A. Magnetic / MRI-Related (Non-Invasive)

1. Functional Connectivity MRI (fcMRI)

Not the same as BOLD; uses correlation structure across voxels. (Probably implicit, but useful to explicitly list.)

2. Resting-State fMRI (rs-fMRI)

Now its own category of technique with unique analytical methodology.

3. Magnetic Particle Imaging (MPI)

A new imaging modality using superparamagnetic nanoparticles for high temporal resolution neurovascular imaging.

4. Susceptibility-Weighted Imaging (SWI)

Useful for venous blood mapping and hemodynamic activity in vivo.

5. Quantitative Susceptibility Mapping (QSM)

Reconstructs iron content and hemodynamic changes related to function.

6. Functional MRS (fMRS)

Measures neurotransmitter fluctuations (Glu, GABA) in vivo in real time.

7. Magnetic Resonance Elastography (MRE)

Measures brain tissue stiffness changes associated with neural activity and neurovascular coupling.

8. Chemical Exchange Saturation Transfer (CEST) fMRI

Detects metabolites and neurotransmitters via exchangeable protons, providing molecular functional imaging.

9. Microvascular Volumetric Pulsatility Mapping

Combines VASO and ASL at ultra-high field to map pulsatile flow in cerebral microvessels linked to activity.

10.Neurite Orientation Dispersion and Density Imaging (NODDI)

Multicompartment diffusion MRI model to estimate neuronal microstructure and

density in vivo.

11.Neuromelanin-Sensitive MRI

Detects neuromelanin in substantia nigra and locus coeruleus as a proxy for catecholaminergic neuron function.

12.Free-Water Diffusion Imaging

Removes extracellular free water contributions from diffusion signals to assess

13.Optically Pumped Magnetometer MEG (OPM-MEG)

Room-temperature, scalp-proximate optically pumped magnetometer arrays for high-sensitivity, flexible MEG recordings in naturalistic and mobile settings.

14.Hyperpolarized 13C Metabolic MRI

Real-time metabolic flux imaging using hyperpolarized 13C tracers to measure rapid changes in brain energy metabolism linked to neural activity.

15.Magnetic Resonance Fingerprinting (MRF)

Rapid, quantitative multiparametric tissue mapping for assessing dynamic physiological changes during brain activity.

16.VASO (Cerebral Blood Volume fMRI)

Non-BOLD fMRI technique sensitive to cerebral blood volume changes for layer-specific functional imaging.

17.Q-ball Imaging

High angular resolution diffusion imaging (HARDI) technique for resolving complex fiber crossings in white matter.

18.Continuous Arterial Spin Labeling (CASL)

Non-invasive perfusion MRI method using continuous RF inversion of arterial water for quantitative CBF mapping.

19.Pulsed Arterial Spin Labeling (PASL)

ASL variant using short RF pulses to label arterial blood, offering different trade-offs

for perfusion imaging.

[NEW]20.31P Magnetic Resonance Spectroscopy

Measures high-energy phosphates like ATP and phosphocreatine to assess metabolic changes during neural activity.

[NEW]21.23Na Sodium MRI

Quantifies sodium ion concentrations and fluxes in brain tissue as a marker of neuronal excitability and activity.

[NEW]22.Intravoxel Incoherent Motion (IVIM) MRI

Separates microvascular perfusion effects from tissue diffusion to map activity-related blood flow changes.

B. PET / Radiotracer Advances

20.Fiber-Coupled PET Detectors (minimally invasive)

Enables localized in vivo PET from freely moving animals.

21.Neuroimmune PET Ligands (TSPO, CSF1R etc.)

For studying microglial/astrocyte activation dynamically. (Not purely activity, but increasingly part of functional neuroimaging.)

22.Total-Body PET Imaging

Enables whole-brain dynamic imaging with unprecedented temporal resolution and sensitivity.

23.Positronium Lifetime Imaging

Emerging PET technique providing information about tissue microenvironment during neural activity.

24.Synaptic Vesicle Glycoprotein 2A (SV2A) PET Imaging

Uses tracers like [^{11}C]UCB-J to quantify synaptic density in vivo.

25.Mitochondrial Complex I PET Imaging

Employs [^{12}F]BCPP-EF to assess mitochondrial function and energy metabolism related to neural activity.

26.CSF1R PET for Neuroinflammation

Tracers like [^{11}C]CPPC to image microglial activation during brain processes.

27.Positron Emission Metabolic Tracing with Short-Lived Isotopes (rapid kinetic PET)

High-temporal-resolution PET protocols using short-lived radiotracers and fast kinetic modeling to track sub-minute metabolic changes associated with neural events.

28.μ-opioid Receptor PET ([^{11}C]carfentanil)

In vivo imaging of endogenous opioid release during various behavioral states.

29.Dopamine D2/D3 Receptor Occupancy PET

Measures dynamic changes in dopamine transmission using radioligands like [^{11}C]raclopride.

30.Cerebral Metabolic Rate of Oxygen (CMRO2) PET

Quantitative imaging of oxygen metabolism coupled to neural activity using ^{15}O-labeled tracers.

31.Astrocyte-Specific PET Tracers (^{11}C-deuterium-L-deprenyl)

Targets monoamine oxidase B in astrocytes for glial activity mapping.

[NEW]32.GABA-A Receptor PET ([^{11}C]flumazenil)

Images inhibitory neurotransmission by binding to GABA-A receptors, reflecting dynamic changes in neural inhibition.

[NEW]33.Serotonin Transporter PET ([^{11}C]DASB)

Quantifies serotonin transporter density and availability as a proxy for serotonergic neural activity.

[NEW]34.AMPA Receptor PET ([^{11}C]K-2)

Detects glutamatergic synaptic activity through AMPA receptor binding in vivo.

C. Electrophysiology & Implant Technologies

32.Neuropixels Probes (latest gen)

Not just "multielectrode"; Neuropixels constitute a distinct class due to ultra-high

channel count (1,000+), used in vivo widely.

33.Silicon Probe Laminar Recordings

For cortical column laminar activity (V1, CA1).

34.High-Density “ECoG Grids” (Neuropixels–ECoG hybrids)

New grids with thousands of micro-electrodes recordings across cortex.

35.EMG-Assisted Brain–Body Coupled Recording

Used in behaving animals to integrate motor output with neural activity.

36.Flexible Bioelectronic Neural Interfaces

Conformable electrode arrays that minimize tissue damage and enable stable long-term recordings.

37.Transparent Graphene Microelectrode Arrays

Allow simultaneous electrical recording and optical imaging/optogenetics.

38.Ultrasonic Neural Dust Motes

Wireless, millimeter-scale implants for chronic neural recording.

39.Optetrode Recordings

Hybrid probes combining electrical electrodes with optical fibers for simultaneous recording and stimulation.

40.CMOS-Integrated Neural Probes

On-chip amplified high-density probes for low-noise in vivo recordings.

41.Sharp Electrode Intracellular Recordings

Historical method using fine glass micropipettes for high-impedance intracellular potential measurements.

42.Wireless High-Density Neural Probes (wireless Neuropixels variants)

Fully wireless, implantable high-channel-count probe systems enabling untethered large-scale neural recordings in freely moving animals.

43.Autonomous Robotic In Vivo Patch-Clamp (AutoPatch / Robopatcher)

Automated robotics-enabled intracellular patch-clamp in awake or anesthetized

44.Graphene Field-Effect Transistor Neurochemical Sensors (gFETs)

Implantable gFET biosensors for direct, high-sensitivity, real-time detection of neurotransmitters and neuromodulators in vivo with electrical readout.

45.Tetrode Recordings

Historical method using four-wire bundles for extracellular recording with improved single-unit isolation.

46.Juxtacellular Recording and Labeling

Technique for extracellular recording followed by intracellular labeling of recorded neurons.

47.Carbon Fiber Microelectrodes

Miniaturized electrodes for electrochemical detection of neurotransmitters with fast-scan cyclic voltammetry.

48.Floating Microelectrode Arrays

Untethered microelectrodes that move with brain tissue for stable chronic recordings.

[NEW]49.Utah Array Recordings

High-density silicon-based electrode arrays for chronic cortical extracellular recordings in primates and humans.

[NEW]50.Michigan Probe Recordings

Flexible silicon shank probes for multi-site extracellular neural activity mapping in deep brain structures.

[NEW]51.Stereotrode Recordings

Two-wire electrode bundles for improved spatial resolution in extracellular unit isolation, historical precursor to tetrodes.

D. Optical / Imaging-Based Techniques

49.Light-Sheet Fluorescence Microscopy (LSFM) In Vivo

Now used in small transparent animals (zebrafish, larval models). Technically in vivo and provides whole-brain fast activity imaging.

50.Swept Confocally-Aligned Planar Excitation (SCAPE) Microscopy

High-speed volumetric neural imaging in freely moving animals.

51.Structured-Light 3D Imaging of Cortical Hemodynamics

Used to map neural activity via intrinsic signals & hemodynamic changes.

52.Mesoscopic Calcium Imaging (NOT miniscope)

Widefield mesoscopic Ca^{2+} imaging in vivo (distinct from fiber photometry).

53.Adaptive Optics for In Vivo Neural Imaging

Corrects deep-tissue optical distortion; rapidly emerging technique.

54.Oblique Plane Microscopy (OPM)

High-resolution, high-speed volumetric imaging for large-scale neural activity monitoring.

55.Multifocal Two-Photon Microscopy

Simultaneous imaging of multiple planes for 3D functional imaging.

56.Line-Scanning Temporal Focusing Microscopy

High-speed volumetric imaging with reduced out-of-focus excitation.

57.Light Field Microscopy

Captures volumetric data in a single exposure for fast 3D neural activity imaging.

58.Kilohertz Two-Photon Fluorescence Microscopy

Ultrafast scanning rates for capturing rapid neuronal dynamics in vivo.

59.NIRE Cranial Window Method

Uses nanosheet-resin windows for large-scale, chronic high-resolution imaging in

60.Volumetric Fluorescence Lifetime Imaging Microscopy (FLIM) for In Vivo Metabolic Readouts

High-speed volumetric FLIM approaches enabling in vivo mapping of metabolic state (NADH, FAD) and oxygen-consumption dynamics across populations of cells.

61.TIRF Microscopy In Vivo

Total internal reflection fluorescence microscopy adapted for superficial cortical

imaging in live animals.

62.Random Access Microscopy

Acousto-optic deflector-based rapid laser positioning for imaging distributed neurons.

63.Reflectance Imaging

Measures intrinsic optical signals from cortical surface without exogenous labels.

64.Second Harmonic Generation (SHG) Microscopy

Label-free imaging of membrane potential and structural proteins in live tissue.

[NEW]65.Lattice Light-Sheet Microscopy

Gentle, high-speed volumetric imaging for long-term monitoring of neural dynamics in vivo with minimal phototoxicity.

[NEW]66.Expansion-Assisted Selective Plane Illumination Microscopy (Ex-SPIM)

Combines tissue expansion with light-sheet imaging for super-resolution whole-brain activity mapping in fixed but activity-tagged samples.

[NEW]67.Digital Holographic Microscopy

Phase-sensitive optical technique for label-free detection of neural activity-induced refractive index changes.

E. Optical Indicators / Novel Sensors

65.Genetically Encoded Dopamine Indicators (GRAB-DA, dLight1)

Used widely in in vivo with fiber photometry and two-photon microscopy.

66.Genetically Encoded Glutamate Indicators (IGluSnFR)

High temporal resolution; used to study excitatory transmission.

67.Genetically Encoded Acetylcholine Indicators (GACh)

Maps cholinergic dynamics in vivo.

68.Genetically Encoded cAMP/PKA/Second-Messenger Sensors

(e.g., Pink Flamindo, G-Flamp) reflect intracellular signaling during neural activity.

69.Genetically Encoded Serotonin Sensors (GRAB5-HT)

Monitor serotonergic transmission in behaving animals.

70.Genetically Encoded Norepinephrine Sensors (GRAB-NE)

Track noradrenergic activity during behavior and cognitive tasks.

71.Fluorescent False Neurotransmitters (FFNs)

Visualize neurotransmitter release and recycling in vivo.

72.Genetically Encoded Chloride Indicators (Cl-Sensor)

Monitor chloride dynamics relevant for inhibitory transmission.

73.Genetically Encoded ATP Indicators (IATPSnFR)

Track cellular energy status and metabolic activity in neurons.

74.Genetically Encoded Lactate Sensors

Monitor lactate shuttling and metabolic coupling between neurons and glia.

75.Genetically Encoded Redox Indicators (roGFP)

Detect oxidative stress and redox-state changes during neural activity.

76.Genetically Encoded Nitric Oxide Sensors (geNOps and related probes)

Fluorescent genetically encoded reporters for nitric oxide dynamics to monitor NO signaling in vivo during neural activity.

77.Genetically Encoded Potassium Indicators (GEPIs)

Fluorescent sensors for monitoring potassium dynamics in extracellular space.

78.pHluorins (pH-sensitive GFPs)

pH-sensitive fluorescent proteins for tracking synaptic vesicle recycling.

79.SypHy

Synaptophysin-pHluorin fusion protein for imaging synaptic vesicle exocytosis.

80.GCamp Variants (GCamp6f, GCamp7f, GCamp8)

Successive generations of genetically encoded calcium indicators with improved kinetics and sensitivity.

[NEW]81.Genetically Encoded GABA Indicators (iGABASnFR)

Fluorescent sensors for real-time monitoring of GABA release and dynamics in vivo.

[NEW]82.Genetically Encoded Histamine Sensors (GRAB-HA)

Track histaminergic signaling and neural modulation during arousal and behavior.

[NEW]83.Genetically Encoded Adenosine Sensors (GRAB-Ado)

Monitor adenosine levels as a marker of neural energy homeostasis and sleep regulation.

F. Photoacoustic & Hybrid Techniques

81.Voltage-Sensitive Photoacoustic Imaging

A new area combining voltage dyes with photoacoustics.

82.Nanodiamond Magnetometry in Vivo

Nitrogen-vacancy (NV) diamond sensors used for in vivo magnetic-field measurements of neuronal activity.

83.Multispectral Optoacoustic Tomography (MSOT)

Provides spectral unmixing of multiple chromophores for functional brain imaging.

84.Photoacoustic Computed Tomography (PACT)

Deep-tissue functional imaging with optical contrast and ultrasound resolution.

85.Functional Photoacoustic Microscopy (fPAM)

High-resolution imaging of hemodynamic responses to neural activity.

86.Photoacoustic Lifetime Imaging Microscopy (PALM)

Measures oxygen consumption and metabolic rates in brain tissue.

87.Microbubble-Enhanced Functional Ultrasound (Contrast-Enhanced fUS)

Use of intravascular microbubble contrast agents to boost sensitivity and spatial resolution of functional ultrasound hemodynamic measurements linked to neural activity.

88.Photoacoustic Neurotransmitter Sensing

Molecular imaging of neurotransmitter release using photoacoustic contrast agents.

89.Granger Causality Photoacoustic Imaging

Combines photoacoustic imaging with Granger causality analysis for functional

connectivity mapping.

[NEW]90.Photoacoustic Elastography

Measures tissue stiffness changes due to neural activity via photoacoustic detection of shear waves.

[NEW]91.Hybrid Photoacoustic-Electrical Tomography

Integrates photoacoustic imaging with electrical source localization for multimodal mapping of neural currents.

[NEW]92.Photoacoustic Voltage-Sensitive Dye Imaging (PA-VSDI)

Uses photoacoustic signals from voltage dyes to map membrane potential changes non-invasively.

G. Neural Activity Through Blood Flow &

Oxygenation

90.Thermal Infrared Functional Imaging (ITIRI)

Detects activity-induced microvascular heating.

91.Speckle-Modulated Optical Coherence Tomography (OCT)

OCT-based neuronal activity mapping (beyond standard laser speckle imaging).

92.Doppler Optical Coherence Tomography (D-OCT)

For real-time blood-flow-linked neural-activity measurements.

93.Visible Light Optical Coherence Tomography (vis-OCT)

Provides oximetry and flow measurements with higher resolution than NIR-OCT.

94.Hyperspectral Imaging of Intrinsic Signals

Spectral unmixing of hemoglobin, cytochrome oxidase, and other chromophores.

95.Time-Domain Near-Infrared Spectroscopy (TD-NIRS)

Offers depth-resolved hemodynamic monitoring with improved accuracy.

96.Functional Diffuse Optical Tomography (fDOT)

3D reconstruction of brain activation through light scattering and absorption.

97.In Vivo Electron Paramagnetic Resonance (EPR) Oximetry

Direct in vivo EPR/Electron Spin Resonance oximetry for quantitative tissue pO22

mapping and dynamic oxygen-consumption measurements coupled to neural activity.

98.Laser Doppler Flowmetry

Continuous measurement of cerebral blood flow using laser Doppler shifts.

99.Oxygen-15 Water PET ([^{15}O]H_2O PET)

Gold standard for quantitative cerebral blood flow measurement using positron

emission tomography.

100.

Hydrogen Clearance CBF Measurement

Historical method using hydrogen electrodes to measure local cerebral blood flow.

101.

Autoradiographic CBF Measurement ([^{14}C]iodoantipyrine)

Ex vivo quantitative mapping of cerebral blood flow using radiotracers.

[NEW]102.Near-Infrared Fluorescence Imaging of Hemodynamics

Uses exogenous fluorescent dyes to track blood flow and oxygenation changes in real time.

[NEW]103.Polarized Light Imaging (PLI)

Measures birefringence changes in myelin and axons as indirect markers of neural activation.

[NEW]104.Functional Near-Infrared Optical Tomography (fNIROT)

Tomographic reconstruction of hemodynamic responses using near-infrared light for 3D activity mapping.

H. Behavioral + Neural Integrated

Techniques

102.

Neuromorphic Cameras Linked With Neural Imaging

High-speed event-driven sensors capturing animal behavior synchronized with brain

activity (not a brain technique per se, but part of modern in vivo pipelines).

103.

Deep Label-Free Microscopy (DLFM)

Uses deep learning to extract neural activity from label-free imaging of scattering changes.

104.

Acoustic Recording of Neural-Related Behavior

Ultrasonic vocalization recording synchronized with neural activity measurements.

105.

Eye-Tracking Integrated Neural Recording

Combines pupil tracking with brain activity to study visual attention and processing.

106.

Pose Estimation with Neural-Activity Synchronization

Uses AI-based body tracking (e.g., DeepLabCut) linked to real-time neural signals.

107.

Real-Time Closed-Loop Neural Decoding & Stimulation Systems

Integrated pipelines that decode ongoing neural activity in real time and deliver contingent stimulation (optogenetic, electrical, ultrasonic) to probe causality during behavior.

108.

Whisker Tracking with Neural Recording

High-speed videography of whisker movements synchronized with neural data.

109.

Operant Conditioning Chambers with Neural Interfaces

Behavioral boxes integrated with neural recording/stimulation for learning studies.

110.

Sleep-Wake Monitoring with EEG/EMG

Polysomnography combined with neural activity measurements across sleep stages.

[NEW]111.Gaze-Contingent Neural Recording

Integrates real-time eye-tracking with adaptive neural stimulation to study visuomotor integration.

[NEW]112.Multi-Animal Social Behavior Tracking with Neural Synchronization

AI-based tracking of social interactions in groups, synced with individual neural activity recordings.

[NEW]113.Virtual Reality-Integrated Neural Imaging

Combines VR environments with in vivo brain recordings to study navigation and spatial cognition.

I. Interference / Modulation Techniques

111.

Focused Ultrasound Blood–Brain Barrier Opening (FUS-BBBO)

Used in vivo to modulate circuits or allow entry of neuromodulators.

112.

Temporal Interference Stimulation (TI Stimulation)

Non-invasive deep-brain electromagnetic stimulation using intersecting

high-frequency currents.

113.

Transcranial Random Noise Stimulation (RNS)

Another electrical non-invasive modulation technique widely used.

114.

Photothermal Neuromodulation (non-genetic)

Uses nanoparticles or infrared light to activate neurons.

115.

Infrared Neural Stimulation (INS)

Pulsed IR light drives neural activity—distinct from optogenetics.

116.

Scanning Ultrasound Neuromodulation (SUN)

Focused ultrasound for precise spatiotemporal neural control.

117.

Optoacoustic Neuromodulation

Uses laser-generated ultrasound for deep-brain stimulation.

118.

Ion-CeMST (Ion Current–Controlled Microfluidic Stimulation)

Microfluidic-based chemical stimulation with spatiotemporal precision.

119.

Transcranial Photobiomodulation (tPBM)

Low-level near-infrared light to modulate brain metabolism and activity.

120.

Vagus Nerve Stimulation (VNS)

Electrical stimulation of vagus nerve to indirectly influence brain circuits.

121.

Deep Transcranial Magnetic Stimulation (dTMS)

Uses H-coil for deeper penetration than standard TMS.

122.

Closed-Loop Responsive Neurostimulation (RNS) for Research

Implantable or external systems that detect electrophysiological biomarkers and

123.

Chemical-Genetic Actuation (PSAM/PSEM)

Pharmacologically selective actuator modules for remote neural control.

124.

Cortical Cooling

Focal cooling for reversible neural inactivation to study functional localization.

125.

Lidocaine Inactivation

Local pharmacological blockade of neural activity for connectivity mapping.

126.

Muscimol Inactivation

GABAA receptor agonist for reversible cortical silencing in behavioral studies.

[NEW]127.Transcranial Focused Ultrasound Stimulation (tFUS)

Non-invasive ultrasound waves for targeted modulation of cortical excitability.

[NEW]128.Galvanic Vestibular Stimulation (GVS)

Electrical stimulation of vestibular nerves to influence balance-related brain activity.

[NEW]129.Trigeminal Nerve Stimulation (TNS)

External electrical stimulation of trigeminal nerve branches to modulate brainstem and cortical activity.

J. Emerging & Frontier Approaches

127.

Bioluminescent Voltage Imaging (e.g., LOTUS-V)

No excitation light; extremely low phototoxicity for in vivo activity imaging.

128.

Upconversion Nanoparticle-Based Neural Imaging

Allows deeper brain optical readout using NIR-to-visible conversion.

129.

Magnetothermal Neural Recording & Readout

Not just thermogenetic stimulation—actual readout emerging via nanomaterials.

130.

Molecular fMRI (m-fMRI)

Probes coupling specific cellular signaling events to MRI contrast.

131.

Functional Ultrasound Localization Microscopy (ULM-fUS)

Super-resolution vascular mapping during activity.

132.

"Neuromodulation via Magnetic Nanodiscs"

A newer mechanogenetic-like frontier method.

133.

Quantum Diamond Microscopy

Uses NV centers for magnetic imaging of neural activity at nanoscale.

134.

X-ray-Induced Acoustic Computed Tomography (XACT)

Combines X-ray absorption with ultrasound detection for functional imaging.

135.

Magnetic Resonance Spectroscopic Imaging (MRSI)

Spatially resolved spectroscopy for mapping neurotransmitter distributions.

136.

Neutron Stimulated Emission Computed Tomography (NSECT)

Emerging nuclear technique for elemental mapping of neural tissue.

137.

Holographic Optogenetic Stimulation

Uses holography for multi-site optical neural control and readout.

138.

Nanowire Intracellular Recordings

Nanoscale wires for minimally invasive intracellular potential measurements.

139.

AI-Augmented Functional Connectivity Analysis

Machine-learning-enhanced mapping of dynamic brain networks from imaging data.

140.

Cryogenic Electron Microscopy for In Vivo Snapshots

Adapted for rapid freezing and imaging of activity states (though borderline in vivo).

141.

In Vivo Quantum Diamond Scalp Magnetometry (NV-MEG)

Scalp-mounted or near-scalp arrays of diamond NV sensors for high-spatial-resolution magnetic field mapping of population neural currents, bridging nanoscale NV sensing advances with whole-head MEG-style recordings.

142.

CLARITY with In Vivo Applications

Tissue transformation for post-mortem structural mapping of functionally identified circuits.

143.

Expansion Microscopy In Vivo

Physical tissue expansion for super-resolution imaging of activated circuits.

144.

Magnetic Resonance Phased Array Microscopy

Ultra-high field MRI with phased array coils for microscopic resolution in live animals.

145.

X-ray Optogenetics

Combining X-ray stimulation with optogenetic actuators for deep brain modulation.

146.

Neutron Scattering Tomography

Emerging technique for mapping light element distributions in neural tissue.

147.

Diamond Quantum Sensing of Neural Magnetic Fields

NV center magnetometry for direct detection of action potentials and synaptic

currents.

[NEW]148.Bioorthogonal Chemistry-Based Neural Activity Reporters

Uses click chemistry to label and image active neurons in vivo without genetic modification.

[NEW]149.Nanopore-Based Ion Channel Activity Sensing

Implantable nanopore devices for real-time monitoring of ion fluxes in single neurons.

[NEW]150.Terahertz Imaging for Neural Activity

Non-ionizing terahertz waves to detect water content changes associated with neural firing.