

# Haptic Assistive Technology for Individuals who are Visually Impaired

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NEW, effective methods of non-visual communication are needed for individuals who are blind or visually impaired in the modern world. Areas of relevance include tasks performed in the workplace, in educational settings, in the pursuit of leisure activities, in daily living, and navigating indoor and outdoor spaces. Providing an equivalent of what can be seen through an alternate sensory channel, such as touch or audition, is problematic owing to the intrinsic differences and significantly more limited information transmission capabilities of these alternate perceptual systems. Thus, one of the vexing challenges in developing assistive technologies for individuals who are blind or visually impaired is to provide information that is functionally equivalent to that obtained through vision without taxing the other sensory channels. The main focus of this special issue is the use of the tactile/haptic channel in assistive technologies for the blind and visually impaired. A significant advantage of using touch, versus audition, is that it leaves audition free to perform its normal function of listening to environmental sounds, such as cars, people and emergency alerts.

The issue begins with an invited paper by Sile O'Modhrain, Nicholas A. Giudice, John A. Gardner, and Gordon E. Legge entitled "Designing Media for Visually-Impaired Users of Refreshable Touch Displays: Possibilities and Pitfalls." One of the difficulties in developing assistive technology for individuals who are blind or visually impaired is that many designers have sight. They may, therefore, make incorrect assumptions about the abilities and accommodation strategies of the target population. On the other hand, those who are end users of assistive technology may have difficulty articulating what an appropriate/desirable substitution mechanism may be. This paper provides insight, particularly with respect to refreshable tactile media, from researchers and developers who have the

unique experience of being both designers and users of assistive technology. Pros and cons of several classes of technology are discussed and some commonsense guidelines for assistive technology design are provided.

The second paper, "Designing Haptic Assistive Technology for Individuals Who Are Blind or Visually Impaired" by Dianne T.V. Pawluk, Richard J. Adams, and Ryo Kitada, provides a review of several elements relevant to the design of tactile/haptic assistive technology for individuals who are blind or visually impaired. This includes the characteristics of the user population and their involvement in the design process, behavioral and neuroimaging research that is relevant to the design of assistive technology, examples of applying insight from behavioral research to assistive technology design, and assistive technologies that have been developed for some key tasks. The areas of focus are Braille reading, tactile diagrams and maps, orientation, and mobility.

The remaining six papers in this issue are original research papers spanning a wide variety of topics. The first paper considers the importance of user characteristics on the outcome of an assessment of a particular assistive technology. In "The Importance of Visual Experience, Gender, and Emotion in the Assessment of an Assistive Tactile Mouse," Luca Brayda, Claudio Campus, Mariacarla Memeo, and Laura Lucagrossi consider the complexity of virtual relief maps, a user's visual experience and a user's gender on performance defined by mental workload, the amount of information acquired, and the user's emotional status. In their study, performance appeared to be affected by the gender of a user but not by their previous visual experience.

The next paper examines two potentially important tactile cues on user performance reading Braille that have implications for refreshable Braille display design. In "Refreshing Refreshable Braille Displays," Alexander Russomanno, Sile O'Modhrain, Brent Gillespie, and Matthew Rodger examine the effects of both sliding contact between the finger and Braille "dots" and proprioceptive information from hand movements on a user's error rate during Braille reading. They also consider the interaction of these effects with Braille reading speed and reading condition. From their results, the authors conclude that sliding motion, but not passive proprioceptive information, improves Braille reading accuracy.

The subsequent two papers consider aspects of assistive technology to support independent and safe navigation from one location to another. In "Identification of Vibrotactile Patterns Encoding Obstacle Distance Information," Yeongmi Kim, Matthias Harders, and Roger Gassert

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compare different methods of providing tactile feedback with four vertically aligned tactile vibrators on the handle of a white cane which provide distance information about nearby obstacles. They examine the effect of using temporal, spatial-temporal, or spatial/temporal/intensity variations in tactile rendering on performance under two hand configurations. The first configuration is with the user holding the handle so that the index finger contacts all four factors along its length. The second is a grip configuration with a single fingertip in contact with each of the factors. Results of the various rendering methods varied with the hand configuration used.

In "Vibrotactile Guidance for Wayfinding of Blind Walkers," German Flores, Sri Kurniawan, Robert Manduchi, Eric Martinson, Lourdes M. Morales and Emrah Akin Sisbot describe the development and assessment of a vibrotactile belt interface compared to an audio spoken dialog interface for wayfinding. The vibrotactile belt system uses an external localization system to measure the position and orientation of the user. The current way point direction from the user is calculated and indicated by activating the closest of eight evenly spaced vibrators on the belt to the given direction. Results show that the vibrotactile belt system enabled closer path following at the expense of speed in comparison to the audio interface.

The last two papers consider the use of force feedback devices in audio-haptic systems in formal and informal educational environments. In "Haptics-Based Apps for Middle School Students with Visual Impairments," Kristen Murphy and Marjorie Darrah examine the use of a low-cost, force feedback device along with speech and high contrast graphics to provide students with visual impairments with low-cost apps to learn about math and science. They also examine the ability of classroom teachers to effectively deploy the haptic-based apps. Results show significant learning gains from students using the apps and the feasibility of teachers to easily set-up and use the system.

In "Telerobotic Haptic Exploration in Art Galleries and Museums for Individuals with Visual Impairments," Chung Hyuk Park, Eun-Seok Ryu, and Ayanna M. Howard develop a system for real-time haptic exploration of items in a museum through the control of a remotely located robot with a Kinect to obtain remote 3D information. The information is transmitted through multimedia encoding to a force feedback platform, which provides real-time 3D haptic rendering of the item. Initial examination of the system for haptic exploration and object perception shows promise for its real-time use in museums.

Finally the special issue concludes with a book review of *Psychology of Touch and Blindness* by Morton A. Heller and Edouard Gentaz. In their book, Heller and Gentaz provide information on the neuroscientific bases for touch and on aspects of haptic perception in sighted individuals. Several chapters are devoted to aspects of haptic perception in individuals who are blind or visually impaired, and to the application of haptics. This book may be of particular relevance as a resource for developers of assistive technology for individuals who are blind or visually impaired.

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and Pilar Hawthorne, for their support and involvement in completing this special issue. We also wish to thank the numerous reviewers who provided high quality and timely reviews.

Dianne Pawluk  
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Nicholas Giudice  
Morton Hayward  
Vinton Heller  
Guest Editors



**Dianne Pawluk** is an associate professor of biomedical engineering at Virginia Commonwealth University. She teaches courses in the areas of computational methods, assistive technology, and rehabilitation engineering. Her active research areas include the *IEEE Transactions on Haptics* development of haptic assistive devices and methods for individuals who are blind or visually impaired, including devices and algorithms for tactile graphics, orientation, and mobility, haptic perceptual organization, and the effective use of multimodal presentations in education. She currently serves as an associate editor for the *IEEE*. She is a member of the *IEEE*.



**Nikolaos Bourbakis (F'06)** received the BS degree in mathematics from the National University of Athens, Greece, and the PhD degree in image processing-analysis from the Department of Computer Engineering & Informatics, University of Patras, Greece. He currently is a distinguished professor in information technology, a professor of geriatrics (j.a.) and the director (Center of Assistive Research Technologies) at Wright State University, Ohio, and a visiting scholar at OSU-ESL at Columbus, Ohio, from 2011 to 2015. He has published 400 articles in refereed international journals, book-chapters, and conference proceedings, and 10 books as an author, co-author, or editor. He has graduated 23 PhDs and 40 Master students. He is the founder and EIC of International Journals on (AI Tools (WSP) and *Monitoring & Surveillance Research* (IGI-Global)), the editor in charge of a Research Series of Books in AI (WSP 1994-2009), the founder and general chair in numerous International *IEEE* Computer Society Conferences, Symposia, and Workshops. He is/was an associate editor in *IEEE T-DKD*, *Multimedia*, and International Journals, and a guest editor in 20 special issues in *IEEE* journals and International Journals related to his research interests (Intelligent Systems, Image Processing & Understanding, Cybersecurity, and Assistive Technologies). He is a fellow of the *IEEE*.



**Nicholas Giudice** received the PhD degree in the cognitive and brain sciences program in the Department of Psychology from the University of Minnesota in 2004 and worked as a postdoctoral research fellow in the Department of Psychology at the University of California, Santa Barbara from 2005 to 2008. Since the Fall of 2008, he has worked at the University of Maine, where he is an associate professor of spatial informatics in the School of Computing and Information Science and directs the Virtual Environments and Multimodal Interaction (VEMI) lab ([www.vemilab.org](http://www.vemilab.org)). His research program combines techniques from experimental psychology and human-computer interaction with an emphasis on studying multimodal spatial cognition (vision, touch, audition, and language). He has specific research interests in the domains of spatial learning and navigation with and without vision across the lifespan and in the specification of information requirements for the design and evaluation of spatial interfaces for use in assistive technology and gerontechnology. He has authored or co-authored more than 80 peer reviewed publications, including journal articles, conference papers, book chapters, and edited volumes with the leading researchers in these areas.



**Vincent Hayward** was a postdoctoral fellow and visiting assistant professor in 1982 at Purdue University, and joined CNRS, France, as Chargé de recherches in 1983. In 1989, he joined the Department of Electrical and Computer Engineering at McGill University as an assistant, associate, and then a full professor in 2006. He was the director of the McGill Center for Intelligent Machines from 2001 to 2004. From 2008 to 2011, he held the “Chaire internationale d’haptique” at the Université Pierre et Marie Curie where he is

now a professor. He is interested in haptic device design and applications, perception, and robotics and published more than 80 articles in scientific journals as well as more than 150 articles in international conferences and collections. Approximately half of these articles are in the field of haptics. He co-founded spin-off companies and received several best paper and research awards. He was on the editorial board of the *IEEE Transactions on Robotics*, the *ACM Transaction on Applied Perception*, and the *IEEE Transactions on Haptics*. He is a fellow of the IEEE.



**Morton Heller** received the BA degree in psychology from the City College of the City University of New York, the MA degree in general psychology, and the PhD degree in experimental psychology from Yeshiva University. He is currently a professor and chair Emeritus of psychology from Eastern Illinois University. His current research interests include tactile graphics, haptic illusions, intermodal relations, and haptic spatial memory. He is on the editorial board of *Perception*.

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