

Recruitment of Small Synergistic Movement Makes a Good Pianist

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What Can We Learn From Pianists?

- Interested in coordination
- How does practice manifest in experienced pianists?



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Are There Differences in How the Fingers Move ...

- Individually? - joints
- Together? - simultaneous movement
- Independently? - sequential movement

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Aim:

Can we identify fundamental differences in movement of novice & experienced pianists

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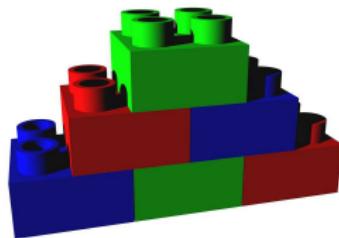
Can we identify fundamental differences in movement of novice & experienced pianists

Subjects:

- 5 novices - little or no experience
- 5 experienced - either grade 8 (1-8) or concert level

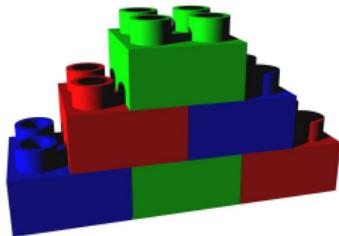
Movement Synergies

- Fundamental patterns of movement
- Serve as building blocks
- Reduce complexity (degrees of freedom) to be controlled
- Requires few components to explain variance in movement



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Kinematics

- Movement recorded using data glove
- 14 sensors
 - 2 per finger (MCP, PIP)
 - 4 abduction
- Rate of flexion analyzed

Music

Practical Exercises for Beginners, Op.599
Carl Czerny

Five-finger Exercises with quiet Hand.

The image shows three staves of musical notation for piano. Each staff begins with a treble clef and a common time signature (C). The first staff consists of eight measures, each containing a single note. Fingerings are indicated above the notes: measure 1 (two notes) has fingerings 1, 3, 1, 3; measure 2 (one note) has finger 5; measure 3 (one note) has finger 2; measure 4 (one note) has finger 5; measure 5 (one note) has finger 4; measure 6 (one note) has finger 2; measure 7 (one note) has finger 3; and measure 8 (one note) has finger 2. The second staff also consists of eight measures, with fingerings 2, 5, 4, 2, 1, 2, 3, 5 respectively. The third staff follows a similar pattern with fingerings 3, 5, 4, 2, 1, 2, 5, 4. Measures are separated by vertical bar lines, and a double bar line with repeat dots is positioned between the second and third staves.

- Taken from Czerny Op. 599 - designed to improve fingering of novice pianists
- Static hand using all 5 fingers

Music

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Five-finger Exercises with quiet Hand.

The image shows three staves of musical notation for piano. The notation is in common time (indicated by 'C') and uses a treble clef. Fingerings are indicated above the notes. A red box highlights a specific sequence of notes on the second staff: a note with finger 1, followed by a note with finger 3, and another note with finger 1. This sequence is part of a larger pattern of eighth-note chords.

For analysis:

- Select 3 consecutive notes
- Capture transitions before & after the key press of interest

Music

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Five-finger Exercises with quiet Hand.

The image shows three staves of musical notation for piano. The notation is in common time with a treble clef. Fingerings are indicated above the notes: the first staff has 1 3 4 3 5; the second staff has 2 5 4 2 1; and the third staff has 4 2 1. A red box highlights a group of three notes on the second staff, specifically the notes 1, 3, and 1. The music consists of a series of eighth-note chords followed by a double bar line and then more chords.

For analysis:

- Select 3 consecutive notes
- Capture transitions before & after the key press of interest
- Identify finger playing middle note

Music

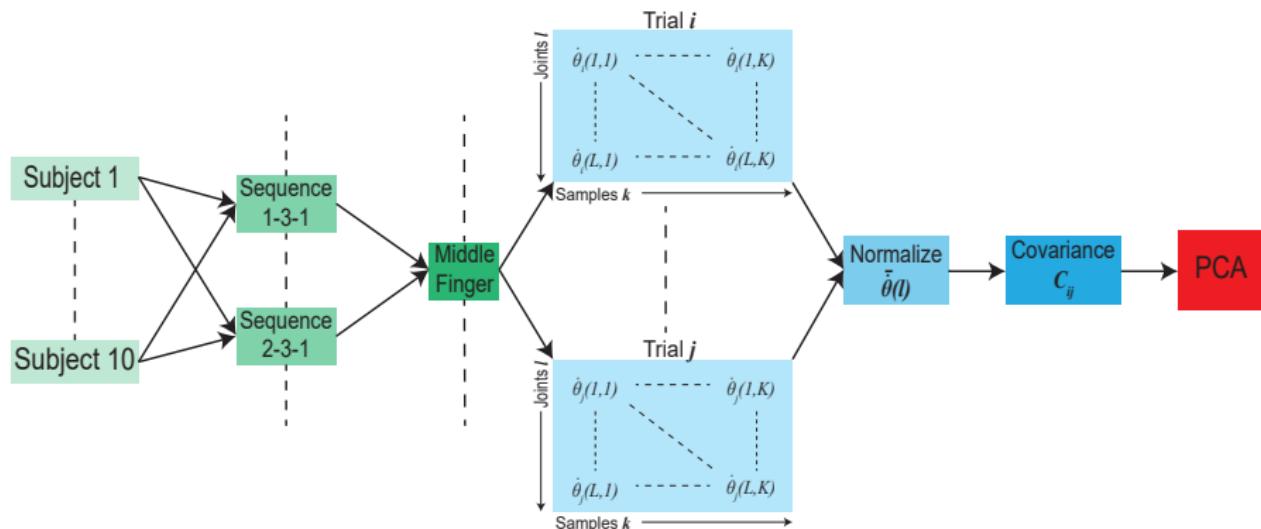
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Five-finger Exercises with quiet Hand.

For analysis:

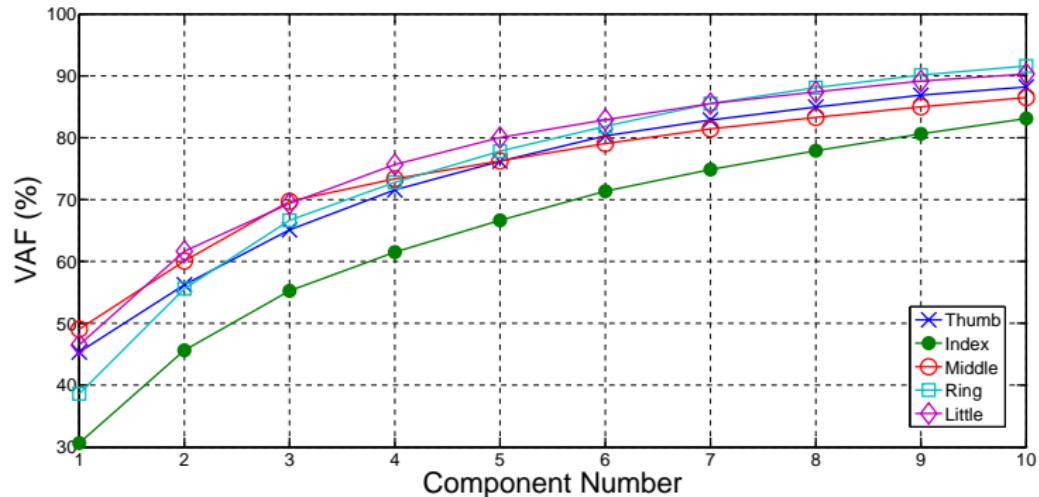
- Select 3 consecutive notes
- Capture transitions before & after the key press of interest
- Identify finger playing middle note
- Group all sets of 3 notes by the finger playing the middle note

Synergy Extraction via Principal Component Analysis



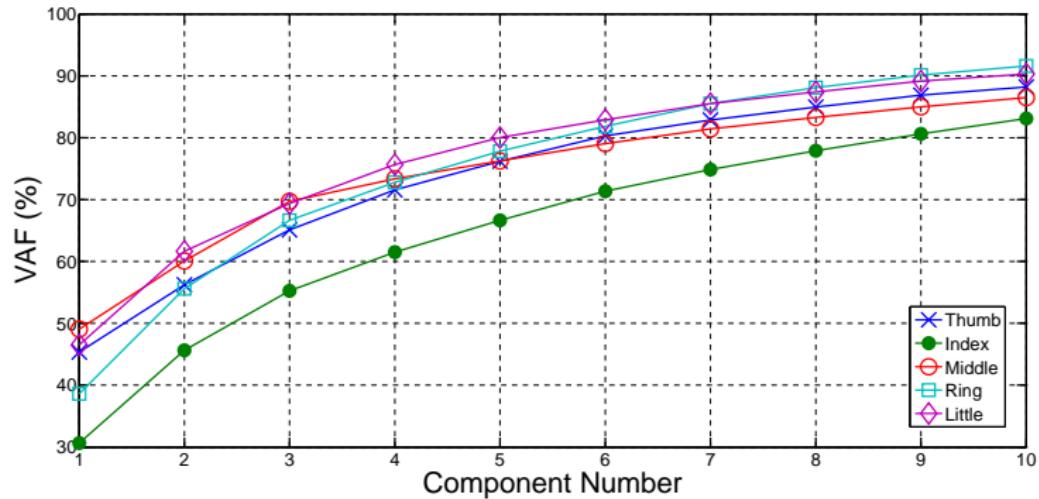
- Extraction performed on all subjects simultaneously
- 1 data set per finger
- Extract time varying synergies with fixed weighting coefficients

Variance Accounted For



- First 4 components account for more than 60% of the variance for all fingers

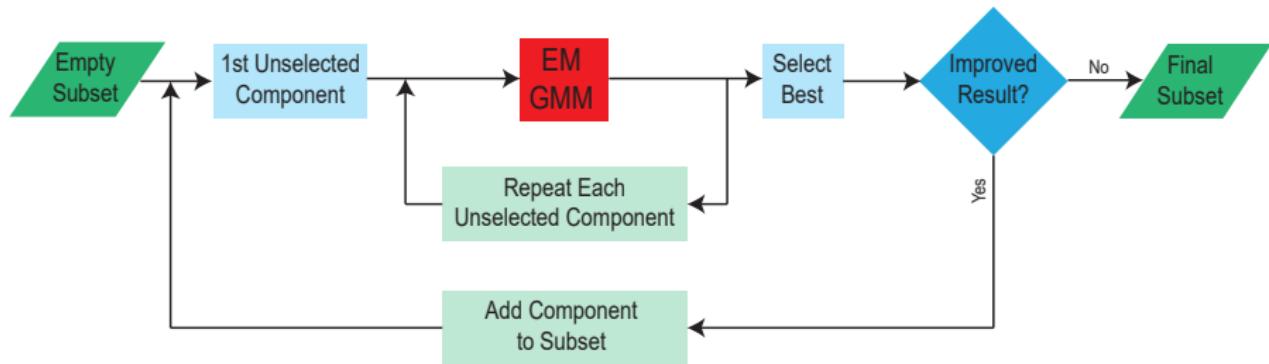
Variance Accounted For



What about the differences?

- We can successfully identify fundamental patterns in the motion of all subjects
- But what can we learn from the differences between experienced & novice pianists?

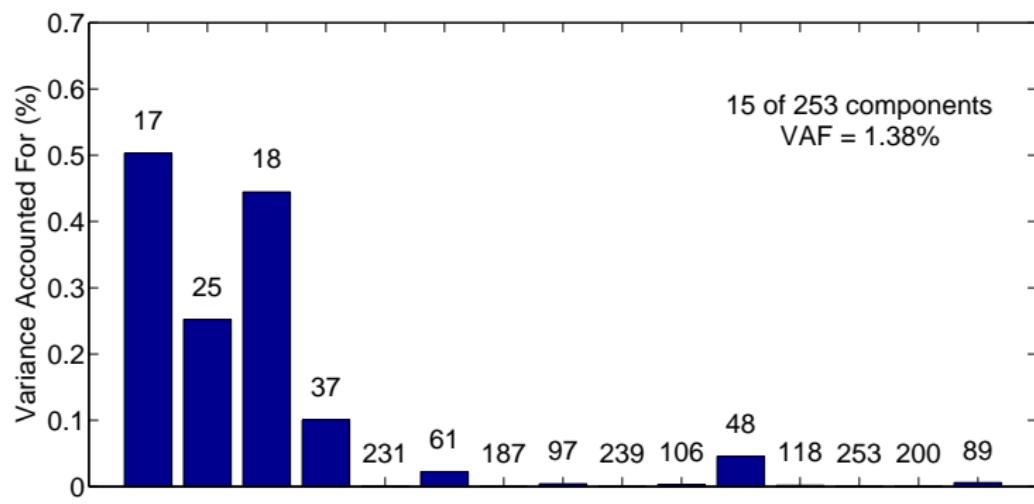
Classification



- Classify the weightings of the PCs
- Expectation Maximization algorithm
 - Fit a 2 class Gaussian Mixture Model
- Iterative forward selection of components

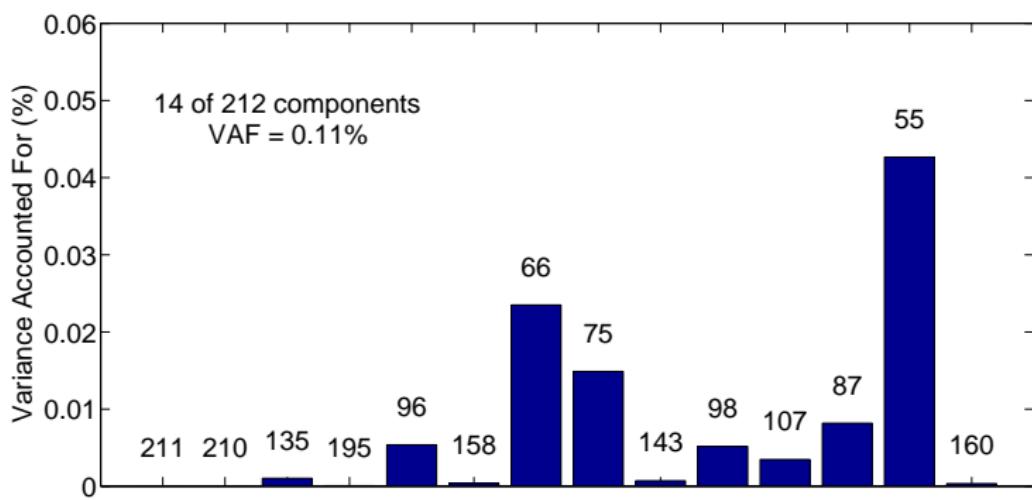
Classification Accuracy

Finger	Accuracy (%)	No. Components	VAF (%)
Thumb	93.68	15/253	1.38



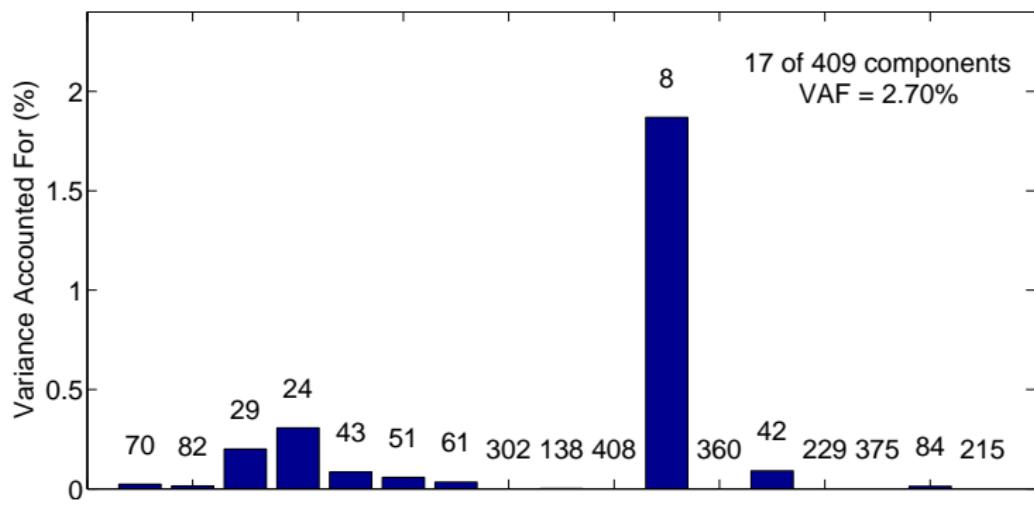
Classification Accuracy

Finger	Accuracy (%)	No. Components	VAF (%)
Thumb	93.68	15/253	1.38
Index	94.81	14/212	0.11



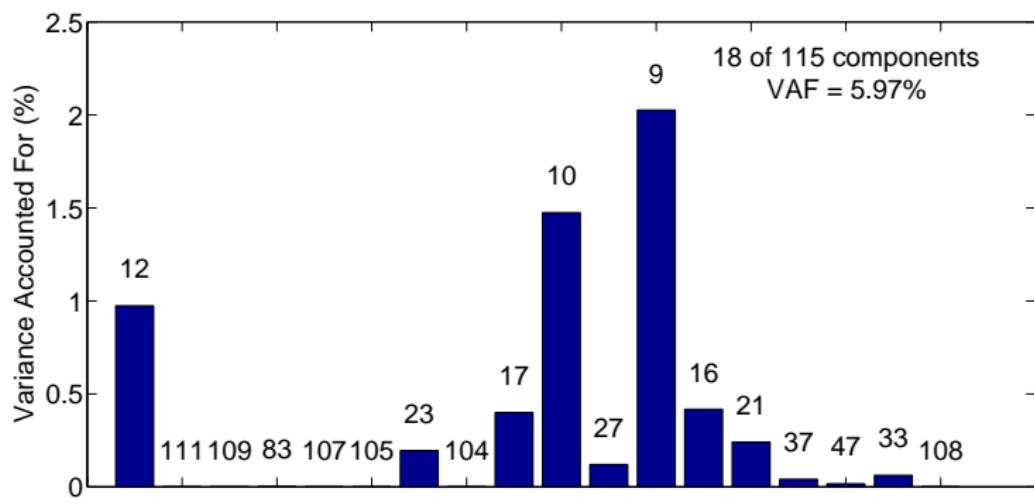
Classification Accuracy

Finger	Accuracy (%)	No. Components	VAF (%)
Thumb	93.68	15/253	1.38
Index	94.81	14/212	0.11
Middle	93.40	17/409	2.70



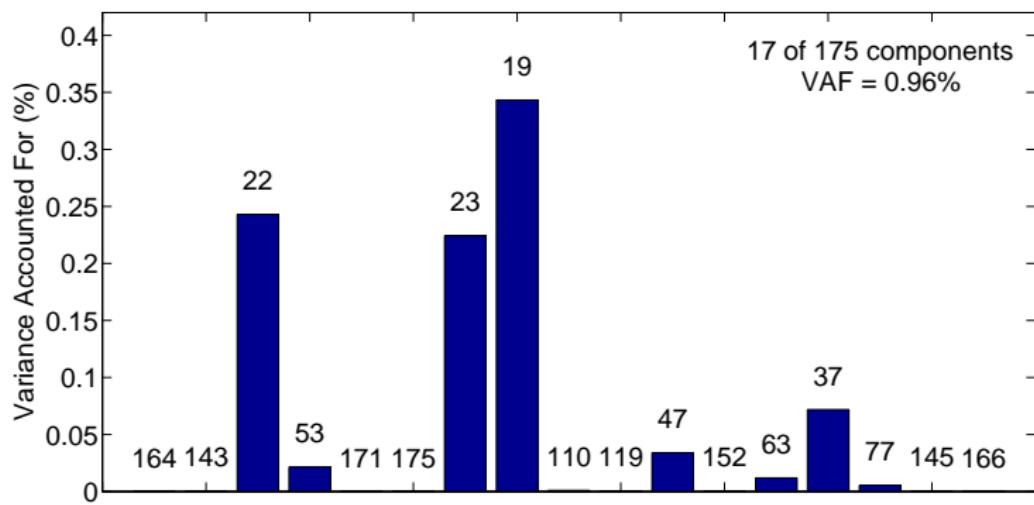
Classification Accuracy

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Index	94.81	14/212	0.11
Middle	93.40	17/409	2.70
Ring	96.52	18/115	5.97

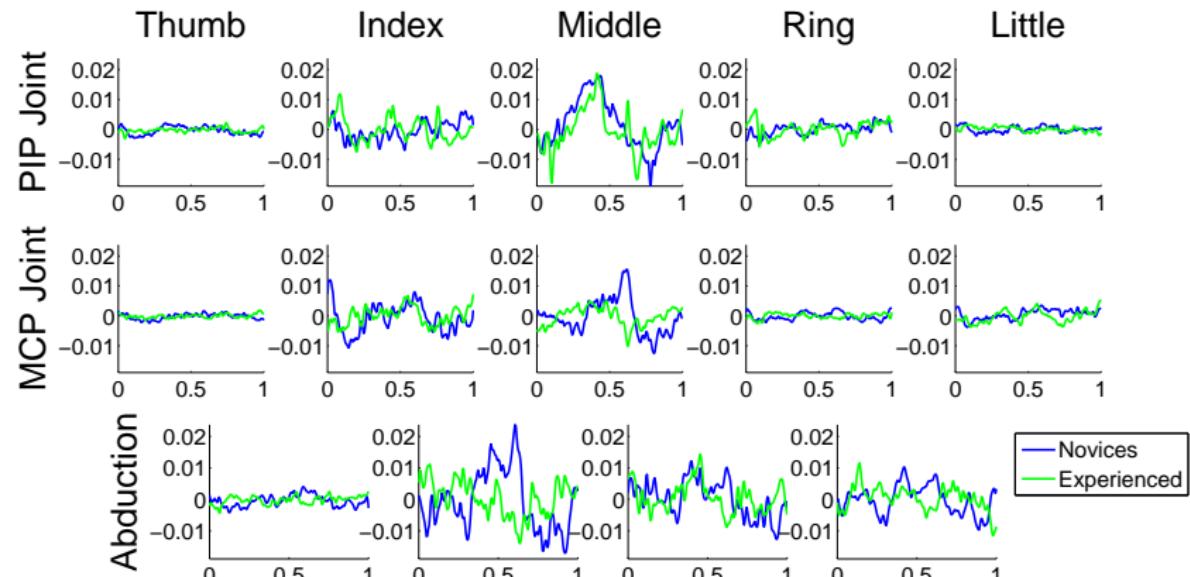


Classification Accuracy

Finger	Accuracy (%)	No. Components	VAF (%)
Thumb	93.68	15/253	1.38
Index	94.81	14/212	0.11
Middle	93.40	17/409	2.70
Ring	96.52	18/115	5.97
Little	98.29	17/175	0.96

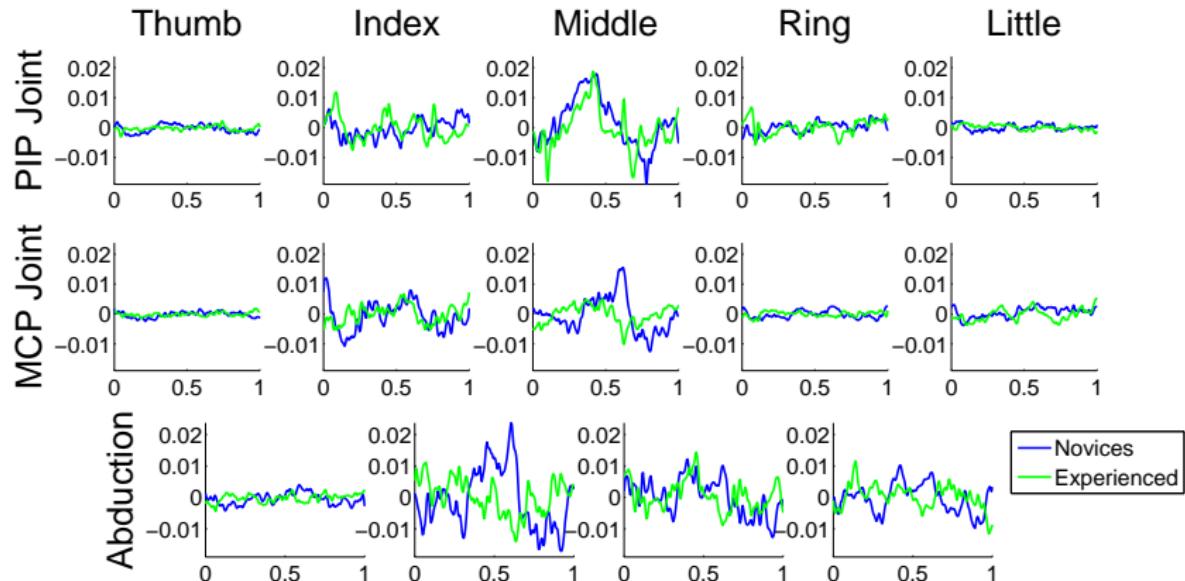


Reconstructed Signals for Middle Finger



- Reconstructed signals using only the selected components
- The movement relating to the greatest separability

Reconstructed Signals for Middle Finger

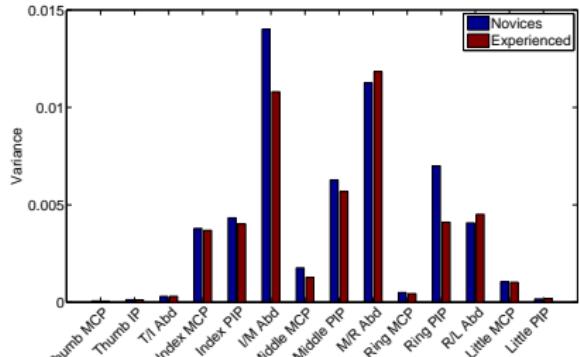


Comparison:

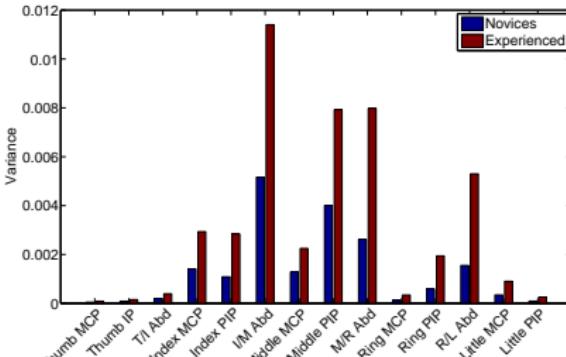
Focus on four long fingers as movement of thumb is different

Variability in Reconstructed Signals

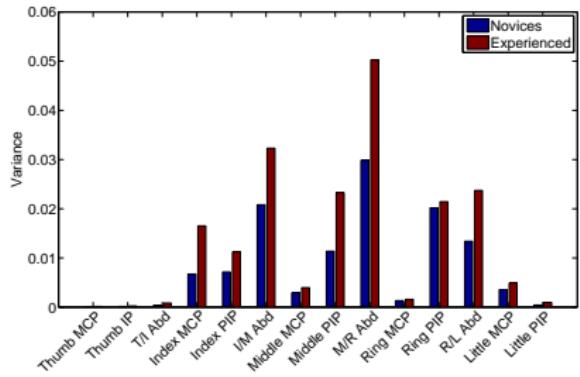
Index Finger



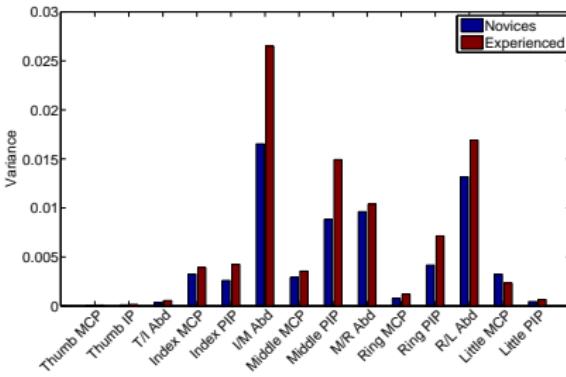
Middle Finger



Ring Finger



Little Finger



In summary...

Conclusions

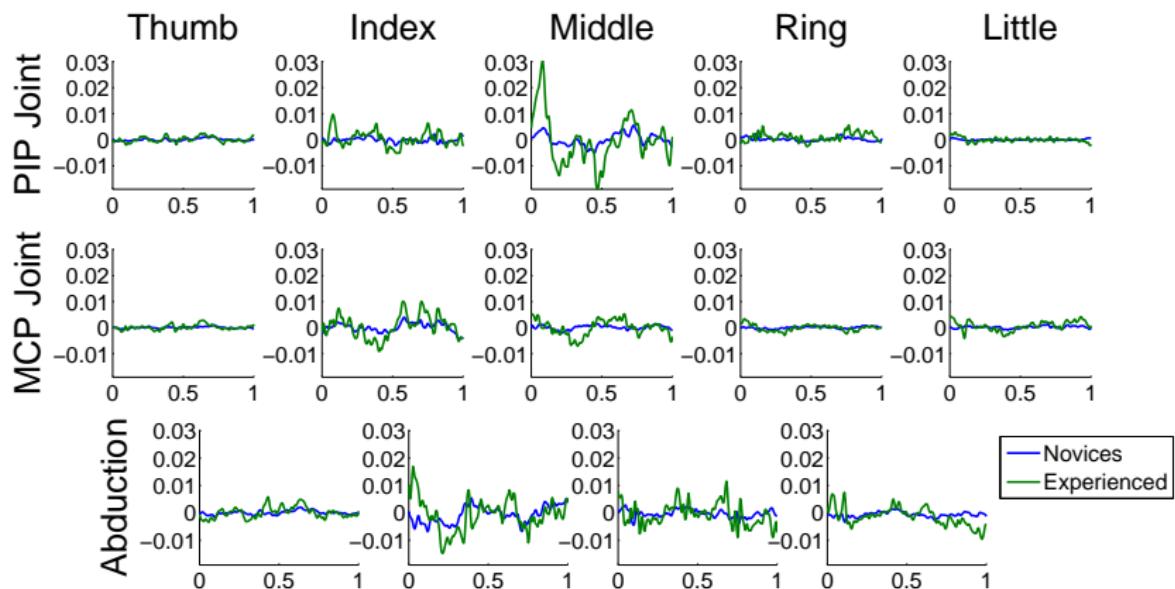
- Patterns of movement common to all our subjects
- Differences between novice & experienced pianists in components accounting for smaller variance
- Distinctions between groups seem to be in how fingers interact with each other
- Is variance accounted for a sufficient measure for coordinated movement?

The End

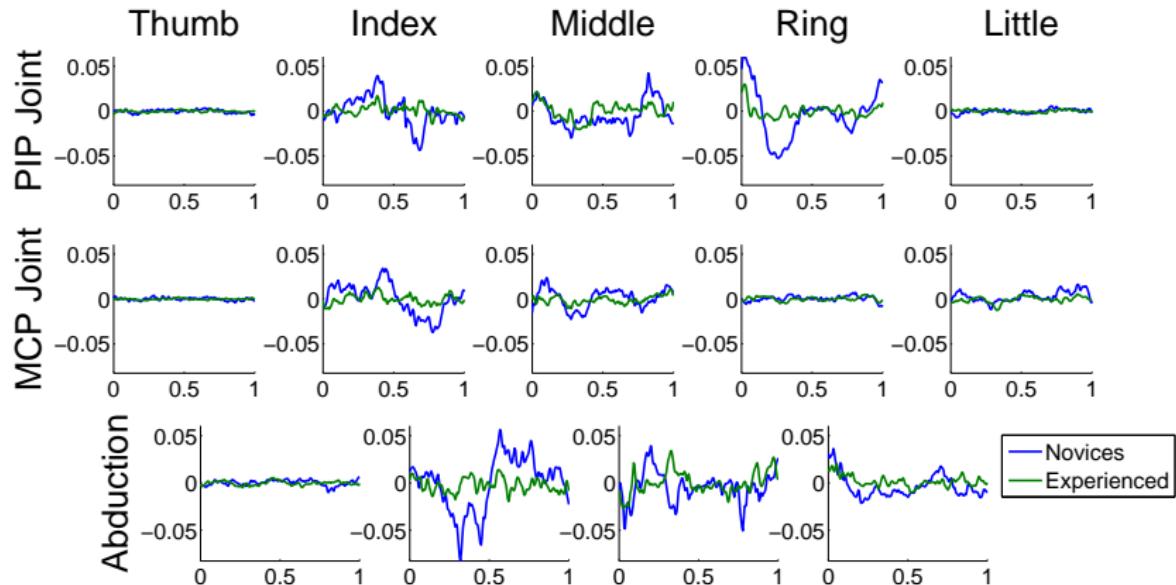
Thank you for listening



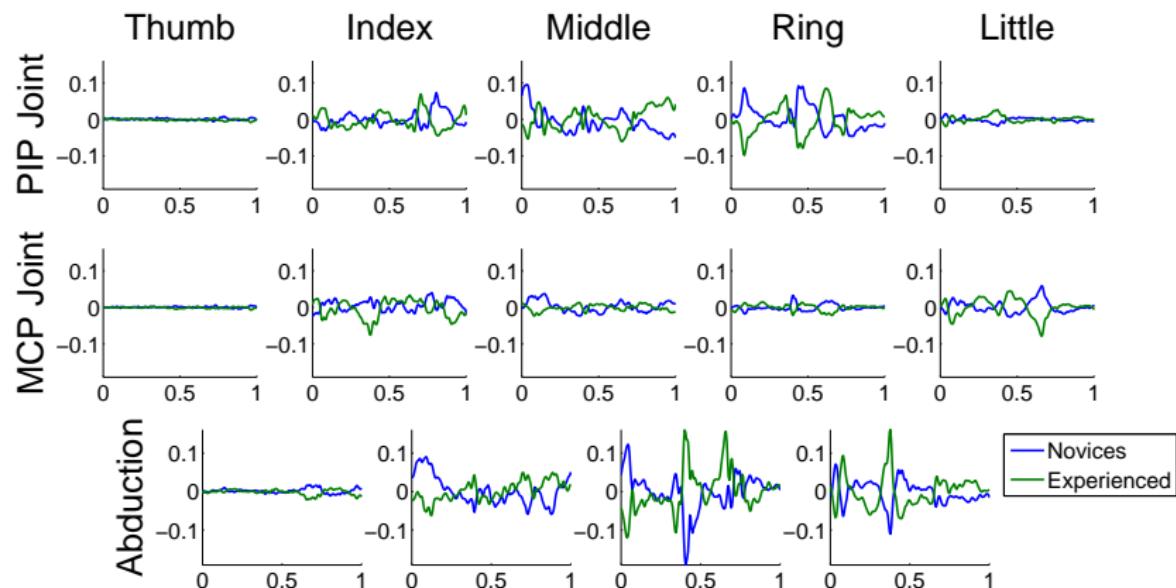
Thumb Reconstruction



Index Finger Reconstruction



Ring Finger Reconstruction



Little Finger Reconstruction

