Tapping onto the visual cortex of the congenitally blind by substituting vision with sounds

Scientists at the Hebrew University have tapped onto the visual cortex of the congenitally blind by using sensory substitution, a way to convert visual information to sounds or touch.

Sensory substitution devices (SSDs) are non-invasive sensory aids that provide visual information to the blind via their existing senses. For example, using a visual-to-auditory SSD in a clinical or everyday setting, users wear a video camera connected to a computer and stereo headphones; the images are converted into "soundscapes" using a predictable algorithm, allowing them to listen to and then interpret the visual information coming from a digital video camera. Remarkably, proficient users who have had a dedicated (but relatively brief, several tens of hours) training as part of a research protocol in Amir Amedi's lab at the Hebrew university are able to use SSDs to identify complex everyday objects, locate people and their postures and read letters and words. In addition to SSDs clinical opportunities, using functional magnetic resonance imaging open a unique window for studying the organization of the visual cortex without visual experience, by studying the brain of congenitally blind individuals. The results of the study, recently accepted for publication in the journal Cerebral Cortex (online publication ahead of print), are surprising. Not only can the sounds, which represent vision, activate the visual cortex of people who have never seen before, but they do so in a way organized according to the large-scale organization and segregation of the two visual processing streams.

Ever since the seminal work by Ungerleider and Mishkin in 1982, it has been repeatedly shown that visual processing is carried out in two parallel pathways. The ventral occipito-temporal "what" pathway, or the "ventral stream", has been linked with visual processing of form, object identity and color. Its counterpart is considered to be the dorsal occipito-parietal "where/how" pathway, or the "dorsal stream", which analyzes visuo-spatial information about object location and participates in visuo-motor planning. This double dissociation between the processing of the two streams has been thoroughly validated by decades of research, as one of most fundamental characteristics of the visual system, if not the most important large-scale one. What remained unclear is the role of visual experience in shaping this functional architecture of the brain. Does this fundamental large-scale organizational principle depend on visual experience?
Using sensory substitution, the Hebrew University scientists lead by PhD student Ella Striem-Amit and ELSC/IMRIC researcher Amir Amedi discovered that the visual cortex of the blind shows that same dorsal/ventral visual pathway division-of-labor when perceiving sounds that convey the relevant visual information, e.g. when the blind are requested to identify either the location or the shape of a SSD "image". This shows that the most important large-scale organization of the visual system into the two streams can develop even without any visual experience, suggesting instead that this division-of-labor is not at all visual in its nature. Recent researches from Amir Amedi's lab (Reich et al. Current Biology 2011) and from other research groups have demonstrated that multiple brain areas (such as object-processing area LOC, motion-selective area MT or the visual word form area for reading) are not specific to their input sense (vision, audition or touch) but rather to the task, or computation they perform, which may be computed with various modalities. Extending these finding to a large-scale division-of-labor of the visual system further contributes crucial information towards postulating that the whole brain may be task-specific but sensory modality-independent, if the relevant computation and task can be achieved from the sensory input. Moreover, these findings suggest that such task-selectivities exist regardless of sensory experience or deprivation, as is the case in blindness.

These findings also suggest that the blind brain can potentially be "awakened" to processing visual properties and tasks even after lifelong blindness, despite ample evidence of plasticity related to non-visual functions such as language and memory in the blind brain. Therefore, they offer hope that critical developmental periods may not limit the blind brain in visual rehabilitation using future medical advances, such as retinal prostheses.

The image depicts on the left panel the general concept of sensory substitution (SSD) and a typical visual-to-auditory and visual-to-tactile setup. SSDs typically include a visual capturing device (for example camera glasses), a computational device transforming the visual input into either a tactile or an auditory display using a simple known transformation algorithm, and an output device, transmitting this information to the user. The right side illustrates an example of an auditory SSD (such as The vOICe by Peter Meijer, used in this study) transmitting the sensory-transformed information using headphones, and on the left side is an example of a tactile device which may transmit the tactile information via an electrode array targeting the tongue or another skin surface, in this case presented in the neck.

On the right panel, the fMRI findings of activation of the ventral "what" and dorsal "where" visual processing streams in the group of congenitally blind participants are depicted.

Read the full study: The large-Scale Organization of "Visual" Streams Emerges Without Visual Experience
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