Measuring distal function in post-stroke paresis

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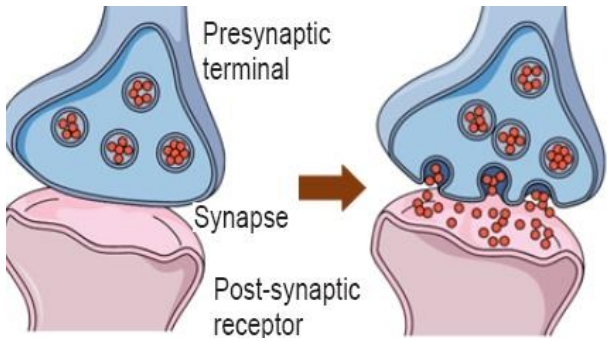
ICF-based approach to post-stroke UL-paresis

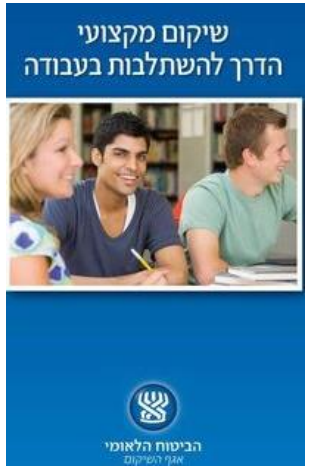
Impairment of Body Structure → Impairment of Body Function → Activity Limitation → Participation Restriction

Restitution Substitution

Compensatory measures

Social & Environmental measures





ICF-based approach to post-stroke UL-paresis

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Impairment of Body Function

Activity Limitation

Participation Restriction

Restitution
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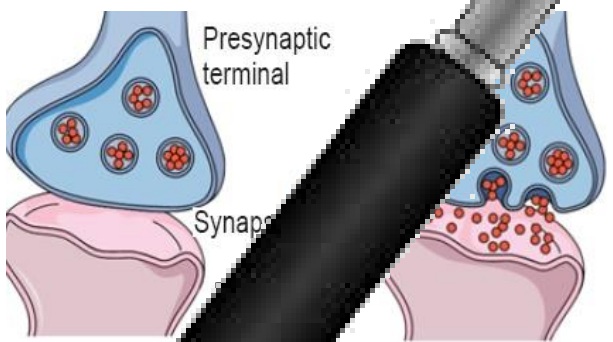
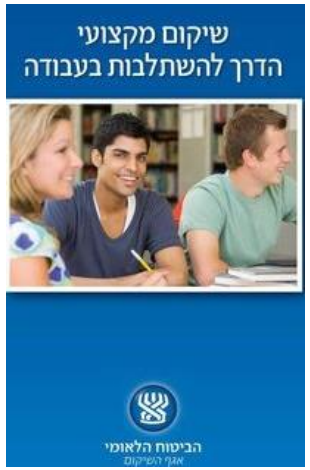
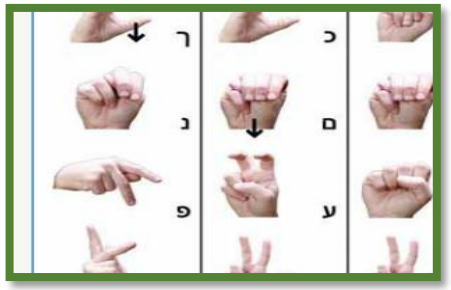
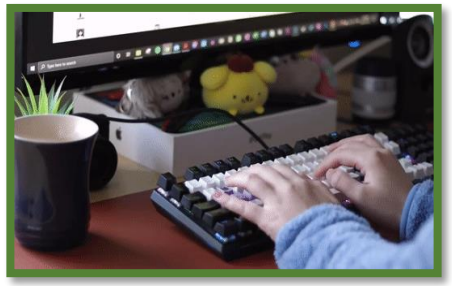
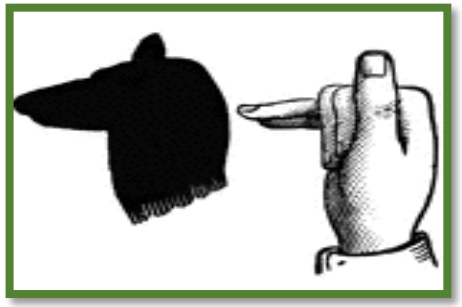




Examples of tasks requiring good distal function







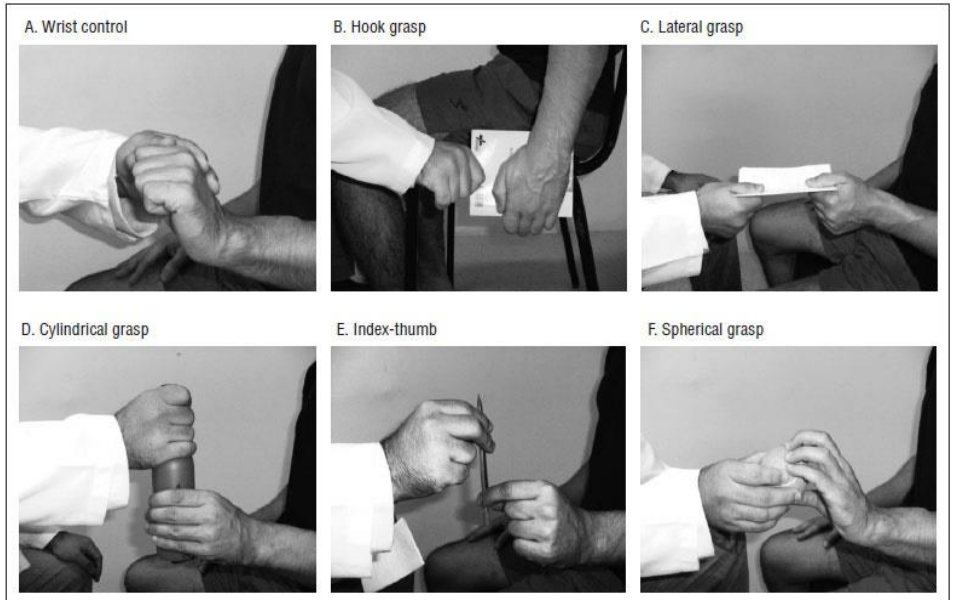
no contact

contact without prehension

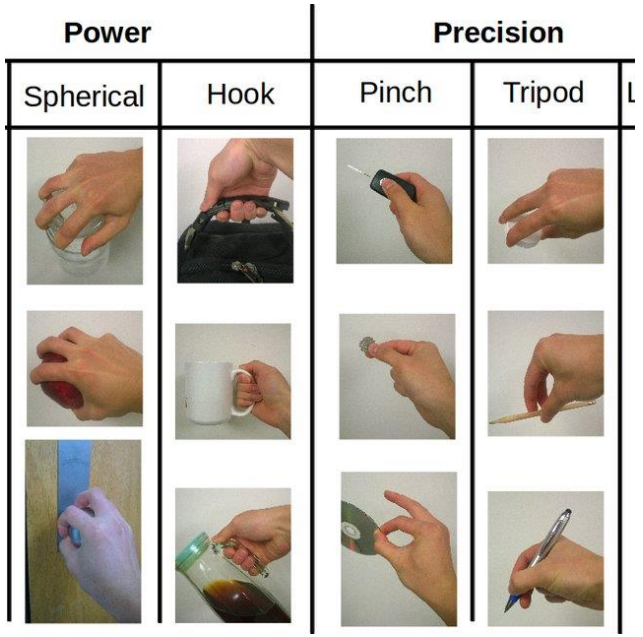
contact with prehension

Measuring distal UL function

- Current clinical tests do are mainly concerned with **prehension**
- However, prehension is not the sole aspect of hand function



FMA-UE



ARAT

Dynamometry

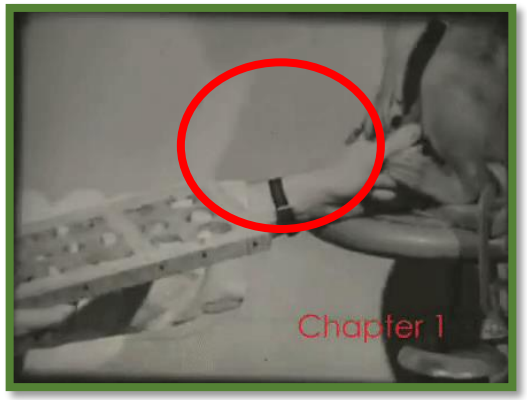
NHPT

B&B

Prehension strength and fingers dexterity are dissociated

- Our understanding of hemiparesis is largely based on animal models.
- Lawrence and Kuypers (1968):

Before CST lesion

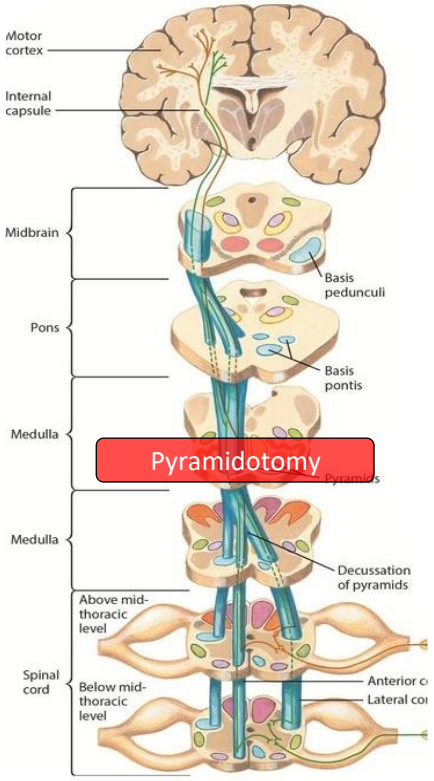


Normal Dexterity

After CST lesion

Impaired Dexterity

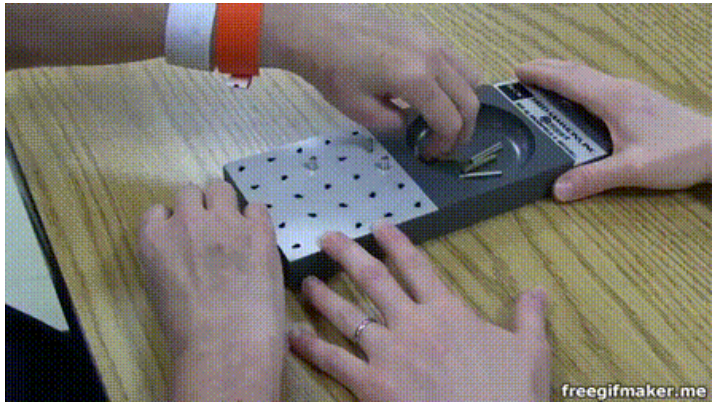
Intact Strength



Corticospinal Tract

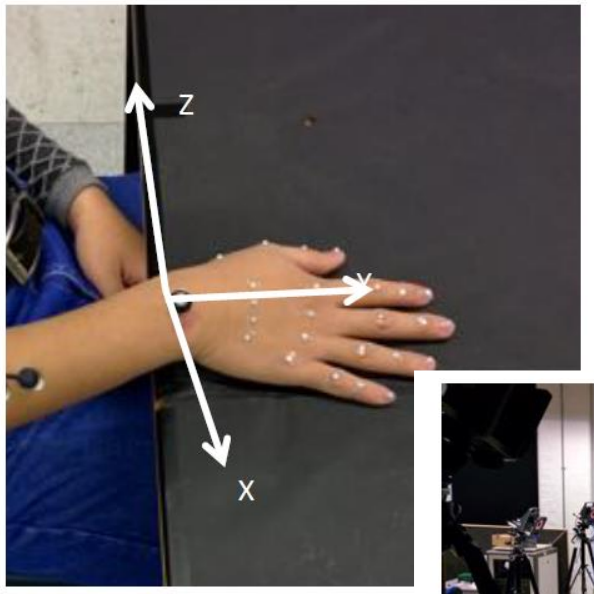
Searching for bio-markers of dexterity

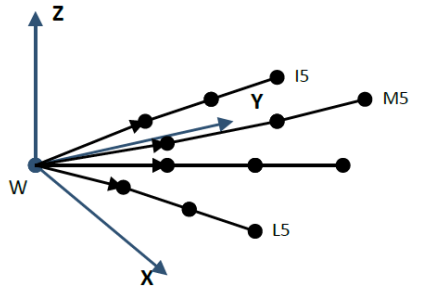
- Dexterous fingers movement requires precise force exertion patterns, not only prehensile strength
- Such patterns differ between tasks and are difficult to standardize
- Proper quantification requires a simplistic task

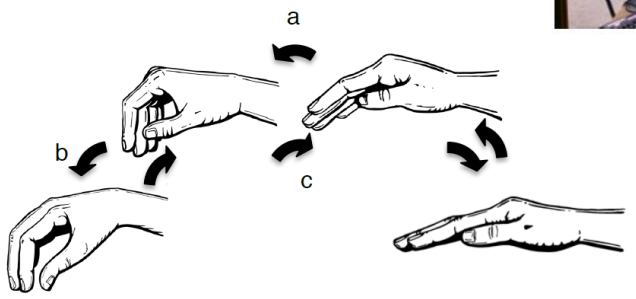


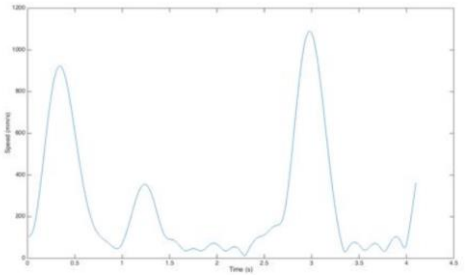
Detailed Kinematic Analysis of Fingers movement

- Requires sophisticated equipment and setup
- Long patient preparation
- Can be done in the context of very specified task
- Difficult for analysis – a multitude potential parameters





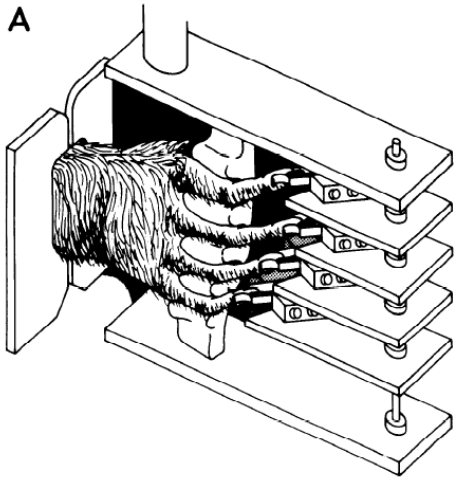


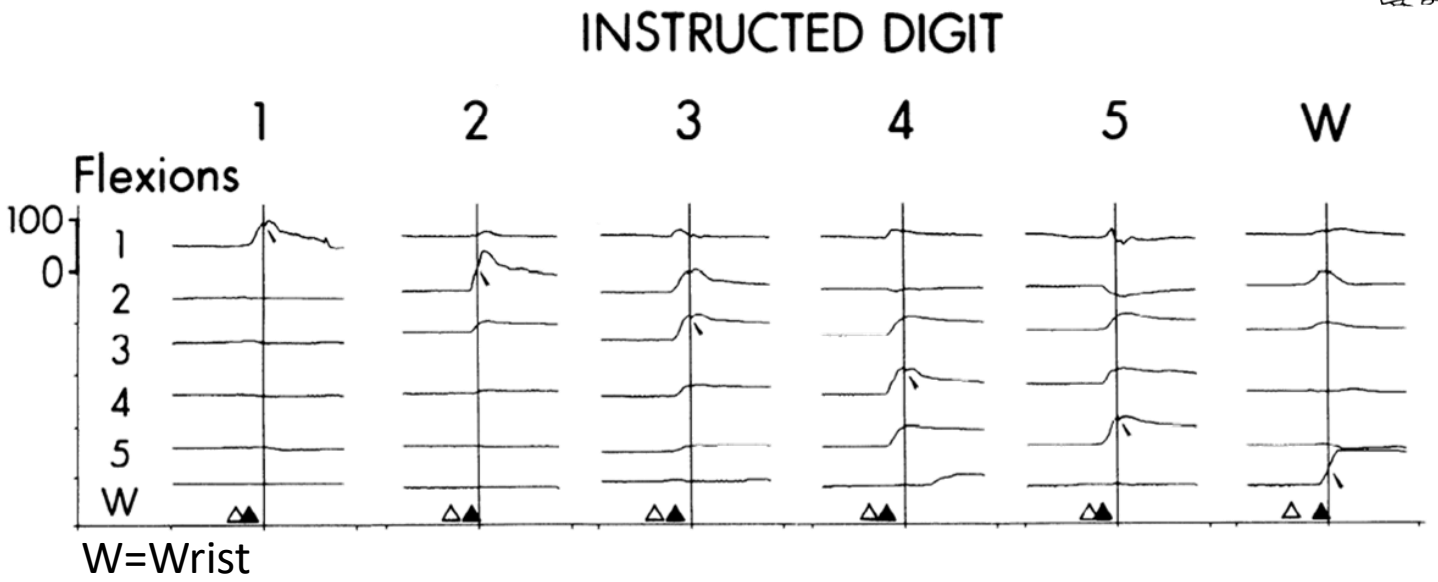


Sanchez 2016: Development of Dexterity Assessment Method (PhD dissertation)

Individuation and Stationarity Indices

- First described by Scheiber in 1991 for non-human primates
- Under ideal conditions, a subject should be able to move one finger without concomitant movements in other fingers

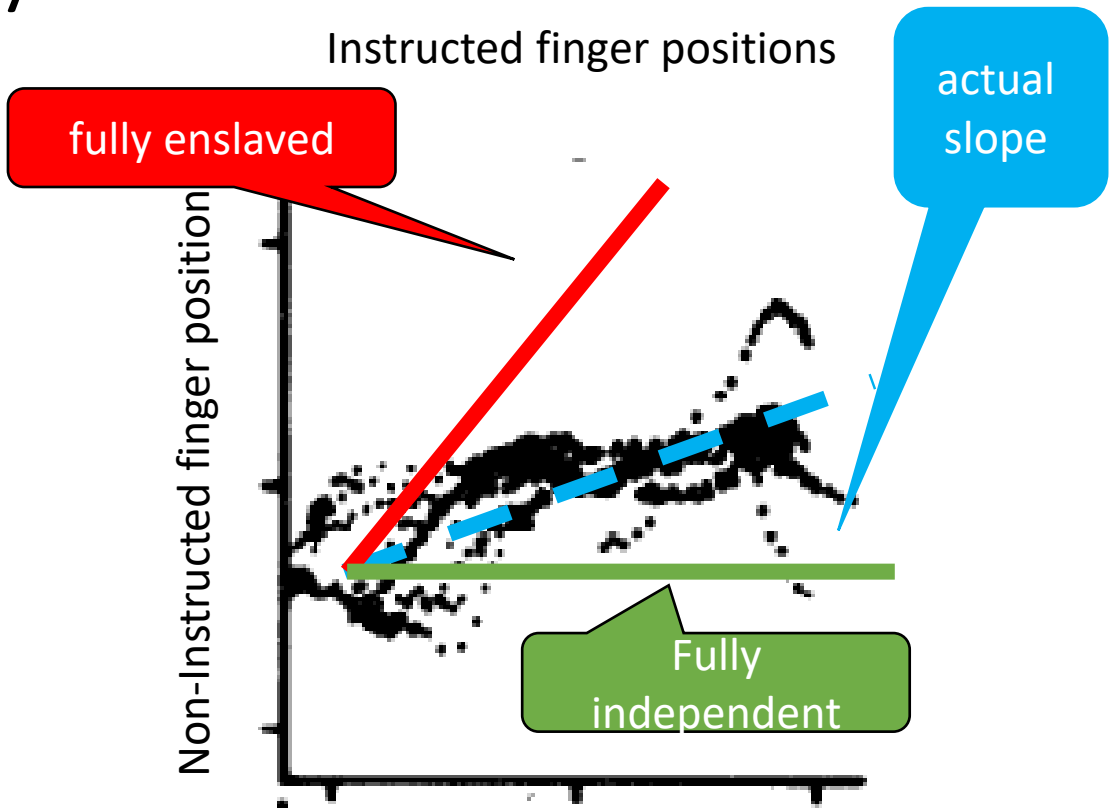




Scheiber, J Neurophysiol, 1991

Individuation and Stationarity Indices

- When plotting the position of a non instructed finger against that on the instructed one, once fit a line using least-squares technique
- The slope of the obtained line expresses the extent to which the non-instructed finger moves together with the instructed one.
- The **individuation index (II)** is a mean of the slopes across instructed fingers
- The **stationarity index (SI)** is a mean of the slopes across non-instructed fingers



$$II_j^d = 1 - \frac{\left(\sum_{i=1}^{n} |\bar{S}_{ij}^{\,d}|\right) - 1}{n - 1}$$

"Selective Activation"

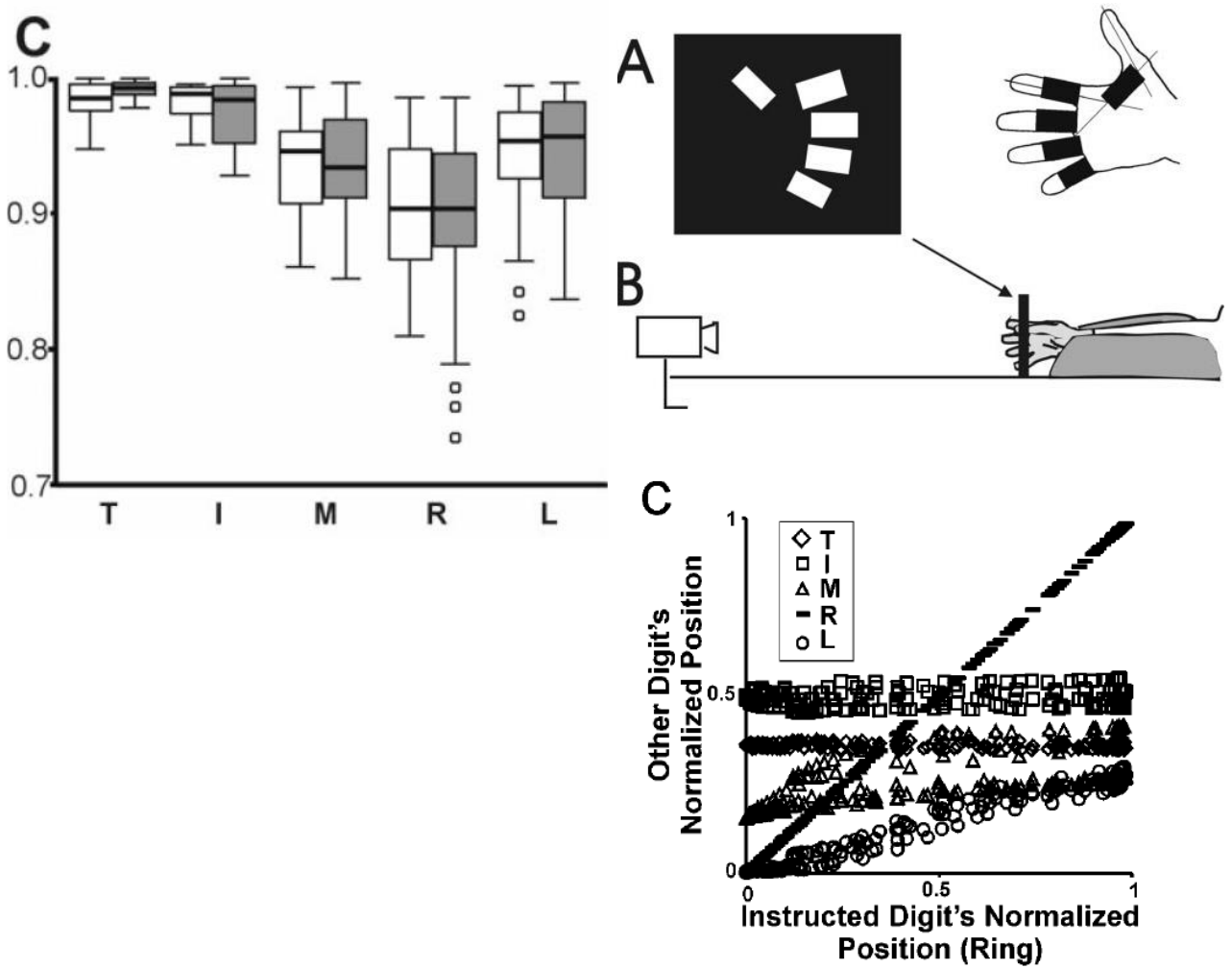
$$SI_i^d = 1 - \frac{\left(\sum_{j=1}^{m} |\bar{S}_{ij}^{\,d}|\right) - 1}{m - 1}$$

"Selective Inhibition"

Scheiber, J Neurophysiol, 1991

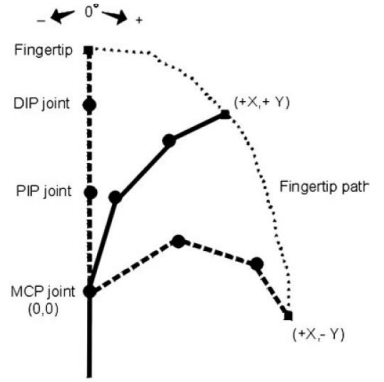
Finger Individuation among humans

- Healthy subjects performed finger flexion and extension, one finger at a time in a comfortable pace
- Amplitude was set to the the length of the proximal phalanx. 1st web
- Humans perform more individuated movement than monkeys.
- There was no significant effect of hand dominance
- Thumb and Index are better than Middle, Ring and Little

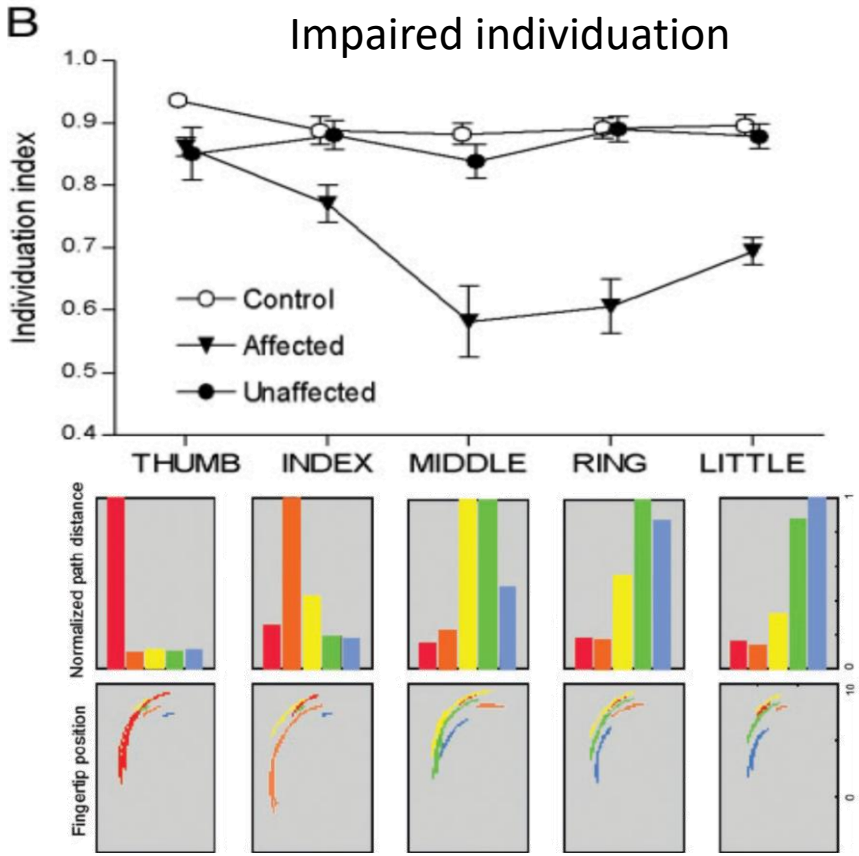


Scheiber & Haggar-Ross, J Neurosci, 2000

Kinematic Finger individuation among stroke subjects



- Stroke patients with hemiparesis demonstrate impaired individuation and stationarity relative to controls
- It seems that the extent of impairment is related to clinical measures.
- The thumb tend to be the least impaired finger

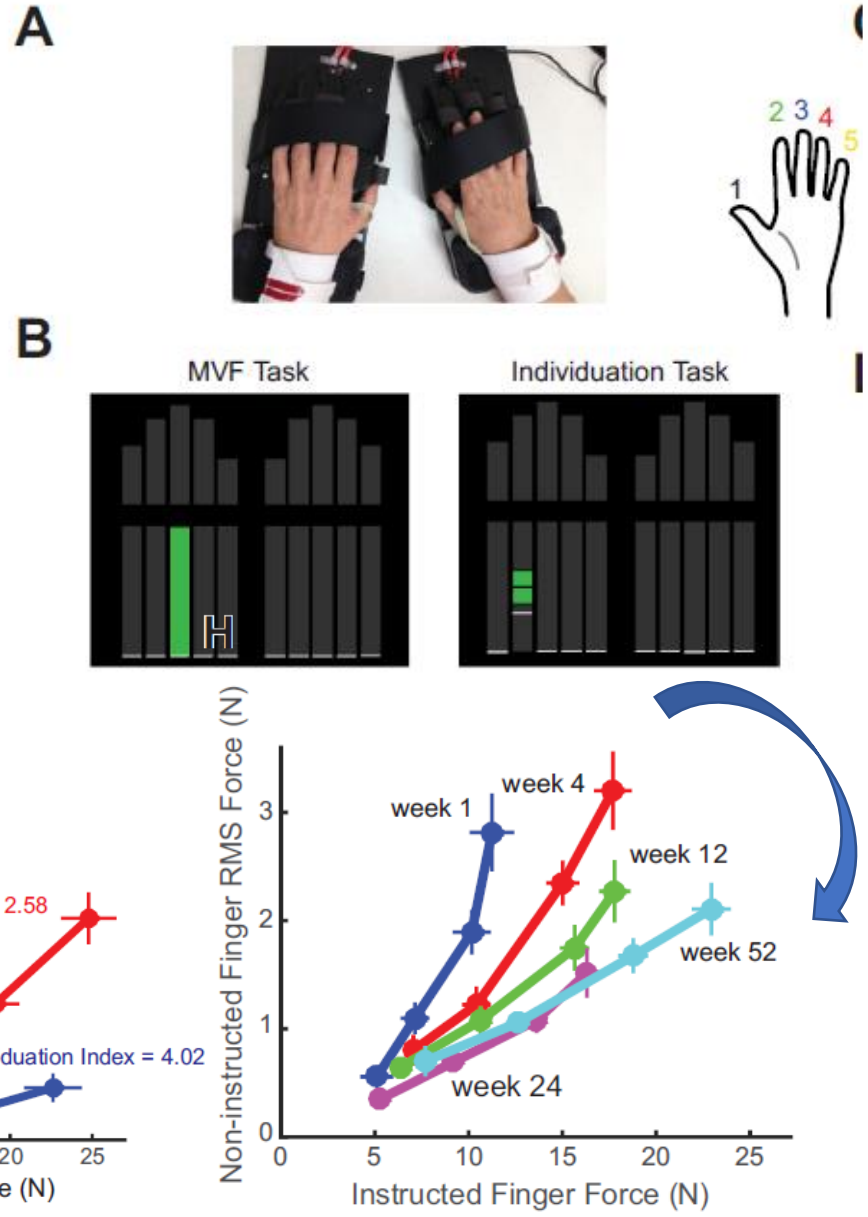


Lang & Scheiber, J Neurophysiol, 2003; Raghavan et al., J Neurophsiol, 2006

Kinetic Individuation Index

- Measurement of finger-exerted forces during isometric task
- Similar idea as in kinematic individuation index

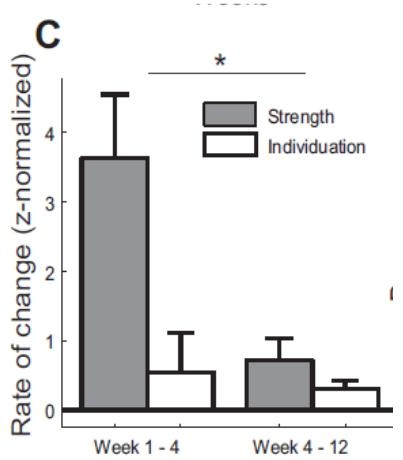
$$II = -\log(slope)$$



Xu et al., J Neurophysiol., 2017

Kinetic Individuation Index might be a bio-marker of dexterity

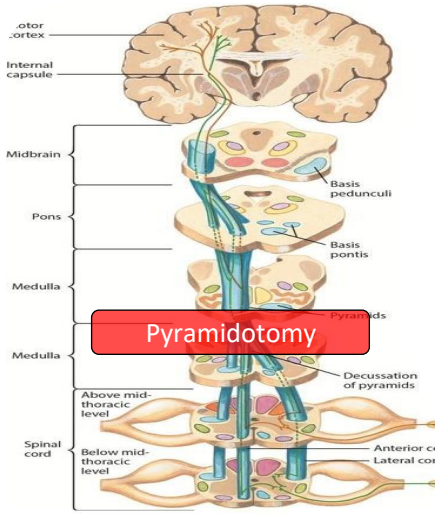
- Kinetic Individuation tend to improve less than strength in the post-stroke months
- Kinetic Individuation improvement is negatively corelated with CST lesion load



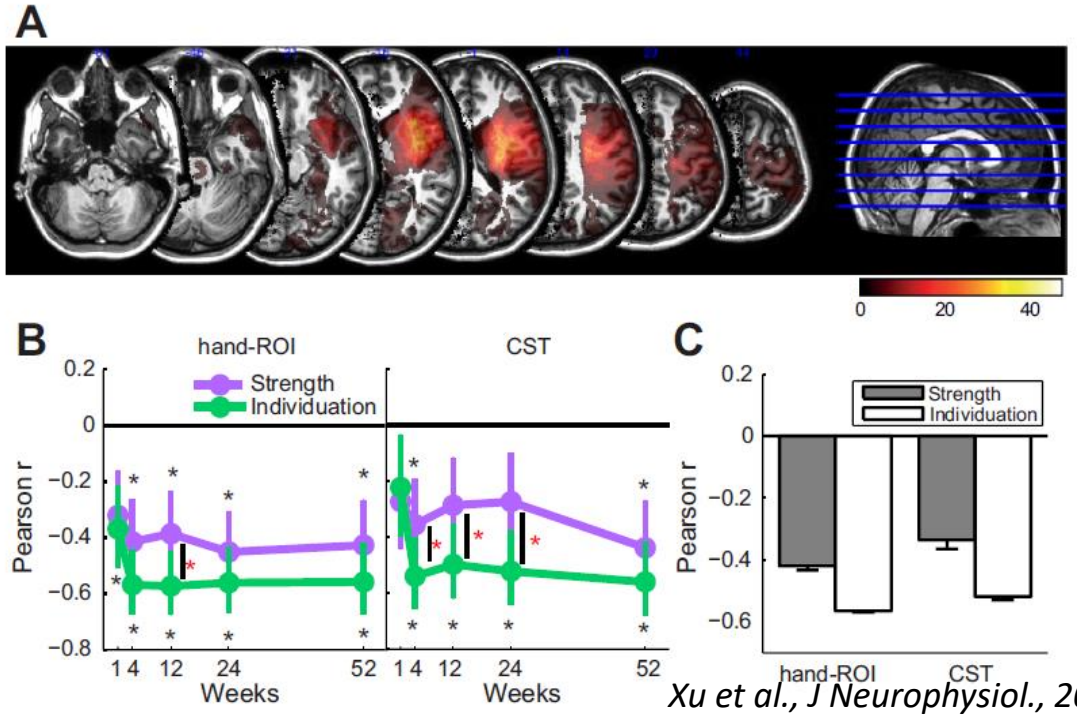
After CST lesion

Impaired Dexterity

Intact Strength



CST



Xu et al., J Neurophysiol., 2017

Correlation of Individuation Index with other clinical measures

- Individuation index generally correlates with FMA-UE, ARAT and other clinical measures
- The correlation is not perfect: clinical measures require both strength and individuation

Correlation of average Kinetic Individuation Index with FMA-UE and ARAT

	Strength Index	Individuation Index	FM-Arm	ARAT
Strength Index		0.73	0.76	0.74
Individuation Index			0.68	0.72
FM-Arm				0.91

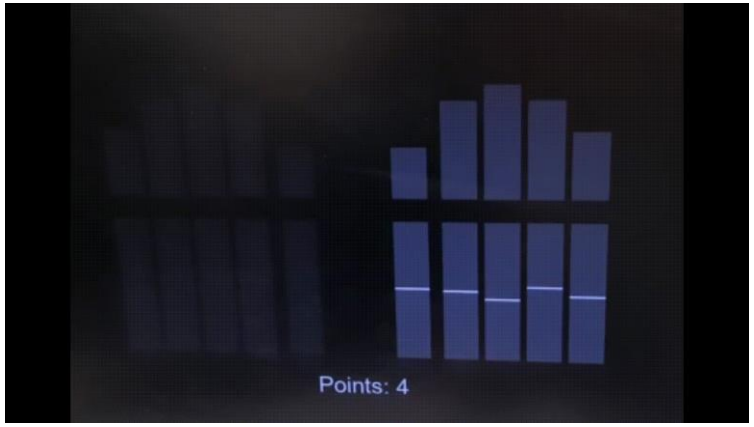
Xu et al., J Neurophysiol., 2017

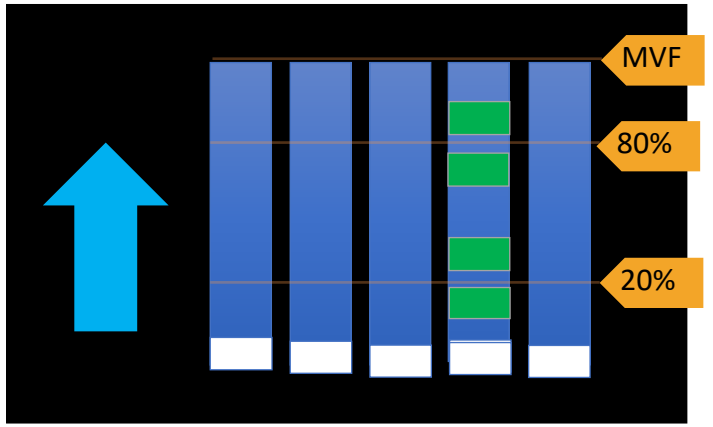
Correlation of Kinematic Individuation Index with Jebsen-Taylor Hand Function Test

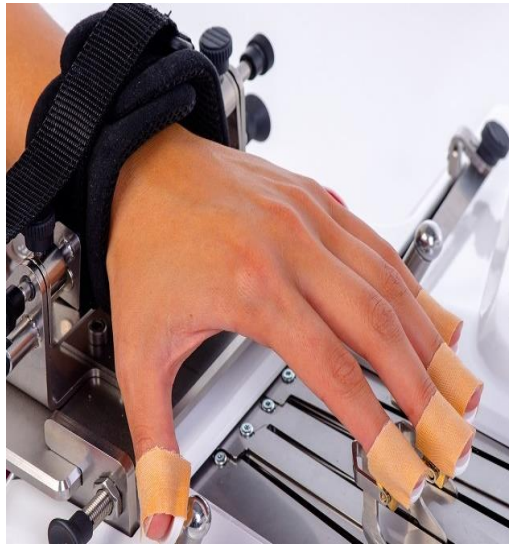
Thumb	-0.528 (p = 0.01)
Index	-0.516 (p = 0.01)
Middle	-0.431 (p = 0.04)
Ring	-0.538 (p = 0.01)
Little	-0.507 (p = 0.01)

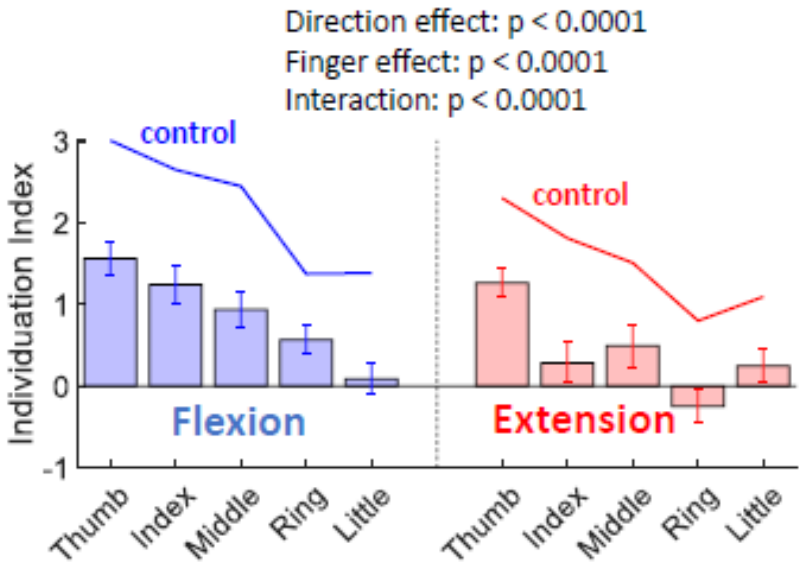
Lang & Scheiber, J Neurophysiol, 2003

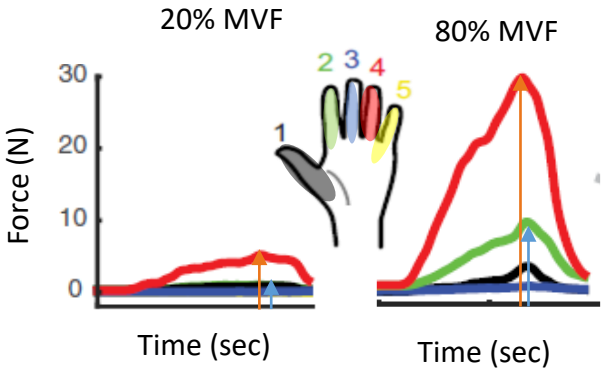
Kinetic Individuation using AMADEO™

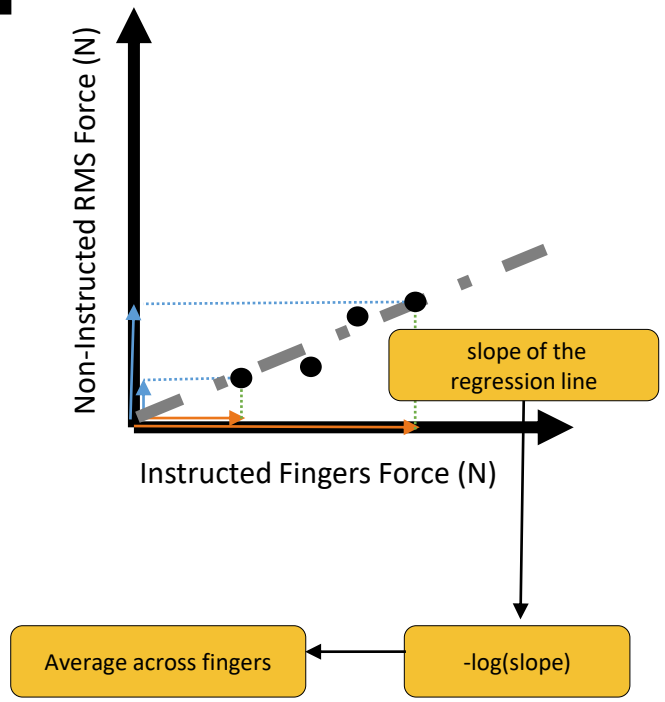












Rejarchrt et. al,2022; Poster

Take Home Messages

- Kinetic and kinematic measures of individuation can capture a unique aspect of dexterity
- This aspect is not captured well by clinical scales which are prehension-dominated
- Albeit, computing these measures require specialized equipment, software and skill
- Incorporating accurate measures of dexterity should be the standard of interventional studies in rehabilitation studies dealing with post-stroke hemiparesis.