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Supplemental Information

Binocular integration of retinal motion information underlies optic flow processing by the cortex

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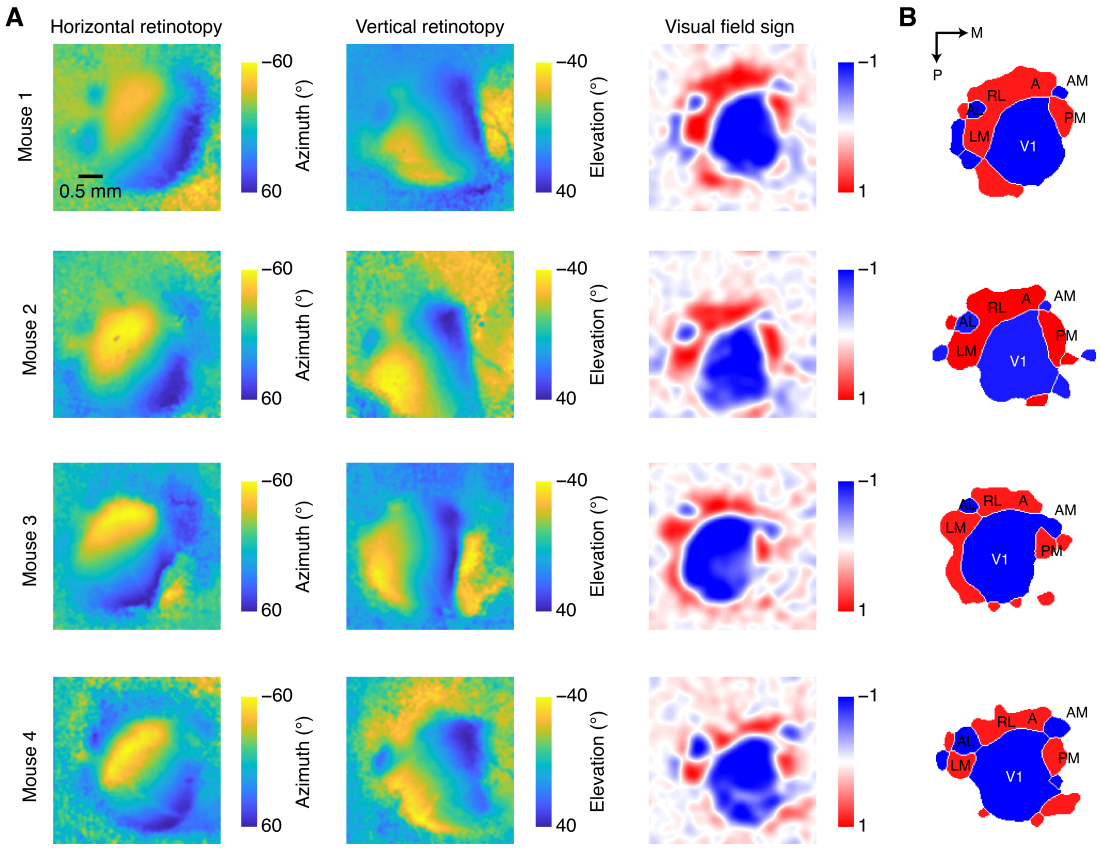

Figure S1. Identification of visual cortical areas using intrinsic signal optical imaging. Related to Figure 1. (A) Maps of horizontal (left) and vertical retinotopy (middle), and the corresponding visual field sign map (right) from four example mice. (B) Thresholded visual field sign patches showing the location of primary visual cortex (V1), and the higher visual areas: lateromedial (LM), anterolateral (AL), rostrolateral (RL), anterior (A), anteromedial (AM), and posteromedial (PM). Coordinates indicate posterior (P) and medial (M) directions.

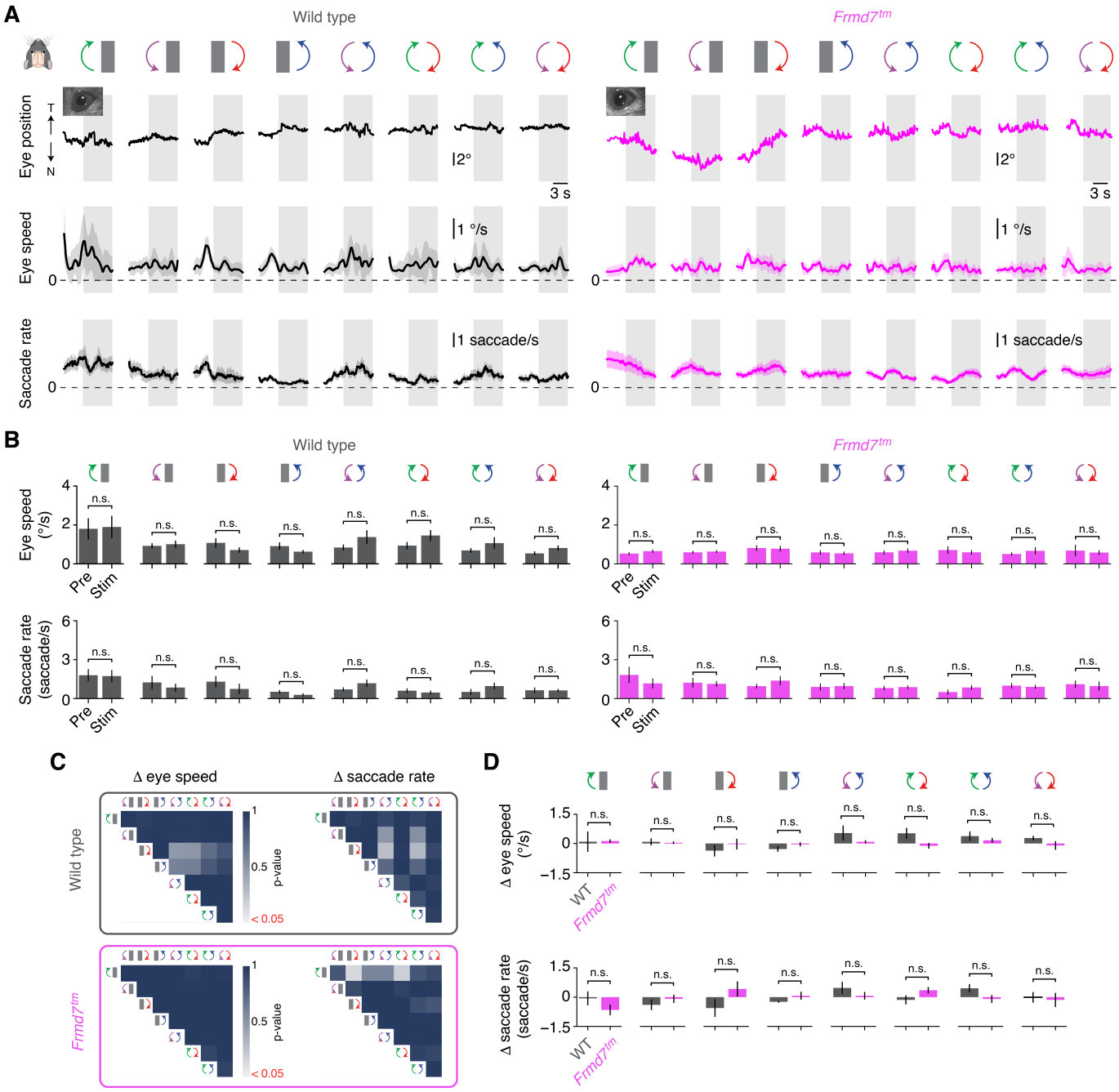

Figure S2. Eye movements in wild-type and *Frmd7^{tm}* mice during visual stimulus protocol. Related to Figure 1. (A) Upper: example traces of the horizontal position of the right eye (T, temporal; N, nasal), recorded in a wild-type mouse (left) and a *Frmd7^{tm}* mouse (right) in response to the monocular and binocular horizontal motion conditions presented at 10 °/s. Middle and lower: trial-averaged horizontal eye speed and saccade rate time courses for the right eye, recorded in wild-type mice (left; n = 9 recordings) and *Frmd7^{tm}* mice (right; n = 9 recordings) in response to the monocular and binocular horizontal motion conditions presented at 10 °/s. Error bars are mean ± SEM. (B) Quantification of mean horizontal eye speed (upper) and mean saccade rate (lower) before and during visual stimulation in wild-type (left) and *Frmd7^{tm}* mice (right). Error bars are mean ± SEM. n.s., not significant, p ≥ 0.05, two-sided paired Student's *t*-test. (C) Pairwise comparison of stimulus-related changes (pre vs stim) in mean horizontal eye speed (Δ eye speed,

left) and mean saccade rate (Δ saccade rate, right) across visual stimulus conditions in wild-type (upper) and *Frmd7*^{tm} mice (lower). Heatmap color indicates p-values computed from the repeated measures ANOVA followed by Tukey honestly significantly different post hoc testing; all p-values ≥ 0.05. (D) Quantification of Δ eye speed and Δ saccade rate between wild-type (WT) and *Frmd7*^{tm} mice across stimulus conditions. Error bars are mean ± SEM. n.s., p ≥ 0.05, two-sided unpaired Student's *t*-test.

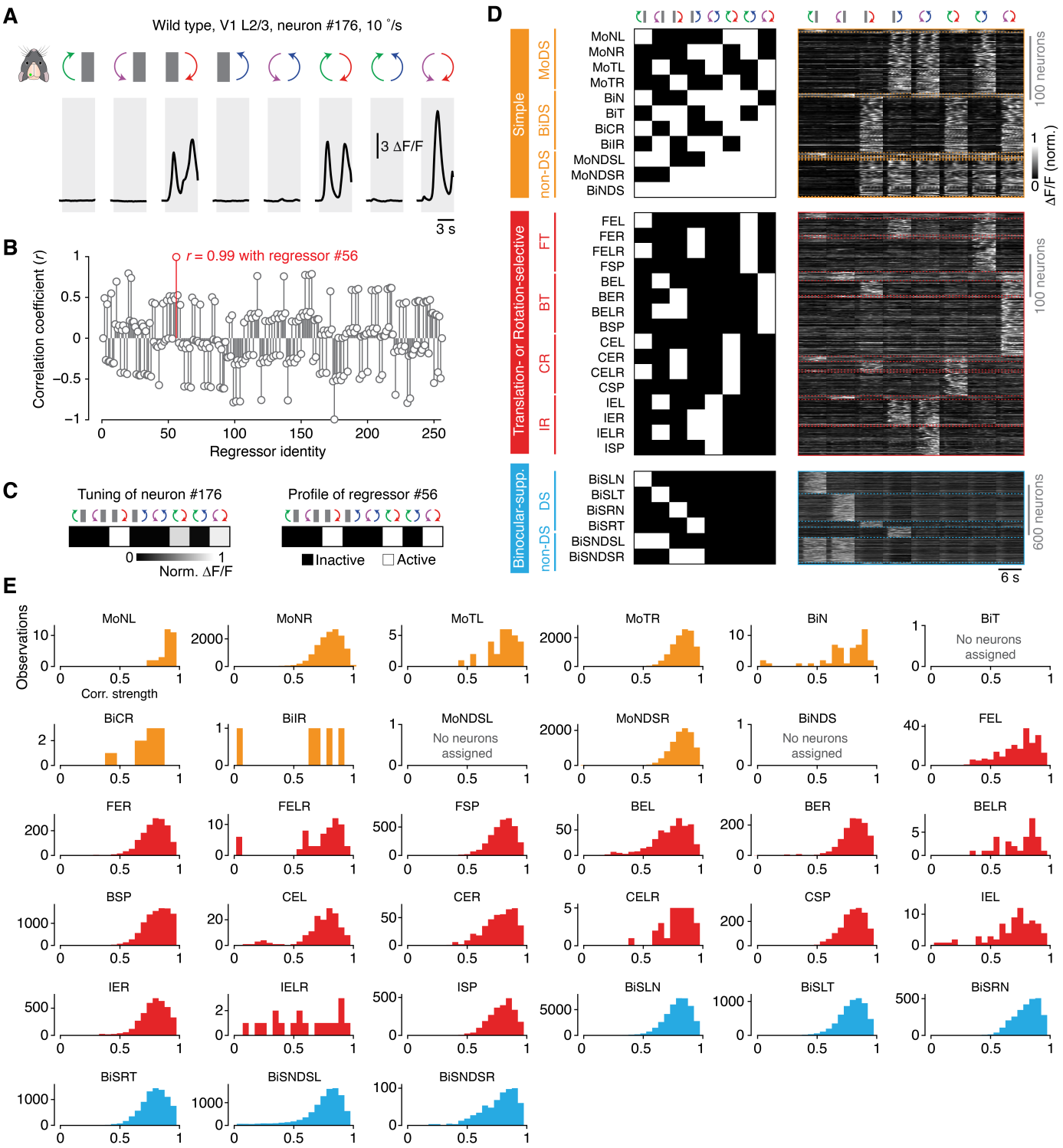

Figure S3. Regression analysis for classifying individual neurons to discrete response types. Related to Figures 1 and 3. (A) Trial-averaged fluorescence intensity (ΔF/F) time course for example layer 2/3 V1 neuron (#176) from a wild-type mouse in response to the monocular and binocular motion conditions at 10 °/s. (B) The tuning curve at the preferred speed was correlated to each of the 256 regressors, yielding a correlation profile. Correlation coefficients were calculated as Pearson's r. Neuron #176 showed the highest correlation with regressor #56 (r = 0.99) and was thus assigned to this response type. (C) Tuning

profile of neuron #176 and response profile of regressor #56. (D) Regressor profiles and response time courses for V1 neurons assigned to functional groups within the simple, translation- or rotation-selective, and binocular-suppressed response classes. MoDS, monocular DS; BiDS, binocular DS; FT, forward translational; BT, backward translational; CR, contraversive rotational; IR, ipsiversive rotational; N, nasalward; T, temporalward; L, left eye; R, right eye; NDS, non-DS; BiS, binocular suppressed; E, excited by; SP, specific. (E) Distributions of the correlation strength of response time courses for neurons assigned to the same regressor profile in the dataset obtained from V1 of wild-type mice.

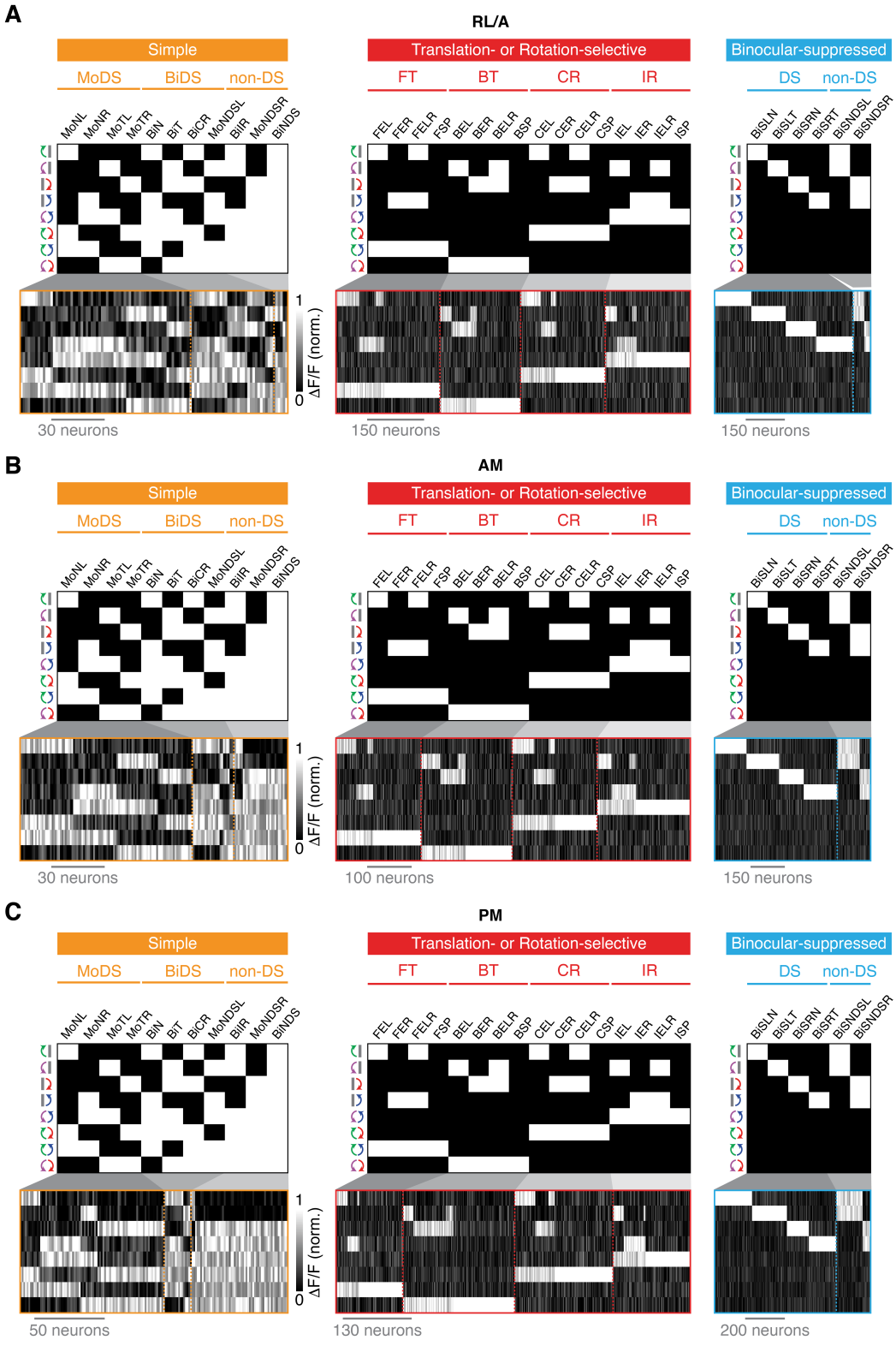

Figure S4. Tuning of HVA neurons assigned to functional groups. Related to Figures 1 and 3. (A–C) Regressor profiles and tuning of RL/A (A), AM (B) and PM (C) neurons from wild-type mice assigned to functional groups within simple, translation- or rotation-selective, and binocular-suppressed response classes. MoDS, monocular DS; BiDS, binocular DS; FT, forward translational; BT, backward translational; CR, contraversive rotational; IR, ipsiversive rotational; N, nasalward; T, temporalward; L, left eye; R, right eye; NDS, non-DS; BiS, binocular suppressed; E, excited by; SP, specific.

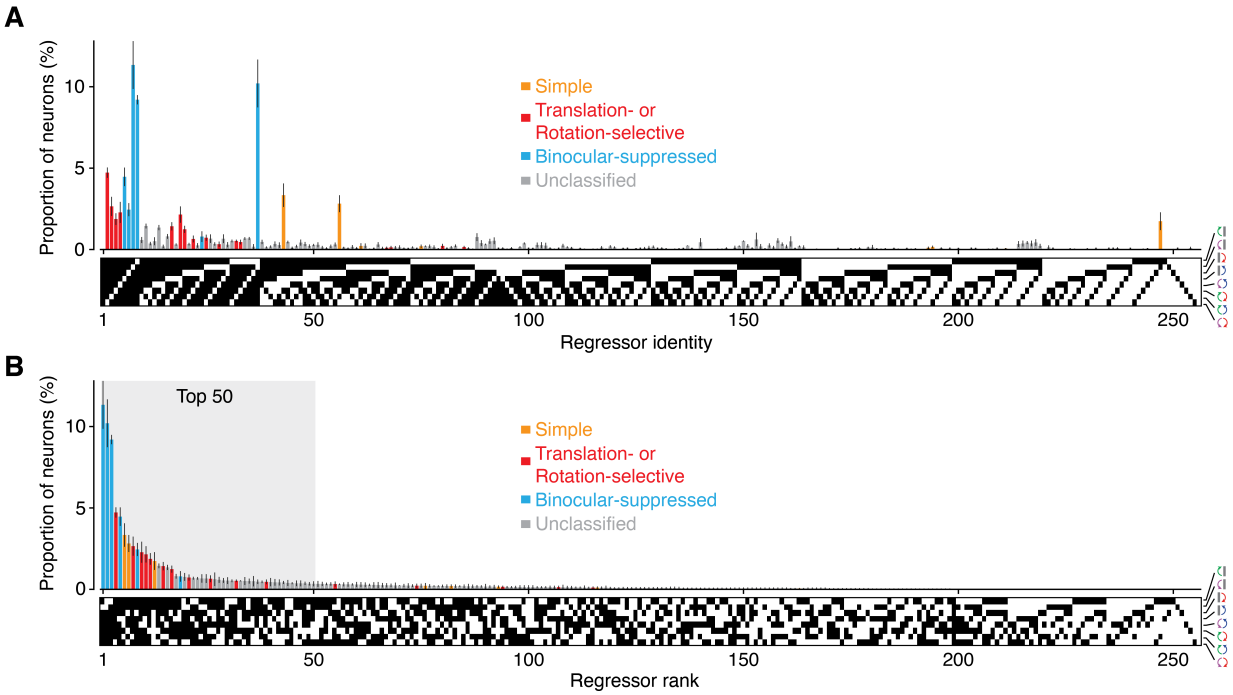

Figure S5. Obtaining regressor frequency distribution. Related to Figure 3. (A) Distribution of all reliably responsive V1 neurons from wild-type mice (n = 3010 neurons from 4 mice) grouped according to the 256 regressor profiles (white, active; black, inactive) and response class (simple, translation- or rotation-selective, binocular-suppressed, and unclassified). Error bars are mean ± SEM. (B) Distribution from (A) ranked according to regressor frequency. The shaded region depicts the 50 most abundant regressors (as shown in Figure 3A).

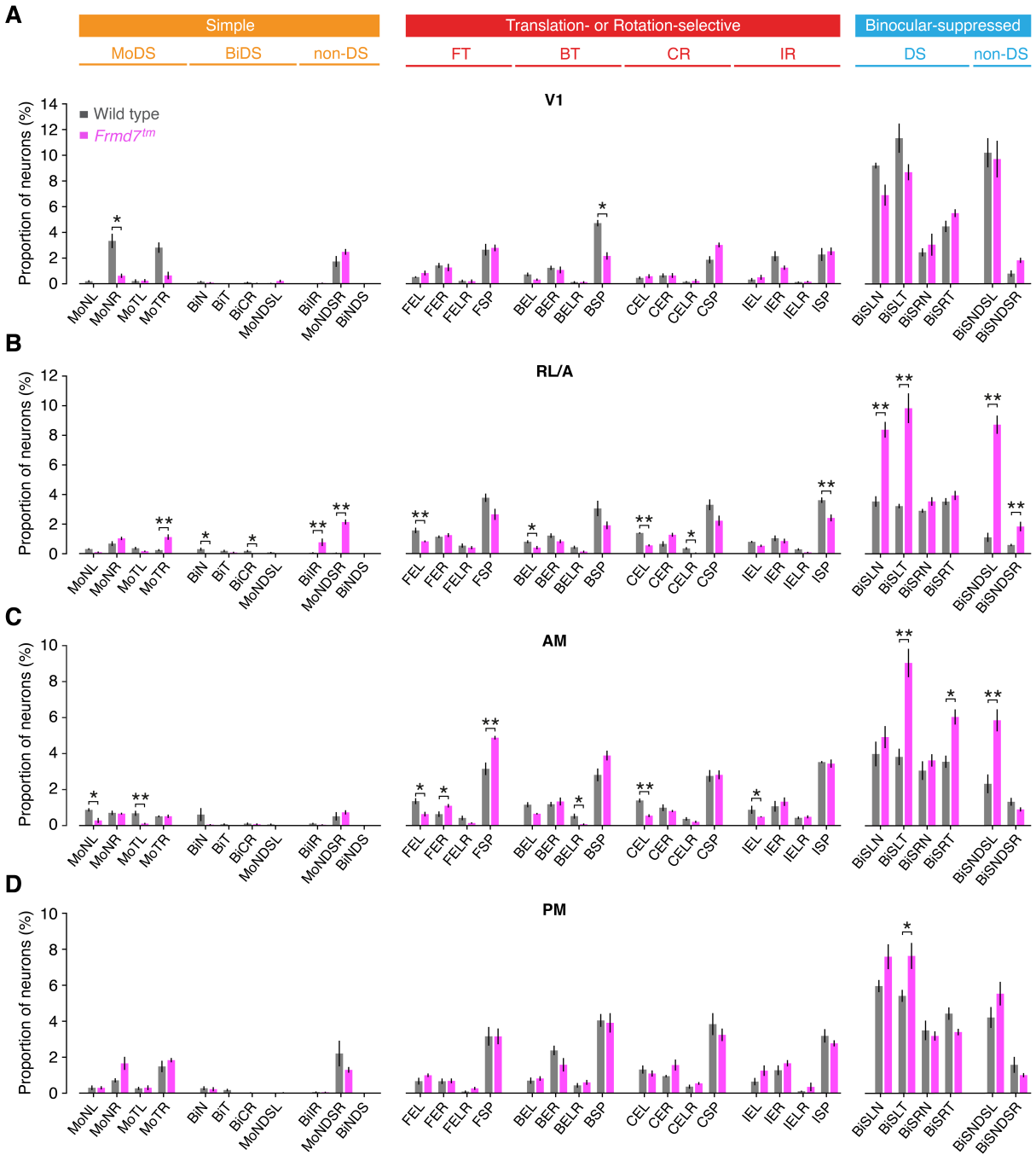

Figure S6. Proportional changes for individual response types in wild-type and *Frmd7^{tm}* mice. Related to Figure 4. (A–D) Proportion of V1 (A), RL/A (B), AM (C), and PM (D) neurons in simple, translation- or rotation-selective, and binocular-suppressed functional response types for wild-type and *Frmd7^{tm}* mice. Error bars are mean ± SEM. *p < 0.05, **p < 0.01, two-sided Mann-Whitney *U* test. MoDS, monocular DS; BiDS, binocular DS; FT, forward translational; BT, backward translational; CR, contraversive rotational; IR, ipsiversive rotational; N, nasalward; T, temporalward; L, left eye; R, right eye; NDS, non-DS; BiS, binocular suppressed; E, excited by; SP, specific.

	Total neurons		Consistently responsive		Animals	
Area	WT: n	*Frmd7^{tm}*: n	WT: n (%)	*Frmd7^{tm}*: n (%)	WT: n	*Frmd7^{tm}*: n
V1	5748	5534	3010 (52%)	2925 (53%)	4	4
RL/A	6563	6746	4165 (63%)	3125 (46%)	5	5
AM	6664	6919	4006 (60%)	3375 (49%)	5	5
PM	5419	5868	3059 (56%)	3047 (52%)	4	4

Table S1. Numbers of neurons sampled by visual cortical area and genetics. Related to Figures 1 and 3. Total neurons: total number (n) of neurons recorded in wild-type (WT) and *Frmd7^{tm}* mice experiments for each visual cortical area. Consistently responsive: number (n) and percent of total of neurons that met the inclusion criteria for responsiveness ($\Delta F/F > 10\%$), reliability ($\delta > 0.5$), and signal-to-noise (SNR > 0.5) and were included for regressor correlation analysis. Animals: number (n) of WT and *Frmd7^{tm}* mice that data were collected from for each area.