

Is scientific research on piano performance useful for pianists?

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Introduction

Recent decades have seen significant progress in research on the physics, physiology, and psychology of piano performance.

So far, little of this research is known to professional pianists, and almost none has found its way into piano teaching.

Our aim was to explore what aspects of this research might be useful to pianists during their training.

The results have implications for:

- post-secondary curriculum design (piano performance, music education)
- future research (to focus on questions of interest to pianists)

Lectures

Method. Participants (henceforth "Ps") were piano students at the University for Music and Performing Arts, Graz (UMPAG, a.k.a. Grazer Musikhochschule). They attended four evening lecture-demonstrations, given jointly by the two authors. The lectures covered well-known general scientific principles and selected relevant recent research, and were supported by handouts that included reference lists. Arguments were presented for and against strategies arising from the research, drawing on the authors' musical experience. Implications for piano teaching, practising and performance were discussed. The main points presented in the lectures were as follows:

Lecture 1: Physics and psychophysics of piano timbre

1.1 (a) The timbre of an isolated piano tone cannot be changed independently of its loudness. (b) The timbre of a chord depends on the timing and relative loudness of the tones. (c) Key-velocity artefact: To achieve simultaneous onsets, louder tones must be struck slightly later than the others.

1.2 The percussive onset is an essential component of the piano's tone quality. There are three sources of noise: finger-key, key-keybed and hammer-string. Only finger-key noise can be varied independently of string amplitude.

Lecture 2: Physics and physiology of piano technique

2.1 Basic principle of leverage: applied force depends on distance from fulcrum.

=> Less muscle force is needed to play with curved than with straight fingers.

2.2 Greater masses need more force to accelerate them, and exert more force when they decelerate. => Fingers are more suited for fast playing, and arms for loud playing; and fast octaves are better played with the wrist than with the forearm.

2.3 For accurate landing, the optimal trajectory for a leap across the keyboard is a skewed ellipse - neither straight nor symmetrical.

2.4 The fingers are to some extent anatomically (and hence irrevocably) interdependent, due to links between the tendons and muscles. Finger independence can be learned, but only to a limited extent.

Lecture 3: Motor control in music performance

3.1 Music instrument technique is acquired (learned, practised) – not inherited.

3.2 Motor patterns may be learned more quickly and accurately by enhancing kinesthetic awareness of limb position, size and direction of movement, and muscle tension.

3.3 Motor patterns may be learned more quickly and accurately under conditions of optimal muscle tension.

3.4 Movements are more kinesthetically salient in larger limbs and at higher (angular) speeds.

3.5 Motor patterns may be learned more quickly and accurately by combining perceptual information from different modes: kinesthetic, touch, vision, hearing.

3.6 Well-learned motor patterns are flexible and adaptable to new contexts. Variation of performance parameters during practice can stabilise underlying motor patterns.

Lecture 4: Psychology of expression and fingering

4.1 Acoustically, pianistic expression and interpretation are limited to variations in timing, dynamics, articulation, and pedal.

4.2 Interpretation can involve expressive reinforcement of grouping, metrical, melodic, and harmonic accents.

4.3 Timing varies relative to a *perceptually* metronomic frame of reference.

4.4 Optimal fingering depends on anatomic, motor, cognitive, & interpretive constraints.

4.5 Knowledge about fingerings can be procedural or declarative.

4.6 Optimal fingering depends on task (sight reading, rehearsed performance) and expertise.

4.7 Consistent fingering can reduce errors.

4.8 In parallel passages, fingering of LH often follows RH.

Interviews

Method. Two months after the last lecture, Ps were interviewed by PH to explore if or how the presented information had been of practical use to them in their piano practice, performance or teaching. During the interview, Ps referred to handouts from the lectures. They brought along scores of their current repertoire, and were encouraged to illustrate points with musical examples. They sat at the keyboard throughout the interview, and were invited to use it. Interviews were recorded on cassette. Main points were transcribed verbatim (in German) by PH. The English summary below was prepared by negotiation between RP and PH. All Ps were asked the questions in sections A to C below.

Quantitative data: Personal details

A Background

A1 How interested were you in science at high school? (0 not at all, 1= a bit, 2 = quite, 3= very)

A2 How many specific science subjects (e.g. physics, pure mathematics, but not general science) did you study at high school?

B The lectures

B1 Which of the four lectures did you attend? List in order from most to least useful.

B2 Before the lectures, how much of the presented scientific content did you already know about? (%)

B3 How much of the scientific material presented in the lectures that you attended, the handouts you read, and the interview did you understand? (%)

B4 Of that material, how much do you think was or will be useful in your own playing? (%)

B5 Of that material, how much do you think might be useful in your present or future piano teaching? (%)

C Interaction with teacher

C1 What proportion of your repertoire pieces do you normally choose yourself, by comparison to the pieces chosen by your teacher? (%)

C2 How much your interpretations is based on your own ideas, by comparison to the ideas of your teacher? (%)

C3 What proportion of your ideas on technical matters are your own, as opposed to those of your teacher? (%)

C4 In your lessons, how much do you prefer to be told what to do ("analytical type"), rather than shown ("intuitive type")? (hypothetical extremes 0 = purely intuitive, prefer to say nothing at all; 100 = purely analytic, prefers only talking)

D Additional questions posed by RP to PH

- PH is a professional pianist and piano teacher in Graz.
- PH knows all Ps both personally and professionally.

D1 How much of the material presented in the lectures do you think each P understood? Consider only those lectures attended by each P. (%)

D2 How do you rate the pianistic standard of each P? (1 = very good, 2 = good, 3 = competent)

D3 How analytical is the approach to piano of each P? In other words, how much can they articulate what they are doing when practising and performing, and how much is their knowledge

declarative rather than procedural? (1 little, 2 average, 3 very analytical)

D4 How willing and able was each P to incorporate scientifically based ideas into their playing? (0 not at all, 1 little, 2 average, 3 very)

Summary of responses

part*	P1	P2	P5	P6	P10	P11
sex	m	m	m	f	f	f
age	18	18	19	32	19	23
A1	0	2	2	3	3	2
A2	5	6	5	5	5	5
B1	21	321	4312	312	41	3241
B2	0	50	15	90	50	50
B3	100	100	90	95	100	70
B4	50	65	45	50	100	70
B5	n.a.	65	15	50	100	70
C1	30	50	30	60	30	60
C2	50	50	40	60	30	70
C3	0	0	70	10	0	50
C4	50	80	50	50	30	50
D1	90	90	90	50	50	80
D2	1	1	3	2	2	3
D3	2	1	3	1	1	2
D4	3	2	3	1	2	2

* see footnote at end

Summary of quantitative data

- A: Most Ps reported having been interested in science at school. This presumably motivated them to participate.
- A2: Most of these science subjects were compulsory.
- B1: In general, lectures 3 & 4 (motor, psychology) seemed useful than 1 & 2 (physics, psychophysics, physiology).
- B2: About half of the material was new for the Ps.
- B3: Ps claimed to have understood most of the material.
- B4: Ps thought about half or most of the material would be useful for their own playing.
- B5: Ditto for their teaching.
- C1: Ps generally chose about half of their own piano repertoire; their teacher chose the other half.
- C2: Ps' interpretations of works in the repertoires tended to be about half their own and half their teachers'.
- C3: Ps varied widely in the extent to which their teachers influenced their ideas on technique.
- C4: Ps did not consider themselves to be either completely intuitive or completely analytical in their approach.
- D1: The interviewer felt that all Ps understood at least half of the material.
- D2: All participants had passed the entrance audition to UMPAG, but varied considerably in absolute standard. We avoided using exam results here, because at the UMPAG these tend to reflect recent changes in pianistic level rather than absolute standard.
- D3: We found our Ps to be considerably more analytical than typical piano students in their approach to piano. They also varied considerably in this regard. Note that the ratings in the table are relative, not absolute.
- D4: There was considerable variation in the extent to which Ps seemed able to incorporate scientific ideas.

In general, there is little agreement between the self-appraisal of Ps and the interviewer's appraisal of them (compare B3 with D1, B4 with D4). A possible explanation is that Ps were judging relative to an internal standard – not relative to their peers.

Qualitative data: Participants' comments on lecture content

Lecture 1: Physics and psychophysics of piano timbre

1.1 (a) The timbre of an isolated piano tone cannot be changed independently of its loudness.

P1 and P2 agree. P5 agrees but generally doesn't like this analytic approach, preferring to imagine desired timbre, not focus on dynamics.

P11 also emphasises the importance of timbral imagery. P10 and P11 think that a *forte* tone can be softened with a relaxed or flexible wrist; a tense wrist produces a hard timbre. P6 talks in detail about the effect of touch and hand shape on timbre of a RH melodic line, and recommends "deep and full" touch for chords and long tones.

(b) The timbre of a chord depends on the timing and relative loudness of the tones.

P2 gave examples of changing the timbre of a chord by playing selected notes louder (with more force).

(c) Key-velocity artefact: To achieve simultaneous onsets, the louder tones of a chord must be struck slightly later than the others.

No P reported deliberately delaying louder tones to achieve synchrony, suggesting that none really understood this principle. In slow practice, P1 and P6 play louder tones in a chord deliberately *earlier* than the others. P1 and P11 practise emphasising tones within chords by playing them more finger-legato than the others.

1.2 The percussive onset is an essential component of piano tone quality. There are three sources of noise: finger-key, key-keybed and hammer-string. Only finger-key noise can be varied independently of string amplitude.

P2 and P10 seemed to be unaware of finger-key noise. P5 avoids finger-key noise by playing close to the keys, allowing the key rebound (not muscle tension) to lift the the finger.

Lecture 2: Physics and physiology of piano technique

2.1 Basic principle of leverage: applied force depends on distance from fulcrum. => Less muscle force is needed to play with curved than with straight fingers.

Consistent with this principle, P1, P6 and P11 already use curved fingers for fast passage work with small intervals; P1, P2 and P11 use flat fingers for chords; and P6 uses flatter fingers for slow melodic lines. P5 doesn't like lever idea, believing it might lead to unnecessary tension.

2.2 Greater masses need more force to accelerate them, and exert more force when they decelerate. => Fingers are more suited for fast playing, and arms for loud playing; and fast octaves are better played with the wrist than with the forearm.

P1 uses wrist for fast octaves. P2 and P5 find this point counterproductive. They prefer to focus on the music. P11 strives for constant arm speed while playing sweeping arpeggiated figures (presumably to promote evenness of tone).

2.3 For accurate landing, the optimal trajectory for a leap across the keyboard is a skewed ellipse - neither straight nor symmetrical.

Consistent with this principle, P11 used to practised leap with a straight trajectory. Later she switched to a freer arch shape. Only the latter really worked. But others found the principle less useful. P1 does not practice leaps at all, P2 and P5 think leaps should happen without conscious control, and P2 focuses on the target tone, not the trajectory.

2.4 The fingers are to some extent anatomically (and hence irrevocably) interdependent, due to links between the tendons and muscles. Finger independence can be learned, but only to a limited extent.

Consistent with this, P1 focuses attention on inactive fingers to enhance control of active fingers, and P2 sees interdependence of fingers as *advantageous* for the playing of detached chord progressions.

Lecture 3: Motor control in music performance

3.1 Music instrument technique is acquired (learned, practised) – not inherited.

All Ps seemed to agree with this point. Several described methods of learning technique that had been helpful for them.

3.2 Motor patterns can be learned more quickly and accurately by enhancing kinesthetic awareness, i.e. by focusing on limb position, size and direction of movement, and muscle tension.

P2, P6 and P11 had tried the described approach and found it helpful.

P5 compared this to the Feldenkreis method in which body movements of all kinds are "relearned" with special emphasis on kinesthetic awareness.

3.3 Motor patterns may be learned more quickly and accurately under conditions of optimal muscle tension.

P6 and P11 had also experimented with this and found it helpful. P6 noted that her wrist became tense in *forte*, and was worried about getting used to an inappropriate dynamic level. P2 said he practices in both *piano* and *forte* to avoid fatigue in the upper side of the forearm (extensors).

3.4 Movements are more kinesthetically salient in larger limbs and at higher (angular) speeds.

In accordance with this, P2, P6 and P11 practice finger passage work in short *staccato* or with exaggerated (but not tense!) finger lifting at slow tempo (P2: to "train the concentration" and "store movements more accurately"). They deliberately reduce the size of the movement as they speed up; none has a problem with this, but P6 notes that it can be difficult for pupils. P2 also practices isolated movements at slow tempo with exaggerated movements, e.g. lifting of the hand between repeated octaves in the first Lied of Schubert's *Erlkönig*.

3.5 Motor patterns may be learned more quickly and accurately by combining perceptual information from different modes: kinesthetic, touch, vision, hearing.

P6 and P11 tried this idea and found it helpful. Other Ps did not comment.

3.6 Well-learned motor patterns are flexible and adaptable to new contexts. Variation of performance parameters during practice can stabilise underlying motor patterns.

Accordingly, P5 finds that practising arpeggios in different improvised contexts (at different tempos and in different keys) improves velocity and evenness.

Lecture 4: Psychology of expression and fingering

4.1 Acoustically, pianistic expression and interpretation are limited to variations in timing, dynamics, articulation and pedal.

All Ps seemed to agree with this.

4.2 Interpretation can involve expressive reinforcement of grouping, metrical, melodic, and harmonic accents.

P10 referred to some examples in Beethoven where grouping accents on weak beats are marked *sf* and so tend to displace metric accents. She says that to get a "longer line", the *sf* should vary in loudness (creating a new hierarchic level). P11 thinks that dynamics are more related to musical structure, and timing more to emotion.

4.3 Timing varies relative to a perceptually metronomic frame of reference.

All Ps seemed to understand this point, but tended not to comment on it.

P5 dislikes the analytical approach of 4.1 to 4.3. He would only use these ideas to analyse afterwards what happened in a performance.

4.4 Optimal fingering depends on anatomic, motor, cognitive and interpretive constraints.

4.5 Knowledge about fingerings can be procedural or declarative.

4.6 Optimal fingering depends on task (sight reading, rehearsed performance) and on expertise.

4.7 Consistent fingering can reduce errors.

4.8 In parallel passages, fingering of LH often follows RH.

Ps generally agreed with these points but had little to say about them. P5 found 4.7 counterproductive; he deliberately changes fingerings regularly (especially while improvising). Generally, P5 finds such a systematic approach to fingering (4.4 - 4.8) counterproductive.

Space limitations prevent us from including (translated) direct quotes from the interviews or musical examples in this poster.

Conclusions

How useful? Our participants found about half of the presented material to be useful. But compared to typical piano students they had a relatively high interest in general science. Most piano students are exposed to relatively little scientific thinking at high school, and none at university. Moreover, the academic backgrounds of piano teachers tend to be in humanities rather than sciences. Teachers of our Ps were unable to comment on the usefulness and suitability of our project, saying they would need to have attended the lectures. Taken together, these observations suggest a need for inclusion of relevant scientific materials into post-secondary music performance curricula.

Intuitive or analytic? Several participants commented that conscious awareness of the phenomena addressed in the lectures seemed counterproductive, preferring a more intuitive approach. For example, they sometimes reported that thinking about the *aim* of a movement was more useful than concentrating on the movement itself. On the other hand, some found that techniques they had arrived at intuitively (procedurally) seemed to correspond to our recommendations based on "scientific" considerations. This suggests that a more systematic approach may help students to arrive at useful technical solutions more quickly, reducing the amount of time needed for experimentation with different possibilities. Similarly, a systematic approach can reduce the chance that teachers pass on intuitively based information that is misleading, e.g. ideas that work for the teacher but not for the student, whether obtained through personal experience or by reading books by other pianists.

Terminology. Work of this kind can clarify terminology used by teachers. Consider the piano teacher who tells a student to "play with your arms". Careful analysis may reveal the following "translation": relax the shoulders and arms so that arm weight is transferred to the key – even in fast passage work, where the fastest movements are inevitably carried out by the fingers (see 2.2 above).

What did we achieve? The study enabled us to improve our selection of lecture material to adapt our presentation of that material to suit the backgrounds, needs and expectations of typical piano students. This will be useful should a course of this kind be incorporated into the curriculum of the UMPAG or similar school.

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***Footnote: Criteria for exclusion of unsuitable Ps**

Only 6 of 13 initial Ps are included in the table and comments above. The other 7 were eliminated from the study for the following reasons:

- P3 could not speak German well enough to understand all the lectures.
- The main instrument of P7 was organ not the piano.
- P4, P9 and P12 were interviewed but had relatively little to say.
- We were unable to contact P8 and P13 for interview.