Digital Instruments and Players: Part I – Efficiency and Apprenticeship

Sergi Jordà
Music Technology Group,
Audiovisual Institute, Pompeu Fabra University
Ocata 1
08003 Barcelona, Spain
+34 93 542 21 04
sergi.jorda@iua.upf.es

ABSTRACT

When envisaging new digital instruments, designers do not have to limit themselves to their sonic capabilities (which can be absolutely any), not even to their algorithmic power; they must be also especially careful about the instruments' conceptual capabilities, to the ways instruments impose or suggest to their players new ways of thinking, new ways of establishing relations, new ways of interacting, new ways of organizing time and textures; new ways, in short, of playing new musics. This article explores the dynamic relation that builds between the player and the instrument, introducing concepts such as efficiency, apprenticeship and learning curve It aims at constructing a framework in which the possibilities and the diversity of music instruments as well as the possibilities and the expressive freedom of human music performers could start being evaluated.

Keywords

Musical instruments design, learning curve, apprenticeship, musical efficiency.

1. INTRODUCTION

Music instruments are used to play and to produce music, transforming the actions of one or more performers into sound. New digital instruments design is a quite broad subject, which includes highly technological areas (e.g. electronics and sensor technology, sound synthesis and processing techniques, computer programming…), human related disciplines (associated with psychology, ergonomics and many human-computer interaction components), plus all the possible connections between them (e.g. mapping techniques…). Low-level and focused research that tries to solve independent parts of the problem is clearly essential for any real progression in this field, but it is also clearly insufficient. Integral studies and approaches, which consider not only ergonomic but also psychological, philosophical and obviously musical issues, even if non-systematic by definition, are also needed; but the fact is that very few attempts are being made at studying the design of new musical instruments -tools for playing and making music- as a conceptual whole.

2. WHERE ARE WE?

New instruments possibilities are endless. Anything can be done and many experiments are being carried out. Yet, current situation and results can hardly be considered awesome.

- The list of new instrument virtuosi and/or professional musicians who use them as their main instrument is surprisingly small (Michel Waisvisz, Laetitia Sonami, Nicolas Collins, Atau Tanaka, Richard Boulanger…).
- Being that live electronics and laptop music is so widespread [5] it is symptomatic and frustrating that so many performers prefer to still rely on the mouse, or at the most, on generic and dull midi fader boxes.
- Commercially available new instruments are scarce and hardly imaginative and ground-breaking (e.g. Korg KAOSS Pad[1]).
- A new standard electronic instrument is yet to arrive.

In effect, not any recent electronic instrument has attained the reduced popularity of the Theremin or the Ondes Marthenot, invented respectively in 1920 and 1928 [2]. Successful new instruments exist, but they are not digital, not even electronic. The latest winner, the turntable, became a real musical instrument in the early eighties, when it started being played in a radically unorthodox and unexpected manner. It has since then developed its own musical culture, techniques and virtuosi [6][14][21]. The fact that so many digital turntables simulators do already exist [1][15], some of them like Stanton's Final Scratch[2], even quite successful commercially, gives us as many clues on the turntable wealth, as it does on the new instruments design sterility. And if commercial success is a complex subject that we may better obviate, all the previous complaints can still be summarized in one critical sentence:

Many new instruments are being invented. Too little striking music is being made with them.

We need useful, playable, thought-provoking enjoyable instruments, capable of interesting, surprising, enjoyable music. How can we create these "good" instruments? What is a good music instrument, anyway? Are there instruments better than others? While it is true that each culture and epoch has praised several music instruments over others[3], some instruments are indeed more powerful, flexible or versatile than others. Some are vocationally 'generic' and others highly specialized. Some take years to master, while others can be played by amateurs or even by complete novices.

3. WHAT IS A *GOOD* MUSICAL INSTRUMENT?

At the opening of the NIME02 conference in Dublin, keynote speaker Tod Machover launched several questions of

[1] http://www.korg.com
[2] http://www.finalscratch.com
[3] If we consider Western culture for example, from Classical Greece to the XXth century, favoritism has switched several times between strings and winds for varied religious, philosophical or acoustical reasons.

which I here retain two: "How do we create controls and interactions that feel inevitable to expert and amateur users?", "how do we create interactive situations that stimulate rather than placate, leading the participant beyond the surface and into thoughtful consideration of rich, expressive, meaningful experiences?". According to Machover, the last two decades have seen successful designs of controllers capable of virtuosity and subtlety, and also of controllers that "hook" novice users, but in this last case, very few systems have been nourishing as well, capable of encouraging deeper exploration and continued discovery and creativity [11]. And this is a feeling shared by many computer music instrument designers and computer music performers.

In this article we will try to define and study concepts such as efficiency, apprenticeship, learning curve, scalability, concepts all them that help to describe and identify the dynamic relation existing between the player and the instrument. We will not be able to give magic formulas on how to better attain certain assets, but we will discuss what these properties may be, how they can affect the relation between the player and the instrument, and what may constitute the essential needs for different types of musicians.

3.1 Nothing is perfect: Anything can get better (and worst!)

Humans have been playing music for thousands of years, but sudden innovations in human performance, even in millenary experienced areas seem indeed possible. Good examples can be found on sports, by far the most advanced and sophisticated area concerned with human responsiveness and techniques: the crawl stroke swimming style and the Fosbury jumping are XIXth and XXth centuries techniques, invented from scratch after millennia of humans swimming[4] and jumping!

Acoustic musical instruments as we know them now are also the fruit of centuries or even millennia of evolution; they have settled into canonical forms. But as we will see, that does not necessarily imply that these instruments are perfect or that they all excel at whatever parameter we evaluate.

4. INTRODUCING THE ODD QUARTET

For the following discussion we will pick four instruments, the kazoo, the kalimba, the piano and the violin (an odd quartet for sure!), and try to figure out some of the aspects that make some instruments more enjoyable than others.

4.1 Balance (Challenge, Frustration, Boredom…)

Many traditional instruments are quite frustrating for the beginner. The violin, for instance, can hardly be taken as a toy (whereas even the piano could). Some instruments are definitely harder to play than others. Wind instruments, for instance, are frequently hard to blow; the absolute novice cannot produce any controllable sound (there are exceptions, such as the recorder family). Fretless string instruments are impossible, for a novice, to play in tune. And with fretted ones, if multistringed, the novice may have a hard way deciding what string to use between all the possible options, in order to obtain a desired pitch. Keyboard instruments seem more direct: they produce sound easily, and there is a bijective relation between pitches and keys. And while piano music can be the most complex music (and therefore the hardest to play) it can also be quite simple though, and an absolute non-musician can still improvise some beautiful piano music.

Music instruments must strike the right balance between challenge, frustration and boredom: devices that are too simple tend not to provide rich experiences, and devices that are too complex alienate the user before their richness can be extracted from them [10]. The kazoo is easy to master, but its possibilities are quickly exhausted. We should be able to design well balanced instruments that can appeal to both professionals and dilettanti; instruments that like the piano, can offer a *low entry fee with no ceiling on virtuosity* [7][25].

4.2 Playability, Progression and Learnability

In our odd quartet, we will discard the violin because it needs a will of iron (not the best feature for initiating digital instruments proselytism!). We also discard the kazoo because it cannot go that far. With the remaining two instruments things get more delicate. The piano definitely offers no ceiling on virtuosity, while a Westerner may lodge some doubts about the kalimba. But what happens during their learning path? An absolute non-musician can still improvise some beautiful piano music, we argued, but still, the piano is a really intimidating instrument and the kalimba is not [8]. At the risk of sounding too hazardous I will suggest that, at least at their first stage, the kalimba is a more efficient instrument than the piano.

4.3 The Learning Curve

The learning curve is a widespread concept, systematically used in all areas that involve any aspect of apprenticeship, and vaguely interpreted as the graphical representation of the progress in learning. The term is also widely used in music education and in new controllers studies (*improve the learning curve*, *steeper learning curve*, *better learning curve…)* e.g. [16][17][23][24]. But was does "learning curve" exactly mean? Is there a way of measuring it?

Learning curve*: A graph showing some measure of the cost of performing some action against the number of times it has been performed. The term probably entered engineering via the aircraft industry in the 1930s, where it was used to describe plots showing the cost of making some particular design of aeroplane against the number of units made. The term is also used in psychology to mean a graph showing some measure of something learned against the number of trials. The psychology graphs normally slope upwards whereas the manufacturing ones normally slope downward but they are both usually steep to start with and then level out. Marketroids often misuse the term to mean the amount of time it takes to learn to use something ("reduce the learning curve") or the ease of learning it ("easy learning curve"). The phrase "steep learning curve" is sometimes used incorrectly to mean "hard to learn" whereas of course it implies rapid learning.* (From hyperdictionary[5]).

This definition does not fit too well within our musical scheme. First because we do not want to evaluate the cost of a given fixed action, as we intuitively assume that as the learning curve evolves, the musical actions undertaken can be more and

[4] The crawl stroke was in fact developed around the turn of XIXth century by English and Australian swimmers who copied techniques used by native peoples in Australia and Ceylon.

[5] Hyperdictionary: http://www.hyperdictionary.com/

more ambitious. Second, even if we considered variable, increasingly complex actions, how could we evaluate their cost? Since we are considering real-time scheduled activities, these can hardly be measured in time (i.e. the time it takes to accomplish the task), as the common practice is.

In a musical context, Levitin [10] describes the learning curve as the amount of time it takes to a novice to gain enough skill with an instrument so the experience of playing it becomes rewarding. Essential as it is, this concept does obviously not define a curve but a (very important) point of this curve, we could call the 'rewarding point'. Wanderley and Orio [24] when studying the usability of different controllers, define learnability as the time needed to learn how to control a performance with a given controller. A time, they suggest, longer than ten years for most traditional instruments [9]. This statement defines therefore another important point of the curve that we could call the 'mastering point'.

We intuitively grasp the learning curve concept; we know it can tell us a lot of information about the relation between a player and an instrument, on how the relation starts and evolves, but we do not know how to clearly define this concept, much less how to evaluate it. Could we, in order to compare different instruments, compare their learning curves? We can compare their learning curves shapes and tendencies, but we cannot evaluate their asymptotes or their inflexion points since we do not know the ordinates absolute values, not even what they represent. A serious attempt at defining the music instruments learning curve concept falls outside the pretension of this article, but that will not dismiss us from trying to manage the concept more intuitively.

The piano has a steeper (i.e. better!) learning curve that the violin. The kalimba has an even steeper learning curve, although its asymptote may remain lower. The learning curve of the kazoo is almost a straight horizontal line, very low when compared to the other three asymptotes (since the abscissa of its 'mastering point' is very close to the time origin, and the ordinate is also close to cero given the reduced capabilities of the instrument). All these approximate criteria are suggested in Figure 1.

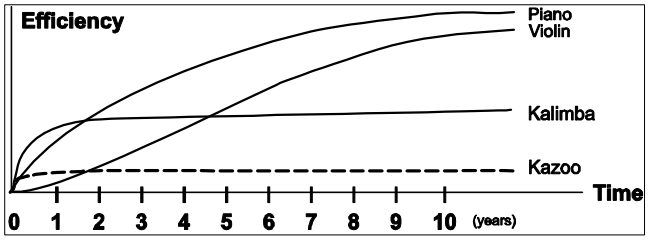

Figure 1. Approximate learning curve for the (a) kazoo, (b) kalimba, (c) piano and (d) violin, within a period of 10 years.

5. EFFICIENCY OF A MUSIC INSTRUMENT

We ended up section 4.2 claiming that the kalimba could be considered a more efficient instrument than the piano, without saying a word about what we should consider by efficiency of a music instrument. In engineering, the term 'efficiency' is commonly understood as the ratio of useful energy output to energy input. Timoshenko and Young [22] define for example the efficiency of a machine, as the ratio of the useful work performed to the total energy expended.

$$Efficiency = \frac{Output}{Input}$$

Macleod el al. [12] studied efficiency in a Human-Computer-Interaction context (HCI), affirming that in a system in which a human is interacting with a computer, the effectiveness with which the user and the computer working together successfully complete a task, is a measure of the useful work performed, or the output. The nature of the output being in this case quite different from the input, no adimensional ratio is possible. According to the authors, this does not imply however that we are not able to express the efficiency of task performance numerically; it simply means that efficiency measures will be now expressed in some units. After which they quantify the amount of effort input from a user's viewpoint, as the mental/physical effort required to complete it:

$$HumanEffiidency = \frac{Effectiveness}{Effort}$$

Our context is not that different. We will start with a quite similar and simple quotient (with quite fuzzy terms, we must admit!) that will allow us to roughly estimate the efficiency of a music instrument according to the following ratio:

$$MusicInstrumentEffiidency = \frac{MusicalOutputComplexity}{ControlInputComplexity}$$

The 'Musical output complexity' of a music instrument depends on all its available sound aspects and variability properties; it should include for example, both the microsonic richness of the violin and the mid-sonic richness of the piano, plus all the potential macrostructural complexities that could be managed by any kind of intelligent instrument. This term can be related to the 'musical range' defined by Blaine and Fels [3] and to the 'expressive range' described by Settel and Lippe [19].

The 'Control input complexity', depends on factors like the degrees of freedom of control, the correlation between these controls and the convenience of the applied mapping. It could also be linked to Orio [13] 'explorability', which is defined as the number of different gestures and gestural nuances that can be applied and recognized, and which relates to controller features such as precision and range and also to the mapping strategy.

Under different names and with slightly diverse approaches, both concepts are clearly being studied. In particular, a thorough understanding of the control input complexity would lead us to areas associated with engineering psychology, closely related to the work of Rubine [18] or Wanderley [24] and other researchers, and completely out of the scope of this exposition. The point is that the idea of 'music instrument efficiency' -a term that to our knowledge, has never been used outside of the acoustic domain- as vague as it still remains, could constitute, when plotted vs. studying or practicing time, a better-than-nothing first approximation for describing the learning curve. As a performer learns to play an instrument, the attainable output complexity increases (while staying below the theoretically limited maximum complexity the instrument is capable of outputting). Meantime, control complexity can also augment, which explains why after a certain period of time, efficiency does not necessarily follow a clear ascending curve. It happens in fact, that after a long period of studying (e.g. 10 years), the input cost needed for maintaining a high-valued output becomes so elevated that many professionals-to-be decide to abandon their instrument. This new approach to

efficiency will also constitute an essential guideline for the remainder of this exposition.

5.1 Playing [with] Music?

Bongers and Wanderley among others, describe interaction in sound installations as a context where one or more persons' actions are sensed to provide input values for an audio generating system. They state that since users do not know precisely how to interact and that no special skills are required, the primary goal of the interaction is not necessarily the expression of some information [4][24]. While these conditions are generally true, we should not forget the cases in which novice users are allowed to take more time to investigate and to learn. Interactive hardware-based music toys as well as software music games, either off-line or on-line, could perfectly illustrate this category.

In ancient Greece, the kithara was usually played by professional musicians as it required some kind of exhibitionism and virtuosity that could be considered vulgar and not adequate for free-born men. The lyra instead, was commonly played by amateurs, and was, according to Plato, a well suited instrument for free citizen [26]. Before the advent of the radio and recorded music, families who could afford it, tended to have an instrument at home (often a piano) and some of the family members were enough talented to become 'animated interactive CD players' every evening.

Considering that the best way to understand and appreciate any discipline, whether artistic or not, and music is no exception, is by doing and being part of it, we do seriously need more efficient instruments in which the basic principles of operation are easy to deduce, while, at the same time, sophisticated expressions are possible and mastery is progressively attainable.

5.2 The Art of Making Music Made Easy (?)

It's true, making music is an Art, traditionally demanding years of study and practice to be successful. -- until now! Enter the new Suzuki Omnicord. If you can read this text, you can play the Omnicord, and play it well. There's no need for lessons or years of study to play and sing your favorite songs right now! Just press a chord button and strum the SonicStrings. It's that easy. (from Suzuki's Omnicord publicity[6])

Is this what we are talking about? Is it there where we are willing to go? Computer aid interactive music systems can have many applications; each of them perfectly licit and with its own place in the market, but it is not the aim of this article to trivialize creation. To insist on this essential point and to try to make it clearer, let's augment our odd quartet with a fifth member, the CD player. It is an instrument very simple to use, yet capable of all the imaginable music variety and complexity; an instrument that allows everyone to play *Répons* as effectively as Boulez "playing" it with the *Ensemble Intercontemporain*[7]. According to our previous formula, the CD player is probably the most efficient instrument we can imagine!

The CD player example clearly parodies the [non-at-all]interactive music system situation. Satirical as it may sound, this tricky illusion is used indeed in many of the current interactive sound installations: seeking to guarantee a complex or predefined musical output, many of these installations do not give to their interactors more than a couple of bits to play with[8]. We could add that this is not only frequent in sound or music installations; faked or useless interactivity is the blot of contemporary Interactive Arts!

To penalize these poorly interactive situations we will introduce into our formula an additional term, we will call 'PerformerFreedom', in such a way that when this 'PerformerFreedom' tends to zero so does 'Efficiency'; an ideological correction that destroys the illusory potential of the Omnicord or of the CD player.

$$MusicInstrEffic_{correct} = \frac{MusicOutputComplexity \times PerformerFreedom}{ControlInputComplexity}$$

How could this performer freedom be evaluated? Once the CD is on the trail, the regular user does not have so many options: zapping tracks, fast-forward listening, volume modifications… In general, we can mainly distinguish between two primary types of freedom: (1) what the performer can do, the ways s/he can express and communicate with the instrument, which we could define as *freedom of movement* and (2) what the performer, by means of these actions, can ask the instrument to do, which could be summarized as *freedom of choice*..

$$PerformerFreedom = PerfFreedMovement \times PerfFreedChoice$$

The 'performer freedom of movement' is directly related to the performer's output potential, which depends on the degrees of freedom available to the performer and the range of each of these degrees. Its evaluation could probably be quite simple, based only in information theory concepts [20], since it does not rely on the ergonomy of the controls or on the mapping applied to them.

The 'performer freedom of choice' may be more difficult to evaluate. It obviously relates with the performer not being the instrument's slave; with the possibilities the performer has to affect the instrument's output. A good instrument should not impose its music to its player. A good instrument should not be able to produce only good music! (What is good music anyway?) A good instrument should also be able to produce "terribly bad" music, either at the player's will or at the player's misuse[9].

Both types of freedom seem essential for an instrument to appeal to professional musicians as well as to complete novices, and for allowing performers to play music and not only to play with music. Because the *performer freedom of movement* is probably too correlated, or even implicitly included in the *control input complexity* that appears on the denominator, in

[6] http://www.suzukimusic.co.uk/suzuki_omnichord.htm

[7] *Répons*, Pierre Boulez and the Ensemble Intercontemporain DG 457 605 2, 1999.

[8] That does not prohibit the CD player from becoming a wonderful music instrument, when played by imaginative musicians such as Yasunao Tone (e.g. *Solo for Wounded CD*, CD Audio, Tzadik #7212, 1997) or Nicolas Collins (e.g. *It Was a Dark and Stormy Night, CD Audio*, Trace Elements, 1992). The same could be said of the Suzuki Omnicord, an incredible surprise when played by the German improviser Joker Nies (*The Art of Circuit Bending*, http://www.klangbureau.de/ cb_E.html).

[9] 'Misuse' should not be interpreted here with ideological, moral or esthetical connotations. What we suggest is that, only when a performer is capable of relating unwanted results (effects) with the actions taken (causes), this performer will be able to learn and to effectively progress.

further studies we will concentrate in the term *freedom of choice*, trying *to* refine it by seeking deeper into the musical output diversity of the instrument and on how the performer is able to control and affect this diversity.

6. CONCLUSIONS

This constitutes only a starting point. We have just scratched possible ways to evaluate the performer's freedom. We have introduced concepts such as efficiency and learnability, but have given no clues on how the goals could be better attained (e.g. how do we build more efficient or learnable instruments?). We have not yet considered any time aspect (time responsiveness, latency, inertia…). All of these and other concepts will need to be studied much deeper.

This article is an initial attempt at trying to study the dynamic relation that exists between a player and an instrument from new points of views, introducing some concepts that can be taken into account, and some questions that could be posed at the time of designing a new music instrument. Who are we designing the instrument for? Are we constructing a music instrument or a music toy? What kind of music should the instrument be able to play? Do we aim to construct an instrument that can appeal to a wide range of musicians, from the perfect novice to the professional? Are we considering the different evolutionary steps of this possible relation? Are we guarantying the minimal elements that can make this instrument enjoyable from the beginning and potentially learnable? And one final reminder: music is, at the end, the final judge. Any instrument is worth the music it makes.

7. REFERENCES

[1] Andersen, T.H. (2003). Mixxx: Towards Novel DJ Interfaces. *Proceedings of the NIME International Conference (NIME-03)*, 30-35.

[2] Battier, M. (2000). Electronic Music and Gesture, in *Trends in Gestural Control of Music*. Paris: Wanderley, M. M. Battier, M. eds. Ircam - Centre Pompidou, Paris.

[3] Blaine, T. and Fels, S. (2003). Contexts of Collaborative Musical Experiences. *Proceedings of New Interfaces for Musical Expression (NIME-03).*

[4] Bongers, B. (2000), Physical Interfaces in the Electronic Arts – Interaction Theory and Interfacing Techniques for Real-time Performance, in *Trends in Gestural Control of Music.* Paris: Wanderley, M. M. Battier, M. eds. Ircam - Centre Pompidou, Paris.

[5] Cascone, K. (2000). The Aesthetics of Failure: Post-Digital Tendencies in Contemporary Computer Music. *Computer Music Journal, 24(4), 12-18*.

[6] Hansen, K.F. (2002). The basics of Scratching. Journal of New Music Research, Vol. 31, No. 4: 357-367.

[7] Jordà, S. (2002). Improvising with Computers: A personal Survey (1989-2001). Journal of New Music Research, 31(1), 1-10.

[8] Jordà, S. (2002). FMOL: Toward User-Friendly, Sophisticated New Musical Instruments. *Computer Music Journal, Vol. 26, No.3. pp 23-39*.

[9] Lehman, A. C. (1997). The Adquisition of Expertise in Music: Efficiency of Deliberate Practice as a Moderating Variable in Accounting for Sub-Expert Performance. In I. Deliège and J. A. Sloboda, eds. *Perception and Cognition of Music*. Hove, east Sussex: Psycology Press, pp. 161-187.

[10] Levitin D.J. et al. (2002). Control parameters for musical instruments: a foundation for new mappings of gesture to sound. *Organised Sound, 7(2), 171-189*.

[11] Machover, T. (2002). Instruments, Interactivity, and Inevitability. *Proceedings of the NIME International Conference (NIME-02).*

[12] Macleod, M., Bowden, R. and Bevan, N. (1997). The MUSiC Performance Measurement Method. *Behaviour and Information Technology*, 16.

[13] Orio. N. (1999). Metodi di Interfacciamento Utente-Elboratore basati sull'Analisi del Signale Audio. PhD thesis, Universit`a di Padova.

[14] Poschardt, U. (1995). *Dj-Culture*. London: Quartet Books Ltd.

[15] Poupyrev, I, (2000). Augmented Groove: Collaborative Jamming in Augmented Reality. *ACM SIGGRAPH 2000 Conference Abstracts and Applications, p. 77*.

[16] Pressing, J. (1990). Cybernetic Issues in Interactive Performance Systems. *Computer Music Journal, 14(1), 12-25.*

[17] Rovan, J., M. M.Wanderley, S. Dubnov, and P. Depalle (1997). Instrumental Gestural Mapping Strategies as Expressivity Determinants in Computer Music Performance. *Proceedings of the Kansei -The Technology of Emotion Workshop*, Genova - Italy, Oct. 1997.

[18] Rubine, D. and McAvinney, P. (1990). "Programmable Finger-tracking Instrument Controllers." Computer Music Journal, Vol. 14, No.1, pp.26-42.

[19] Settel, Z. and Lippe, C. (2003), Convolution Brother's Instrument Design. *Proceedings of the New Interfaces For Musical Expression Conference (NIME-03), pp. 197-200.*

[20] Shannon, C. E.. A mathematical theory of communication. *Bell Systems Technical Journal*, 27(3):379-423, July 1948. Continued 27(4):623-656, October 1948.

[21] Shapiro, P. (1999). The Primer: Turntablism. *The Wire*, 179: 40-45.

[22] Timoshenko and Young (1937). *Engineering Mechanics - Statics*, McGraw-Hill.

[23] Vertegaal, R., T. Ungvary, and M. Kieslinger. (1996). Towards a musician's cockpit: transducers, feedback and musical function. *Proc. Intl. Computer Music Conf. 1996*, 308–311.

[24] Wanderley, M. and Orio, N. (2002). Evaluation of Input Devices for Musical Expression: Borrowing Tools from HCI. *Computer Music Journal, Vol. 26, No.3. pp 62-76.*

[25] Wessel, D. and Wright, M. (2002). Problems and Prospects for Intimate Musical Control of Computers. *Computer Music Journal* 26(3): 11-22.

[26] Winnington-Ingram, R. P. (1980). Greece, ancient. In *The new Groove dictionary of music and musicians*, ed. S. Sadie, vol. 7:659-72. London: Macmillan.