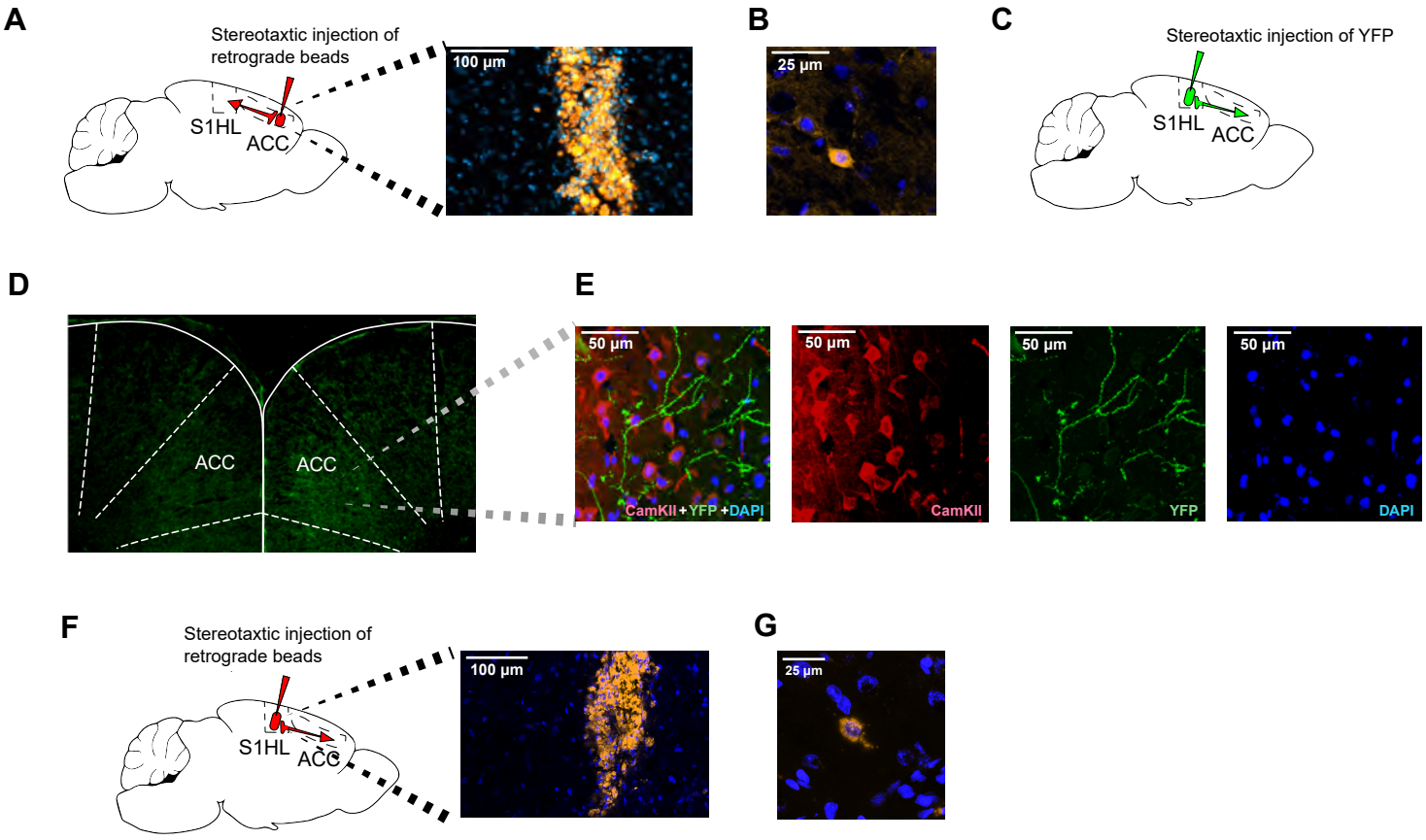

Figure S1. Anatomic projection from the S1 to the ACC. Related to Figure 1. (A) Schematic showing the retrograde tracer injected into the ACC. **(B)** Retrograde tracer expression in the hind limb region of S1. **(C)** Schematic showing the YFP injected into the S1. **(D)** Anterograde expression of YFP in the ACC. **(E)** Higher magnification view of the expression of YFP in the ACC. **(F)** Schematic showing the retrograde tracer injected into the S1. **(G)** Retrograde expression in the ACC.

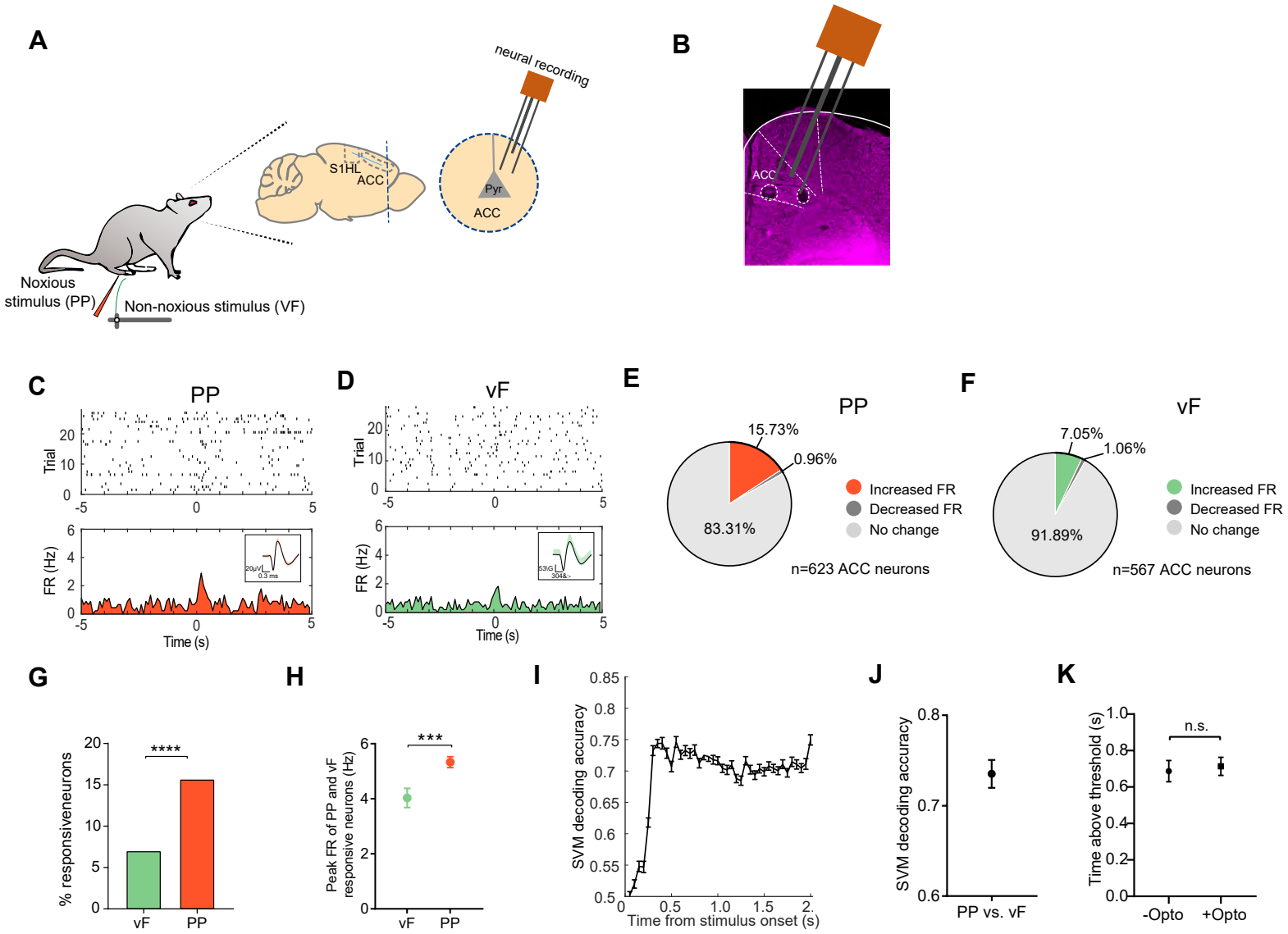

Figure S2. ACC nociceptive responses in freely behaving rodents. Related to Figure 1. (A) Schematic showing electrode implants in the ACC. **(B)** Histology showing electrode locations in the ACC. **(C)** Raster plots and peri-stimulus time histograms (PSTHs) of a representative ACC neuron. Time 0 indicates the onset of noxious pin prick (PP) stimulation. FR: firing rates. Inset shows representative single cell recordings. **(D)** Raster plots and PSTHs of a representative ACC neuron. Time 0 indicates the onset of non-noxious von Frey filament (vF) stimulation. **(E)** About 15.73% of recorded ACC neurons (n = 623 from 6 rats) responded to PP. See **Methods** for criteria of stimulus-responsive neurons. **(F)** About 7.05% of recorded ACC neurons (n = 567 from 6 rats) responded to vF. **(G)** The difference in the proportion of neurons that increased their firing rates in response to vF and PP was statistically signification. $p < 0.0001$, Fisher's exact test. **(H)** Among neurons that responded to both stimuli, PP induced higher firing rates than vF. Data represented as mean ± SEM. n1 = 40 for vF, n2 = 98 for PP; $p = 0.0009$, Wilcoxon paired signed rank test. See **Methods** for calculations of stimulus-evoked firing rates. **(I)** A representative session of SVM-based population-decoding analysis to distinguish between noxious and non-noxious stimulations. Time zero denotes the onset of stimulus

(PP or vF). The black curve denotes the decoding accuracy (n1 = 25 trials for PP, n2 = 25 trials for vF; C = 8 ACC neurons) derived from the data with true labels; the error bar denotes the SEM from 50 Monte Carlo simulations based on 2-fold cross-validation. See **Methods** for details. **(J)** SVM-based population-decoding analysis, based on ACC neuronal activity, demonstrated the ability to distinguish between noxious and non-noxious stimulation. n = 40 sessions from 5 rats. **(K)** There is no significant difference in response time among neurons in the ACC with no activation (n = 98) and with optogenetic activation (n = 131) of S1 inputs to the ACC. p = 0.7075, Mann-Whitney U test.

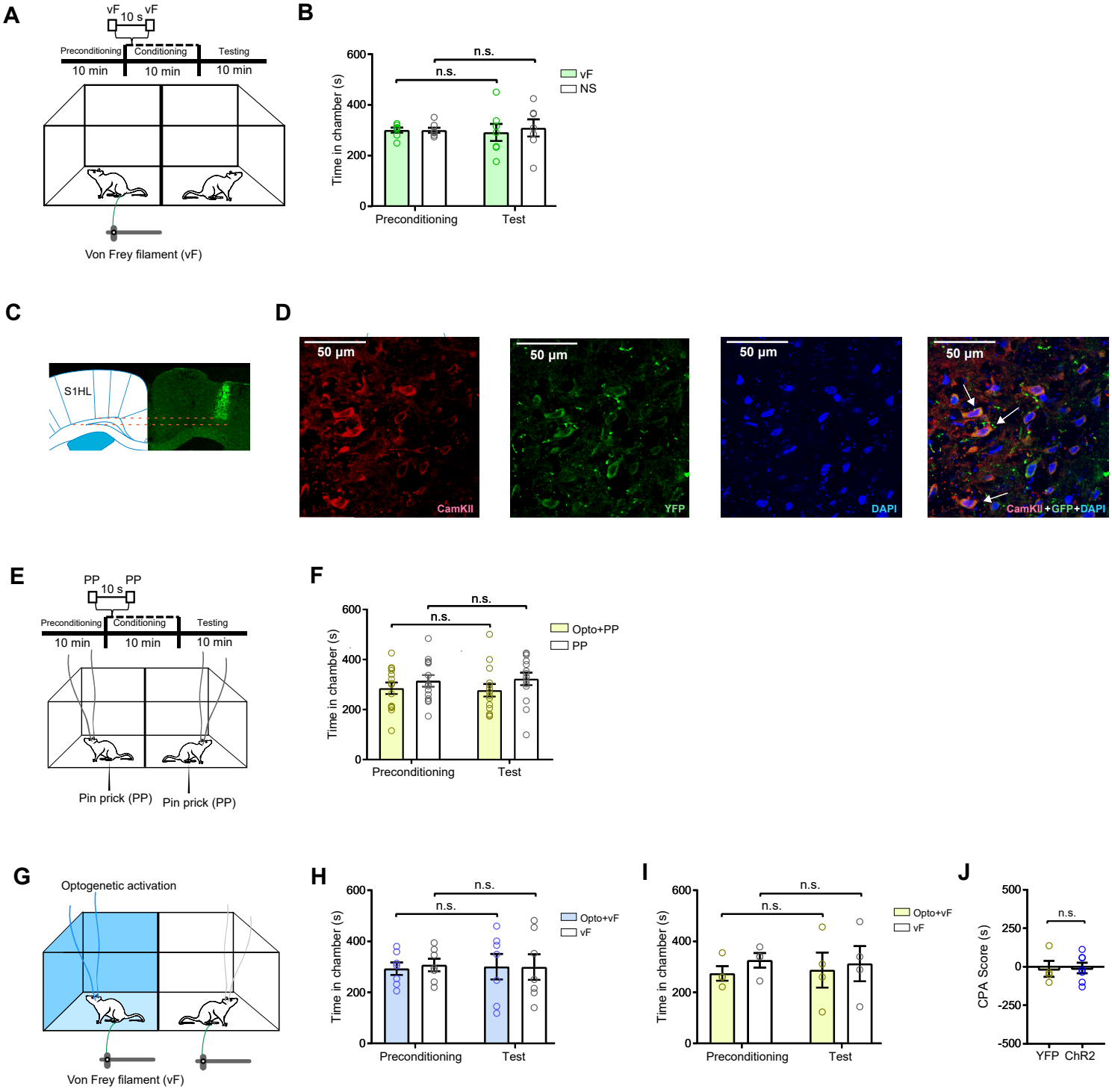

Figure S3. Rats do not demonstrate aversive response in control conditions. Related to Figure 2. (A) Schematic of the conditioned place preference (CPA) assay, when rats are presented with vF stimulation to hind paws. **(B)** Rats displayed no aversive response to non-noxious mechanical stimulus. One of the chambers was paired with vF, the other chamber was not paired with a noxious stimulus (NS). n = 7; p = 0.8117, paired Student's t test. **(C)** Low magnification (10x) view of histologic expression of channelrhodopsin (YFP-ChR2) in the S1 hind limb region after injection. **(D)** Higher magnification

(63x) view of the expression of YFP-ChR2 in pyramidal neurons of the S1 demonstrated the co-staining of glutamatergic neuronal marker CaMKII with YFP. From left to right: CaMKII staining; ChR2-eYFP staining; DAPI staining and merged images. **(E)** Schematic of the conditioned place preference (CPA) assay. One of the chambers was paired with light treatment and PP; the other chamber was paired with PP alone. **(F)** Control rats that expressed YFP alone did not demonstrate preference for either chamber, when presented with PP. n = 14; p = 0.8087, paired Student's t test. **(G)** Schematic of the conditioned place preference (CPA) assay, when rats are presented with vF to hind paws. One chamber was paired with S1→ACC activation and the other chamber was not. **(H)** Rats did not avoid the chamber associated with S1→ACC activation, when presented with vF. n = 7; p = 0.8232, paired Student's t test. **(I)** YFP control rats did not avoid the chamber associated with S1→ACC activation, when presented with vF. n = 4; p = 0.8154, paired Student's t test. **(J)** CPA score for S1→ACC activation in the presence of vF stimulus.

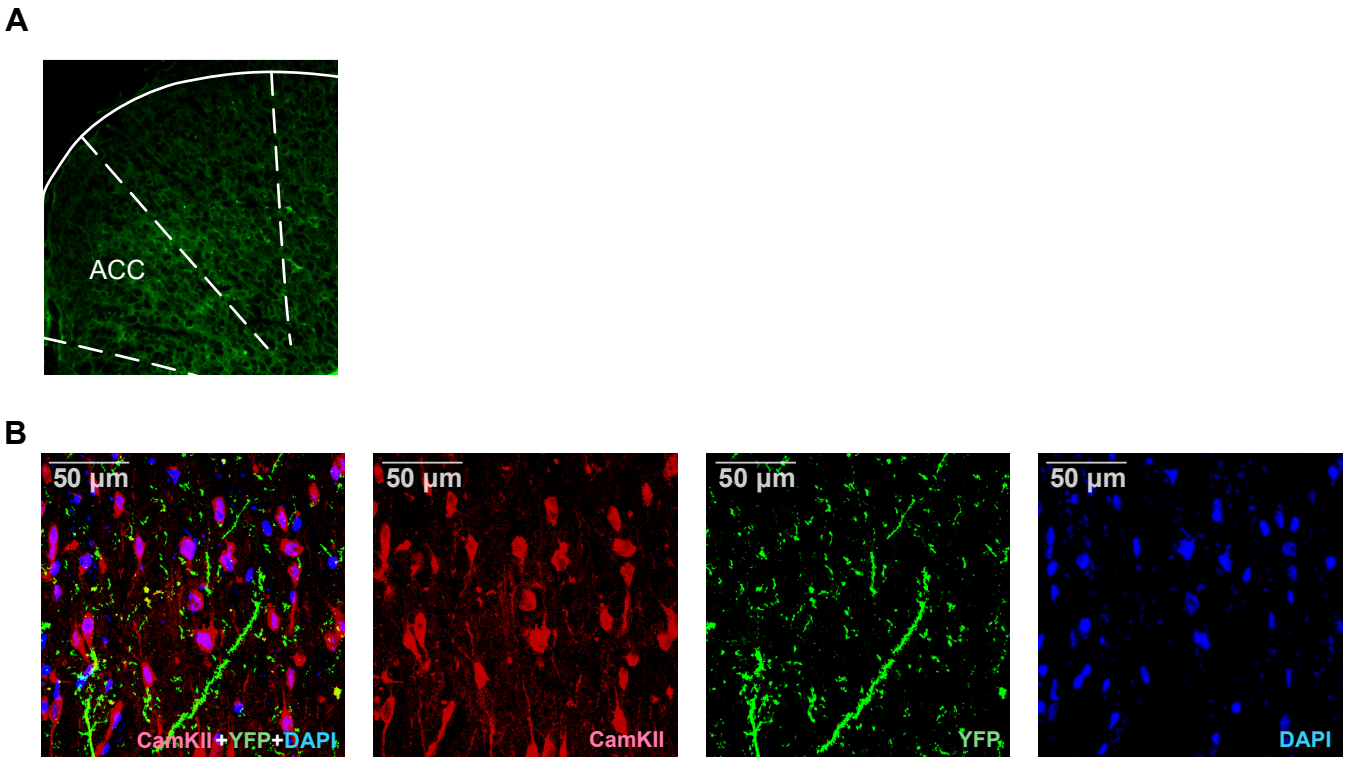

Figure S4. Expression of Halorhodopsin (NpHR) in the ACC. Related to Figure 2. **(A)** Expression of Halorhodopsin (NpHR) in the ACC. **(B)** Higher magnification view of the expression of HR in the ACC.

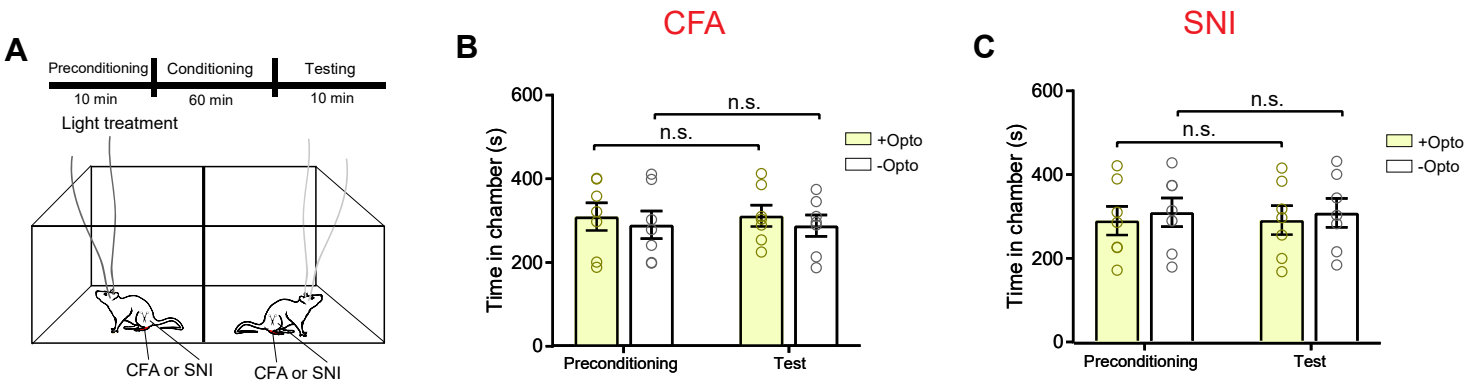

Figure S5. YFP control rats do not demonstrate avoidance of the chamber associated with light treatment in the chronic pain condition. Related to Figures 4 and 5. **(A)** Schematic of the conditioned place preference (CPA) assay in chronic pain rats. One of the chambers was paired with light treatment; the other was not. No peripheral stimulus was given. **(B)** CFA-treated rats with YFP (control) expression did not demonstrate any chamber preference. n = 7; p = 0.9502, paired Student's t test. **(C)** SNI-treated rats with YFP control did not demonstrate any chamber preference. n = 7; p = 0.9723, paired Student's t test.