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Haptic object identification

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Introduction

The study of touch has interested psychologists and neuroscientists for a long time but interestingly, the world of touch is flourishing nowadays. Important developments are taking place in psychology of touch, neurosciences, virtual reality and robotics. Today, haptics is more than ever a multidisciplinary field as well as a world research effort. In 2005, after a number of interesting and successful conferences organised independently in the United States and Europe, the First World Haptics Conference took place in Pisa (Italy). The Second World Haptics Conference was celebrated in Tsukuba (Japan) in 2007. The papers presented at World Haptics cover three main areas; the Science of Haptic Perception, the Technology of Haptic Interfaces, and the Applications of Haptic Interfaces and Teleoperation Systems. The great success of these international worldwide scientific meetings made us feel that the world of touch is more vibrant than ever.

The startling growth experienced by the field of haptics during the last decade represents a realisation that fundamental perceptual problems may be solved in this modality [1]. Recent approaches to the study of touch from the experimental psychological methodology and sophisticated neuroscience techniques are likely to provide interesting advances in the field.

In this chapter we first consider the 'hot' issue of active *versus* passive touch. Tactile passive perception refers to stimulating the stationary finger or hand with a moving or static external stimulus whereas the term haptic perception is reserved for referring to the active exploration and manipulation of surfaces and objects with our hands. This mode of exploration allows one to extract a wealth of sensory information for further processing. The central core of the chapter is devoted to the perception of a series of important dimensions experienced in surfaces and to the recognition of two-dimensional raised-outline stimuli and the identification of three-dimensional objects by active touch.

Active *versus* passive touch

Gibson [2, 3] drew a distinction between active and passive touch. For Gibson, haptics did not consist of the mere addition of kinaesthesis and cutaneous information as one experiences objects or patterns. We do not simply act as receptor surfaces, with an existence that merely serves the needs of experimenters in perception. People are actors and perceivers in a real world. This means that we often act in a manner that maximises the quantity and quality of information that we obtain from the environment. Gibson was critical of much of the older research that assumed that we can generalise from passive cutaneous stimulation to other, more normal circumstances in which we engage in active movement to obtain information from the world. Active touch differs from passive touch in the intentionality of our exploratory behaviours. The distinction is somewhat different from the older reafferance/exafference dichotomy. Gibson thought that active touch was more likely to yield objective percepts and veridical perception, while passive touch tended towards subjectivity.

There are certainly circumstances where stimulation is imposed on a stationary and passive perceiver. The question is whether these are

atypical, or whether or not we can generalise from the study of passive touch to more natural, active situations.

The distinction that Gibson drew between active and passive touch has certainly been controversial [4]. In his original experimental report, Gibson [2] pressed cookie-cutter shapes on the palms of subjects in a passive condition, and allowed subjects the option of actively feeling the outlines of the shapes, in an active condition. In all cases, the subjects made visual matches to the haptically experienced stimuli. While there were a number of different passive conditions, active touch yielded clearly superior recognition performance. Unfortunately, there were some serious methodological difficulties with the experiment. Confirmation of these sorts of findings can be found in the literature [5]. Mode of touch was confounded with the sensitivity of the receptor surface in Gibson's [2] study, since the fingertips are far more sensitive than the surface of the palm. However, Heller [6] showed that active touch maintains a superiority, even when the sensitivity of the receptor surface is comparable. Furthermore, Heller, Rogers and Perry [7] reported better numeral recognition using the Optacon, when the subjects were allowed to move their preferred index finger actively over the vibrotactile display.

There is a constraint on the advantages of active touch. It is hardly universal. There are a number of clear cases where passive touch can yield exceptionally high levels of recognition accuracy, especially when the stimuli are limited in scope or are highly familiar. Thus, a passive form of touch can be found when numbers or letters are drawn on the skin of the palm or fingers. It is relatively easy for subjects to name these patterns when they are drawn on the skin, and blindfolded sighted individuals can read words, if the letters are drawn large enough, and there is enough time between patterns. Passive touch is subject to after sensations when stimuli are drawn on the skin. Note that the digit span is relatively normal for drawing on the skin, given slow rates of presentation [8]. Deaf-blind people learn to communicate with sighted persons using this method, and one sees failures in identifying numerals printed on the fingers in parietal damage [9].

High performance with passive touch is possible, but is likely dependent upon familiarity and experience with the stimuli. This aids us to resolve the apparently conflicting results. Certainly, the advantages of active touch evaporate when we print letters or numbers on the skin. The answer involves familiarity, practice and skill. If one does not have categorical information about the nature of the stimuli that are passively presented, then recognition fails. Performance suffers when letters are printed with an irregular and unfamiliar writing style. These data support the notion that practice and skills are valuable to help overcome some of the limitations of passive touch.

We should also point out that the notion of active *versus* passive touch is often theoretically vague. Kinaesthesis can be active or passive, and intention is very difficult to operationalise. Nonetheless, there has been considerable interest in this theoretical issue, with a large number of studies in the literature [4].

Hand movements and haptic exploration

Lederman and Klatzky [10] showed that according to the type of information that people want to extract from an object, they executed different hand movements. They called these stereotyped hand movements exploratory procedures (EPs). Lederman and Klatzky [10] analysed the videotaped hand movement patterns executed by their participants while they intended to match objects in terms of different object attributes. Lederman and Klatzky proposed six different exploratory procedures. These authors reported that observers moved their hand systematically as a function of the attribute they were asked to look for. For example, when observers wanted to judge the weight of a certain object, they lifted the object from a supporting surface (*unsupported holding*