Impaired sensorimotor integration for multi-digit grasping in patients with Carpal Tunnel Syndrome

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Introduction: In healthy individuals, feedback provided by tactile mechanoreceptors is processed and integrated with voluntary control of hand muscles to ensure successful interactions with objects of different properties. However, the ability to use cutaneous feedback to scale digit forces can be disrupted by a number of neurological and musculo-skeletal diseases, such as Carpal Tunnel Syndrome (CTS).

Materials and Methods: The goal of this study is to determine the extent to which patients with CTS can integrate tactile feedback from CTS-affected and non-affected digits to control forces during a 5-digit grasp. Our hypothesis is that patients with CTS will be less successful than controls at using prior sensory information to plan appropriate forces for object manipulation. We asked patients with CTS (n=6) and age- and gender-matched controls to grasp, lift, hold and maintain vertical a grip device using 5 digits. We changed object center of mass (CM) by placing a weight (0.1 Kg) at one of 3 locations at the base of the device, two of which produce an external torque causing the object to tilt. To assess the extent to which patients could appropriately sense object tilt and use this information in subsequent trials to modulate forces and minimize tilt, we changed object CM using a blocked design. Subjects performed a block of 7 trials (first two being practice trials)with the same CM, one block for each of the 3 CM locations. Repeated manipulation of the same object allows healthy subjects to plan the temporal evolution of manipulative forces such that their force coordination patterns are appropriate for use in subsequent trials. The extent to which forces were properly planned was assessed by measuring (a) force magnitude and across-trial variability during object hold, (b) magnitude of object tilt during lift and (c) linear covariation of forces across digit pairs during force rise phase (i.e., period from last digit-object contact until object lift). Correct force planning is revealed by (1) small across-trial force variability and (2) linear relations between digit pairs that are consistent across trials. Object tilt should be minimal when forces are appropriately planned as subjects can generate a net torque that matches the external torque with- out having to first sense object tilt during the lift. T-tests were computed to test for significant differences between the patients and control subjects.

Results: The results support our hypothesis that patients with CTS are less capable of using tactile information from previous experience to plan appropriate grip forces for subsequent manipulations. This is supported by 3 main findings. First, patients with CTS exhibited greater across-trial variability (coefficient of variation) in digit forces than did controls (Range across conditions and digits: 0.11-0.31 vs. 0.08 – 0.19, respectively). The difference in variability is evident in Fig. 1 showing representative force traces for one patient with CTS and one control subject.

Discussion: The larger variability in digit force coordination, coupled with the lower ability to control object orientation during lift, suggest impaired sensorimotor integration in patients with CTS. Unlike controls, patients with CTS adopted a strategy of producing very large forces at all digits to counteract the torque. This is inefficient as it may lead to fatigue and further exacerbate median nerve compression and is also ineffective for dextrous object manipulation. These behavioral deficits could lead to problems in activities of daily living and patients’ feelings of “clumsiness”, e.g., difficulties with fine manipulation, dropping objects, spilling drinks, etc. Ongoing work is addressing the extent to which patients with CTS are able to coordinate digit actions as a function of the number of digits involved in the grasp.

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Fig. 1. Forces for each digit (rows) over all trials for one control subject (A) and one patient with CTS (B). Left and right columns show data from finger and thumb side CM, respectively.

This figure also illustrates the fact that patients produced significantly larger forces than did controls (means ± std: 30.69 ± 9.25 N vs. 23.5 ± 8.04 N, respectively; P < 0.001). Grasping literature indicates that preparation of grip forces is evident prior to object lift, i.e., during the force rise phase, at which time grip forces are highly coordinated. Therefore, we examined the linear covariation of forces across all digit pairs during this phase of the grasp. As illustrated in Fig. 2, the linear relations (i.e., slopes) of forces between digit pairs were more variable across-trials in the patients than in the controls (Range across conditions and digit pairs: 0.03-1.35 vs. 0.03 – 0.43, respectively). These impairments resulted in greater object tilt in patients than in controls (1.71° ± 0.86° vs. 1.18° ± 0.61°; P < 0.001, respectively).

Fig. 2. Force covariation of three digit pairs during force rise phase (CM on finger side) for the same control and patient (top and bottom panels, respectively) as in Fig. 1.

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