



# Spatiotemporal integration in somatosensory perception: effects of sensory saltation on pointing at perceived positions on the body surface

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In the past, sensory saltation phenomena (Geldard and Sherrick, 1972) have been used repeatedly to analyze the spatiotemporal integration capacity of somatosensory and other sensory mechanisms by means of their psychophysical characteristic. The core phenomenon consists in a systematic mislocalization of one tactile stimulus (the attractee) toward another successive tactile stimulus (the attractant) presented at another location, increasing with shorter intervals. In a series of four experiments, sensory saltation characteristics were studied at the forearm and the abdomen. Participants reported the perceived positions of attractees, attractants, and reference stimuli by pointing. In general, saltation characteristics compared well to those reported in previous studies, but we were able to gain several new insights regarding this phenomenon: (a) the attractee–attractant interval did not exclusively affect the perceived attractee position, but also the perceived attractant position; (b) saltation characteristics were very similar at different body sites and orientations, but did show differences suggesting anisotropy (direction-dependency) in the underlying integration processes; (c) sensory saltation could be elicited with stimulation patterns crossing the body midline on the abdomen. In addition to the saltation-specific results, our experiments demonstrate that pointing reports of perceived positions on the body surface generally show pronounced systematic biases compared to veridical positions, moderate intraindividual consistency, and a high degree of inter-individual variability. Finally, we address methodological and terminological controversies concerning the sensory saltation paradigm and discuss its possible neurophysiological basis.

**Keywords:** illusion, somatosensory perception, spatiotemporal integration

## INTRODUCTION

### THE SENSORY SALTATION PHENOMENON

Cutaneous perception relies on spatial and temporal integration mechanisms, which are limited to particular stimulation characteristics. Stimulation patterns not meeting these specifications may give rise to illusions and other paradoxical perceptions. Sensory saltation is one of these illusions, consisting of systematic distortions in the spatial perception of spatiotemporal stimulus patterns: if two stimuli are presented at two different positions with a short delay, the perceived position of the first stimulus is mislocalized toward the position of the second stimulus and this mislocalization increases with decreasing delays between the two stimuli. This phenomenon was first systematically evaluated by Frank A. Geldard and colleagues, originally introduced as cutaneous rabbit effect (Geldard and Sherrick, 1972); but Geldard later proposed sensory saltation as a more formal term (Geldard, 1973).

Saltation is not restricted to the tactile domain, but has also been demonstrated for cutaneous heat-pain stimuli (Trojan et al., 2006), auditory (Brenner et al., 1977; Hari, 1995; Shore et al., 1998; Phillips and Hall, 2001; Boehnke and Phillips, 2005; Getzmann, 2009) and visual spatial perception (Lockhead et al., 1980) as well as auditory pitch perception (Getzmann, 2007). These findings suggest that sal-

tation at the perceptual level reflects general spatiotemporal processing features of the sensory system. In line with an earlier suggestion by Geldard and Sherrick (1983), Wiener et al. (2000) argued that the saltation phenomenon may be the perceptual correlate of the dynamic behavior of sensory maps in the brain, more specifically, the primary somatosensory cortex. This assumption is supported by neurobiological studies, which demonstrate that the topography of activations found in the primary somatosensory cortex is a function of the spatial and temporal input statistics (Clark et al., 1988; Braun et al., 2006). In addition, a recent neuroimaging study demonstrated that activation in the primary somatosensory cortex indeed related to the perceived “illusory” position of saltatory stimuli (Blankenburg et al., 2006). It is conceivable that phenomena like the tau illusion (Helson and King, 1931; Ledholt and Borchert, 1977) or the ventriloquist effect (e.g., Alais and Burr, 2004; Soto-Faraco et al., 2004) may have similar neurophysiological bases.

A number of different, sometimes quite complex stimulus patterns were used in the classic studies at Geldard’s lab. However, the psychophysical characteristics of the core phenomenon are demonstrated best in the so-called *utterly reduced rabbit* and *reduced rabbit* patterns. In the *utterly reduced rabbit* pattern, only two stimuli are presented: the first stimulus is termed *attractor* and the second is

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