Supplementary Table 1. Injection coordinates and virus details

Region	AP (mm)	ML (mm)	DV (mm)	Volume (nL) or iontophoresis protocol	Virus	Virus titer
Hippocampal schaffer collateral (CA3-contralateral CA1)						
CA3	-2.06	-2.4	-1.9/ -2.04	75/75	AAV2/9_CAG_pre-mGRASPi-V5-2A-iCre	5.5 x 10^{12}
		-2.63	-1.9/ -2.04/ -2.14	75/75/75		
CA1	-2	1.6	-1.15/ -1.05	50/50	AAV2/9_CAG_post-mGRASP-2A-dTomato	1.58 x 10^{13}
Multiplexed mossyfiber projection (13- DG granule cells)						
DG1	-1.58	1.03	-2.30	5µA, 7s interval, 5min	AAV2/9_CAG_pre-mGRASPi-HA-Myc-2A-iCre	1 x 10^{12}
DG2	-1.58	1.23	-2.20		AAV2/9_CAG_pre-mGRASPi-V5-HA-Myc-2A-iCre	
DG3	-1.58	1.43	-2		AAV2/9_CAG_pre-mGRASP-V5-Myc-2A-iCre	
DG4	-1.58	1.63	-2.30		AAV2/9_CAG_pre-mGRASPi-V5-HA-2A-iCre	
DG5	-1.58	1.63	-1.90		AAV2/9_CAG_pre-mGRASPi-V5-2A-iCre	
DG6	-1.58	1.84	-1.90		AAV2/9_CAG_pre-mGRASPi-V5-HA -Ollas-2A-iCre	
DG7	-1.58	2.00	-1.90		AAV2/9_CAG_pre-mGRASPi-Ollas-2A-iCre	
DG8	-2.19	1.03	-2.30		AAV2/9_CAG_pre-mGRASPi-V5-HA-Myc-Ollas-2A-iCre	
DG9	-2.19	1.23	-2.20		AAV2/9_CAG_pre-mGRASPi-V5-Myc-Ollas-2A-iCre	
DG10	-2.19	1.43	-2		AAV2/9_CAG_pre-mGRASPi-Myc-Ollas-2A-iCre	
DG11	-2.19	1.63	-1.90		AAV2/9_CAG_pre-mGRASPi-HA-Myc-Ollas-2A-iCre	
DG12	-2.19	1.82	-1.90		AAV2/9_CAG_pre-mGRASPi-HA-Ollas-2A-iCre	
DG13	-2.19	2.00	-1.90		AAV2/9_CAG_pre-mGRASPi-V5-Ollas-2A-iCre	
DG convergence (4 inputs)						
LEC	-3.4	4.3	-4.05/ -3.95	30/30	AAV2/9_CAG_pre-mGRASPi-V5-Ollas-2A-iCre	3.2 x 10^{12}
MEC	-4.72	3.37	-2.6/ -2.1	50/ 50	AAV2/9_CAG_pre-mGRASPi-V5-2A-iCre	
MC	-2	-1.6	-1.7	50	AAV2/9_CAG_pre-mGRASPi-Ollas-2A-iCre	
SuM	-2.7	0.40	-5	50	AAV2/9_CAG_pre-mGRASPi-V5-Myc-Ollas-2A-iCre	
DG	-2.0	1.6	-1.6/ -1.8	30/30	AAV2/9_CAG_Jx-rev-post-mGRASP-2A-dTomato	4.8 x 10^{12}
mPFC convergence (13 inputs)						
mPFC-ACC	2.1	-0.25	-1.5	30	AAV2/9_CAG_pre-mGRASPi-V5-HA-Myc-2A-iCre	1 x 10^{12}
mPFC-PL	2.1	-0.25	-1.8	30	AAV2/9_CAG_pre-mGRASP-V5-Myc-2A-iCre	
mPFC-IL	2.1	-0.25	-2	30	AAV2/9_CAG_pre-mGRASPi-V5-2A-iCre	

AI	1.78	2.4	-2.2	50	AAV2/9_CAG_pre-mGRASPi-HA-Ollas-2A-iCre	
VM	-1.34	0.95	-4.3	30	AAV2/9_CAG_pre-mGRASPi-V5-Ollas-2A-iCre	
BLAd	-1.06	3	-4	30	AAV2/9_CAG_pre-mGRASPi-V5-HA -Ollas-2A-iCre	
BLAv	-1.46	3.4	-4.5	30	AAV2/9_CAG_pre-mGRASPi-V5-HA-2A-iCre	
VTAm	-3.28	0.2	-4.13	30	AAV2/9_CAG_pre-mGRASPi-V5-Myc-Ollas-2A-iCre	
VTAl	-3.28	0.5	-4.25	30	AAV2/9_CAG_pre-mGRASPi-Myc-Ollas-2A-iCre	
MD	-0.58	0.5	-3.4	50	AAV2/9_CAG_pre-mGRASPi-HA-Myc-2A-iCre	
DR	-4.9	0.2	-3.4	100	AAV2/9_CAG_pre-mGRASPi-Ollas-2A-iCre	
vCA1	-3.3	3.1	-3.6/ -3.5/ -3.4	50/ 50/ 50	AAV2/9_CAG_pre-mGRASPi-HA-Myc-Ollas-2A-iCre	
BF	1	0	-4/ -3.5	50/50	AAV2/9_CAG_pre-mGRASPi-V5-HA-Myc-Ollas-2A-iCre	
mPFC	2.1	0.25	-1.8/ -1.9/ -2	30/ 30/ 30	AAV2/9_CAG_Jx-rev-post-mGRASP-2A-dTomato	4.8 x 10^{12}
					AAV2/9_CAG_FLPo + AAV2/9_CAG_fDIO_rev_post-mGRASP-2A-dTomato (1:25,000)	4 x 10^{8}, 1 x 10^{13}
Axonal trafficking efficiency test						
MOp	2	2	-0.9	200nl	AAV2/9_CAG_pre-mGRASPi-V5-2A-iCre or AAV2/9_CAG-smFP-V5	2.5 x 10^{12}
CA3	-2.06	-2.4	-1.9/ -2.04	75/75		
		-2.63	-1.9/ -2.04/ -2.14	75/75/75		
Neurotransmitter defined circuit						
mPFC	2.1	-0.25	-1.8/ -1.9/ -2	30/ 30/ 30	AAV2/9_CAG_pre-mGRASPi-V5-2A-iCre	5.5 x 10^{12}
Gpe	-0.15	1.92	-3.5	50	AAV2/9_CAG_pre-mGRASPi-Ollas-2A-iCre	2.5 x 10^{13}
SNc	-3.00	1.40	-4	50	AAV2/9_CAG_pre-mGRASPi-V5-2A-iCre	5.5 x 10^{12}
DR	-4.9	0.2	-3.4/ -3.3	100/ 100		
contra. mPFC	2.1	0.25	-1.8/ -1.9/ -2	30/ 30/ 30	AAV2/9_CAG_Jx-rev-post-mGRASP-2A-dTomato	4.8 x 10^{12}
STR	0.80	2.00	-2.5	100		
BLA	-1.16	3.4	-5.1	100		
Hippocampus related circuits						
DG convergence (4 inputs)	as described above					
DG	-2.0	1.6	-1.7	30	AAV2/9_CAG_pre-mGRASPi-Ollas-2A-iCre	2.5 x 10^{13}
CA3	-2.06	2.63	-1.9	75	AAV2/9_CAG_post-mGRASP-2A-dTomato	1.58 x 10^{13}

SuM	-2.7	0.40	-5	50	AAV2/9_CAG_pre-mGRASPi_V5_2A_iCre	5.5 x 10^{12}
CA2	-2	2.30	-1.5	80	AAV2/9_CAG_post-mGRASP-2A-dTomato	1.58 x 10^{13}
CA3	-2.06	-2.4	-1.9/ -2.04	75/75	AAV2/9_CAG_pre-mGRASPi-V5-2A-iCre	5.5 x 10^{12}
		-2.63	-1.9/ -2.04/ -2.14	75/75/75		
CA1	-2	1.6	-1.15/ -1.05	50/50	AAV2/9_CAG_Jx-rev-post-mGRASP-2A-dTomato	4.8 x 10^{12}
CA3-1	-1.58	1.80	-2.04	5µA, 7s interval, 5min	AAV2/9_CAG_pre-mGRASPi-V5-2A-iCre	1 x 10^{12}
CA3-2	-1.58	2.00	-2.04		AAV2/9_CAG_pre-mGRASPi-V5-Ollas-2A-iCre	
CA3-3	-1.58	2.20	-2.04		AAV2/9_CAG_pre-mGRASPi-V5-Myc-Ollas-2A-iCre	
CA3-4	-1.58	2.40	-1.90		AAV2/9_CAG_pre-mGRASP-V5-Myc-2A-iCre	
CA3-5	-2.06	2	-2		AAV2/9_CAG_pre-mGRASPi-V5-HA-Myc-2A-iCre	
CA3-6	-2.06	2.2	-2		AAV2/9_CAG_pre-mGRASPi-HA-Myc-2A-iCre	
CA3-7	-2.06	2.4	-2		AAV2/9_CAG_pre-mGRASPi-Ollas-2A-iCre	
CA3-8	-2.06	2.64	-1.9		AAV2/9_CAG_pre-mGRASPi-Myc-Ollas-2A-iCre	
CA3-9	-2.46	2.2	-1.9		AAV2/9_CAG_pre-mGRASPi-V5-HA-Myc-Ollas-2A-iCre	
CA3-10	-2.46	2.3	-2		AAV2/9_CAG_pre-mGRASPi-V5-HA -Ollas-2A-iCre	
CA3-11	-2.46	2.5	-2		AAV2/9_CAG_pre-mGRASPi-V5-HA-2A-iCre	
CA3-12	-2.46	2.7	-2.15		AAV2/9_CAG_pre-mGRASPi-HA-Ollas-2A-iCre	
CA3-13	-2.46	2.9	-2.2		AAV2/9_CAG_pre-mGRASPi-V5-HA -Ollas-2A-iCre	
CA1	-2	1.6	-1.1	30	AAV2/9_CAG_Jx-rev-post-mGRASP-2A-dTomato	4.8 x 10^{12}
Cortex related circuits						
mPFC convergence (13 inputs)	as described above					
DR	-4.9	0.2	-3.4/ -3.3	100/ 100	AAV2/9_CAG_pre-mGRASPi-V5-2A-iCre	5.5 x 10^{12}
BLA	-1.16	3.4	-5.1	100	AAV2/9_CAG_post-mGRASP-2A-dTomato	1.58 x 10^{13}
Basal ganglia related circuits						
MOp	2	2	-0.9	200	AAV2/9_CAG_pre-mGRASPi-Ollas-2A-iCre	2.5 x 10^{13}
Gpe	-0.15	1.92	-3.5	50	AAV2/9_CAG_pre-mGRASPi-V5-2A-iCre	5.5 x 10^{12}
SNc	-3.00	1.40	-4	50		
VTA	-3.00	0.80	-4.1	50		
Gpe	-0.15	1.92	-3.5	50		
STN	-1.65	1.62	-4.55	50	AAV2/9_CAG_post-mGRASP-2A-dTomato	

STR	0.80	2.00	-2.5	100		1.58 x 10^{13}
NAc	1.5	1.00	-4	50		

* Three different strategies were used for postsynaptic labeling depending on experimental requirements. Conventional post-mGRASP was used for robust postsynaptic detection in pairwise labeling experiments. For convergent synapse labeling, sparser postsynaptic expression was achieved using Cre-dependent post-mGRASP combined with anterograde trans-synaptic Cre delivery via 2A-iCre-tagged pre-mGRASPi, enabling cell-level identification of structurally simple neurons such as granule cells. For single-cell-level convergent synapse analysis of morphologically complex neurons such as pyramidal neurons, further reduced postsynaptic labeling density was achieved by co-injection of Flpo with Flp-dependent post-mGRASP-2A-dTomato.

Supplementary Table 2. Antibodies and reagents

Antibodies	Dilution rate	Vendor	cat#
Mouse anti-V5	1:200	Bio-rad	MCA1360G
Rat anti-Ollas	1:200	Novus	NBP1-06713
Chicken anti-HA	1:200	Aveslab	AB_2313511
Rabbit anti-cMyc	1:200	Abcam	152146
Rabbit anti-DsRed	1:1000	Takara	632496
Guinea pig anti-vGluT1	1:1000	Sigma	AB5905
Mouse anti-vGAT	1:500	Synaptic Systems	131 011
Rabbit anti-DAT antibody	1:1000	Synaptic Systems	284 003
Guinea pig anti-SERT antibody	1:1000	Synaptic Systems	640 004
Mouse anti-Bassoon	1:500	Enzo	ADI-VAM-PS003-D
Rabbit anti-Homer1	1:500	Synaptic Systems	160 003
Goat anti-Mouse Alexa Fluor™ 405	1:200(for epitopes) 1:500 (for vGAT)	Invitrogen	A31553
Goat anti-Mouse Alexa Fluor™ 488	1:200	Invitrogen	A11001
Goat anti-Mouse Alexa Fluor™ 514	1:200	Invitrogen	A31555
Goat anti-Mouse Alexa Fluor™ 555	1:200 (for epitopes) 1:500 (for DsRed)	Invitrogen	A21422
Goat anti-Mouse Alexa Fluor™ 633	1:200	Invitrogen	A21071
Donkey anti-mouse CF® 633	1:200	Biotium	20124
Goat anti-Rabbit Alexa Fluor™ 405	1:200	Invitrogen	A31556
Goat anti-Rabbit Alexa Fluor™ 488	1:200	Invitrogen	A11008
Goat anti-Rabbit Alexa Fluor™ 546	1:200	Invitrogen	A11035
Goat anti-Rabbit Alexa Fluor™ 555	1:200	Invitrogen	A21428
Goat anti-Rabbit Alexa Fluor™ 633	1:200(for epitope) 1:500 (for DAT)	Invitrogen	A21070
Goat anti-Rat Alexa Fluor™ 405	1:200	abcam	ab175673
Goat anti-Rat Alexa Fluor™ 488	1:200	Invitrogen	A11006
Goat anti-Rat Alexa Fluor™ 555	1:200	Invitrogen	A21434
Goat anti-Rat Alexa Fluor™ 633	1:200	Invitrogen	A21094
Goat anti-Chicken Alexa Fluor™ 405	1:200	abcam	ab175674
Goat anti-Chicken Alexa Fluor™ 488	1:200	Invitrogen	A11039
Goat anti-Chicken Alexa Fluor™ 555	1:200	Invitrogen	A21437
Goat anti-Chicken Alexa Fluor™ 633	1:200	Invitrogen	A21103
Goat anti-Guineapig Alexa Fluor™ 633	1:500 (for vGLUT1 and SERT)	Invitrogen	A21105
DAPI	1:1000	Sigma-Aldrich	D9542

Reagent name	Vendor	cat#
Normal goat serum	Jackson lab	005-000-121

Bovine Serum Albumin	RMBIO	BSA-BSH-1XG
AffiniPure Fab Fragment Donkey Anti-Mouse IgG (H+L)	Jackson lab	715-007-003
Triton X-100	Sigma-Aldrich	T8787
paraformaldehyde	Sigma-Aldrich	158127
20X TBS	Tech&Innovation	BTB-9120
PBS (10X), pH 7.4	Gibco	70011-069
sodium phosphate monobasic	Sigma-Aldrich	S3139
sodium phosphate dibasic	Sigma-Aldrich	S3264
VECTASHIELD® HardSet™ Anti-fade Mounting Medium	Vector Laboratories	H-1400
Reagents for Expansion microscopy		
Sodium acrylate (AA)	Sigma-Aldrich	408220-25G
Acrylamide (AAm)	Sigma-Aldrich	A9099
N, N'-methylenebisacrylamide (BIS)	Sigma-Aldrich	M7279
Sodium chloride	Sigma-Aldrich	71376
Ammonium persulfate (APS)	Sigma-Aldrich	A3678
N,N,N',N'-tetramethylethylenediamide (TEMED)	Sigma-Aldrich	T7024
4-hydroxy-2,2,6,6-tetramethylpiperidine-1-oxyl (H-TEMPO)	Sigma-Aldrich	176141
SE (6-((acryloyl)amino)hexanoic acid) (Acryloyl-X, AcX)	Thermo Fisher	A20770
Dimethyl sulfoxide (DMSO)	Sigma-Aldrich	276855
Tris hydrochloride solution	Sigma-Aldrich	T3038
Triton X-100	Sigma-Aldrich	T9284
Sodium azide	Sigma-Aldrich	S2002
Ethylenediaminetetraacetic acid (EDTA)	Sigma-Aldrich	EDS
Phosphate-buffered saline (PBS)	Invitrogen	AM9625
Proteinase K	New England Biolabs	P8107S
Poly-L-lysine solution	Sigma	25988-63-0
No.1 coverglasses	Brain Research Lab	4860-1