This is an excerpt from a report on the Sensory Substitution and Augmentation Conference at the British Academy in March of 2013, written by Kevin Connolly, Diana Acosta Navas, Umut Baysan, Janiv Paulsberg, and David Suarez, available at http://networksensoryresearch.utoronto.ca/Events_%26_Discussion.html

3. How does sensory substitution interact with the brain's architecture?

One of the important questions about the working of sensory substitution devices (SSDs) is how these devices feed information to the brain. The way in which the brain processes information delivered by these devices could potentially give us clues as to the nature of the experience that is generated by these devices. There are two interrelated questions that are relevant to this topic. First, how do SSDs interact with the pre-existing brain architecture? And second, does this interaction reveal anything about the experiences of SSD users?

On the first question, we might start by asking whether sensory substitution devices are capable of feeding information to the brain systems that normally process visual information. The answer is that, not only do SSDs feed information to the visual areas of the brain, but (as Maurice Ptito mentioned in his talk) they also make use of the parallel architecture of the visual system. That is, they feed information to both the ventral and the dorsal streams, following a pattern of task-dependent specialization. This shows that the continued use of SSDs exploits the plasticity of the brain, in a way such that, after training, the brain is capable of processing this new kind of information making use its pre-existing systems and modules. During periods of training there is a significant alteration in the subjects' sleeping behavior, which is normally indicative of learning processes taking place via neuronal plasticity. After such periods, the brain activity caused by the use of the devices presents interesting patterns.

In the workshop, Peter Konig presented on the Feelspace belt (which is designed to help subjects orient in space by indicating the magnetic North through vibrations around subjects' waist), He reported that after a training period of six weeks, the belt causes activation in both the right supplementary motor cortex and some parietal areas that are typically involved in processing egocentric spatial information for navigation. This is accompanied by an alteration in subjects' phenomenal experience of space. Subjects' reports show that the belt has a positive influence on their subjective experience of spatial navigation: trained users of the belt reported an improved orientation and navigational ability in unknown territories, along with a continuous improvement of their knowledge of spatial relations. However, these reports contrast with the behavioral data which showed only a minor improvement in tasks of navigation and orientation.

Laurent Renier reported on the PSVA, a visual-auditory SSD similar to the vOICe. He presented evidence that after a training period, when sighted subjects use the PSVA to perform visual tasks of object location, distance estimation and object recognition, there was activation of the visual areas that are normally recruited for the performance of this tasks by use of visual information. At the behavioral level, it was shown that early and congenitally blind subjects (unlike late blind and sighted subjects) are insusceptible to visual illusions induced by effects of perspective. This indicates that the perception of perspective is dependent on strictly visual perception, and cannot be acquired. These behavioral studies show that even though the brain is capable of rewiring in order to use the SSDs, there seems to be a limitation of the way in which SSDs can exploit bran plasticity: Some processes, like the perception of perspective, are dependent on a previous training of the visual system.

Maurice Ptito presented on the tongue display unit (TDU)—a visual-tactile SSD that stimulates the tongue. He explained that when trained blind subjects use a TDU for visual tasks, like shape, motion and orientation identification, the normal visual areas are recruited. His results show that when blind subjects use the TDU to perform visual tasks that are known to activate the dorsal and ventral visual streams in the sighted, they activate the same brain areas. This suggests that motion and shape processing are organized in a supramodal manner in the human brain, and that vision is not necessary for the development of the functional architecture characteristic of motion and shape processing areas.

Ptito also used the TDU in spatial navigation tasks and showed that in contrast to blindfolded sighted subjects, blind subjects activated their visual cortex and right parahippocampus during navigation, suggesting that in the absence of vision, cross-modal plasticity permits the recruitment of the same cortical network used for spatial navigation tasks in sighted subjects. This can be explained by saying that training with the TDU caused the brain to rewire in a way that makes it capable to process tactile stimuli as though they were visual. However, it is known that when a sensory modality is damaged, its part of the sensory cortex normally adapts to represent other kinds of sensory stimuli. So it is not clear whether the activation of visual cortex is a product of the training with the TDU or if it was there before, and the TDU merely exploits this preexisting rewiring of the visual areas.

Amir Amedi's talk made clear an idea that was suggested by other talks: the activation of visual areas is not stimulus-dependent, but task-dependent. Fixing the stimuli but changing tasks resulted in different areas being activated. On the other hand, his results indicate that training increases the selective recruitment of specialized visual areas for certain tasks. That is, there is an increasing specialization of visual areas for the performance of certain tasks, which is driven by training with the SSDs. So, it seems that learning to use SSDs causes a rewiring of the sensory cortex, which allows subjects to perform visual tasks, by processing other kinds of stimuli (tactile and auditory). It is not clear up to what point this rewiring is caused by the training, and how much builds on a preexisting adaptation of the visual areas for the processing of other stimuli.

Finally, there is the question whether this interaction between the brain and SSDs reveals any clues about the kind of experience that is generated by the devices. Even though there seems to be a correlation between the activation of visual areas for perceptual tasks and reports of changes in the subjects' experience, most researchers are skeptical of that claim that this means the subject is having a visual experience. At the conference, Kevin O'Regan claimed that changes in the subjects' experience should not be explained in terms of cortical plasticity, but rather in terms of the acquisition of sensorimotor skills and knowledge. Fiona Macpherson also rejected this approach, claiming that since visual areas also serve non-visual functions, the activation of these areas doesn't settle whether users of SSDs have visual experiences or not.