

Target region	Coordinates (mm)			Cannula (mm)		
	ML	AP	DV	Dual	Internal	Volume ( $\mu$ L)
Amygdala	$\pm 2.80$	$-1.60b$	$-4.75$	—	$-0.75$	1.2-1.5
Periaqueductal gray, dorsal <sup>1</sup>	$\pm 0.60$	$-0.45\lambda$	$-2.20$	1.2	$-0.50$	0.6-0.8
Superior colliculus, medial	$\pm 0.50-0.60$	$-0.20\lambda$	$-1.50$	1.0-1.2	$-0.50$	1.0
V1	$\pm 2.50$	$+0.50\lambda$	$-0.30$	—	$-0.75$	1.0
Parabigeminal nucleus <sup>2</sup>	$\pm 2.40$	$-0.35\lambda$	$-2.75$	—	$-0.75$	0.8

<sup>1</sup> For combined optogenetic experiments in Extended Data Fig. 6, mSC VGluT2::Chr2 and optic fiber implant performed in same surgery

<sup>2</sup> Performed in mSC VGluT2::Chr2 animals with optic fiber implanted in same surgery. Infusion cannulae angled 15° lateral from zenith.

**Supplementary Table 1 | Experimental parameters for pharmacological inactivation of circuit elements.**

Cannula implant coordinates are specified from bregma (b) or lambda ( $\lambda$ ). The final target depth is the sum of the DV and internal lengths. When dual implants were used, the width between the cannulae is given.