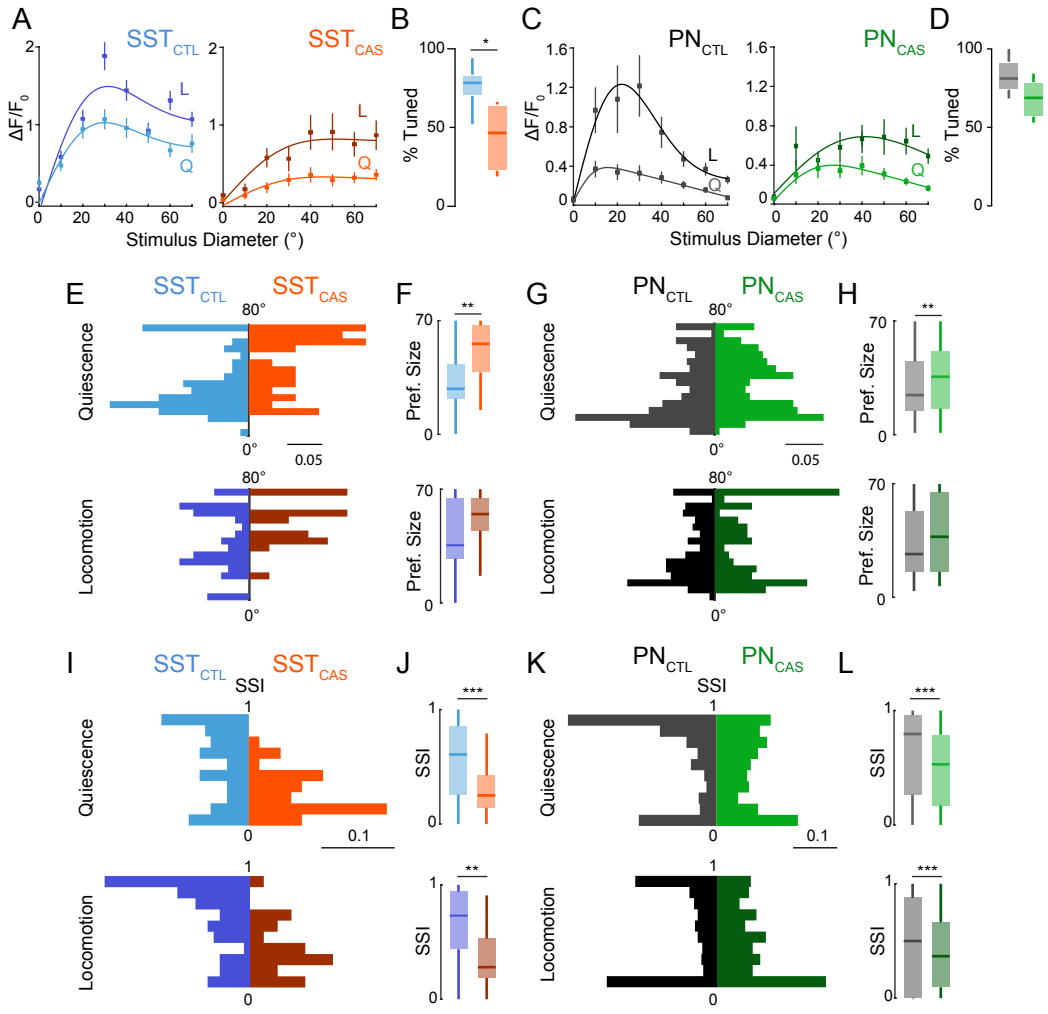
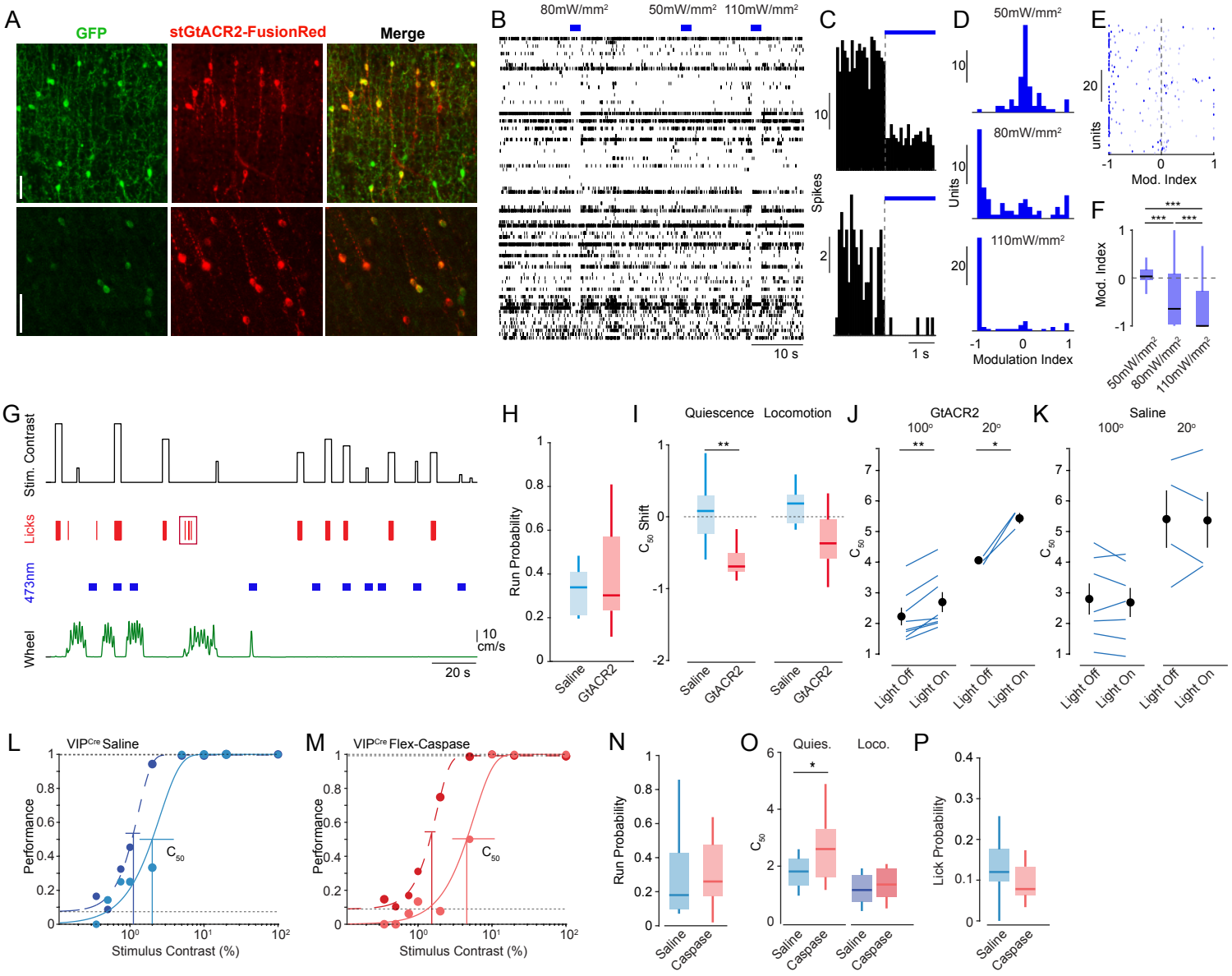


Supplemental Figure 1. Ablation of VIP-INs by expression of caspase-3 and impact on the structure of local cortical activity. (A) Histology from an example VIPCreAi9F/0 mouse expressing tdTomato selectively in VIP-INs. VIP-INs (red) are present in V1 of the control hemisphere (left) but absent in the V1 injected with AAV-Syn-FLEX-taCasP3-TEVP. Scale bar = 70μm. (B) Percent survival of VIP-INs over time following caspase virus injection, calculated as [VIP-INs$_{caspase}$/VIP-INs$_{control}$] in each animal (n = 3 mice). (C) Density of VIP-INs in layer 2/3 of V1 cortex at 10, 14, and 21 days post caspase virus injection (n = 3 mice). (D) Density of VIP-INs in layer 2/3 of V1 cortex in animals used for 2-photon imaging (n = 4 control, 4 caspase mice). Unpaired t-test for histology, ** p<0.01, *** p<0.001. (E) Noise correlation distributions of ΔF/F0 for control (SST-INs, upper left, blue; PNs, upper right, grey) and VIP ablated (SST-INs, lower left, orange; PNs, lower right, green) animals. Correlations for sitting (lighter shades) and running (darker shades) are shown separately, with the overlap indicated by the darkest shade. SST control: n = 2180 pairs, 6 mice; SST VIP-ablated: n = 447 pairs, 4 mice; PN control: 1077 pairs, 5 mice; PN VIP-ablated: 2481 pairs, 6 mice. (F) Same as in E, but for deconvolved traces. SST control: n = 2180 pairs, 6 mice; SST VIP-ablated: n = 447 pairs, 4 mice; PN control: 1077 pairs, 5 mice; PN VIP-ablated: 2481 pairs, 6 mice. (G) Same as in E, but for mean-matched deconvolved data (see Methods). SST control: n = 1293 Q, 975 L pairs, 6 mice; SST VIP-ablated: n = 261 Q, 202 L pairs, 4 mice; PN control: 748 Q, 748 L pairs, 6 mice; PN VIP-ablated: 1658 Q, 1786 L pairs, 6 mice (H) Coefficient estimates of linear mixed effects model for noise correlations in G, with experiment type (control or VIP ablation), and state (quiescence or locomotion) with the interaction term (denoted state*exp) as fixed effects, and imaging field of view nested in the mouse as random effects. Horizontal bars for confidence intervals, red bar indicates significance (p<0.01).



Supplemental Figure 2. Preferred stimulus size for SST-INs and PNs. (A) $\Delta F/F_0$ visual responses of SST cells for periods of quiescence (Q, light lines) and locomotion (L, dark lines) for control (blue; SST_{CTL}) and VIP ablation animals (orange; SST_{CAS}). Baseline (F_0) was set as the 1s period before the stimulus onset, where $\Delta F/F_0 = (F-F_0)/ F_0$. (B) Boxplots of the percent of visually responsive cells that are visually tuned (see Methods) in SST control (blue; n= 6 mice) and VIP-ablation animals (orange; n= 4 mice). (C) Same as in A, but for PNs in control (gray; PN_{CTL}) and VIP ablation (green; PN_{CAS}) animals. (D) Same as in B but for PNs in control (gray; n = 6 mice) and VIP ablation (green; n= 5 mice) animals. (E) Probability distribution for the preferred stimulus size of SST-INs in control (blue; SST_{CTL}) and VIP ablation (orange; SST_{CAS}) animals. Distributions during quiescence are shown in light colors (upper; SST controls: n = 86 cells, 6 mice; SST VIP-ablation: n = 30 cells, 4 mice) and during locomotion in dark colors (lower; SST controls: n = 66 cells, 4 mice; SST VIP-ablation: 21 cells, 4 mice). (F) Boxplot of the population preferred stimulus size during quiescence (upper) and locomotion (lower). (G) Same as in E, for PNs in control (black; PN_{CTL}) and VIP ablation (green; PN_{CAS}) animals. (Quiescence, upper: PN controls: n = 254 cells, 6 mice; PN VIP-ablation: n = 175 cells, 5 mice. Locomotion, lower: PN controls: n = 202 cells, 3 mice; PN VIP-ablation: 122 cells, 3 mice). (H) Same as in F, for PNs. (I) Probability distribution for the surround suppression index (SSI) of all visually responsive SST-INs (tuned and untuned) in control (blue; SST_{CTL}) and VIP ablation (orange; SST_{CAS}) animals. Distributions during quiescence are shown in light colors (upper; SST controls: n = 134 cells, 6 mice; SST VIP-ablation: n = 69 cells, 4 mice) and during locomotion in dark colors (lower; SST controls: n = 121 cells, 4 mice; SST VIP-ablation: 53 cells, 4 mice). (J) Boxplot of the population SSI of all visually responsive cells during quiescence (upper) and locomotion (lower). (K) Same as in I, for PNs in control (black; PN_{CTL}) and VIP ablation (green; PN_{CAS}) animals. (Quiescence, upper: PN controls: n = 397 cells, 6 mice; PN VIP-ablation: n = 243 cells, 5 mice. Locomotion, lower: PN controls: n = 479 cells, 6 mice; PN VIP-ablation: 234 cells, 5 mice). (L) Same as in J, for PNs. * p<0.05, ** p<0.01, ***p<0.001. Percent tuned: unpaired Student's t-test. Preferred size and SSI: 0/1 inflated beta mixed effects regression model, with experiment type (control or VIP ablation) as fixed effect, mouse with nested imaging field of view as random effect.



Supplemental Figure 3. Modulation of perceptual behavior by manipulation of VIP-IN activity. (A) Example images of conditional GtACR2 expression (red) in GFP-expressing VIP-INs in V1 of an example animal (percent overlap: 79.8 ± 3.5; n = 3 mice). Scale bars = 50μm. (B) Raster plot of the spiking of 83 single neurons and multi-units in V1 cortex of a mouse expressing GtACR2 in excitatory pyramidal neurons. Light pulses (2 seconds duration) were given at 50, 80, or 110mW/mm² to suppress firing. (C) Histograms of the firing of two example V1 neurons in response to pulses of blue light. (D) Histogram of the modulation index of recorded neurons in response to light pulses at 50, 80, or 110mW/mm². (E) Raster plot of the modulation index for the 83 units, separated by light power. (F) Box plots of the population modulation index values of recorded neurons for 50, 80, or 110mW/mm². *** p<0.001. Wilcoxon signed-rank test. (G) Schematic of events during one segment of an example contrast detection task session, including visual stimuli (black), lick responses (red), periods of bilateral illumination with 473nm light (blue), and wheel speed (green). False alarm lick responses are denoted by the red box. Height of the black trace denotes contrast from 0 to 100% on a log scale. (H) Box plots of probability of locomotion behavior in saline-treated (blue) and GtACR2-expressing (red) animals. (I) Change in perceptual threshold for contrast (C50) in response to activation of GtACR2 in VIP-INs during quiescence (left) and locomotion (right). (J) Raw C50 values for task periods with and without light activation of GtACR2 for 100º (left) and 20º (right) diameter stimulus sizes. Lines indicate values for individual animals. (K) Same as J, but for saline-treated animals. GtACR2: n = 8 mice for 100º, n = 3 mice for 20º. Saline: n = 7 mice for 100º, n = 4 mice for 20º. ** p<0.01, unpaired (I), paired (J,K) t-test. (L) Performance curves for an example saline-treated animal in the visual contrast detection task during quiescence (light blue) and locomotion (dark blue). (M) Same as in L, for an example VIP ablation animal. (N) Box plots of probability of locomotion behavior in saline-treated (blue) and VIP-ablated (red) animals. (O) C_{50} values for task performance during quiescence (left) and locomotion (right) in control (blue) and VIP ablation (red) animals. (P) False alarm rate for saline-treated and VIP ablation animals. VIP ablation: n = 8 mice. Saline: n = 14 mice. * p<0.05, Unpaired t-test.