Lumbrical Muscles of the Hand as Sensors of Finger Position

Kenneth Horch

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While there are differences of opinion about the relative contributions of cutaneous, joint and muscle receptors to proprioception in the fingers, the consensus is that for static position sense (i.e., a sense of the absolute position of the fingers with respect to the hand) as distinct from a sense of movement or displacement of the fingers, stretch receptors in the muscles operating the fingers serve as the primary, if not exclusive, source of information (Clark et al., 1985; Clark and Horch, 1986; Clark et al., 1989; Ferrell and Craske, 1992; Cordo et al., 2000; Collins et al., 2005). This concept has been supported by our demonstration that dynamic and static control of joint position with peripheral nerve stimulation could be readily accomplished using recordings from muscle spindle afferents in stretched muscles as the sole source of feedback information (Yoshida and Horch, 1996). Thus we found it puzzling that intrafascicular micro-stimulation of ulnar and median nerve stumps in amputees could give rise to illusions of finger flexion but not extension, even though these nerves innervate only finger flexors and activation of stretch receptor afferents from these muscles should produce sensations of finger extension (Dhillon et al., 2004; Dhillon et al., 2005).

The answer to this conundrum may lie in the nature of the sensations the amputees report and in models of the intrinsic muscles of the hand by Leijnse and Kalker (Leijnse and Kalker, 1995) and Biggs(Biggs and Horch, 1999a, b). Intrafascicular stimulation of tactile afferents in the median and ulnar nerve stumps of amputees restores or creates the illusion of a “normal” hand in the subjects with some location on the volar aspect of the hand or finger being touched or pressed upon (Dhillon et al., 2005). The hand itself is perceived as being in a rest position with the fingers fully or nearly fully extended. Activation of proprioceptive afferents induces a sensation of one or more fingers curling (flexing) inward as if making a fist. The extent to which the fingers are flexed is a function of the rate of stimulation through the intrafascicular electrode (Dhillon et al., 2004; Dhillon et al., 2005). Since the fascicles in question innervate only the volar aspect of the hand and fingers, these sensations could not have arisen from stimulation of afferents from cutaneous stretch receptors on the back of the hand.

As Biggs has pointed out (Biggs and Horch, 1999b), the lumbrical muscles of the hand are unique in that both their origins and insertions are on tendons: they extend between the extensor hood and the extrinsic flexor tendons of the fingers at the level of the metacarpal-phalangeal (MCP) joint. As such, they are stretched by flexion of any of the three finger joints by the extrinsic muscles, alone or in combination. Leijnse and Kalker focused on trying to make a case for the lumbricals serving to make fine, rapid flexions of the MCP joint, but admit that their case is weakened by the relatively long stains required for these muscles to do so. Rather, the relatively large excursions experienced by these muscles during finger flexion, also noted by Biggs in his model, and their rich muscle spindle population make them prime candidates as sensors of finger position (Ranney and Wells, 1988). Since the spindles in these muscles cannot identify which of the three finger joints is being stretched, in the absence of any other information, the central nervous system would interpret increasing activity from these receptors alone as reflecting unloaded flexion of the fingers, which naturally assumes a fist-like pose.

On the basis of these considerations, I propose that the stretch receptors in the lumbrical muscles comprise a major source of information about finger position and that proprioceptive sensations evoked by focal electrical stimulation of ulnar and median nerve stumps in amputees arise for activation of lumbrical muscle spindle afferents.

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