



Investigating Neural Circuit Mechanisms Underlying Perceptual and Cognitive Behaviors

KAIST

KAIST Department of Biological Sciences

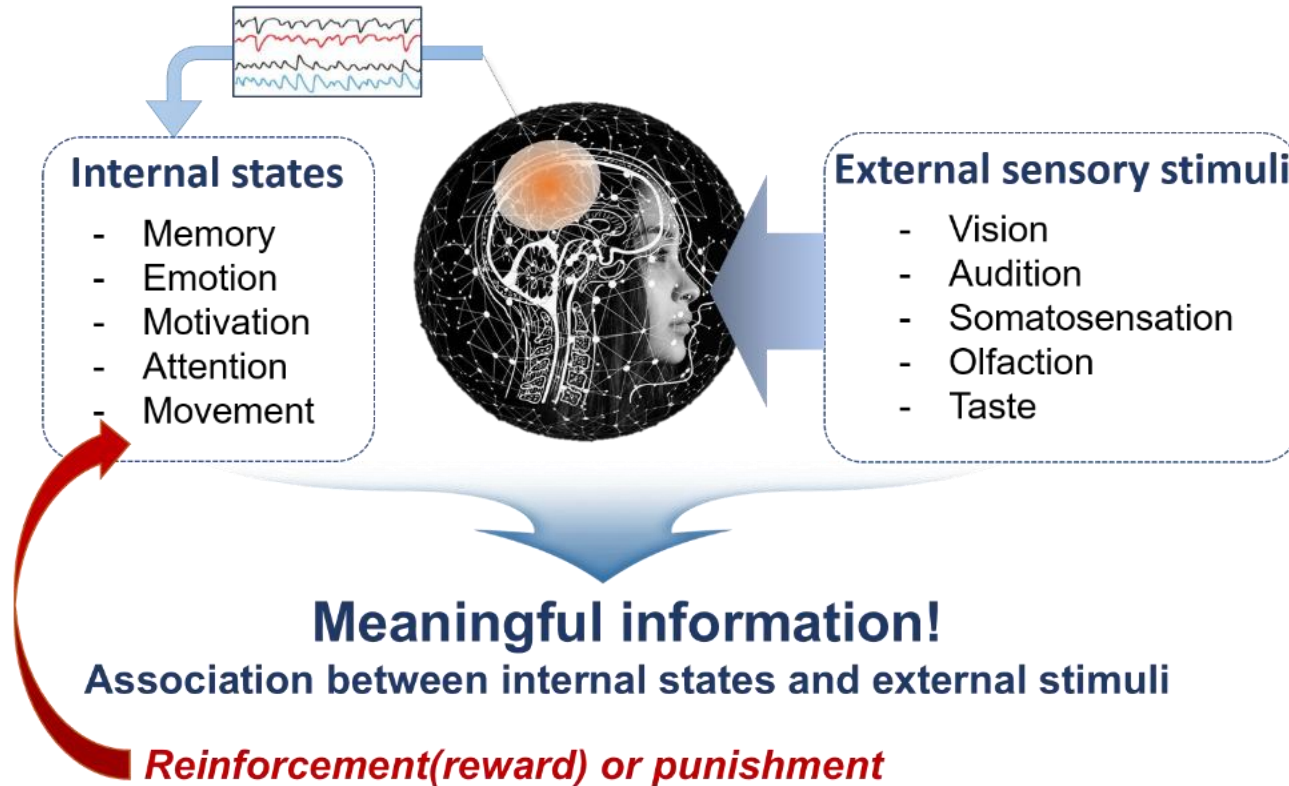
iBS

기초과학연구원
Institute for Basic Science

IBS Center for Synaptic Brain Dysfunctions

Neural Systems for Sensory Integration Laboratory
Seung-Hee Lee, Ph.D.

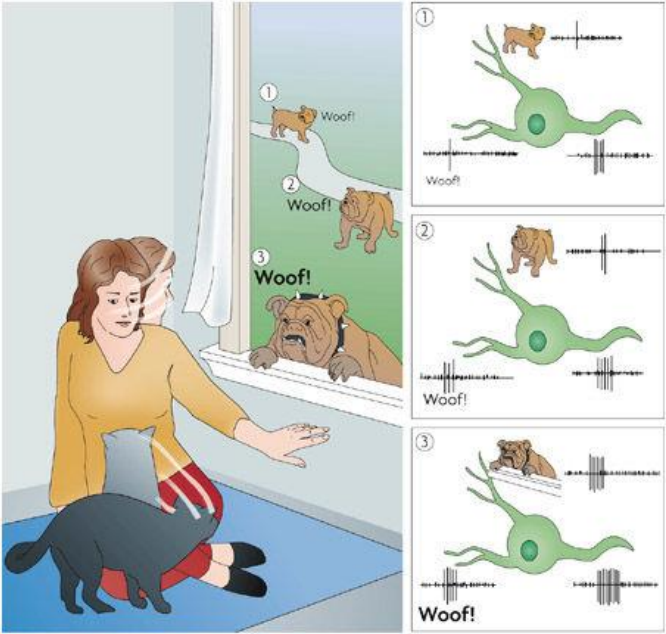
How does the brain represent external sensory information?



Question #1. Sensory processing and integration

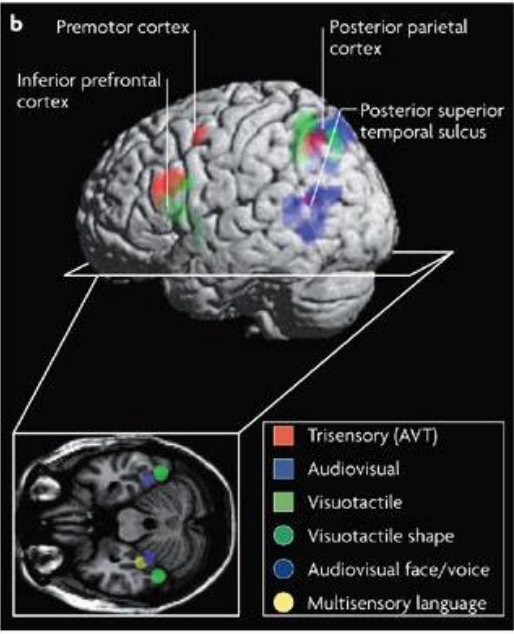
Multisensory (audiovisual) integration

Multisensory neuron

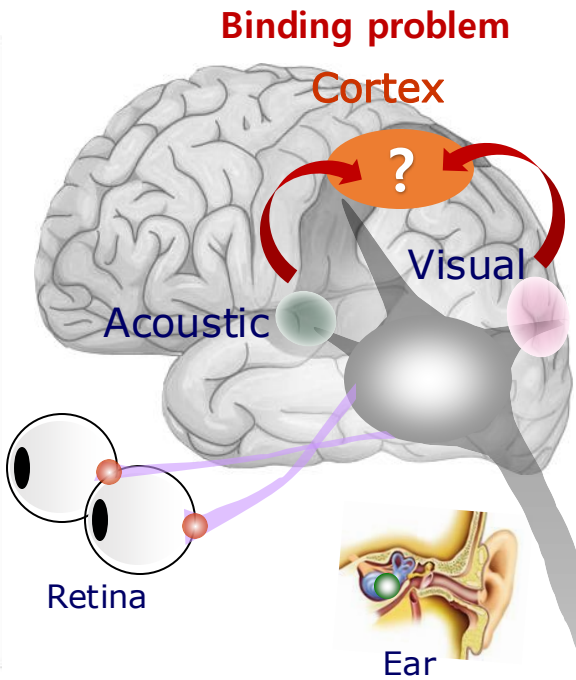


Nature Reviews | Neuroscience

Multisensory brain areas

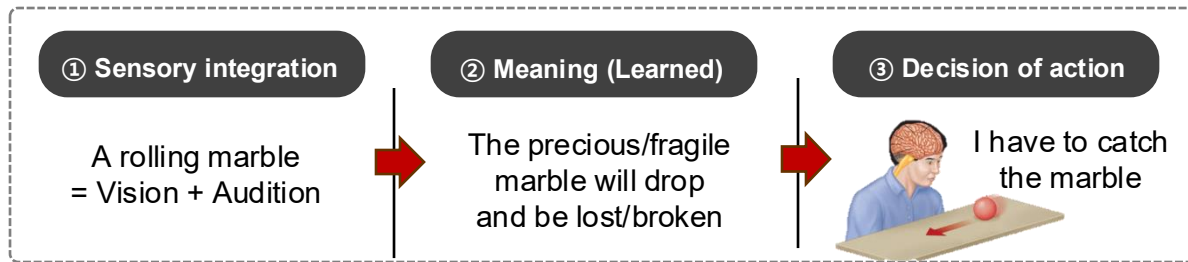
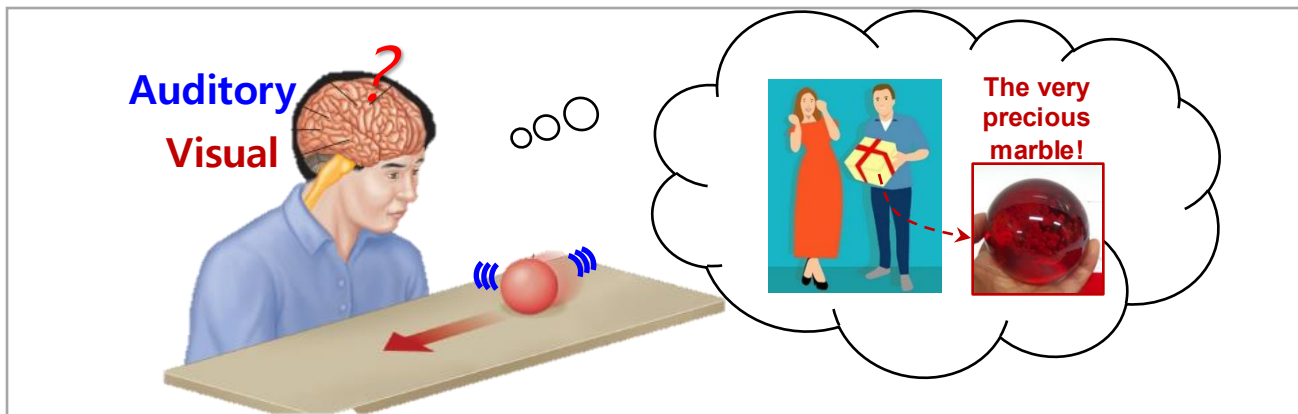


(Stein & Stanford, 2008, Nature Rev. Neurosci.)



Question #2. Action decision (sensory-to-motor transformation)

Perception guides goal-directed action (perceptual decision-making)



“Information flow: sensory-to-motor transformation”

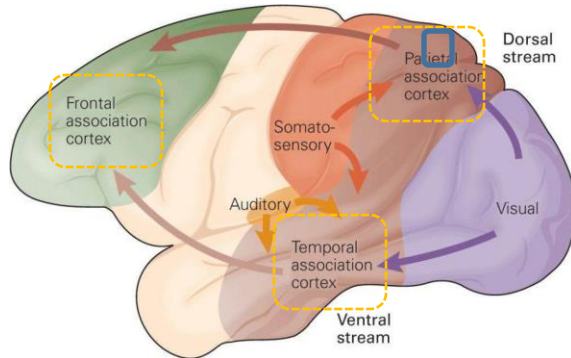
Flexibility & Gating: Brain areas, circuits, cell types, neuromodulators!

Where in the brain?

Association cortex:
higher-order cortical areas for multisensory integration & decision-making

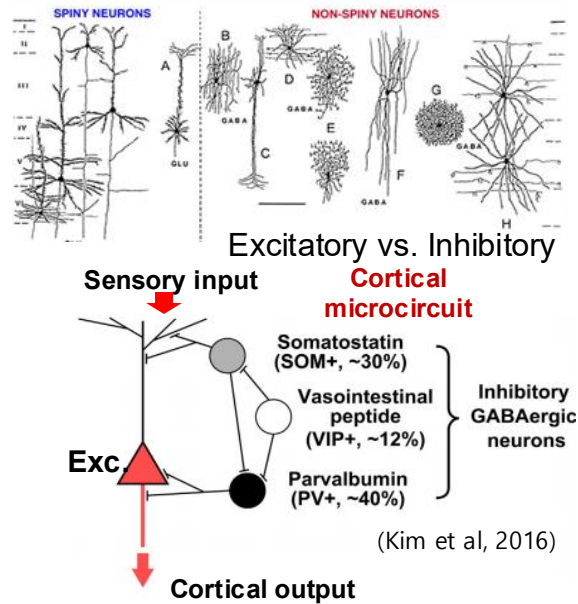
Where in the brain?

1mm³ Cortex: ~50,000 neurons
1 neuron: ~6,000 synapses



Cell type?

Circuits?

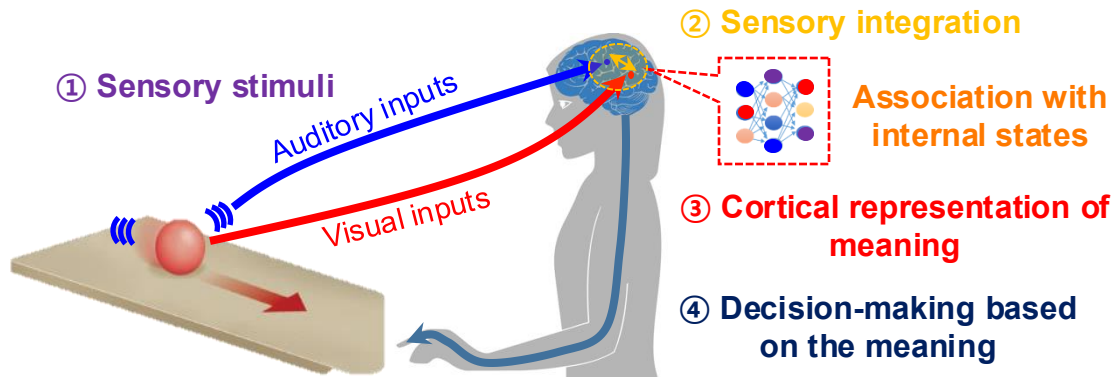


Our research goal:

Identifying **cell-type/circuit-specific** mechanisms for multisensory integration and perceptual decision-making in behaving animal

How do we study?

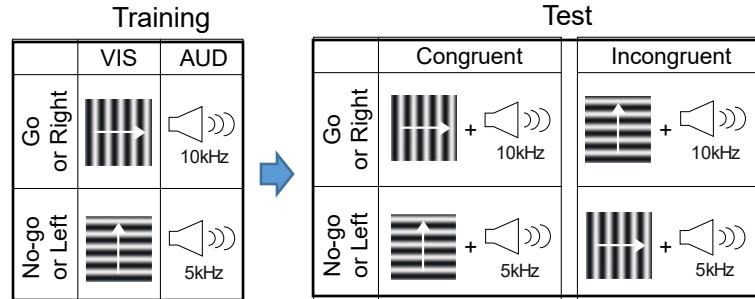
‘Record and analyze’ the flow of the sensory information in the brain!



Key technical approaches

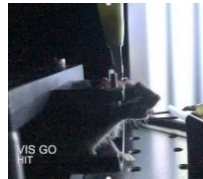
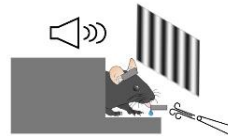
- **Behavior**: mouse perceptual behaviors & social behaviors
- **Anatomy**: mapping area/cell-type-specific circuits (tracing)
- **Physiology**: wide-range, circuit-specific recording & imaging *in vivo*
- **Manipulation**: real-time manipulation of neural activity *in vivo*

Behavior: mouse audiovisual discrimination task

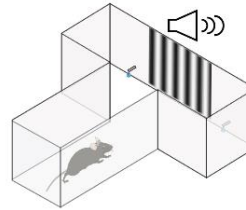


Established systems

Head-fixed



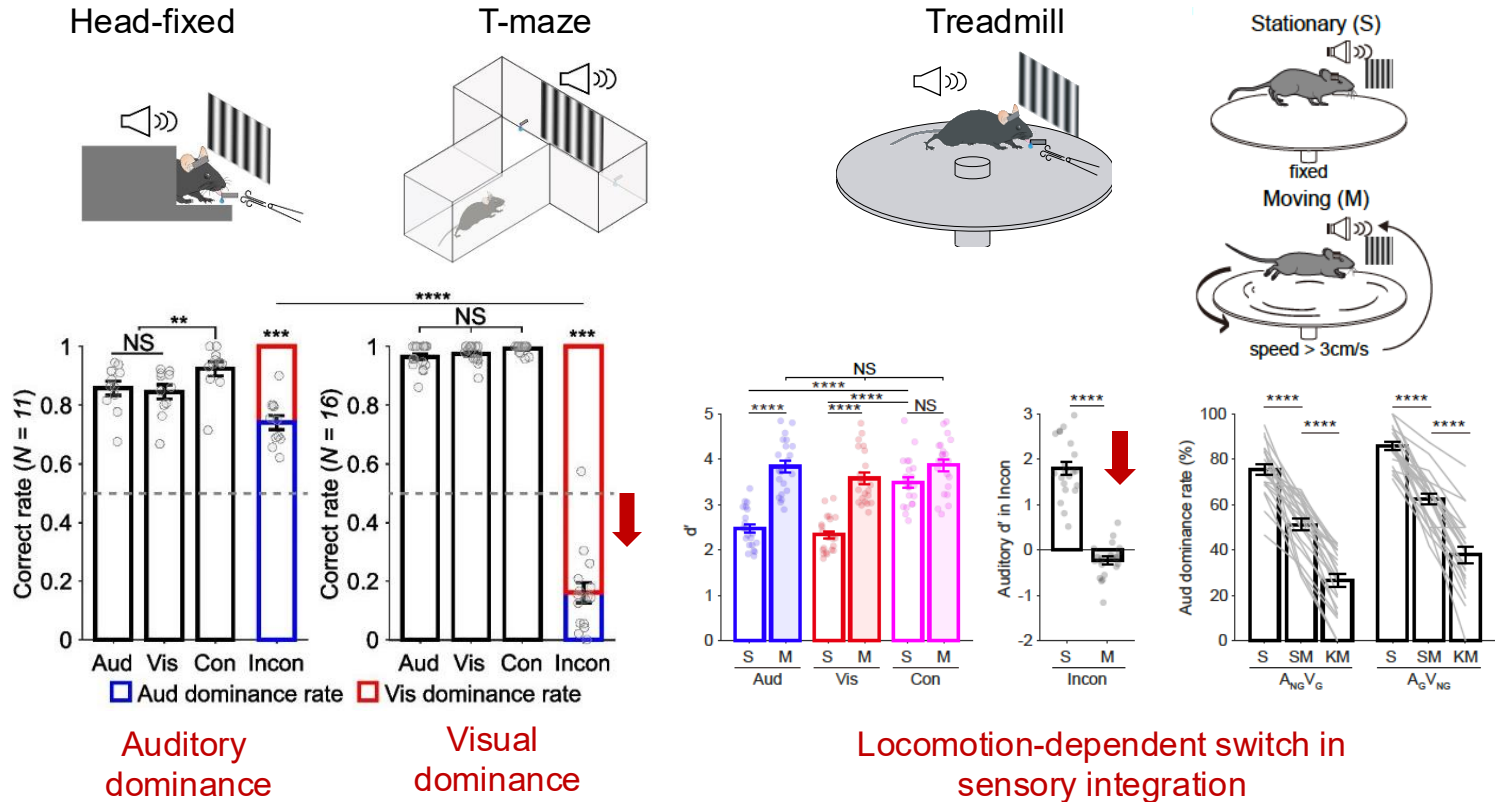
T-maze



Treadmill



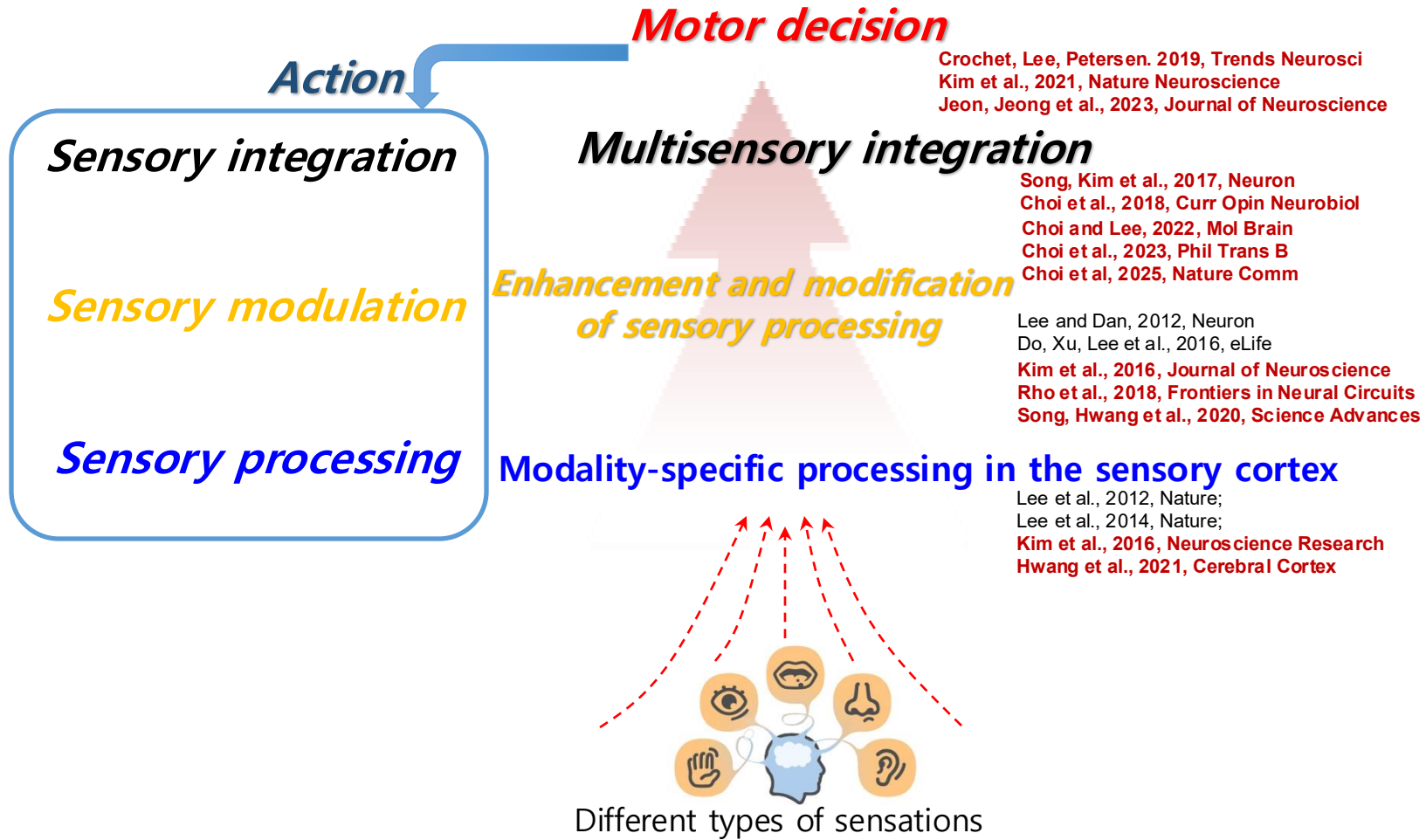
State-dependent multisensory decisions in mice



(Song et al., 2017, Neuron;
Choi and Lee, 2022, Molecular Brain)

(Choi et al., 2025, Nature Comm)

Information flow: sensory-to-motor transformation



The ability to perceive external sensory information is impaired in various neurological disorders

Dementia, Alzheimer's disease



Why and how to treat...?

Post-traumatic stress disorder

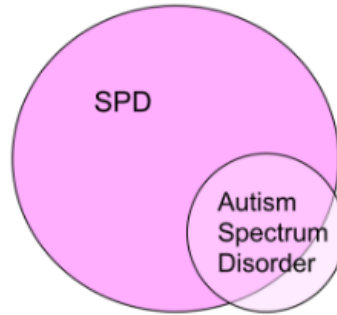


Autism, Schizophrenia



Problems in sensory processing and perceptual deficits in ASD

Autism Spectrum Disorder



Harrison and Hare, 2004
DSM-5

Diagnostic and Statistical Manual of Mental Disorders (DSM-5)

- Repetitive behavior
- Impairment on social communication
- **Sensory processing disorder (SPD)** (~90 %)

Hypersensitivity

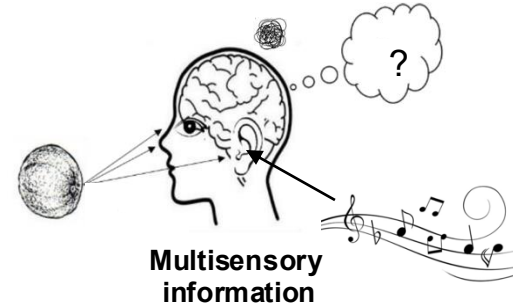


Hyposensitivity



Why and how...?

Impaired multisensory integration



On-going Research

Neural circuits for sensory processing and integration in health and disease

(1) Sensory processing and modulation

Visual cortex, inhibitory neurons, neuropeptides

(2) Multisensory integration

Posterior parietal cortex, auditory vs. visual

(3) Sensory-to-motor transformation

Frontoparietal cortex, **gating**, **flexibility**

(4) Social perception

Orbitofrontal cortex, maturation, learning

Approaches

| **Behavior**: mouse perceptual behaviors & social behaviors

| **Anatomy**: circuit tracing

| **Physiology**: *In vivo* recording & imaging

| **Manipulation**: Circuit-specific (e.g., optogenetics)

| Disease **mouse models** (e.g., ASD/AD models)

On-going Research

Neural circuits for sensory processing and integration in health and disease

Sensorimotor gating:

Visuomotor gating (Go vs. No-go)

Kim et al., 2021, Nature Neuroscience

Neuromodulation

Ma et al., unpublished

Audiomotor gating

Kim et al., unpublished

Visual perception:

Microcircuits

Lee et al., 2012, 2014, Nature;

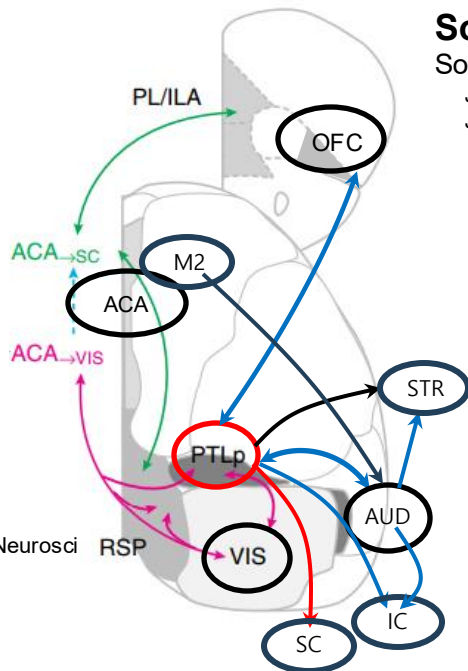
Lee et al., 2012, Neuron; Kim et al., 2016, J Neurosci

Hwang et al., 2021, Cerebral Cortex

Neuromodulators

Song et al., 2020, Science Advances

Yoon et al., unpublished



Social perception:

Social value and approach

Jeon and Jeong et al., 2023, J Neurosci

Jeon et al., unpublished

Flexible decisions:

Auditory Go-no-go reversal learning

Jung and Lee et al., unpublished

Ryu et al., unpublished

Deterministic vs. probabilistic reversal learning

Kim et al., unpublished

Multisensory integration:

Resolving conflicts between modalities

Song et al., 2017, Neuron; Choi and Lee, 2022;

Choi et al., unpublished;

Locomotion and gating

Choi et al., unpublished

Learning and making decisions

Choi et al., unpublished

Demir et al., unpublished

Modified from
Zhang et al. (Nat Neurosci, 2016)

Autism Spectrum Disorder

Yoo et al., unpublished

Park/Oh/Song et al., unpublished

Alzheimer's Disease

Park et al., unpublished