Motoric Stroke Differentially Affects Finger Independence

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1. Introduction

Cerebrovascular accidents, resulting in hemiparesis, often lead to difficulty making hand and finger movements. Although it is well-known that hemiparetic patients are often unable to produce fine finger movements, the capacity to move each finger independently has never been studied quantitatively in people with lesions of the motor cortex or the corticospinal tract. The purpose of this study was to examine the effects of motoric stroke on individuated finger movements. We wondered if motoric stroke would affect the ability to independently move each finger to the same degree or if it would affect some fingers more than others.

2. Methods

Subjects. We studied 4 subjects with motoric stroke and 10 control subjects (age range: 19 – 47 yrs). Characteristics of the subjects with motoric stroke are given in the table below. Subjects with motoric stroke had ischemic lesions to the motor cortex or its descending pathways. All of the stroke subjects had motor hemiparesis without concommitant sensory or cognitive losses. Additionally, all of these subjects had had substantial recovery in the severity of their initial clinical symptoms.

SUBJECT	AGE	GENDER	LESION LOCATION	TIME SINCE STROKE	INITIAL HEMIPARESIS IN:	CURRENT HEMIPARESIS IN:
MST-01	70	M	Left motor cortex	34 months	Face, Arm, Hand	Hand
MST-02	72	F	Left corona radiata	29 months	Arm, Hand, Leg	Arm, Hand
MST-03	66	M	Left pons	5 months	Face, Arm, Hand, Leg	Arm, Hand, Leg
MST-04	55	M	Left pons	2 months	Face, Arm, Hand, Leg	Arm, Hand, Leg

Paradigm. We tested the ability of the subjects to make individuated finger movements. Subjects were seated with their forearm and wrist supported on a table in front of them. Subjects were instructed to make cyclic flexion/extension movements of each finger in turn, and to keep the other, non-instructed fingers still. Subjects moved their fingers at a self-selected "comfortable pace" and through a "comfortable range of motion".

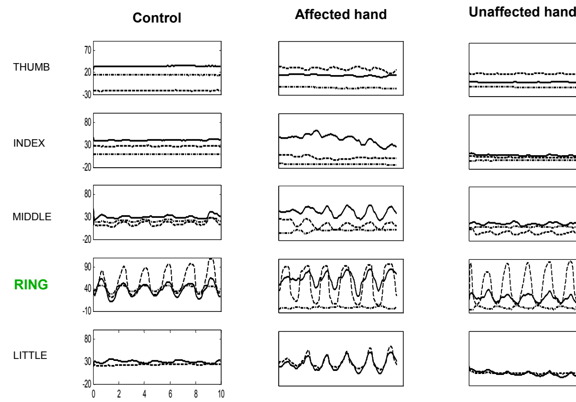
Data Collection. Finger joint movement was recorded using a right or left instrumented glove. We examined data from 15 of the available 22 sensors: opposition, metacarpophalangeal (MCP) and interphalangeal (IP) sensors of the thumb and the MCP, proximal IP (PIP) and distal IP (DIP) sensors for the other 4 fingers. Prior to data collection, the glove sensors were calibrated for each subject's hand.

Analysis. Fingertip position was calculated from measured finger segment lengths and joint angles. Averaged path distance for each fingertip for each instructed movement were normalized to the average path distance when that finger was the instructed one. This normalized average path distance was our measure of relative motion. We quantified finger independence by calculating an Individuation Index (II) and Stationarity Index (SI) for each finger (modified from methods in Schieber 1991).

$$II_{ij} = 1 - [(\sum_{i=1}^{n} |D_{ij}|) - 1]/(n-1) \qquad SI_i = 1 - [(\sum_{j=1}^{m} |D_{ij}|) - 1]/(m-1)$$

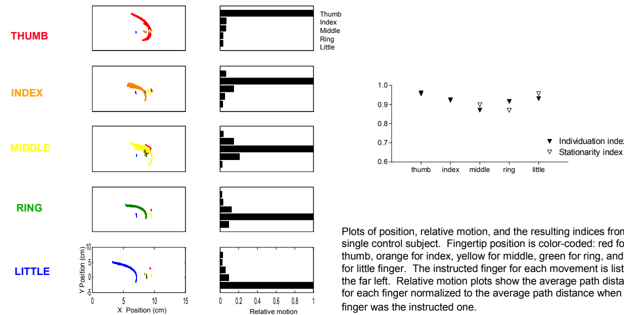
The II shows the extent to which a finger is able to move independently, i.e. without the other fingers moving. The SI shows the extent to which a finger is able to remain motionless, when it is not the instructed one. The indices will be close to 1 for a finger that moves alone (II) or does not move when not instructed (SI).

3. The non-instructed fingers in the affected hand of a stroke subject (MST-03) move more than the non-instructed fingers in the unaffected hand and in a control hand.



Plots of the 15 measured joint angles vs. time for a control subject and the affected and unaffected hand of a stroke subject during one trial. The ring finger was the instructed finger in this trial. The solid line shows MCP movement, the dashed line shows PIP movement, and the dash-dot line shows DIP movement, except for the thumb, where the dashed line represents opposition and the dash-dot line represents IP movement.

4. The fingers of a control subject move almost, but not completely independently.



Plots of position, relative motion, and the resulting indices from a single control subject. Fingertip position is color-coded: red for thumb, orange for index, yellow for middle, green for ring, and blue for little finger. The instructed finger for each movement is listed on the far left. Relative motion plots show the average path distance for each finger normalized to the average path distance when that finger was the instructed one.

5. The fingers of the affected hand of a stroke subject (MST-03) are much less able to move independently. Independence of the thumb is the most preserved. The fingers of the unaffected hand are similar to controls.

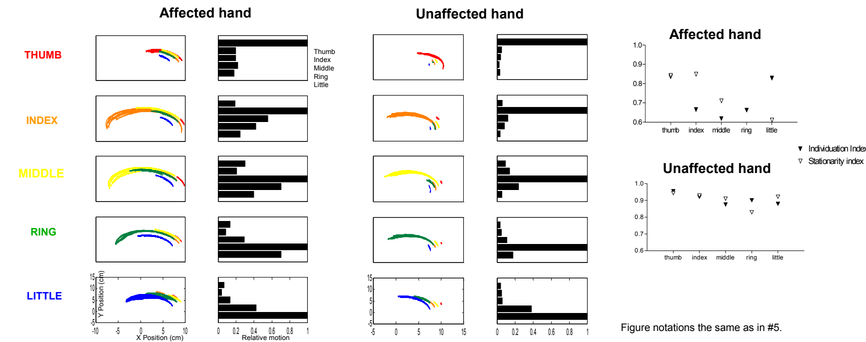
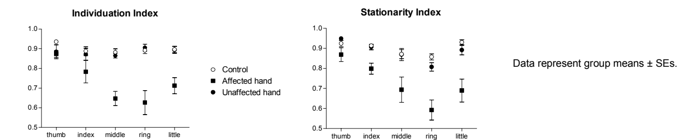


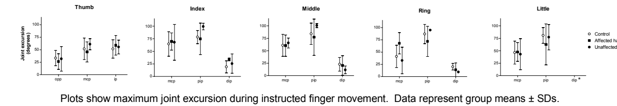
Figure notations the same as in #5.

6. The loss of ability to move the fingers independently is most pronounced in the middle, ring, and little fingers on the affected hand of the stroke group.



Data represent group means ± SEs.

7. The control, affected and unaffected fingers move through similar joint excursions.



Plots show maximum joint excursion during instructed finger movement. Data represent group means ± SDs.

8. Conclusions

The ability to move independently is most impaired in the middle, ring, and little fingers on the affected hand of stroke subjects in our small sample.

The unaffected hand of stroke subjects is not different from control subjects.

We hypothesize that the differential effects of motoric stroke on finger independence may be due to: 1) greater cortical representation of the thumb and index finger, 2) greater rehabilitative training on tasks requiring individuated thumb and index finger movements, and/or 3) an unmasking of subcortical, spinal, and peripheral constraints on finger independence that have a greater effect on the middle, ring, and little fingers.

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