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Reduced complexity, task-relevant information and altered spatiotemporal coordination in finger control after stroke

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Introduction

The complex, dynamic and variable nature of the human hand movement contributes to difficulties in injury assessment and design of effective rehabilitation strategies. Previous investigations into hand function have revealed much about the complexity of end-point hand postures (Yan & Bensmaia, 2020) and the loss of the complexity after stroke (Xu et al, 2021), but yet to explore the spatiotemporal structures of multi-finger coordination. Investigating these structures remains a challenge because it is difficult to quantify across individuals, diseases, and tasks.

Goal: To investigate the spatiotemporal structures underlying paretic hand movement by using Principal Component Analysis (PCA) and Linear Discriminant Analysis (LDA) to analyze trajectories of isometric fingertip forces.

Hypothesis: Spatiotemporal coordination structures underlying impaired finger individuation will show **(1)** Reduced complexity, **(2)** Reduced task relevant information, and **(3)** Altered spatiotemporal coordination structures compared to healthy controls' dominant hand.

Methods

Participants: Healthy older adults (N=30) and individuals with stroke (N=13).
3D Isometric fingertip forces recorded from stroke survivors' non-paretic and paretic hands and healthy control's dominant hand.

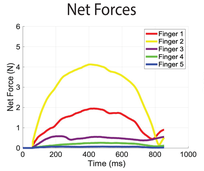
+X: adduction of MCP
-X: abduction of MCP
+Y: extension of PIP
-Y: flexion of PIP
+Z: extension of MCP
-Z: flexion of MCP

SCAN US!!!

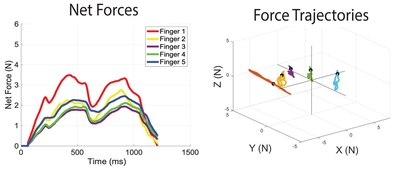
Exemplar healthy control hand

Exemplar paretic hand

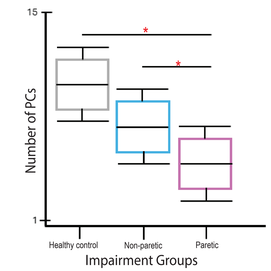
Healthy Individual
Finger 1 (Thumb) X+



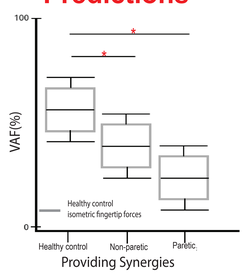
Stroke Survivor
Finger 1 (Thumb) X+



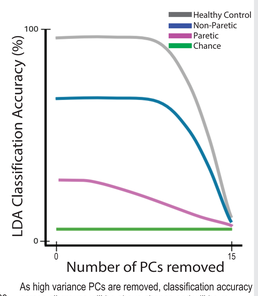
Predictions



Paretic hands will require fewer PCs compared to non-paretic and paretic hands to explain the same amountof variance

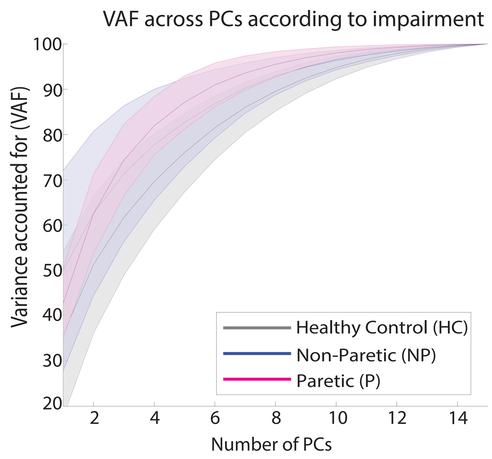


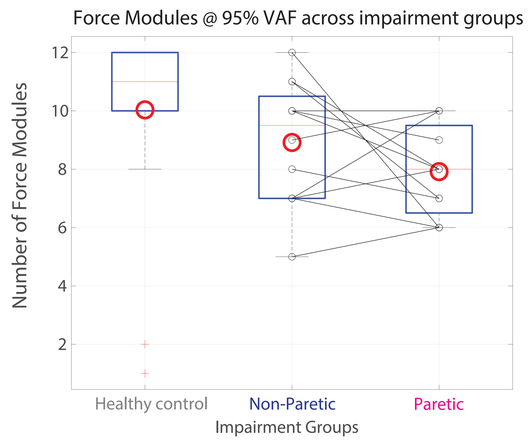
Spatiotemporal structures extracted from post-stroke hands will be unable to reconstruct healthy hands' isometric fingertip forces



As high variance PCs are removed, classification accuracy across all groups will be above chance and will be reduced for stroke hands compared to healthy

Reduced complexity in paretic hands compared to healthy and non-paretic hands

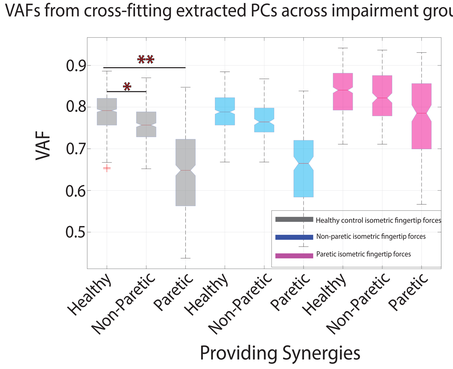




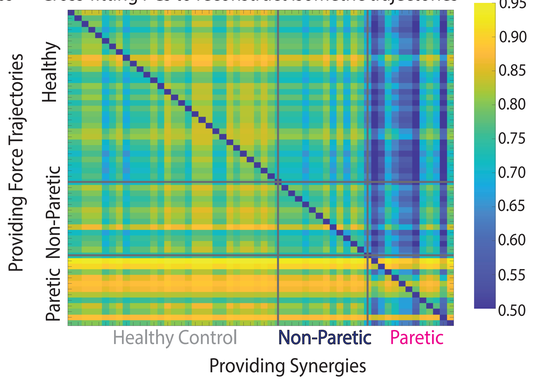
Paretic hands (M = 7.92, SD = 1.56) required fewer Principal Components than healthy hands (M = 10.02, SD = 2.96) ($p = 0.012$) to explain 95% of variance in force trajectories.

Spatiotemporal structures underlying impaired finger individuation are altered post-stroke

VAFs from cross-fitting extracted PCs across impairment groups

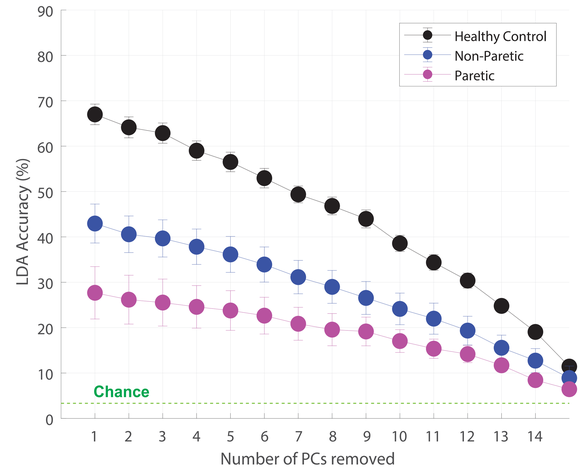


Cross-fitting PCs to reconstruct isometric trajectories



Spatiotemporal coordination structures extracted from paretic and non-paretic hands were less able to reconstruct healthy controls' isometric fingertip force trajectories than structures extracted from healthy controls' dominant hands (paretic vs. healthy control: $p < 0.001$; non-paretic vs. healthy control: $p = 0.046$).

Reduced task-relevant information post-stroke hands than healthy hands



- Classification accuracy across groups were above chance after gradual PC removal from the largest to the smallest VAF.
- Reduced mean task classification accuracy for paretic hands compared to non-paretic hands (paretic vs non-paretic: $p = 0.008$) and healthy control (paretic vs. healthy control: $p < 0.001$), and non-paretic compared to healthy control (NP vs. HC: $p = 0.005$).

Discussions

- Stroke reduces complexity, task-relevant movement, and alters spatiotemporal structure of isometric fingertip force coordination.
- Insights from this study serves as the foundation to further explore how spatiotemporal structures are altered post-stroke.
- These insights may help to further advance precise and personalized theraputics aimed at correcting impairments in the hand's spatiotemporal coordination.
- A limitation of this study is that does not consider alternative methods of extracting spatiotemporal coordination structures for linear behaviors (e.g. Non-negative Matrix Factorization) and non-linear methods (e.g. Autoencoders and Recurrent Neural Networks).

References

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