ERGONOMICS OF TACTILE AND HAPTIC INTERACTIONS

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The area of tactile and haptic interactions has produced a number of exemplar systems and an even greater number of research papers. The time has come to systematize the knowledge that has been gained in order to produce guidance. The Ergonomics of Tactile and Haptic Interactions symposium provides an analysis of some of the complexities of tactile/haptic interactions and provides a number of ergonomic insights on how they should be designed and evaluated. Papers in this symposium present a model for analyzing and designing the complexities of tactile/haptic interactions, a research-based understanding of and guidance on the many dimensions of tactile/haptic encoding, application-based guidance on designing and utilizing tactile/haptic interaction techniques, and insights on how international standards are providing a compendium of ergonomic guidance in designing and evaluating tactile/haptic interactions.

INTRODUCTION

Touch-based interactions can be used in many more ways than just tapping on keyboards and moving or clicking with mice. Tactile and haptic interactions are unique in that they use a single modality to combine input and output operations. They are also unique in the large number of dimensions that can be used for encoding information and actions.

Tactile and haptic interactions provide a new means of interacting that can expand the range of computing applications and users. While there are many exemplary examples of tactile/haptic uses that can be replicated, there is a need for empirical ergonomic guidance that can help developers design usable systems involving tactile and haptic interactions.

THE SENSE OF TOUCH: WHAT IS IT, AND WHAT IS IT GOOD FOR?

The sense of touch is often defined as the sensation elicited by non-painful stimuli placed against the body surface. The sense of touch is a very complex system with many different receptors in joints, muscles and the skin, each having its own characteristics and responding to different stimuli (Kandel, Schwartz & Jessell, 1991). The system is responsible for many perceptual qualities such as mass, size, structure, resistance, roughness, pressure, orientation, etc. Although people are inclined to think that only vision and audition can shape our mind and enable us to understand the world, the case of Helen Keller who became deaf and blind in infancy and learned to communicate solely on the basis of touch shows that this is not true.

The skin contains several different types of mechanoreceptors to process stimuli, of which the following four main types are found in hairless skin: Pacinian corpuscles, Meisner corpuscles, Merkel disks and Ruffini endings. Generally, stimuli will evoke a response in multiple types, and the experience will be based on the combined response in mechanoreceptors (e.g., Johansson, 1978; Johansson & Birznieks, 2004) Thought to be less important for touch perception are the hair follicles and the bare nerve endings. The Meisner corpuscles react to light touch and lower frequency vibrations (resulting in a perceptual quality described as light touch or flutter), while the Pacinians react to gross pressure changes and higher frequencies and result in a flutter or vibration percept. The Ruffini endings enable pressure perception while the Merkel disks are thought to be involved in tactile form and roughness perception. The Merkel disks also differentiate between the form of the indentation (e.g., sharp versus flat surfaces) and are used for high resolution tactile discrimination. The unspecialized free nerve endings are responsible for detecting stretch stimuli and other mechanical stimulations such as pressure.

There are four additional types of so-called muscle and skeletal mechanoreceptors primarily used to keep our balance and move about in the world: the muscle spindles (primary and secondary), the Golgi tendon organ, and the joint capsule mechanoreceptor. Through joint angles and muscle stretch, they provide data on limb position and movement, and on forces. This data is also necessary to derive clues about other mechanical properties of objects in the environment, such as force, stiffness, viscosity, and mass (Jones & Hunter, 1990).

The sense of touch is the earliest sense to develop in an embryo (Gottlieb, 1971). Within eight weeks, an embryo shows reflexes based on touch. Also, most of the major reflexes of full-term neonates are based on the sense of touch (Shaffer, 1989). The brain uses tactile sensations to develop awareness of the body in space, to perceive space, time, shape, form, depth, texture and all other kinds of (physical) object properties. Touch is indispensable in building a complete picture of the world around us as we know it.

Touch is also essential as a feedback mechanism in motor control, illustrated by the ease with which we can find the light switch in the dark. We also experience difficulty walking with a numb leg, difficulty controlling equipment or lighting a match with numb fingers, or difficulty talking after local anesthesia. Touch is not only critical in interaction with objects, but also between individuals. Some examples include: in greetings (shaking hands, embracing, kissing, backslapping, and cheek-tweaking), in intimate communication (holding hands, cuddling, stroking, back scratching, massaging), in corrections (punishment, spank on the bottom), and of course in sexual relationships.

Finally, imagine what it would be like to live without touch. Even if you survived as a newborn without many basic reflexes, it would be doubtful if you could grow up into a normal functioning human being, it would be difficult to stand, walk, and talk; to interact socially with others, to find your way in dusk or dawn, to hold a glass without breaking it, to eat nuts without dropping some, to enjoy the feel of smooth silk, to interpret the back patting of an acquaintance, the stroking of a friend and the tender loving care of your lover, to turn pages one by one, to find your keys in your pocket, to relieve your headache by stroking and so forth and so on.

AN OVERVIEW OF THIS SYMPOSIUM

This symposium contains an introduction and four papers that are intended to provide a survey of important issues in tactile/haptic interaction and of some of the work being done to resolve these issues.

The symposium starts with a presentation on the use of touch, which elaborates on the information provided above. It will explain how touch might be the most complex of senses that can be utilized in human-computer interaction.

The first paper, The Range of Tactile and Haptic Interaction Techniques (Andrew, 2006), builds on this introduction to identify the diverse set of tactile/haptic interaction techniques that may be utilized and that should be considered in the design of tactile/haptic interactions within an application. It illustrates the richness of this means of interaction and the need for a careful understanding of its possibilities and issues before choosing which interaction techniques to include in an application.

The second paper, Applying the GOTHI Model of Tactile and Haptic Interactions (Nesbitt & Carter, 2006), discusses the breadth of applications in this area and provides a structured framework of the range of the issues involved with understanding and applying tactile and haptic interactions. This framework can help developers to understand and consider all the possibilities of different types of tactile/haptic interactions.

The third paper, The Multi-dimensional Nature of Encoding Tactile and Haptic Interactions: from psychophysics to design guidelines (van Erp, 2006), focuses on the potential content of tactile/haptic interactions. It ties this content both to the capabilities of users, as discussed in this introduction, and the capabilities of systems, as discussed in the first paper.

The fourth paper, Existing and Future Guidance on Tactile and Haptic Interactions (Fourney & Carter, 2006), discusses a set of technology transfer activities intended to synthesize the large body of tactile/haptic research into guidelines to help developers to ergonomically utilize tactile/haptic interactions. It discusses the creation of international standards based on research and practice and outlines a set of tactile/haptic standards now being developed.

TOWARDS THE FUTURE

There is a considerable body of knowledge based on research and practice with tactile/haptic interactions. However, to date, this is largely understood by a relatively small group of specialists. It is now time to make this knowledge available to a wider set of developers. This symposium and the activities it reports on is one step in making this knowledge available to a wider group of practitioners.

REFERENCES

Andrew, I. (2006). The range of tactile and haptic interaction techniques. In *Proceedings of the 50th Annual Meeting of the Human Factors and Ergonomics Society*.

van Erp, J. (2006). The multi-dimensional nature of encoding tactile and haptic interactions: From psychophysics to design guidelines. In *Proceedings of the 50th Annual Meeting of the Human Factors and Ergonomics Society*.

Fourney, D., & Carter, J. (2006). Existing and future guidance on tactile and haptic interactions. In *Proceedings of the 50th Annual Meeting of the Human Factors and Ergonomics Society*.

Gottlieb, G. (1971). Ontogenesis of sensory function in birds and mammals. In: E. Tobach, L.R. Aronson, & E. Shaw (Eds.). *The biopsychology of development*. New York: Academic Press.

Johansson, R.S. (1978). Tactile sensibility in the human hand: Receptive field characteristics of mechanoreceptive units in the glabrous skin area. *Journal of Physiology*, *281*(1), 101-125. Available at: http://jp.physoc.org/cgi/content/abstract/281/1/101

Johansson, R.S., & Birznieks, I. (2004). First spikes in ensembles of human tactile afferents code complex spatial fingertip events. *Nature Neuroscience*, *7*(2), 170-177.

Jones, L.A., & Hunter, I.W. (1990). A perceptual analysis of stiffness. *Experimental Brain Research*, *79*(1), 150-156.

Kandel, E.R., Schwartz, J.H., & Jessell, T.M. (1991). *Principles of neural science*. Amsterdam: Elsevier.

Nesbitt, K., & Carter, J. (2006) Applying the GOTHI model of tactile and haptic interactions. In *Proceedings of the 50th Annual Meeting of the Human Factors and Ergonomics Society*.

Shaffer, D.R. (1989). *Developmental psychology* (2nd ed.). Pacific Grove, CA: Brooks/Cole publishing.