SoundSight: The sight of sound: how vision shapes the development of auditory inputs to the occipital cortex

Main area: Development and maturation of cognitive processes and multisensory integration at micro- and macro-scales
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Abstract

Despite the fact that what we see, hear, feel, taste and smell is processed separately by our senses, we perceive our environment as a unified and coherent whole. This is because brain regions that process the inputs from different senses are interconnected and provide contextual information to each other, allowing multisensory integration, which creates a better representation of the world than what is achieved by each sense separately. How these crossmodal inputs develop and are fine-tuned by experience has not been studied extensively. Experiments in the Collignon lab with congenitally blind human subjects have revealed that some visual cortical regions start responding to auditory inputs. For example, regions that normally respond to visual motion are selectively activated by auditory motion. In parallel, work from the Nieto lab showed an exuberancy of intracortical developmental axonal projections. We hypothesize that during early postnatal development, an extensive network of crossmodal axonal projections is laid out between related brain regions that is mostly pruned away through activity of feedforward inputs of the dominant modality. The remaining crossmodal connections allow for multisensory integration in the adult cortex. In the congenitally blind, the crossmodal connections are not pruned, but strengthened, and become drivers of the network. While this plasticity improves the non-deprived senses, it may interfere with the restoration of vision later in life.

In this proposal, we will test this hypothesis and its implications for the restoration of vision in the blind from the level of individual synapses in mice to the level of perception in humans. We will study the effects of visual experience during development on functional crossmodal connectivity in visual cortex using newly developed tracing approaches and chronic calcium imaging in mice and functional magnetic resonance imaging (fMRI) studies in human subjects. The functional anatomy of crossmodal connections will be mapped down to the level of dendritic integration in different excitatory and inhibitory neuronal subtypes, using RNAseq and electrophysiological and imaging approaches in mice. We will validate these findings in human subjects with ultra-high-field fMRI and intracranial electrophysiological recordings in humans. We will examine the effects of visual deprivation on the development of the visual system's functional anatomy and use a neuronal modeling approach to understand how crossmodal innervation and visual deprivation affect neuronal dynamics in visual cortex. Finally, we aim to understand the mechanisms underlying the regulation of crossmodal plasticity in mice, and use this information to explain long lasting effects of early visual deprivation in human subjects and mice and take initial steps to improve restoration of vision at a later age.

Consortium

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