Hand Muscle Activity for Digital Coarticulation in Pianists

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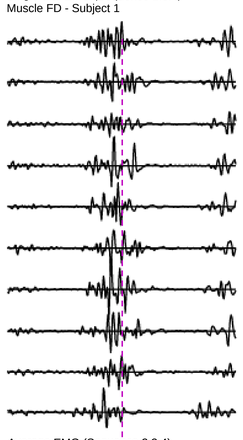
Data from: Winges, Furuya, Faber, and Flanders (2013). *Patterns of muscle activity for digital coarticulation.* Manuscript submitted for publication.

Single-trial EMG (Sequence 2.3.4)
Muscle FD - Subject 1



Average EMG (Sequence 2.3.4)
All Muscles - Subject 1

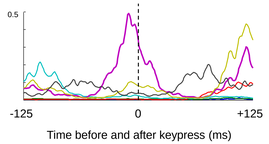
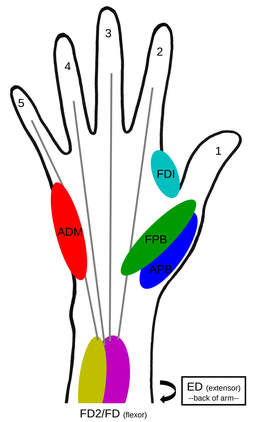
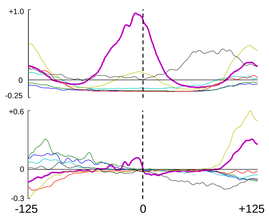


Table 1. *Subjects' piano training and performance*

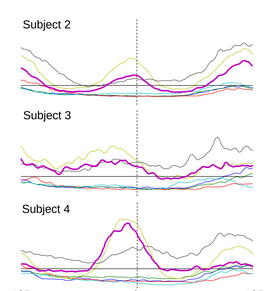
Subject #	Pro. or Amateur	Age	Age started training	Total # yrs training	IKI (ms)	MIDI velocity
1	P	26	6	20	124 ±12	90 ±11
2	P	28	8	20	124 ±11	94 ±12
3	P	36	4	32	124 ±17	96 ±12
4	P	44	3	40	124 ±9	99 ±9
5	A	33	5	25	132 ±15	92 ±10
6	A	19	5	13	160 ±18	87 ±12
7	A	54	45	10	172 ±35	80 ±12
8	A	54	6	48	140 ±18	71 ±13
9	A	40	4	30	126 ±13	80 ±10
10	A	34	7	7	150 ±29	92 ±11



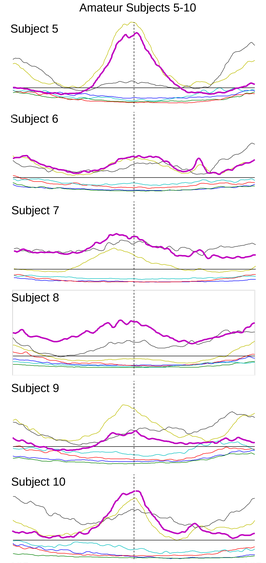
PC1 and PC2 (All Middle-centered Keypress)
All Muscles – Professional Subject 1



PC1 Middle-centered
Professional Subjects 2-4



PC1 Middle-centered
Amateur Subjects 5-10



Introduction

This study exploited the variability across a group of normal, healthy pianists to provide a comprehensive description of the patterns of muscle activity used for various sequences of keypresses. The goal was to determine which features did and did not change across the various skill levels.

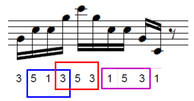


Table 2. *Keypress sequences and postural index change (Amount hand is opening (+) or closing (-) during a sequence*

Thumb				Index				Middle				Ring				Little			
F_{i-1}	F_i	F_{i+1}	ΔPI	F_{i-1}	F_i	F_{i+1}	ΔPI	F_{i-1}	F_i	F_{i+1}	ΔPI	F_{i-1}	F_i	F_{i+1}	ΔPI	F_{i-1}	F_i	F_{i+1}	ΔPI
2	1	2	0	1	2	3	1	1	3	1	1	1	4	1	1	1	5	1	-1
2	1	2	0	1	2	3	-2	1	3	2	-3	1	4	3	1	1	5	2	0
2	1	2	0	1	2	3	-2	1	3	4	6	1	4	3	-5	1	5	2	1
2	1	2	0	1	2	4	-2	1	3	5	0	1	4	3	1	1	5	3	6
2	1	3	-1	1	2	4	0	2	3	1	0	1	4	3	-5	1	5	3	5
2	1	3	-6	1	2	5	0	2	3	2	0	1	4	3	1	2	5	1	0
2	1	4	-3	2	1	2	2	2	3	4	-1	1	4	3	6	2	5	2	0
2	1	4	3	2	1	2	2	2	3	4	0	2	4	1	1	2	5	3	0
2	1	4	-3	3	2	1	2	2	3	4	0	2	4	1	-5	3	5	2	0
2	1	4	3	3	2	1	2	2	3	4	0	2	4	2	0	3	5	3	0
2	1	4	-3	3	2	1	2	4	3	2	0	2	4	5	1	3	5	4	-1
2	1	4	-8	3	2	1	1	4	3	2	0	2	4	5	0	4	5	2	1
2	1	5	-4	3	2	1	2	4	3	2	0	3	4	1	-6	4	5	3	0
3	1	2	0	3	2	1	2	4	3	2	0	3	4	2	1	4	5	3	1
3	1	5	-6	3	2	1	1	4	3	2	0	3	4	2	0	4	5	3	1
4	1	2	8	3	2	3	0	4	3	2	0	3	4	3	0				
4	1	3	8	3	2	3	0	4	3	2	0	3	4	3	0				
4	1	5	-1	3	2	4	0	4	3	4	0	3	4	5	0				
4	1	5	-4	3	2	4	0	5	3	1	0	5	4	5	0				
5	1	3	6	4	2	1	-1	5	3	2	-2								
5	1	4	0	4	2	1	2	5	3	4	0								
5	1	5	0	5	2	1	0	5	3	5	0								
				5	2	1	-2	5	3	5	0								
				5	2	4	0												
				5	2	4	0												
				5	2	5	0												
				5	2	5	0												

$$PI_j = sgn\left(F_j - F_{j-1}\right) * \left[\left(P_j - P_{j-1}\right) - \left(F_j - F_{j-1}\right)\right]$$
$$\Delta PI = PI_{i+1} - PI_i$$

Methods

Subjects: Ten pianists participated in the experiment: 4 professionals and 6 amateurs. Ages and training backgrounds covered a wide range (Table 1).

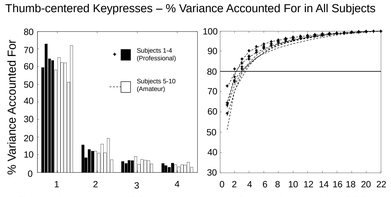
EMG: Electromyographic signals were recorded from 7 channels to characterize the bursts of action potentials in spinal motoneurons. EMG data were rectified and averaged across 10 repeats of the same sequence.

Sequences: Pianists played several musical scores from which we selected 106 three-key sequences (Table 2). Sequences varied in pitches (P) as well as fingering (F) causing the hand to change shape during the sequence. To characterize this, we calculated the change in postural index (ΔPI) using the equation above.

IKI: The sequences were played with the right hand as a metronome signaled an inter-keypress interval of 125 ms.

PCA: Principal components analysis combined data from each EMG channel across the 22-15 sequences centered on each digit.

Thumb-centered Keypresses – % Variance Accounted For in All Subjects

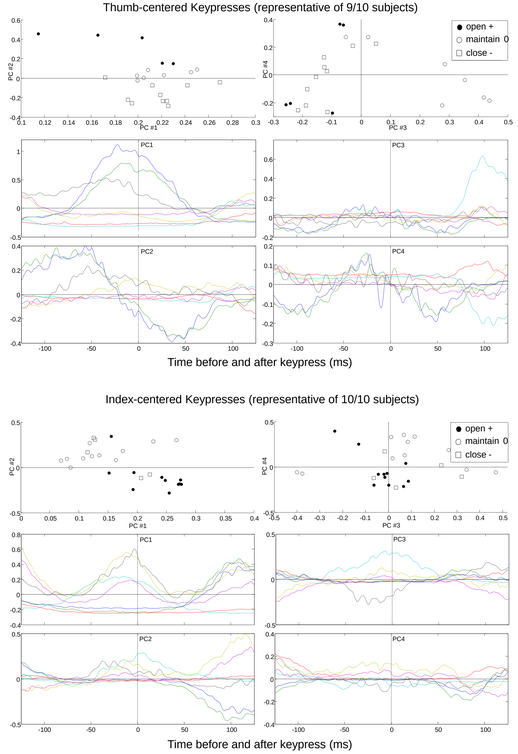


Results

Coarticulation

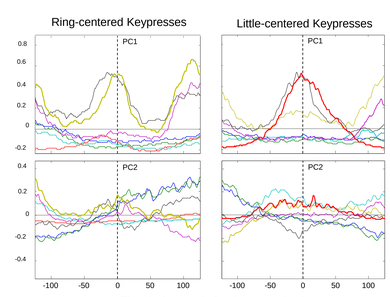
The multi-muscle EMG pattern for each sequence could be reconstructed as a weighted sum of PCs. PC2 weighting coefficients differed for sequences involving hand opening or closing, providing evidence that the central agonist bursts differed depending on which digits/keys were used before and after the central keypress.

Thumb-centered Keypresses (representative of 9/10 subjects)



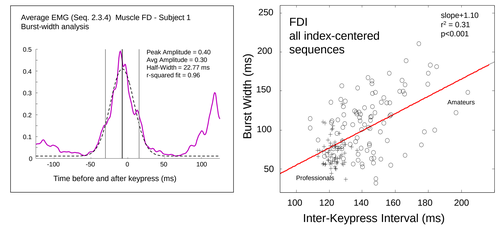
Index-centered Keypresses (representative of 10/10 subjects)

In the PC analysis (above), especially in the 3.2.1 sequence, hand opening (+) EMGs were reconstructed with negative PC2 weighting coefficients. In the burst analysis (to the right), hand opening (+) was classified with 76% accuracy using the burst amplitudes of the antagonist (ED) and two agonists (FDI, FD2), for 10 subjects and 17 sequences.

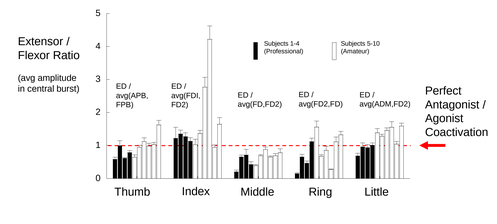


Coactivation

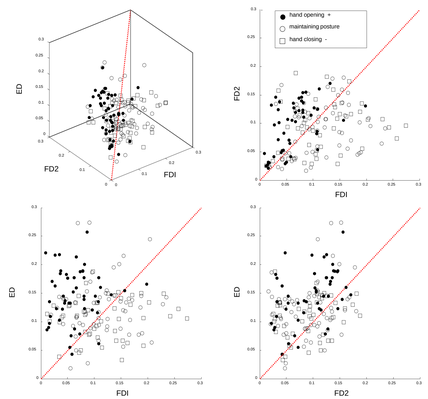
The duration of the central agonist burst, and the amount of antagonist/agonist coactivation tended to increase with the slight increases in inter-keypress interval that occurred across subjects (especially across the amateur subjects, open symbols).



Coactivation Index



Discriminate analysis to test for coarticulation during the central burst



Conclusion

Ten normal subjects were found to be remarkably consistent in their patterns of coarticulation. There were slight differences in playing speed (inter-keypress interval, IKI) that were associated with changes in burst duration and levels of antagonist/agonist coactivation (stiffening).

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