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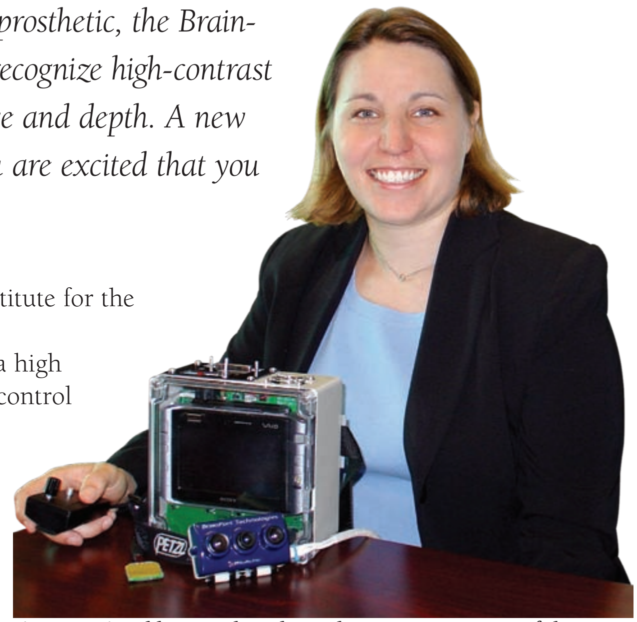
PointofView
THE EYE RESEARCH INSTITUTE UNIVERSITY OF WISCONSIN–MADISON

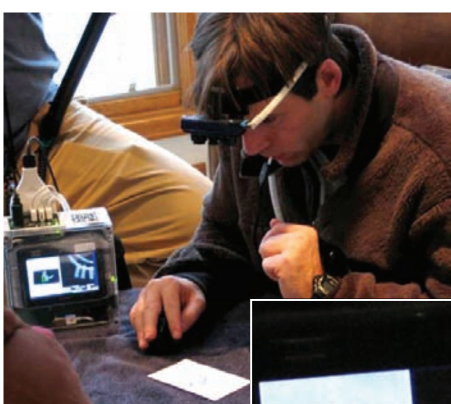
On the Tip of Your Tongue

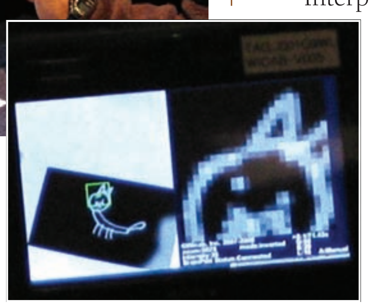
Imagine your world limited to light perception only, your blindness necessitating reliance upon guide dog, white cane, and exploratory touch. Aimee Arnoldussen, a research neuroscientist at Wicab, Inc. and member of the Eye Research Institute, invites you to test a prototype visual prosthetic, the Brain-Port vision device. After a few hours of training you are able to recognize high-contrast objects, their location, movement, and some aspects of perspective and depth. A new door opens in your experiential world, and for the first time, you are excited that you can "see."



Aimee L. Arnoldussen, PhD, shows the current prototype of the BrainPort vision device. Components include a hand-held controller, tongue array, base Central Processing Unit, and digital video camera image system.

For the past two years, Arnoldussen has been guiding blind subjects—those with no better than light perception—through pilot tests of a novel technology engineered at UW-Madison by the late Paul Bach-y-Rita, Wicab's co-founder and former UW faculty member. Patented by the Wisconsin Alumni Research Foundation (WARF), BrainPort electrotactile sensory substitution technology is the core of this vision device. Based on the idea that the brain's remarkable adaptability allows interpretation of sensory information from touch as if it were traditionally perceived via sight, the device helps the tongue substitute for the eyes.





***Top:** Using the BrainPort vision device, blind subject Eric Weihenmayer can "see" his daughter's drawing of their cat. **Bottom:** The base unit screen allows the trainer to see the digital camera image as well as the portion of the cat's head that Eric perceives.*

"The system consists of a high resolution tongue display, a control box, and a digital video camera. Visual information collected from a head-mounted camera is translated into an electrical pattern that is 'drawn' or mapped on the tongue," explains Arnoldussen. In the current prototype, the inch-square, 25 x 25 electrode array that rests on the tongue includes over 600 contact sensors. Via tingling electrical pulses, experienced by users as soda bubbles or champagne effervescence, these sensations are transmitted from tongue to brain and the subject "sees" due to the brain's ability to analyze and interpret the stimuli as visual information.

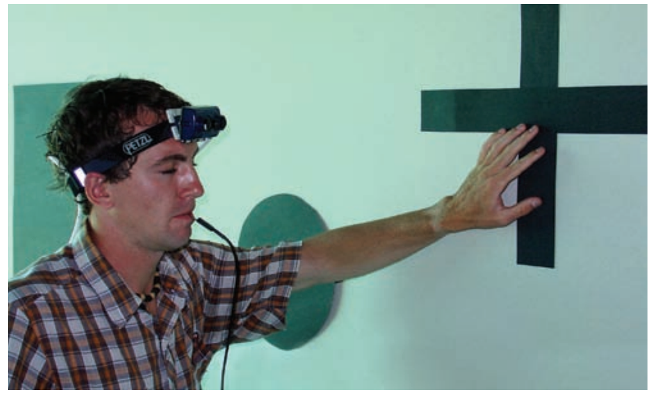
Interpretation of this unusual input requires training and practice, like learning any new language, and Arnoldussen is an able and enthusiastic teacher. She has used the vision device herself, believing it essential to know what it feels like and to discern how the body is cued and how it responds to stimuli. "My teaching focuses on facilitating user interactions and helping them match their multisensory experiences with the patterns registering on their tongues." Users must learn to move their heads around to survey images, objects, and surroundings—just as sighted people move their eyes. Arnoldussen structures the training to encourage users to first identify what they know, putting contextual knowledge to work in deducing an object's identity or spatial orientation—such as recognizing that the vertical lines under a chair are likely its legs.

By building exercises around perceiving directional orientation and shape of objects, discerning letters and shapes of various sizes, following black-line pathways delineated on a warehouse floor, and recognizing standing and suspended barriers in an obstacle course, Arnoldussen has led over twenty blind subjects to remarkable levels of success.

After training for an average of 8 to 10 hours in individual sessions lasting 2 to 3 hours, users can navigate independently, make deliberate movements to connect with physical surroundings (eliminating groping), and identify close and distant images. What were initially puzzling shapes and lines become recognizably distinct and meaningful.

Arnoldussen's fascination with the brain's incredible function and capability was sparked by an introductory neuropsychology class at UC San Diego, where the Cognitive Science Department's balance of psychology, computer science and neuroscience fostered her interest in the study of intelligent systems and human-computer interactions. An undergraduate internship with the Archimedes Project (then at Stanford's Center for the Study of Language and Information), where she worked to design technology that assists and includes those with disabilities, advanced her interest in brain computer interfaces and rehabilitation technologies. Arnoldussen pursued graduate studies in biology and neuroscience at USC in Mark Seidenberg's Language & Cognitive Neuroscience Lab, electing to move to Madison when Seidenberg was recruited to the UW Department of Psychology. As a doctoral student in UW's Neuroscience Training Program, she researched reading, language impairment and dyslexia by using functional Magnetic Resonance Imaging (fMRI) to learn about brain activity in subjects looking at letters and words. "I observed the brain recognize letters as objects, and tracked the pathways and processes in the left fusiform gyrus, an area involved in reading."

In her Wicab neuroscientist role, Arnoldussen builds on this strong research and training foundation to advance the BrainPort vision device from a research tool to a broadly available prosthetic product. Supported by a National Eye Institute grant, she and the Wicab team investigate device-augmented perception in users who are blind. Their foremost goal is to refine the prototype to create a durable, rugged, and affordable instrument with improved resolution and a smaller size. Subject feedback continues to be invaluable in the developmental process, as every individual who has trained with this device has received useful information from it—and, in turn, has provided substantive and creative input that spurs further refinements.


In training, a user learns to distinguish between dark shapes against a light background, reaching out to identify the "+."

Work with recent veterans blinded in military conflict—a cohort driven to adapt, eager to collaborate, and optimistic about the device's possibilities—underscores users' excitement; as one man expressed, "I'd love to use this to help me run a marathon!" Subjects testing the device want to utilize it full time, anticipating that regular use will augment brain training and improve perception and signal interpretation. "I want to get this into people's hands on a daily basis rather than an hourly basis," Arnoldussen declares. "Consistent use will bring awareness of user benefits that accrue over time. There will be 'Aha!' moments that develop along with skill level transformation and increased competencies, and we will be able to learn so much more!"

Wide publicity regarding initial success with the BrainPort vision device has built expectation and anticipation, creating product demand in advance of the FDA approval process still to come. Arnoldussen has discussed and demonstrated the vision device on the CBS Evening News, the NBC Today Show, PBS Wired Science, and the German TV shows *Nano* and *Die grosse Show der Naturwunder*. Numerous newspaper, magazine, and internet articles have called attention to the promise of BrainPort technology, and to the partnership between UW scientists and WARF in translating research concepts into a business venture. (Yuri Danilov, Kurt Kaczmarek, and Mitchell Tyler, all of the Department of Orthopedics & Rehabilitation Medicine, were closely involved with Bach-y-Rita in developing both vision and balance applications of BrainPort technology.)

Potential research and development projects include creating an assistive device to replace central vision for people with age-related macular degeneration, designed to capture information in the exact area where the user has lost vision and display that on the tongue so that the area of loss can be 'filled in' by the brain. Ultimately, use of BrainPort technology may provide insight into fundamental questions of what we believe constitutes "vision," as those with complete vision loss are able to "see" the world. Excitement and dedication are evident, as is advocacy for connectivity, as Arnoldussen looks to the future. "I am hopeful that ERI membership will foster new local and university collaborations, mutually beneficial for developing visual technologies, and I am confident that we can cultivate relationships that will strengthen UW's presence in the promising new field of visual prosthetics."

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