

Learning effects in haptic perception

Hubert R. Dinse, Claudia Wilimzig and Tobias Kalisch

Introduction

Human haptic perception is not a constant, but subject to manifold modifications throughout lifespan. Major determinants are development and aging as well as alterations following injury and compensatory brain reorganization. While during early development haptic perception is refined due to maturation and experience, haptic perception during aging deteriorates due to many factors, not all of them fully understood. Besides these lifespan factors, it is common wisdom that haptic perception and skills in general improve through practice (Fig. 1), see also [1]. Perceptual learning involves relatively long-lasting changes to an organism's perceptual system that improve its ability to respond to its environment and are caused by this environment. In case of Blinds or in Musicians, both characterized by superior haptic perception, improvement is assumed to be due to use-dependent or experience-dependent neuroplasticity mechanisms. In any case, enhanced haptic perception is due to learning processes occurring in brain areas devoted to processing of haptic information. Modeling these processes not only contributes to a better understanding of perceptual learning, but also of cortical processing constraints present under baseline conditions.

Hierarchy of tactile-haptic performance

Gibson [2] defined the haptic system as “*The sensibility of the individual to the world adjacent to his body by use of his body*”. The haptic perceptual system includes the peripheral recep-

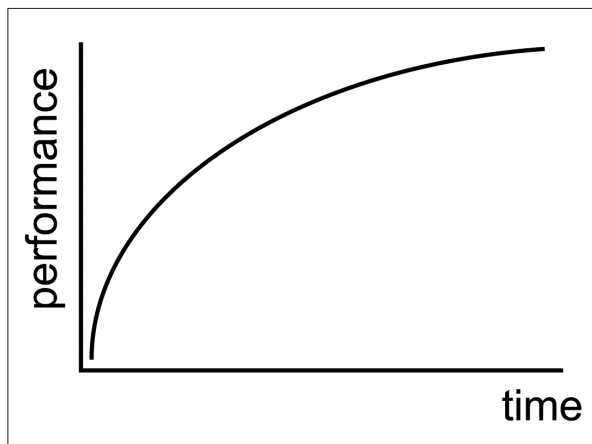


FIGURE 1. TIME COURSE OF IMPROVEMENT OF SKILLS OVER TIME.

Note rapid gain during the very early phase of practicing, while later additional improvement develops much slower indicating different mechanisms (see text).

tors and is closely linked to the movement of the body. Many people have emphasized that haptic perception is closely linked to the concept of active touch. In our studies on haptic learning we refer to the idea of a hierarchy of tasks and task complexities that differentially involves in a graded way influences from the periphery, cortical processing with differing amount of cognitive demand, and tasks including motor aspect such as fine motor performance. Haptic learning can target specific tasks without necessarily altering the entire hierarchy. The investigation of either connected or unrelated aspects of tactile and haptic performance can help to unravel underlying mechanisms of haptic performance.

TABLE 1. HIERARCHY OF TACTILE – HAPTIC-SENSORIMOTOR PERFORMANCE

Test	Peripheral	SI cortex Low cognitive	SI + higher areas High cognitive	sensorimotor action
	touch threshold Nerve cond. velocity	spatial discrimination two-point acuity hyperacuity gratings, dot pattern localization	recognition of known or arbitrary objects letters Braille characters	reaction times tapping peg board grasping grip strength
		everyday or arbitrary textures surfaces	symmetry shapes faces heights or widths	
		temporal discrimination frequency interval		

Dependence of haptic perception and learning on skin accessibility

The crucial role of skin coverage of the finger tips on tactile and haptic sensations and motor execution has been addressed in many studies. Figure 2 summarizes a comparison of different tasks performed in young adults and healthy elderly demonstrating that skin coverage severely impairs tactile function, however, in a highly task-dependent way. Moreover, the susceptibility is age-dependent, where some tasks such as two-point discrimination suffer little, while haptic object recognition suffers dramatically (Kalisch and Dinse, unpublished data, cf. also [3]). Remarkably, also motor performance depends on intact skin sensitivity. Recording of finger movement in expert touch typists under anesthesia of the right index fingertip increased typing errors of that finger seven-fold [4]. These studies emphasize that maximal tactile-haptic performance requires unrestricted skin access. However, little is known how prolonged skin coverage and training under coverage conditions

as is the case in surgeons alter dependence of haptic performance from coverage.

Perceptual learning in haptic perception

Although training and practicing plays a crucial role mediating improvement of skills, perceptual learning is not achieved by a unitary process [5, 6]. Psychophysicists have distinguished between relatively peripheral, specific adaptations and more general, strategic ones [7–9], and between quick and slow perceptual learning processes [10]. Cognitive scientists have distinguished between training mechanisms driven by feedback (supervised training) and those that require no feedback, instead operating on the statistical structure inherent in the environmentally supplied stimuli (unsupervised training). In any case, perceptual learning exerts a profound influence on behavior because it occurs early during information processing and