Allowing blind people to see and deaf people to hear: sensory substitution and multimodal interaction

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For the last 50 years scientists from many disciplines have been attempting to solve the challenge of sensory substitution for blind, deaf and deafblind people. Sensory substitution is the concept that information in the sense or senses that a person a sensory impairment lacks can be re-coded into another sense (usually the auditory or tactile sense) and thus be accessible and usable by that individual. Such systems, if truly successful, would have enormous potential for people with sensory impairments. People blind from birth might be able to have an experience similar to vision and all blind people might be able to navigate through the world independently, to read signs and texts directly. Deaf people might be able to see or feel speech and music while people who are deafblind, who are currently a greatly neglected group in terms of assistive technologies, would benefit from using their tactile sense along with residual sight and hearing to understand and interact with the world. Thus this challenge relates to the Assisted Living Challenge. In addition, addressing this set of issues would undoubtedly result in many interesting developments in the use of multi-sensory and multi-modal interaction for people only temporally disabled or not disabled at all. For example, firefighters might be provided with tactile and auditory information about how to navigate in buildings filled with smoke; people learning sports, musical instruments or other physical skills might be provided with tactile and haptic feedback to enable them to become skilled more quickly and easily (see an example in Bird, Marshall and Rogers, 2009).

Research on sensory substitution started with the revolutionary work of Paul Bach-y-Rita, a neuroscientist interested in the concept of neuroplasticity. In the 1960s he developed the first version of the Tactile Vision Substitution System (TVSS) which consisted of a chair with a bank of 400 vibrating pins in a 20 x 20 matrix on the back. Images from a television camera were simplified to a grey-scale representation that were then converted vibrations of different frequencies conveyed to a person sitting in the chair (Bach-y-Rita et al, 1969). The greatest success of the TVSS was in allowing a congenitally blind person to “see” the outline of a flame of a candle after “only” 25 hours of practice with the system (Guarniero, 1974).

However, after this initial success, surprisingly little progress has been made in developing these concepts into useable and useful systems that are used widely by disabled people. Bach-y-Rita continued to work in the field throughout his life, and developed a tongue interface to the TVSS (Sampaio, Maris & Bach-y-Rita, 2001), using electrotactile rather than vibrotactile stimulation for the users. Other researchers have pursued related lines of enquiry. The Optacon was a device for presenting text to blind readers, using a small vibrotactile display that presented the letter shapes directly, rather than transcribing them into Braille (Linvill & Bliss, 1966). Other systems have attempted to re-code visual information into auditory information for blind people. These have included general purpose systems such as the vOICe (Meijer, 1992), the Prosthesis Substituting Vision for Audition (PSVA) (Capelle et al,1998) and the Vibe (Auvray et al, 2005). There has been some success in using haptic virtual reality for blind people (Colwell et al, 1998; Kornbrot et al, 2007), but these ideas also need much further development.

The reason for this lack of progress may well be that this is a multi-disciplinary challenge with number of issues to be solved that have never been addressed in a sufficiently integrated manner. Although scientists from a number of disciplines need to contribute, computer science is very much at the centre of this challenge and could lead an endeavour to solve the issues, using 21st century technologies and techniques. At a broad conceptualization the challenges that need to be addressed are:

Hardware: what is the appropriate hardware that should be used for a sensory substitution system. It needs to be attuned to the sensory capabilities of users, portable, reliable, and above all acceptable for the users. It is not clear that a tongue-mounted device meets that last criteria.
Image processing: Bach-y-Rita's original work made some progress with very primitive image processing. Current state-of-the-art image processing and computer vision work needs to be brought to bear on this problem.
Artificial intelligence processing of information: understanding the enormously complex visual world is one of the feats of the human brain. Extracting meaning information out of the complex visual stimuli could now be tackled with techniques from artificial intelligence, to lessen the cognitive load on users.
Human-computer interaction: creating an interface to a system that allows users to interact with information very easily, and to bring their own human knowledge to bear on the problem of understanding information, so that computer and human are working together.

References

Auvray M., Hanneton S., Lenay C., O'Regan, K. (2005). There is something out there: distal attribution in sensory substitution, twenty years later. *Journal of Integrative Neuroscience*, 4, 505-21

Bach-y-Rita, P., Collins, C.C., Saunders, F.A., White, B. & Scadden L. (1969). Visual substitution by tactile image projection. *Nature*, 221, 963 – 964.

Bird, J., Marshall, P. and Rogers, Y. (2009). Low-Fi Skin Vision: A Case Study in Rapid Prototyping a Sensory Substitution System. *Proceedings of HCI*, 55-64.

Capelle C, Trullemans C, Arno P, Veraart C (1998). A real-time experimental prototype for enhancement of vision rehabilitation using auditory substitution. *IEEE Transactions Biomedical Engineering*, 45, 1279-1293.

Colwell, C., Petrie, H., Kornbrot, D., Hardwick, A. and Furner, S. (1998). Haptic virtual reality for blind computer users. *Proceedings of ASSETS '98: The Third International ACM Conference on Assistive Technologies*. New York: ACM Press.

Guarniero, G. (1974). Experience of tactile vision. *Perception,* 3(1), 101 – 104.

Kornbrot, D., Penn, P., Petrie, H., Furner, S. and Hardwick, A. (2007). Roughness perception in haptic virtual reality for sighted and blind people. *Perception and Psychophysics*, *69*(4), 502 – 512.

Lauer, H. (2003). The reading machine that hasn't been built yet. *AccessWorld*, 4(2). Available at:www.afb.org/afbpress/pub.asp? DocID=aw040204

Linvill, J.G. & Bliss, J.C. (1966). A direct translation reading aid for the blind *Proceedings of the IEEE*, 54(1), 40-51.

Meijer P.B.L. (1992). An experimental system for auditory image representations. *IEEE Transactions Biomedical Engineering*, 39, 112-121.

Sampaio, E., Maris, S. and Bach-y-Rita, P. (2001). Brain plasticity: "visual" acuity of blind persons via the tongue. *Brain Research*, 908(2), 204 – 207.