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Quantitative multidimensional approach of technical pianistic level

Paul Molin

LEAD CNRS, University of Burgundy, France

The purpose of this study is to examine whether it is possible to define quantitatively the technical level of a pianist by summarizing the individual characteristics of the pianist's technical ability in a few—at most three—independent variables. These variables could be used in competitions and examinations as well as by piano teachers to measure students' progress, or by the students themselves in their daily work.

Keywords: pianistic level; principal component analysis; pianist motor skill; correlation of difficulties; MIDI

A statistical approach to measuring the biomechanical characteristics of piano playing was used by Altenmüller and Jabusch (2005) to measure pianist's focal dystonia, then by the same authors (2007, 2009) to measure the development of adults' and children's motor skill, using the Musical Instrument Digital Interchange (MIDI) recording format. An ordinary MIDI file contains a succession of events, each event being characterized by three parameters: occurrence time of the event (T), duration (D), and pitch (P). From these parameters, many characteristics (tone overlap, equality of produced sound velocity, equality of rhythm, etc.) can be computed, each variable giving an insight of the technical level of a pianist. The advantages and disadvantages of MIDI coding are widely discussed by Clarke (2004). Keyboard technical skill and how to improve it was studied early, for example by J. S. Bach (Klavierübung) and D. Scarlatti (Exercizi), and C. P. E Bach wrote a treatise "Essai sur la véritable manière de jouer les instruments à clavier" in 1762. A systematic study of piano playing difficulties was completed by Alfred Cortot (1928), with the author recommending a detailed daily work based on five-finger exercises, scales, arpeggios, trills, double notes, and octaves, with daily key transposition. This well known book is the basis of the daily training of pianists. Our purpose is, from a sample of these typical training patterns, to extract the qualities and flaws of a pianist, and summarize them by synthetic graphs and synthetic variables.

METHOD

Participants

Eighteen pianists (mean age 22.5 years, ranging from 12-59), from middle level music conservatories to professional level participated in the experiment. They had played piano for a mean of 14.5 years (range=4-52) and received either course credit or payment for their participation.

Materials

The pianists performed on a classical upright piano (Yamaha U2) with MIDI interface. MIDI data were collected on a DELL® laptop PC, by using the Cubase SX® program. All statistic programs were written in the Matlab® programming language by members of the LEAD-CNRS laboratory.

Procedure

The pianists were submitted to a series of exercises containing the most common classical difficulties in piano playing (scales, trills, and arpeggios). In order to obtain a "photograph" of the pianist, a few attempts only (up to 5) were authorized for each exercise. The tempo of each exercise was free. The pianists were allowed 20 minutes for warming up and getting used to the piano prior to the actual performances. Not all the pianists used this warm up time. An operator was always present to guide the participants, verify the fingering, and record the performances. The detailed exercises were as follows:

- Four *scales* (E*b* major, E major, B*b* major, E*b* minor) were requested from participants, played on four octaves twice without interruption, hands together at a pitch distance of one octave. The choice of scales was motivated by the fact that these scales have a very natural fingering, so all pianists used the same fingering. There were two easy scales (E*b* major, E major), one more difficult (B*b* major), and a difficult scale (E*b* minor).
- All the possible combinations of fingers (1-2, 1-3, ...4-5) were used for the *trill* exercise.
- Eight *arpeggios* (C major, C major 4/6, D*b* major, D*b* major 4/6, C# minor, C# minor 4/6, B*b* minor, B*b* minor 4/6), played on four octaves twice without interruption, hands together at a pitch distance of one octave.

Fingering was verified by the operator to be 1-2-3 for the right hand and 1-4-2 for the left hand for the natural arpeggio state, 1-2-4 for right hand and 1-3-2 for left hand in the upward direction, and the reverse for the down direction.

RESULTS

Defining and computing the relevant variables

For all exercises, the first indices of quality are a high tempo and few false notes. But these are not the only qualities of a good piano technique; for scales and arpeggios, the main word characterizing the quality of playing is "homogeneity." This means rhythmic homogeneity for each hand, rhythmic homogeneity between hands, homogeneity of velocity (intensity of key depressing force) for each hand, velocity homogeneity between hands, and overlap homogeneity (legato homogeneity). Of course, in an artistic performance of a piece of music, this homogeneity is not observed; all the discrepancies in an artistic performance are voluntary acts, guided by the artistic sensibility. But the homogeneity required in the exercises is the way to gain the control of the movements, in order to play with expression.

We then retained seven variables: (1) tempo (TPO), (2) tempo coefficient of variation (CVTPO), (3) number of false notes (FN), (4) intra-hand velocity standard deviation (STDVEL), (5) intra-hand overlap standard deviation (STDOVL), (6) lag time between hands (LAGLR), and (7) velocity difference between hands (DVELLR). For trills, only the first five variables were used, since the exercise was performed hand-by-hand.

Why a free tempo?

In the experiments of Jabusch *et al.* (2004, 2007, 2009), the authors fixed the tempo of the exercises (scales) and allowed the subjects to repeat them 10-15 times. They then computed a "mean scale" for each subject. Our point of view is slightly different. An important part of the technical level is the pianist's awareness of his own skill—e.g. "I will not begin a scale at a metronomic tempo of 160 if I know that I will not finish the scale." We then left the subjects free to choose their tempos and considered the tempo variable as a level variable among others.

Principal component analysis (PCA) (Hotelling 1933) for scales

We present complete results and graphs for the E*b* major scale. Table 1 shows the correlation matrix of the seven variables for the scale. It is not surprising

Table 1. Correlation matrix between the seven quality variables for E*b* major scale.

	Tempo (TPO)	*False notes (FN)*	*Inter hand velocity variations (DVELLR)*	*Intra hand velocity STD (STDVEL)*	*CV tempo (CVTPO)*	*Overlap STD (STDOVL)*	*Time lag between hands (LAGLR)*
TPO	1	-0.179	**-0.610**	-0.165	-0.468	-0.503	-0.198
FN	-0.179	1	-0.024	0.422	**0.682**	0.187	**0.686**
DVELLR	-0.610	-0.024	1	0.291	0.128	0.516	0.134
STDVEL	-0.165	0.422	0.291	1	0.220	0.242	**0.724**
CVTPO	-0.468	0.682	0.128	0.220	1	0.540	0.432
STDOVL	-0.503	0.187	0.516	0.242	0.540	1	0.159
LAGLR	-0.198	0.686	0.134	0.724	0.432	0.159	1

that the tempo variable is negatively correlated with all other variables: intuitively, tempo is a positive index of quality, while the other variables are negatives. Some other correlations, intuitively expected, can be noticed: for example, the high correlation (0.682) between the false notes and CV. Tempo variables can be understood as "a false note induces a stress for the pianist, then an irregularity of tempo." In the same way, the high correlation between the CV tempo and the time lag can be understood as "a false note in one hand does not affect the other hand, and then increases the time lag between hands."

Figure 1 shows the graphic results of the E*b* major PCA, which is consistent with respect to the correlation matrix. The left part of the figure is the correlation circle, which represents the correlations between variables and principal components. The first two principal components account for about 70% of the total variance of the data, and thus the bi-dimensional representation is reliable. As expected, the tempo variable is opposed to all others. It is very interesting to see that the correlation between tempo and false notes is low (-0.179). A good pianist can do many wrong notes—a known joke of Alfred Cortot: "if you picked all my false notes in a concerto, it could be a second concerto."

In order to interpret the graph of subjects, let us describe some of them: pianists 3, 4, and 9 are beginning the second cycle of studies in a regional conservatory, pianist 18 is a concert pianist, pianist 2 is a piano teacher, and pianist 1 is an amateur (the author). All other pianists are second or third cycle students in a regional conservatory. Then the first principal component

Table 2. Metronomic and adjusted tempos (scores) for the E*b* major scale.

Subject	*1*	*2*	*3*	*4*	*5*	*7*	*9*	*10*	*12*	*13*	*14*	*15*	*16*	*17*	*18*
Tempo	86.7	79.2	65.9	31.0	36.7	71.7	54.5	41.8	35.6	64.8	85.5	94.6	71.7	64.2	143.3
Score	63.0	59.8	26.7	1.7	16.6	50.0	13.8	25.1	7.1	30.1	62.7	64.0	49.2	38.7	125.0

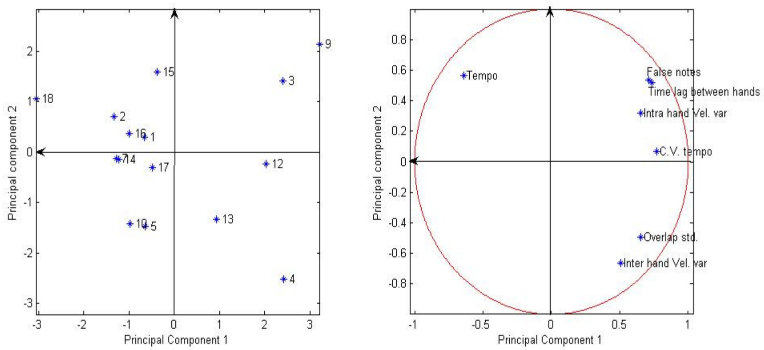

Figure 1. Principal component analysis of the E*b* major scale. The right panel represents the variables and the left panel the subjects.

can be easily interpreted as the technical level axis. The second axis can describe more precisely the flaws of the pianist: for example, a pianist far above the second axis is characterized by many false notes, a bad synchronism between hands, but a good legato (little overlap STD).

DISCUSSION

The PCA analysis appears to be a good visualization tool for a synthetic presentation of the technical level of a pianist. The results for trills and arpeggios are similar to those of scales. All the default variables are positively correlated, and all negatively correlated with the tempo variable. As we stated in the section on PCA above, the principal components cannot be used as they are, but they suggest an overall evaluation in a form opposing the tempo with all the other variables. For example, for the E*b* major scale, the first principal component has the following equation:

PC1=-0.3595*TPO+0.3991*FN+0.2860*DVELLR+
0.3682*STDVEL+0.4331*CVTPO+0.3668*STDOVL+ 0.4147*LAGLH

All the coefficients have the same magnitude. The idea is then to give the results to the musician in the form of an adjusted tempo, very understandable by musicians:

TPOADJ=PC1/-.3595=TPO-1.1102*FN-0.7956*DVELLR
-1.0244*STDVEL-1.2049*CVTPO-1.0205*STDOVL -1.1537*LAGLH

This formula gives the results in Table 2. Under this system, a pianist who plays fast and has many flaws gets the same score as a pianist who plays slower but with good legato, good rhythmic homogeneity, few false notes, etc.

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Address for correspondence

Paul Molin, LEAD CNRS, University of Burgundy, Esplanade Erasme, Dijon, Côte d'Or 21000, France; *Email:* paul.molin@u-bourgogne.fr

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