NIME, Musicality and Practice-led Methods

Owen Green
Edinburgh College of Art
University of Edinburgh
Edinburgh, UK
owen.green@ed.ac.uk

ABSTRACT

To engage with questions of musicality is to invite into consideration a complex network of topics beyond the mechanics of soundful interaction with our interfaces. Drawing on the work of Born, I sketch an outline of the reach of these topics. I suggest that practice-led methods, by dint of focussing on the lived experience where many of these topics converge, may be able to serve as a useful methodological 'glue' for NIME by helping stimulate useful agonistic discussion on our objects of study, and map the untidy contours of contemporary practices. I contextualise this discussion by presenting two recently developed improvisation systems and drawing from these some starting suggestions for how attention to the grain of lived practice could usefully contribute to considerations for designers in terms of the pursuit of musicality and the care required in considering performances in evaluation.

Keywords

NIME, musicality, practice-led research, interdisciplinarity

1. INTRODUCTION

> "If our goal is musical expression we have to move beyond designing technical systems." [25][1]

So stated Michel Waisvisz in the guiding text for a panel discussion at NIME 2006. My purpose in this paper is to outline a way in which I think practice-led methods can be helpful to NIME in moving beyond technical concerns and developing a firmer, more nuanced grasp on complex, vexatious questions of musicality.

The proposal is neither a call for wholesale revision of NIME's outlook or methods, nor is it a prescription for the only appropriate manner in which to approach practice-led research in this area. Rather, this is suggested as a useful way of complementing NIME's already impressive achievements and of strengthening the kind of contribution that practice-led researchers are able to make.

In live electronics, in particular, NIME has become something of a centre of gravity, as its proceedings represent the closest thing to a specialist literature of technique that we

---

[1]Many thanks to Marco Donnarumma for drawing my attention to this quotation

have. However, as such it also exerts a kind of gravitational pull because there is relatively little from within the sub-disicipline that reflects on how the goals of, say, interaction designers and practice researchers may well differ, despite their obvious overlap. The danger here is that practice researchers bring amateur interaction designs, rather than capitalising on the distinct perspectives and insights afforded by their mode of investigation.

This paper will make a particular argument for how knowledge claims can be situated for practice-led research, and position this in interdisciplinary relation to the activities of NIME. I will contextualise this by presenting two pieces of work and suggesting how insights and experiences from the lived texture of practice may usefully enrich the kinds of discussion NIME is able to have about musicality.

2. THE EVALUATIVE HORIZON

To confront questions of *musicality* is to move beyond a focus on technical systems and bring into consideration questions of context. Whilst the evaluative focus of many NIME contributions has concentrated on these technical systems, there is evidence of a willingness to expand the analytical frame. Stowell *et al* [23] consider the relative strength of quantitive and qualitative methods, and develop usefully sensitive guidelines for when each may be appropriate. O'Modhrain [17] retainins a focus on the technical artefact but recognises the range of involved parties and the diversity of perspectives that follow from this. She proposes that performance is the most appropriate focus for evaluation. Lai and Boverman [15] draw on this to develop an approach to evaluating audience experience.

Meanwhile, Gelineck and Serafin [11] develop another important extension to considering artefacts in isolation by acknowledging the diachronic nature of musical practice and the shortcomings of evaluation through first impressions (something anticipated also in [17]). They develop a longitudinal study with a focus on evaluating a system when integrated into 'real world scenarios'. Johnston [14] develops a different perspective on what the goals of evaluation studies might be in the context of his practice-led research and tries to assess the extent to which interfaces act as provocations to creative action.

Each of these studies widens the analytical frame but retains the technical artefact at the centre, which is perfectly appropriate if this is the primary outcome of research. But to consider musicality is to invite an greater broadening of focus. This breadth has been systemically mapped by Born's [5] outline of a programme for an interdisciplinary musicology that encompasses four topics:

sociality Born divides social aspects of music into four irreducible planes: the micro-social aspects of musical action (1st) and associated 'imagined communities'

(2nd), through to larger formations, such as the ways in which music mediates relations of race, gender and class (3rd) and is bound up in political and historical currents (4th).

temporality is likewise given four aspects. The first addressing the most immediate temporalities of musical experience, through to the ways in which music refers back to or anticipates other music (2nd), the currents of genre formation and change (3rd) and the broader epochs of musical history such as classicism, avant-gardism and so forth (4th).

technology Born's discussion focuses primarily on recording, but can comfortably incorporate the concerns with instrumentality, interaction and so forth that serve as focal points for NIME.

ontology Here Born incorporates a productively pluralist stance on the diversity of conceptions of what music (or indeed musicality) *is*, and underscores the important point that ontologies have a formative role in structuring the direction and priorities of researchers.

Born's motivation here is to allow for the development of perspectives that afford richer discussion of cultural activity than can be achieved by oppositional dualisms between music as a social formation or music as a sensuous experience. One reduces music to games of social positioning, the other to texts, sounds or technologies. Considering musical *expression*, then, entails admitting in to the discussion some consideration of aesthetics that avoids reduction or determinism. This is noted by Gurevich and Treviño [12], who are critical of a tendency within NIME to reduce musical expression to a framework of text and act, instead proposing a more ecological understanding (see also [26]).

The reach of the questions raised by such broad considerations exceeds the scope of NIME and, indeed, of any single discipline. What I wish to discuss here is whether, and how, practice-led methods might bring to NIME's discourse insights and perspectives that help to develop further an approach to musicality that is responsive to the manifest complexities of the topic.

3. PRACTICE-LED RESEARCH

Practice-led methodologies have received a deal of attention in recent decades as an effort has been undertaken to formalise the nature and protocols of artistic research in the academy [22, 1]. However, there has been less discussion of this with reference to musical scholarship, despite the longstanding academic presence of musical practitioner-researchers, and even less within the electronic music sub-disciplines[2].

One exception comes from Brown and Sorensen [8] who cast the relationship between their live-coding practice and research activities in iterative terms: periods of research activity produce findings and artefacts that can then be mobilised in episodes of musical practice and subjected to evaluation that then influences the direction of further research. This account raises a number of good points. Like O'Modhrain, the authors usefully acknowledge that any evaluation of the results of musical practice-led research speaks to a range of audiences with distinct evaluative criteria. They also go into detail about the approaches they take to assessing the aesthetic value of their work. The degree

---

[2]Which may well be due, in part, to the somewhat distinct relationship with academia that music has had *vis-a-vis* other artistic practices

of compartmentalisation they achieve between what is research and what is practice also affords clarity about the types of knowledge claim they are respectively concerned with during each iteration.

However, such clean separation of concerns is not a given for all practitioners. Barbara Bolt [4, 3] proposes a different approach, where the knowledge claims of practice-led research can lie in *embracing* the extent to which the complexities of practice confound repeatability. By this account, supplementing our technological or musical outcomes with reflections on how these complexities interacted with the development of our work (Born's framework may be a useful mapping device here), allows us to develop a discourse of shared observations about our conventions and practices that may otherwise go unnoticed.

This describes a mechanism for valuable contribution to NIME from scholars whose primary research focus is the doing of music but that are otherwise engaged in a similar palette of activities to those engaged in more artefact-centred projects. The potential of this type of contribution, as I see it, is the possibility for a productively agonistic type of interdisciplinary engagement [2] which allows to seriously and frankly, but convivially, ask questions of each other's conceptions about foundational aspects of NIME's areas of interest, such as musicality. This is borne from my experience that interdisciplinary borrowings, such as signal processing in the pursuit of music, can not necessarily be characterised as the simple addition of one body of techniques to another (though sometimes they can), but can be more like a *convolutive* mixture: elements of each could be highlighted or suppressed. Consequently, the respective 'handlings' of the same materials by different researchers with different questions in mind could generate wholly, productively distinct ways of understanding the same phenomena.

A paradigmatic example of work in this vein is John Bowers' 'Improvising Machines' [6]. Bowers impressively manages to trace the textures of his practice such that the various contingencies of social and technological forces are accounted for in the way that they affected design and musical activity and gave rise to a set of practical priorities that made clear the extent to which making and musicking can be productively and performatively intertwined. In doing so, he brings forth a distinctive illustration of how he has come to know his various technologies and is able to articulate how this informs and is informed by the qualities of his musicking.

4. TWO EXAMPLES

In order to provide some context and make this discussion more concrete, I wish briefly to present two examples of my work. I shall give an overview of their operational details before drawing out some strands that illustrate the sorts of issue that these sorts of observation of practice can afford.

4.1 And Now For Some Music

And Now For Some Music is a piece for a single improvising player with miniature microphone and *infra-instruments* [7]. The software is implemented in Max and 'listens' to the microphone on the basis of a very simple musical model that divides sound in to two classes: pitched and noisy, using a PSOLA [27] scheme from IRCAM's FTM framework [20].

One layer of the electronics is an immediate extension of the player's gestures, and can therefore be thought of in quasi-instrumental terms. The player's sounds are deconstructed into atoms of pitched and noisy material and reassembled, but in an errant way. Pitched material is drawn out beyond its original duration, and quantised in frequency,
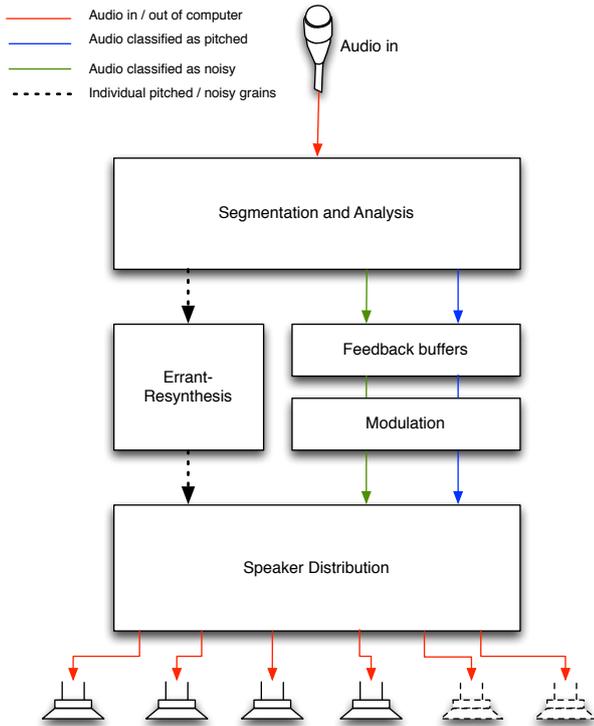
Figure 1: *And Now For Some Music* signal flow overview

Figure 2: *And Now For Some Music* typical performance ecology

to give it the character of an auto-tune process that pushes back. At the same time, the threshold between pitchedness and noisiness is subject to continual adaptation, not on the basis of trying to establish more 'truthful' estimates but simply of maintaining a longish-term equality between the relative quantity of pitched and noisy segments. This endows the system with a kind of resistance from a player's perspective: the production of particular effects is no longer a matter just of the action at hand but is made deliberately contingent on the qualities of what has gone before.

Meanwhile, the electronics contribute two further layers that are more gesturally removed. Two recirculating textures are constructed from the noisy and pitched materials respectively. New material is transformed and overdubbed into the current texture, whilst short, looping snatches of the textures are periodically written on top at arbitrary points, so that we are left with constantly shifting and mutating recapitulations of prior moments. The articulation of these textures in the final mix is derived from various control signals constructed, again, from the microphone input. Rather than trying to infer specific qualities of the player's action through sophisticated feature extraction, these control signals tend to be based on cruder measures subjected to some degree of transformation.

Amplitude envelopes of various speeds are generated, but then interfered with in a variety of ways: buffered and radically resampled, or treated to pronounced non-linearities like fold-over with low thresholds. The effect of these is to interrupt continuity and a sense of conspicuous gestural legibility without disrupting entirely the possibility of there being a phenomenological connection between what the player and computer do.

Pulse tracks are generated that eschew the orthodox approach of using some measure of inter-onset intervals to de-
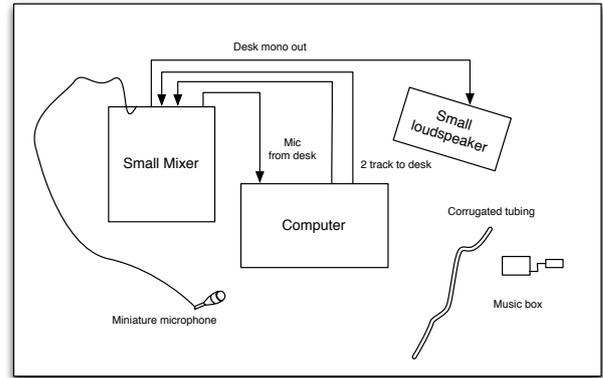
rive an underlying tactus. Instead, irregular trains are produced by subjecting the incoming signal to extreme downsampling (a factor of hundreds or thousands, which dictates the general time-scale of emerging sequence) and using a long-term autocorrelation measure of the resulting signal to produce a pulse-rate. These trains are by no means metrical, but do (generally / sometimes) have a musical timeliness about them appropriate to my improvised preferences. The trains then control the articulation of the patch in various ways, most notably in controlling moments at which certain variables are subject to change. Again, this disrupts at tendency towards continual variation in the electronics in an attempt to imbue a sense of rhythmicity and punctuation at once linked, yet not bound, to my playing.

A further pitch tracker is employed, additional to the one controlling the initial segmentation of the microphone input. However, all it is used for is determining the quantity of disagreement between the two feature extraction processes. This measure of disagreement then controls various aspects of the signal processes that may result in lesser or greater senses of roughness or timbral disruption of the recirculated material.

Although the software could be considered in isolation, it is worth stressing that it was neither developed, nor ever played in that way, not least because the sound world of the resulting music is highly dependent on the materiality of what goes into the microphone. Rather, it has always been conceived as a component in what Bowers terms a 'performance ecology' [6]: some more heterogeneous coalition of materials and circumstances.

Elements of this ecosystem have taken root over time. Most particularly, in addition to an array of limited-interaction sounding objects, I have take to having available a small loudspeaker that reproduces the computer output additional to any front-of-house reinforcement: the input to the system can optionally be its own output, mediated by the speaker cabinet and surrounding air (playing the bass port of a speaker can be rewarding in this context). Furthermore, the use of a small mixer has also become integral. Being able to actively *play* the microphone gain, for instance, has established itself as a key component of being musical with system. Likewise, having a means of modulating the level and composition of what emerges from the feedback speaker affords a further dimension for play. As such, the piece is conceived of as a terrain of possibilities that are, in naked homage to Bowers, available for playful disruption.

4.2 Exchange. Value

Exchange. Value(2012) is a piece for three laptoppists using the Ableton Live software. It was written for a laptop trio with who I have been playing for some years. We generally use commercial controllers, with a cultivated lack of attention to concerns of bodiliness, performativity or signal processing athleticism, preferring to use this a forum for making music with the means immediately to hand. We tend to share audio with each other over ADAT connections, in the interests of stealing each other's sounds and confusing ourselves and our audiences about who is doing what. The impulse for what I developed here was to build upon this interconnectedness and to indulge my own tendencies towards despotism, whilst imposing as little restriction as possible on the flexibility of controllers and musical process available to the players.

The most noteworthy feature is that the electronics for this piece don't produce sound, but take it away. The primary signal processing at work is the targeted muting of players, based on analyses of their sounds and actions (by proxy, via MIDI events), and their relation to the other players. Each participant runs a Max For Live patch in their Ableton session that performs these analyses, and will periodically mute the outputs of that player. This muting can happen at different rates, with different musical effects: fast chopping, slower articulations, and prolonged withdrawals, or combinations of all three, as there is no attempt to explicitly synchronise the interventions of each player's patch.

The primary metaphor for controlling when this muting happens is that of a bucket filling. Each patch has an accumulator, and the rate at which this is filled is driven by the analyses described above, which also determines the amount of time the patch spends in mute-mode. Two factors affect how quickly a bucket fills, all else being equal. One of these is the player's level relative to the overall level of the trio, taken as a fraction of the overall maximum level in the preceding 5 second window. The other factor is based on analysis of audio and MIDI onsets. The ratio of these onsets is subject to further analysis by measurement of its standard deviation over a sliding 25 second window. This tracks the amount of variety the player is bringing to proceedings. If this falls below a threshold, then the filling rate of the bucket is affected proportionally. Players are able to also manually adjust the sensitivity of their bucket or, of course, opt-out entirely by disabling the object at any time. The relative certainty of detecting MIDI onsets, it is worthwhile to note, is counterbalanced by a purposely lightweight and crude approach to detecting onsets that uses a simplified version of the scheme presented in [13] to estimate signal flux.

What happens when a muting cycle takes place is based on an assessment of the relationship between a player's levels of physical activity relative to the amount of audio activity. This is taken in terms of a ratio of audio to MIDI onsets accumulated over a time window. This ratio, taken at the time a bucket fills, determines which of three possible rates muting takes place at: fast (semi-quaver-ish), medium (crotchet-ish), slow (whole-bars). The mapping is not linear with respect to the audio midi ratio, as this would encourage gaming the patch. Rather, lots of relative MIDI activity[3] will yield medium muting, so that short bursts of rapidly changing textures might emerge. Little MIDI activity will yield fast muting, so the computer takes over the role of articulator, in a sense. The slow mutes happen when there is

---

[3]MIDI activity is derived from Note On events, and CC changes. De-bouncing is used to filter out rapid repetitions of CCs within a single gesture.
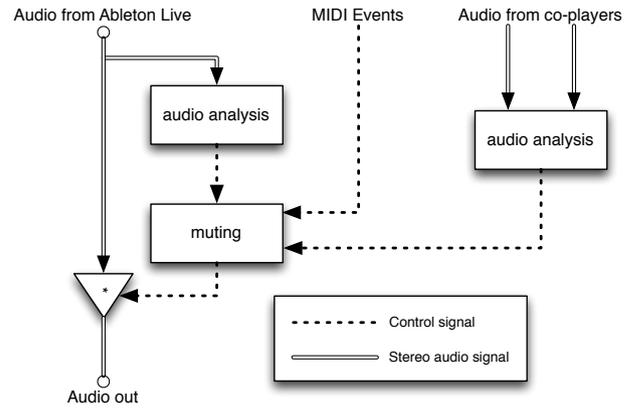

Figure 3: Sceheme for each player's patch in *Exchange. Value*

a middle of the road audio-MIDI relationship on the—quite groundless—assumption that this is the most boring kind of material. A future embellishment will be to make this more sophisticated by nesting time scales within a cycle in more complex ways.

The muting is also subject to a rhythmic patterning, so as to make it less monotonic. These patterns are generated on the basis of the patterning of the detected onsets from the other two players by using a Schillinger-inspired method to generate a new rhythm from these two seeds. This can, contingent upon a variety of factors, produce rhythmic behaviours that feel musically congruent with the overall sound, but is equally apt to produce surprising results.

The measured MIDI activity is also used to set the tempo of Live's clock, using a simple scheme from [18]. This is done as an alternative to having all clocks synced to one master clock, which can bring a lack of flexibility, or just having all players running free. By linking the tempo to inferred physical activity, the possibility (but by no means certainty) exists that the resulting sonic flow could tie itself to the physical rhythmicity of the player and that a common groove could emerge between each sequencer. This is implemented in such a way that the player is still able to manually intervene and set the clock themselves, so that, again, opt-out is possible.

5. DISCUSSION

5.1 Designing and Wayfinding

In both pieces, the process of development was guided by an exploratory attitude where the endpoint was not something established in advance of commencing work, but emerged through the process of making, and remains somewhat contingent insofar as the systems are liable to further modification and development if that seems attractive. In this sense they depart somewhat with the notion of design being geared towards the implementation of a set of known, preexisting requirements and have more in common with what Tim Ingold calls 'wayfinding', whereby a terrain is explored intuitively and attentively. Similarly, it chimes with Bolt's characterisation of practice as something proceeding from the unknown to the known. As an outlook and orientation, it also owes a good deal towards the improvisatory nature of the musicking that I seek to do with these systems; these are not names for works in any strong sense so much as labels for territories.

Particular technical decisions, then, were guided less by a process of modular, cleanly decoupled development and more by a processes of looking for (more) musicality. One way of characterising this might be by analogy to the way David Sudnow [24] describes 'grabbing' for music in his account of developing a skilled be-bop practice with the piano. This pertains, in particular, to teasing out the musicality of longer-term dynamic interactions with these systems: one thing that characterised my working process when I started trying to design these things was to not to leave sufficient time for programmatic changes to bed-in to my playing based, I believe, on an unquestioned assumption that the musicality (or not) of the results rested on the strength of the algorithm. This always gave development something of a fidgety character of too-quick cycles between playing and tweaking.

However, what distinguishes the current forms of *And Now For Some Music* and *Exchange. Value* has been a gradual assumption of greater responsibility for my playing in the musicality (or not) of the results. Besides helping me develop less haste in development, I find I have also become less anxiously goal driven in the kinds of processing, for instance, that I design and err increasingly often towards Bowers' dictum of 'crude but generally useable' solutions [6]. Furthermore, I have found that less and less of what I do is orientated towards *modelling*. Whilst it was one thing to derive interesting short-term signal features from some reasonably informed model of the mechanics at work, when it came to longer musical time-scales the corollary seemed to be to model *musicality*, which seemed not only like a tall order, but also generated such constrains as to militate against musicality rather than encourage it, as I left myself nowhere to go in play. This tallies with recent warnings by both Linson [16] and Poepel [19] about the perils of over-formalising or constraining one's musical interface.

So it is that the various mechanisms described above, such as that for deriving pulse in *And Now For Some Music*, are based on schemes that might work as imagined, some of the time, but are not *brittle* with respect to unexpected input and tend, in their own ways, to bestow on the software its own wayfinding-like behaviour, in favour of predictable or repeatable contributions.

Beyond the details of my own experiences and proclivities, however, a more general question is raised about the transition or relationship between designing and practising (in the conventional musical sense). How do people manage the business of discovering and cultivating musicality on systems that are available to perpetual modification and tweaking? Is it just a matter of self-discipline? Are we even sure what skills it is that we're practising at any given moment? Very little seems to have been written about how this process is navigated specifically by maker-musicians, although the subject is broached in effect by Collins [9] who considers possible practising techniques for live coders, who of course integrate the making into the musicking. However, a broader discussion of the breadth of practitioners approaches to this developed from situated accounts of practice—many of which will have much to recommend them over my own sometimes neurotic working patterns— seem like a worthwhile thing to bring into NIME's purview in the interests of developing new *coping strategies* to accompany new interfaces.

5.2 Livedness

Navigating such folds, such as those between designing and practising, emphasises the extent to which the concerns of practice are diachronic and, as such, *lived*. To do music in any capacity is to integrate a set of habits and proclivities into the texture of one's various activities and relationships.

Co-dwelling with my instruments and systems invites a slightly different perspective on the central role of performance as a site of evaluation that we saw in section 2, insofar as performances are not singular, focal points but rather periodic, albeit critical moments in the texture of one's practice. Introducing consideration of this sense of *livedness* can, I believe, usefully supplement a concern with liveness by attracting our collective attention to formative aspects of musicality that may otherwise fall between the cracks of focussing on works, instruments or performances as discrete outcomes.

In particular, I see this as a way of usefully correcting a temptation to treat 'performance' in the abstract, without due attention to the many social and material contingencies that can have a profound impact not just on the way that music is made but also on the way it is received. There are many types of gathering and ritual that we are happy to group together as 'performance', and the various conventions that give these their character are by no means coincidental to the way that musicality is perceived and assessed.

There are two principal risks that arise from not taking this variety into account. First is a tendency to homogenise conceptions of what performance consists of or what may be desirable. To the extent that these conceptions can feed into design assumptions for makers of interfaces, this could interfere with making interfaces that are sensitively targeted to particular types of performance context, or for being able to communicate clearly and effectively with the community about the worth of specialist approaches. In other words: an assessment of musical suitability necessarily entails a detailed engagement with the aesthetic priorities at work in context. Second, to insist on performance as a preferable site of evaluation without considering the enormous range of things that this can mean, particularly given perspectives like those of Small [21] and Frith [10], can result in over-idealising some notion of performance in relation to, say, recordings (as Born is critical of Auslander for doing [5]) which in turn blocks off ranges of perfectly legitimate practice from consideration.

In this sense, the addition of situated, practice-led discourses to NIME can help by more accurately mapping the contemporary performance-scape, albeit at the cost of some certainty of operating assumptions. At a minimum, we need a considerably more developed vocabulary for describing the range and grain of current practices. More desirable would be to be able to meaningfully communicate about the ways in which particular approaches to technology, and particular types of social gathering relate to and inflect the conduct of particular ways of being musical.

6. CONCLUSION

These are opening thoughts on an approach to practice-led methods may contribute helpfully to NIME by affording richer and more sophisticated understandings of musicality in context. Nevertheless, I believe that they have a degree of promise. I have suggested that practice-led researchers— who I take to form part of the NIME community—can bring valuable insights, complementary to the technical focus of interaction designers. I focused in particular on how such insights might relate to the grain of lived experience with respect to technological work and to performing.

Obviously, there is much to be developed. Priorities for immediate future research in this area involve considering specific methodologies geared at co-practice and at ways of eroding the residual cultural barrier to wider participation

presented by the institutional boundary. My aim here is to facilitate richer exchange between musical practice-led researchers and allied colleagues by promoting discussion around the development of richer methodologies within the sub-discipline.

A guiding idea is that much of this hinges on *communication* and that there may be value in reflecting on the communicative tactics employed by musicians more generally as possible blueprints for more formally developed methods. For instance, if musicians play together as a means of communication—to learn about each other—then can this be formalised as a practice-research method? Similarly, what might we learn about each other by engaging in the kinds of exchanges of musical material that characterise interactions between practitioners more generally, or by drawing more explicitly on the broad range of cultural contexts outwith the university that our work takes us to?

References

[1] E. Barrett and B. Bolt, eds. *Practice as research: approaches to creative arts enquiry*. I.B. Tauris, London; New York, 2007.

[2] A. Barry, G. Born, and G. Weszkalnys. Logics of interdisciplinarity. *Economy and society*, 37:20–49, 1, 2008.

[3] B. Bolt. A performative paradigm for the creative arts? *Working papers in art and design*, 5, 2008.

[4] B. Bolt. *The magic is in handling*. In. *Practice as research: approaches to creative arts enquiry*. B. Bolt and E. Barrett, editors. I.B. Tauris, London and New York, 2007, pp. 27–34.

[5] G. Born. For a relational musicology: music and interdisciplinarity, beyond the practice turn. *Journal of the royal musical association*, 135:205–243, 2, 2010.

[6] J. Bowers. Improvising machines: ethnographically informed design for improvised electro-acoustic music. *ARiADATexts*, 4, 2003.

[7] J. Bowers and P. Archer. Not hyper, not meta, not cyber but infra-instruments. In *Proceedings of the 2005 international conference on New Interfaces for Musical Expression (NIME05)*, 2005, pp. 5–10.

[8] A. R. Brown and A. C. Sorensen. Integrating creative practice and research in the digital media arts. *Practice-led research, research-led practice in the creative arts*:153–165, 2009.

[9] N. Collins. Live coding practice. In *Proceedings of the 2007 international conference on New Interfaces for Musical Expression (NIME07)*, 2007, pp. 112–116.

[10] S. Frith. *Performing rites: evaluating popular music*. Oxford University Press, Oxford, 1996.

[11] S. Gelineck and S. Serafin. Longitudinal evaluation of the integration of digital musical instruments into existing compositional work processes. *Journal of new music research*, 41(3):259–276, 2012.

[12] M. Gurevich and J. Treviño. Expression and its discontents: toward an ecology of musical creation. In *Proceedings of the 7th international conference on new interfaces for musical expression*. In NIME '07. ACM, New York, NY, USA, 2007, pp. 106–111.

[13] R. Holopainen. The constant-Q IIR filterbank approach to spectral flux. In *Proceedings of the 9th Sound and Music Computing conference*. Copenhagen, Denmark, 2012, pp. 419–425.

[14] A. Johnston. Beyond evaluation: linking practice and theory in new musical interface design. *Proceedings of the international conference on new interfaces for musical expression*, (30):280–283, 2011.

[15] C.-H. Lai and T. Bovermann. Audience experience in sound performance, 2013.

[16] A. Linson. Unnecessary constraints: a challenge to some assumptions of digital musical instrument design, 2011.

[17] S. O'Modhrain. A framework for the evaluation of digital musical instruments. *Computer music journal*, 35(1):28–42, 2011.

[18] B. Pardo. Tempo tracking with a single oscillator. In *Proceedings of the 5th international conference on Music Information Retrieval, Barcelona*, 2005.

[19] C. Poepel. *Formalized and non-formalized expression in musical interfaces*. In. *Transdisciplinary digital art. sound, vision and the new screen*. R. Adams, S. Gibson, and S. M. Arisona, editors. (7) in Communications in Computer and Information Science. Springer Berlin Heidelberg, 2008, pp. 358–373.

[20] N. Schnell et al. FTM—Complex data structures for max. In *In proc. ICMC*, 2005.

[21] C. Small. *Musicking: the meanings of performances and listening*. Wesleyan University Press, Hanover, NH, 1998.

[22] H. Smith and R. T. Dean, eds. *Practice-led research, research-led practice in the creative arts*. Edinburgh University Press, Edinburgh, 2009.

[23] D. Stowell et al. Evaluation of live human–computer music-making: quantitative and qualitative approaches. *International journal of human-computer studies*, 67(11):960–975, 2009.

[24] D. Sudnow. *Ways of the hand: the organization of improvised conduct*. Routledge and Kegan Paul, London and Henley, 1978.

[25] M. Waisvisz. Manager or musician? - about virtuosity in live electronic music. In. NIME, 2006, p. 415.

[26] S. Waters. Performance ecosystems: ecological approaches to musical interaction. In *Proceedings of Electroacoustic Music Studies Network conference 2007*, 2007.

[27] U. Zölzer. *DAFX : digital audio effects*. Wiley, Chichester, 2002.